HALBLEITERPHYSIK (HL)

Prof. Dr. R. J. Haug
Institut für Festkörperphysik
Universität Hannover
Appelstraße 2
30167 Hannover
E-Mail: haug@nano.uni-hannover.de

ÜBERSICHT DER HAUPTVORTRÄGE UND FACHSITZUNGEN

(Hörsäle TU P164, TU P270, TU P-N201, TU P-N202, TU P-N229, TU P-N226)

Hauptvorträge

HL 1.1	Fr	10:00	(TU P270)	**One-, two-, and three-dimensional quantum dot crystals**, Oliver G. Schmidt
HL 9.1	Fr	14:15	(TU P270)	**Ferromagnetic III-V Semiconductors Spintronics**, Hideo Ohno
HL 18.1	Sa	09:00	(TU P270)	**Coupled quantum systems with quantum dots**, Ulrike Woggon
HL 19.1	Sa	09:45	(TU P270)	**Manipulations of a qubit in a semiconductor quantum dot**, Artur Zrenner, Stefan Stufler, Patrick Ester, Max Bichler
HL 28.1	Sa	14:15	(TU P270)	**Electron spin relaxation in semiconductors**, Daniel Hägele, Stefanie Döhrmann, Jörg Rudolph, Michael Oestreich
HL 41.1	Mo	14:15	(TU P270)	**Negative index materials: New frontiers in optics**, C. M. Soukoulis
HL 47.1	Di	10:00	(TU P270)	**Physics and quantum device applications of semiconductor nanowires**, Lars Samuelson
HL 52.1	Di	14:15	(TU P270)	**2D electron gas under microwaves: Theory of oscillatory photoresistivity and zero-resistance states**, A.D. Mirlin, I.A. Dmitriev, M.G. Vavilov, I.L. Aleiner, D.G. Polyakov
HL 60.1	Mi	10:00	(TU P270)	**Chemistry and Electronic Properties of Metal Interfaces to Organic Semiconductors**, Dietrich R.T. Zahn

Preisträgervortrag: Walter-Schottky-Preis

HL 40.1	Mo	12:30	(TU P270)	**Quantum noise in mesoscopic systems**, Wolfgang Belzig

Symposium: ZnO - Rediscovered

HL 2.1	Fr	10:45	(TU P270)	**Excitonic Properties on ZnO**, Claus Klingshirn, Heiko Priller, Joachim Zeller, Heinz Kalt
HL 2.2	Fr	11:15	(TU P270)	**Electrical properties of ZnO thin films and optical properties of ZnO-based nanostructures**, Marius Grundmann
HL 2.3	Fr	11:45	(TU P270)	**Bound exciton recombinations in ZnO**, Bruno K. Meyer, Joachim Sann, Detlev M. Hofmann, Christian Neumann, Arndt Zeuner
HL 2.4	Fr	12:15	(TU P270)	**Microscopic Luminescence Properties of ZnO and ZnO based Heterostructures**, Jürgen Christen, Frank Bertram
HL 2.5	Fr	12:45	(TU P270)	**Transition metal ions in ZnO a challenge for spintronic applications**, Axel Hoffmann, Enno Malguth, Martin Strassburg, Mathew H. Kane, Ian T. Ferguson

Symposium: Single Photon Sources and Spectroscopy of Individual Quantum Systems

HL 20.1	Sa	10:45	(TU P270)	**Read-out and manipulation of single electron and nuclear spins and spin pairs**, J. Wrachtrup
HL 20.2	Sa	11:15	(TU P270)	**Solid-state single-photon-sources for quantum cryptography**, H. Weinfurter, Ch. Wang, Ch. Braig, P. Zarda, Ch. Kurtsiefer
HL 20.3	Sa	11:45	(TU P270)	**Optically initialization of single spins in semiconductor quantum dots**, Jonathan Finley, Miro Kroutvar, Dominik Heiss, Max Bichler, Gerhard Abstreiter
HL 20.4	Sa	12:15	(TU P270)	**Spectroscopy of single nanowire heterostructures**, V. Zwiller, M. Borgström, A. Imamoglu
HL 20.5	Sa	12:45	(TU P270)	**Voltage-Controlled Optics of a single Quantum Dot**, Khaled Karrai, Alexander Högele, Stefan Seidl, Martin Kroner, Richard J. Warburton, Brian D. Gerardot, Pierre M. Petroff

Symposium: Photonic Crystals

HL 42.1	Mo	15:00	(TU P270)	**The mid-field microscope: Development of a 50 nm resolution microscope based on surface plasmon effects**, Ian T. Young, Yuval Garini, Margreet Docter
HL 42.2	Mo	15:30	(TU P270)	**Controlled coupling of a subwavelength dipole to a photonic crystal microcavity**, V. Sandoghdar, F, Koenderink, B. Buchler
HL 42.3	Mo	16:00	(TU P270)	**Noise properties of supercontinua generated in photonic crystal fibres (PCFs)**, Harald R. Telle, Nils Haverkamp
HL 42.4	Mo	16:30	(TU P270)	**Novel photonic quasicrystal geometries and waveguide designs for applications in dispersion engineering**, M. D. B. Charlton, M. E. Zoorob, G. J. Parker, N. Perney, M. C. Netti, P. Ayliffe, S. J. Cox, J. J. Baumberg, J. S. Wilkinson
HL 42.5	Mo	17:00	(TU P270)	**Interaction between Photonic Gaps and Material Excitations in 1- and 1-Dimensional Structures**, Carl G. Ribbing, Herman Högström, Andreas Rung
HL 42.6	Mo	17:30	(TU P270)	**Sol-Gel Approaches to Photonic Crystal Systems**, Frank Marlow, Denan Konjhodzic, Helmut Bretinger, Hongliang Li

Symposium: Bio- and Neurotransistors

HL 48.1	Di	10:45	(TU P270)	**Transistors with Ion Channels, Nerve Cells and Brain Tissue**, Peter Fromherz
HL 48.2	Di	11:15	(TU P270)	**Interfacing cells with mircoelectronics**, Günter Wrobel, Frank Sommerhage, Sven Ingebrandt, Andreas Offenhäusser
HL 48.3	Di	11:45	(TU P270)	**Detecting DNA Hybridization by a Microfabricated Field-effect Sensor**, Jürgen Fritz
HL 48.4	Di	12:15	(TU P270)	**A BiosFET on the basis of intact insect antennae**, M. J. Schöning, S. Schütz, H. E. Hummel, H. Lüth, C.-D. Kohl
HL 48.5	Di	12:45	(TU P270)	**Biosensor Applications of AlGaN/GaN Solution Gate Field Effect Transistors**, Georg Steinhoff, Barbara Baur, Martin Stutzmann, Martin Eickhoff

Einstein Symposium: Der Photoeffekt im Licht neuester Forschung, Fr, HU Senatssaal, siehe SYPE

Symposium: Measurements at the Quantum Limit, Fr, TU HE 101, siehe SYQL

Symposium: Nichtflüchtige Festkörperspeicher, Sa, TU HE 101, siehe SYFS

Symposium: Organic Optoelectronics and Photonics, Mo, TU HE 101, siehe SYOO

Symposium: Mesoscopic Physics of Ultracold Atoms, Mi, HU Audimax, siehe SYUA

F. J. Himpsel: Low-dimensional electrons at Si surfaces, Sa 09:00-09:45, TU EB 301, siehe Oberflächenphysik

Bart van Wees: Spin Pumping in a Mesoscopic Spin Battery, Mo 11:00, TU H3027 siehe TT

Suichi Murakami: Intrinsic Spin Hall Effect, Mo 11:30, TU H3027 siehe TT

Fachsitzungen

HL 1	**Hauptvortrag Schmidt**	Fr	10:00–10:45	TU P270	HL 1.1–1.1
HL 2	**Symposium ZnO - Rediscovered**	Fr	10:45–13:15	TU P270	HL 2.1–2.5
HL 3	**Spintronik I**	Fr	10:45–13:15	TU P164	HL 3.1–3.10
HL 4	**Quantenpunkte und -drähte: Optische Eigenschaften I**	Fr	10:45–13:30	TU P-N201	HL 4.1–4.11
HL 5	**Grenz- und Oberflächen**	Fr	10:45–11:45	TU P-N202	HL 5.1–5.4
HL 6	**Optische Eigenschaften**	Fr	10:45–13:00	TU P-N229	HL 6.1–6.9
HL 7	**Transporteigenschaften**	Fr	10:45–13:00	TU P-N226	HL 7.1–7.9
HL 8	**III-V Halbleiter I**	Fr	11:45–13:15	TU P-N202	HL 8.1–8.6
HL 9	**Hauptvortrag Ohno**	Fr	14:15–15:00	TU P270	HL 9.1–9.1
HL 10	**Spintronik II**	Fr	15:00–16:30	TU P270	HL 10.1–10.6
HL 11	**II-VI Halbleiter I**	Fr	15:00–16:30	TU P164	HL 11.1–11.6
HL 12	**Quantenpunkte und -drähte: Optische Eigenschaften II**	Fr	15:00–16:30	TU P-N201	HL 12.1–12.6
HL 13	**III-V Halbleiter II**	Fr	15:00–16:30	TU P-N202	HL 13.1–13.6
HL 14	**Heterostrukturen**	Fr	15:00–16:15	TU P-N229	HL 14.1–14.5
HL 15	**Elektronentheorie**	Fr	15:00–16:00	TU P-N226	HL 15.1–15.4
HL 16	**Poster Ia**	Fr	16:30–19:00	Poster TU E	HL 16.1–16.28
HL 17	**Poster Ib**	Fr	16:30–19:00	Poster TU F	HL 17.1–17.69
HL 18	**Hauptvortrag Woggon**	Sa	09:00–09:45	TU P270	HL 18.1–18.1
HL 19	**Hauptvortrag Zrenner**	Sa	09:45–10:30	TU P270	HL 19.1–19.1
HL 20	**Symposium: Single Photon Sources and Spectroscopy of Individual Quantum Systems**	Sa	10:45–13:15	TU P270	HL 20.1–20.5
HL 21	**Spintronik III**	Sa	10:45–13:00	TU P164	HL 21.1–21.9
HL 22	**GaN: Präparation und Charakterisierung I**	Sa	10:45–13:15	TU P-N201	HL 22.1–22.10
HL 23	**II-VI Halbleiter II**	Sa	10:45–13:15	TU P-N202	HL 23.1–23.10
HL 24	**Bauelemente**	Sa	10:45–12:30	TU P-N229	HL 24.1–24.7
HL 25	**Si / Ge**	Sa	10:45–12:45	TU P-N226	HL 25.1–25.8
HL 26	**SiC**	Sa	12:30–13:15	TU P-N229	HL 26.1–26.3
HL 27	**Störstellen / Amorphe Halbleiter**	Sa	12:45–13:15	TU P-N226	HL 27.1–27.2
HL 28	**Hauptvortrag Hägele**	Sa	14:15–15:00	TU P270	HL 28.1–28.1
HL 29	**Spintronik IV**	Sa	15:00–16:15	TU P270	HL 29.1–29.5
HL 30	**II-VI Halbleiter III**	Sa	15:00–16:30	TU P164	HL 30.1–30.6
HL 31	**GaN: Bauelemente**	Sa	15:00–16:30	TU P-N201	HL 31.1–31.6
HL 32	**Halbleiterlaser I**	Sa	15:00–16:30	TU P-N202	HL 32.1–32.6
HL 33	**Kohlenstoff/Diamant**	Sa	15:00–16:00	TU P-N229	HL 33.1–33.4
HL 34	**Neue Materialien**	Sa	15:00–15:45	TU P-N226	HL 34.1–34.3
HL 35	**Hybride Systeme**	Sa	15:45–16:30	TU P-N226	HL 35.1–35.3
HL 36	**Quantenpunkte und -drähte: Optische Eigenschaften III**	Mo	10:00–12:15	TU P164	HL 36.1–36.9
HL 37	**Photonische Kristalle I**	Mo	10:00–12:15	TU P270	HL 37.1–37.9
HL 38	**Halbleiterlaser II**	Mo	10:00–12:15	TU P-N201	HL 38.1–38.9
HL 39	**Quantenpunkte und -drähte: Transporteigenschaften I**	Mo	10:00–12:15	TU P-N202	HL 39.1–39.9
HL 40	**Preisträgervortrag Belzig**	Mo	12:30–13:15	TU P270	HL 40.1–40.1
HL 41	**Hauptvortrag Soukoulis**	Mo	14:15–15:00	TU P270	HL 41.1–41.1
HL 42	**Symposium: Photonic Crystals**	Mo	15:00–18:00	TU P270	HL 42.1–42.6
HL 43	**GaN: Präparation und Charakterisierung II**	Mo	15:00–16:45	TU P164	HL 43.1–43.7
HL 44	**II-VI Halbleiter IV**	Mo	15:00–17:45	TU P-N201	HL 44.1–44.11
HL 45	**Quantenpunkte und -drähte: Transporteigenschaften II**	Mo	15:00–17:30	TU P-N202	HL 45.1–45.10
HL 46	**Quantenpunkte und -drähte: Herstellung und Charakterisierung I**	Mo	16:45–18:00	TU P164	HL 46.1–46.5

HL 47	**Hauptvortrag Samuelson**	Di 10:00–10:45	TU P270	HL 47.1–47.1
HL 48	**Symposium: Bio- and Neurotransistors**	Di 10:45–13:15	TU P270	HL 48.1–48.5
HL 49	**Photonische Kristalle II**	Di 10:45–13:15	TU P164	HL 49.1–49.10
HL 50	**Nanodrähte**	Di 10:45–13:30	TU P-N201	HL 50.1–50.11
HL 51	**GaN: Präparation und Charakterisierung III**	Di 10:45–13:15	TU P-N202	HL 51.1–51.10
HL 52	**Hauptvortrag Mirlin**	Di 14:15–15:00	TU P270	HL 52.1–52.1
HL 53	**Transport im hohen Magnetfeld/Quanten-Hall-Effekt**	Di 15:00–16:45	TU P270	HL 53.1–53.7
HL 54	**Photonische Kristalle III**	Di 15:00–16:30	TU P164	HL 54.1–54.6
HL 55	**Quantenpunkte und -drähte: Herstellung und Charakterisierung II**	Di 15:00–16:30	TU P-N201	HL 55.1–55.6
HL 56	**Photovoltaik I**	Di 15:00–16:30	TU P-N202	HL 56.1–56.6
HL 57	**Poster IIa**	Di 16:30–19:00	Poster TU E	HL 57.1–57.30
HL 58	**Poster IIb**	Di 16:30–19:00	Poster TU F	HL 58.1–58.71
HL 59	**Mitgliederversammlung**	Di 18:00–19:00	TU P-N202	
HL 60	**Hauptvortrag Zahn**	Mi 10:00–10:45	TU P270	HL 60.1–60.1
HL 61	**Organische Halbleiter**	Mi 10:45–13:15	TU P270	HL 61.1–61.10
HL 62	**Photonische Kristalle IV**	Mi 10:45–13:30	TU P164	HL 62.1–62.11
HL 63	**Ultrakurzzeitphänomene**	Mi 10:45–13:30	TU P-N201	HL 63.1–63.11
HL 64	**Photovoltaik II**	Mi 10:45–13:30	TU P-N202	HL 64.1–64.11

Mitgliederversammlung des Fachverbands Halbleiterphysik

Di 18:00–19:00 TU P-N202

1. Begrüßung und Bericht
2. Stichwortkatalog
3. Wahlen
4. Verschiedenes

Postersitzungen:

Für die Postersitzungen (Fr und Di) die Poster bitte vormittags aufhängen und abends nach der Postersitzung abnehmen.

Zeit	Vorträge	Nr.	Sitzung	Ort
04.03.2005	**FREITAG**			
10:00 - 10:45	Hauptvortrag	HL 1	O. G. Schmidt: One-, two-, and three-dimensional quantum dot crystals	TU P270
10:45 - 13:15	Symposium	HL 2	ZnO - Rediscovered	TU P270
10:45 - 13:15	Kurzvorträge	HL 3	Spintronik I	TU P164
10:45 - 13:30		HL 4	Quantenpunkte und -drähte: Optische Eigenschaften I	TU P-N201
10:45 - 11:45		HL 5	Grenz- und Oberflächen	TU P-N202
10:45 - 13:00		HL 6	Optische Eigenschaften	TU P-N229
10:45 - 13:00		HL 7	Transporteigenschaften	TU P-N226
11:45 - 13:15		HL 8	III-V Halbleiter I	TU P-N202
14:15 - 15:00	Hauptvortrag	HL 9	H. Ohno: Ferromagnetic III-V Semiconductors Spintronics	TU P270
15:00 - 16:30	Kurzvorträge	HL 10	Spintronik II	TU P270
15:00 - 16:30		HL 11	II-VI Halbleiter I	TU P164
15:00 - 16:30		HL 12	Quantenpunkte und -drähte: Optische Eigenschaften II	TU P-N201
15:00 - 16:30		HL 13	III-V Halbleiter II	TU P-N202
15:00 - 16:15		HL 14	Heterostrukturen	TU P-N229
15:00 - 16:00		HL 15	Elektronentheorie	TU P-N226
16:30 - 19:00	Postersitzung	HL 16	Poster Ia	Poster TU E
16:30 - 19:00		HL 17	Poster Ib	Poster TU F
05.03.2005	**SAMSTAG**			
09:00 - 09:45	Hauptvortrag	HL 18	U. Woggon: Coupled quantum systems with quantum dots	TU P270
09:45 - 10:30	Hauptvortrag	HL 19	A. Zrenner: Manipulations of a qubit in a semiconductor quantum dot	TU P270
10:45 - 13:15	Symposium	HL 20	Single Photon Sources and Spectroscopy of Individual Quantum Systems	TU P270
10:45 - 13:00	Kurzvorträge	HL 21	Spintronik III	TU P164
10:45 - 13:15		HL 22	GaN: Präparation und Charakterisierung I	TU P-N201
10:45 - 13:15		HL 23	II-VI Halbleiter II	TU P-N202
10:45 - 12:30		HL 24	Bauelemente	TU P-N229
10:45 - 12:45		HL 25	Si/Ge	TU P-N226
12:30 - 13:15		HL 26	SiC	TU P-N229
12:45 - 13:15		HL 27	Störstellen / Amorphe Halbleiter	TU P-N226
14:15 - 15:00	Hauptvortrag	HL 28	D. Hägele: Electron spin relaxation in semiconductors	TU P270
15:00 - 16:15	Kurzvorträge	HL 29	Spintronik IV	TU P270
15:00 - 16:30		HL 30	II-VI Halbleiter III	TU P164
15:00 - 16:30		HL 31	GaN: Bauelemente	TU P-N201
15:00 - 16:30		HL 32	Halbleiterlaser I	TU P-N202
15:00 - 16:00		HL 33	Kohlenstoff/Diamant	TU P-N229
15:00 - 15:45		HL 34	Neue Materialien	TU P-N226
15:45 - 16:30		HL 35	Hybride Systeme	TU P-N226
07.03.2005	**MONTAG**			
10:00 - 12:15	Kurzvorträge	HL 36	Quantenpunkte und -drähte: Optische Eigenschaften III	TU P164
10:00 - 12:15		HL 37	Photonische Kristalle I	TU P270
10:00 - 12:15		HL 38	Halbleiterlaser II	TU P-N201
10:00 - 12:15		HL 39	Quantenpunkte und -drähte: Transporteigenschaften I	TU P-N202
12:30 - 13:15	Preisträgervortrag	HL 40	W. Belzig: Quantum noise in mesoscopic systems	TU P270
14:15 - 15:00	Hauptvortrag	HL 41	C. M. Soukoulis: Negative index materials: New frontiers in optics	TU P270
15:00 - 18:00	Symposium	HL 42	Photonic Crystals	TU P270
15:00 - 16:45	Kurzvorträge	HL 43	GaN: Präparation und Charakterisierung II	TU P164
15:00 - 17:45		HL 44	II-VI Halbleiter IV	TU P-N201
15:00 - 17:30		HL 45	Quantenpunkte und -drähte: Transporteigenschaften II	TU P-N202
16:45 - 18:00		HL 46	Quantenpunkte und -drähte: Herstellung und Charakterisierung I	TU P164

Zeit	Vorträge	Nr.	Sitzung	Ort
08.03.2005	**DIENSTAG**			
10:00 - 10:45	Hauptvortrag	HL 47	L. Samuelson: Physics and quantum device applications of semiconductor nanowires	TU P270
10:45 - 13:15	Symposium	HL 48	Bio- and Neurotransistors	TU P270
10:45 - 13:15	Kurzvorträge	HL 49	Photonische Kristalle II	TU P164
10:45 - 13:30		HL 50	Nanodrähte	TU P-N201
10:45 - 13:15		HL 51	GaN: Präparation und Charakterisierung III	TU P-N202
14:15 - 15:00	Hauptvortrag	HL 52	A. D. Mirlin: 2D electron gas under microwaves: Theory of oscillatory Photoresistivity and zero-resistance states	TU P270
15:00 - 16:45	Kurzvorträge	HL 53	Transport im hohen Magnetfeld/Quanten-Hall-Effekt	TU P270
15:00 - 16:30		HL 54	Photonische Kristalle III	TU P164
15:00 - 16:30		HL 55	Quantenpunkte und -drähte: Herstellung und Charakterisierung II	TU P-N201
15:00 - 16:30		HL 56	Photovoltaik I	TU P-N202
16:30 - 19:00	Postersitzung	HL 57	Poster IIa	Poster TU E
16:30 - 19:00		HL 58	Poster IIb	Poster TU F
18:00 - 19:00	Mitgliederversammlung	HL 59		TU P-N202
09.03.2005	**MITTWOCH**			
10:00 - 10:45	Hauptvortrag	HL 60	D. R. T. Zahn: Chemistry and Electronic Properties of Metal Interfaces to Organic Semiconductors	TU P270
10:45 - 13:15	Kurzvorträge	HL 61	Organische Halbleiter	TU P270
10:45 - 13:30		HL 62	Photonische Kristalle IV	TU P164
10:45 - 13:30		HL 63	Ultrakurzzeitphänomene	TU P-N201
10:45 - 13:30		HL 64	Photovoltaik II	TU P-N202

Fachsitzungen

– Haupt-, Kurzvorträge und Posterbeiträge –

HL 1 Hauptvortrag Schmidt

Zeit: Freitag 10:00–10:45 Raum: TU P270

Hauptvortrag HL 1.1 Fr 10:00 TU P270

One-, two-, and three-dimensional quantum dot crystals — •Oliver G. Schmidt — Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, D-70569 Stuttgart, Germany

Over the last decade self-assembled semiconductor quantum dots (QDs) have become a major research field in materials science, physics and technology. The rapid progress is driven by the recent demonstration of several front end single quantum dot devices, which are envisioned to form the base of a future quantum information technology. The road, however, is long and it is foreseeable that the full advantage of QDs can only be deployed if a controlled positioning and high integration of these nanostructures on a single chip can be realized.

In this talk I report on the fabrication of one-, two-, and three dimensional QD crystals, which are seeded by lithographically defined surface patterns. Such seeded QD crystals experience a high structural integrity both on a short as well as on a long-range scale. Many novel phenomena are revealed such as the occurrence of lateral strain field interferences, lateral QD replication during layer stacking, or the formation of periodic second order QD arrays.

In analogy to crystal defects, we develop the notion of QD defects, which can occur during the growth of a QD crystal. Such QD defects include QD vacancies and interstitials, which develop if the growth conditions do not perfectly match the seeding layer geometry. We try to understand our experimental results by kinetic Monte Carlo simulations that take into account realistic growth conditions, strain fields and surface curvatures.

HL 2 Symposium ZnO - Rediscovered

Zeit: Freitag 10:45–13:15 Raum: TU P270

HL 2.1 Fr 10:45 TU P270

Excitonic Properties on ZnO — •Claus Klingshirn, Heiko Priller, Joachim Zeller und Heinz Kalt — Universität Karlsruhe, Institut für Angewandte Physik, Wolfgang-Gaede-Str. 1, 76131 Karlsruhe

After some introductory comments on the history of ZnO research, we present data on bulk ZnO epilayers, quantum wells, nano rods and dots covering the properties of free excitons in reflection, luminescence (dynamics) and absorption spectroscopy, high excitation processes and optical gain including biexcitons, scattering processes or the transition to an electron hole plasma. Finally we give a few comments on the presently revisited question of the valence band ordering.

HL 2.2 Fr 11:15 TU P270

Electrical properties of ZnO thin films and optical properties of ZnO-based nanostructures — •M. Grundmann — Universität Leipzig, Institut für Experimentelle Physik II

We compare the electrical properties of ZnO bulk crystals and ZnO thin films grown with pulsed laser deposition with regard to carrier concentration and mobility. Both by making highly pure layers and by compensation with acceptors very low carrier concentration can be achieved ($n < 10^{14} cm^{-3}$). We present Schottky diodes, e.g. Pd/ZnO, of high quality ($j = 4 \cdot 10^{-5} A/cm^2$ at a bias of -5V, n=1.4). The quality of the contacts is limited by the lateral homogeneity of the barrier height. Using the Schottky contacts the depletion layer can be investigated (CV, DLTS, admittance). We discuss the energetic position of various shallow and deep levels in bulk and thin films detected this way. ZnO allows the fabrication a various nanostructures such as belts, sheets and pillars. The latter mostly exhibit a hexagonal cross section. Using whispering gallery modes (WGM) in the visible and UV spectral region with mode numbers down to N=1, the size and cross-sectional shape of the pillars and needles (tapered pillars) can be detected spatially resolved. The polarization-dependent WGM spectra compare rather well to numerical simulations. This work was supported by Deutsche Forschungsgemeinschaft in the framework of SPP 1136 and FOR 522 and is in collaboration with H. v. Wenckstern, R. Pickenhain, A. Rahm, Th. Nobis and M. Lorenz.

HL 2.3 Fr 11:45 TU P270

Bound exciton recombinations in ZnO — •Bruno K. Meyer, Joachim Sann, Detlev M. Hofmann, Christian Neumann, and Arndt Zeuner — I. Physikalisches Institut, Justus-Liebig-Universität-Giessen, Heinrich-Buff-Ring 16, D-35392 Giessen, Germany

In order to realize controlled p-type doping in ZnO the role of extrinsic and intrinsic donors have to be clarified. The extrinsic n-type dopants Al, Ga and In are commonly found in bulk ZnO crystals. Also hydrogen acts as a shallow donor, and appears in relevant concentrations in nominally undoped ZnO. The optical properties of excitonic recombinations in bulk, n-type ZnO are investigated by photoluminescence (PL). At liquid helium temperature the neutral donor bound excitons dominate in the PL spectrum. Two electron satellite transitions (TES) of the donor bound excitons allow to determine the donor binding energies ranging from 46 to 73 meV. The H, Al, Ga and In donor bound exciton recombinations are identified based on doping and diffusion experiments, magnetic resonance and using secondary ion mass spectroscopy. The influence of acceptor doping on the band edge recombinations will be discussed.

HL 2.4 Fr 12:15 TU P270

Microscopic Luminescence Properties of ZnO and ZnO based Heterostructures — •Jürgen Christen and Frank Bertram — Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, PSF 4120, Magdeburg, D-39016, Germany

ZnO has re-emerged into the center of international attention. Although know for many years, there is still a lack of information on its microstructure and in particular its microscopic electronic and optical properties. We present spatially resolved luminescence investigations directly correlating the optical characteristics to the nano-scale morphology. The strong impact of local internal fields (Franz-Keldysh-Effect) is evidenced. Expected for hetero-interfaces (spontaneous / piezo-polarization), this is also found at homo-interfaces and even in ZnO single crystals at domain boundaries. In epitaxially grown Zno films, a direct correlation between defects and morphology and specific spectral features is found. The bound exciton luminescence I8 directly images the dislocation network and its spectral position maps the lateral strain profile. A selective incorporation of those impurities associated with I0 and I1 at the micro-domain boundaries is evidenced. The situation further complicates when adding ternary alloys such as MgZnO or CdZnO, needed for heterostructures and Quantum Wells. A one-by-one correlation of local stoicheometry and micro-morphology as well as its impact on the relaxation and recombination kinetics is presented.

HL 2.5 Fr 12:45 TU P270

Transition metal ions in ZnO a challenge for spintronic applications — •Axel Hoffmann[1], Enno Malguth[1], Martin Strassburg[2], Mathew H. Kane[2], and Ian T. Ferguson[2] — [1]Institut für Festkörperphysik, Technische Universität Berlin, D - 10623 Berlin, Germany. — [2]Georgia Institute of Technology, School of Electrical and Computer Engineering, Atlanta, GA 30332, U.S.A.

Increased efforts on transition metal (TM) doped wide bandgap materials, such as ZnO and GaN, were triggered by theoretical predictions suggesting ferromagnetism of diluted magnetic semiconductors

with Curie temperatures above room temperature. Experimental results have demonstrated room temperature ferromagnetism in these systems, though many growth techniques used to date for this system are not ideal for device applications. Non-equilibrium growth methods, such as molecular beam epitaxy (MBE) and metal-organic vapor phase epitaxy (MOCVD), have been applied to achieve high carrier and dopant concentrations. This paper reports on optical and magneto-optical properties of TM doped ZnO and on the state of the art of ferromagnetism in ZnO.

HL 3 Spintronik I

Zeit: Freitag 10:45–13:15 Raum: TU P164

HL 3.1 Fr 10:45 TU P164

A microscopic approach to semiconductor spin dynamics — •Christian Lechner and Ulrich Rössler — Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany

In recent years the spin degree-of-freedom of carriers in semiconductors and semiconductor heterostructures has become essential for the development of *spintronic* devices. For their realization the understanding of *spin relaxation* and *spin dephasing* is of central importance. The corresponding relaxation times have so far mostly been described by phenomenological models.

Here we present a microscopic theory of the spin dynamics with emphasis on spin-relaxation and -dephasing due to electron-phonon interaction. We use the *density matrix approach* known from the description of ultrafast carrier dynamics [1]. This scheme has been extended towards coherent spin dynamics using the Hartree-Fock truncation [2]. We go beyond this approximation by explicitly including the electron-phonon interaction on a microscopic level [3]. An extension of the equations of motion to entries of the phonon-assisted density matrix is required to account for scattering. They are treated in the Boltzmann-limit as well as beyond this limit leading to microscopic expressions for the spin relaxation times. Furthermore we give an analytical solution of the derived equations by applying the *Jaynes-Cummings model* [4].

[1] F. Rossi et al., Rev. Mod. Phys. **74** (2002).
[2] U. Rössler; phys. stat. sol. (b) **234** (2002).
[3] C. Lechneret al.; cond-mat/0407358v2 (2004).
[4] E.T Jaynes et al.; Proc. IEEE **51** (1963).

HL 3.2 Fr 11:00 TU P164

Zitterbewegung of electronic wave packets in semiconductor nanostructures — •John Schliemann[1], Daniel Loss[1], and R.M. Westervelt[2] — [1]University of Basel — [2]Havard University

We study the zitterbewegung of electronic wave packets in III-V zincblende semiconductor quantum wells due to spin-orbit coupling. Our results suggest a direct experimental proof of this fundamental effect, confirming a long-standing theoretical prediction. For electron motion in a harmonic quantum wire, we find a resonance condition maximizing the zitterbewegung. We also consider the zitterbewegung of heavy holes in quantum wells under the influence of Rashba spin-orbit coupling.

HL 3.3 Fr 11:15 TU P164

Spin-double refraction in two-dimensional electron gas — •Vincenzo Marigliano Ramaglia[1], Dario Bercioux[1,2], Vittorio Cataudella[1], Giulio De Filippis[1], and Carmine Antonio Perroni[1] — [1]Coherentia-INFM and "Federico II" University of Naples, I-80126, Italy — [2]Institut für Theoretische Physik, Universität Regensburg, D-93040, Germany

Spin-double refraction [1] is observed in two-dimensional electron gas when electrons are injected with an angle out of normal on an interface separating a region without Rashba effect [2] from a region with it. The behavior of the electron spin in such scattering is analogous of the polarization of the light in a biaxial crystal.

This phenomenon can be used to realize a spin-field effect transistor [3] without ferromagnetic contact [4]. The source and the drain could be realized using n^+-semiconductors. The main characteristic of this device is that, fixed the injection angle, above a critical value of the Rashba effect, the transmission and the polarization behave in the same oscillating way [4].

[1] V. Marigliano Ramaglia, D. Bercioux, V. Cataudella, G. De Filippis,A.C. Perroni and F. Ventriglia, Eur. Phys. J. B **36** 365 (2003). [2] Yu A. Bychkov and E.I. Rashba, J. Phys. C: Solid State Phys. **17**, 6039 (1984). [3] S. Datta and B. Das, Appl. Phys. Lett. **56**, 665 (1990). [4] V. Marigliano Ramaglia, D. Bercioux, V. Cataudella, G. De Filippis and A.C. Perroni, cond-mat/0403534.

HL 3.4 Fr 11:30 TU P164

Spinrelaxation bei Anwesenheit eines elektrischen Feldes — •Olaf Bleibaum — Institut für Theoretische Physik, Otto-von-Guericke Universität Magdeburg, PF 4120, 39016 Magdeburg

Der Einfluss eines elektrischen Feldes auf die Spinrelaxation in einem Halbleiter mit Rashba-Wechselwirkung wird im Rahmen einer feldtheoretischen Formulierung studiert. Die Untersuchung zeigt, dass ein elektrisches Feld direkten Einfluss auf die Relaxationsrate und den Charakter der Relaxation hat. Überschreitet das Feld ein kritisches Feld, so führt es zu einer zusätzlichen Drehung der Magnetisierung, die mit Hilfe optischer Techniken leicht beobachtet werden könnte. In dem Beitrag untersuchen wir die Abhängigkeit der Rotationsfrequenz und des kritischen Feldes von den Materialparametern und der Stärke des elektrischen Feldes und studieren den Einfluss von Quantenkorrekturen auf die Relaxation.

HL 3.5 Fr 11:45 TU P164

First-principles studies of $Mg_xZn_{1-x}O$ alloys — M. Bouhassoune[1], A. Ernst[1], •J. Henk[1], P. Bruno[1], M. Däne[2], D. Ködderitzsch[2], and W. Hergert[2] — [1]MPI für Mikrostrukturphysik, Halle/S., Germany — [2]Martin-Luther-Universität Halle-Wittenberg, Halle/S., Germany

Recent research on O-based semiconductors (e. g., ZnO, MgO) suggested an enormous potential for applications in optics and electronics. One important parameter in device design is the width of the fundamental bandgap which, for example, determines the conductance of tunneling devices. One method to modify the band gap is alloying ('bandgap engineering'). We report on a first-principles study of $Mg_xZn_{1-x}O$ for various concentrations x and crystal structures. The phase transition from the wurtzite (ZnO) to the rock-salt structure (MgO) was found at $x = 0.36$, i. e., close to the experimental value of $x_{\mathrm{exp}} = 0.4$. The fundamental band gap increases upon alloying of ZnO with Mg. Although its size is underestimated due to the local-density approximation, the trends in experiment are fully reproduced.

HL 3.6 Fr 12:00 TU P164

Properties of a nondispersive Mn-3d band in $(Ga_xMn_{1-x})As$ — A. Ernst, L. M. Sandratskii, M. Bouhassoune, •J. Henk, and P. Bruno — MPI für Mikrostrukturphysik, Halle/S., Germany

The magnetic properties of Mn-based diluted magnetic semiconductors (DMS) depend significantly on the energy position of the Mn-3d levels. Recent photoemission experiments [1] reported on a nondispersive band at 0.3 eV binding energy in $(Ga_xMn_{1-x})As$ which was attributed to Mn impurities. The combination of low dispersion and small Mn-3d contribution makes the nature of this band puzzling. Hence, first-principles KKR-CPA calculations were performed for both Mn substituting Ga and for Mn in the interstitial in various magnetic configurations. A nondispersive band with the experimental binding energy shows up in the Mn-interstitial case, but does not in the pure substitutional alloy. It has Mn-3d character, and its low experimental intensity is explained by its low spectral weight. Further, its occurrence is robust against various magnetic configurations of the substitutional and the interstitial Mn atoms.

[1] J. Okabayashi, A. Kimura, O. Rader, T. Mizokawa, A. Fujimori, T. Hayashi, and M. Tanaka, Phys. Rev. B **64** (2001) 125304.

HL 3.7 Fr 12:15 TU P164

Spin Transport and Manipulation by Dynamic Quantum Dots — •James A. H. Stotz, Rudolph Hey, Paulo V. Santos, and Klaus H. Ploog — Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin, Germany

We present a spatially resolved photoluminescence (PL) study of spin transport in confined geometries via a new form of quantum dots – denoted as dynamic quantum dots (DQDs). The DQDs are produced by the superposition of piezoelectric fields from surface acoustic waves (SAWs) propagating along orthogonal directions on a GaAs/(Al,Ga)As quantum well sample. Within the DQD array, spin polarized carriers are excited

by circularly polarized laser light and captured by the DQDs. The carriers are then transported at a velocity determined by the SAWs, and the spin transport is detected by the circular polarization of the resulting PL. The photogenerated electrons and holes are spatially separated by the piezoelectric potential of the DQDs resulting in a dramatic increase of the spin-polarized PL signal and, conseqently, of the electron-spin lifetime. In addition, we demonstrate that the electron spins can be transported over distances exceeding 70 μm, which corresponds to a further increase in their spin lifetimes of more than an order of magnitude. These long spin lifetimes are attributed to the reduction of the D'yakonov-Perel' spin scattering mechanism within the confinement potential of the DQDs. Futhermore, application of an external magnetic field enables the electron spin state to be manipulated during transport.

HL 3.8 Fr 12:30 TU P164

Spin Transport by Surface Acoustic Waves in (110) GaAs Quantum Wells — •Yang Guang, Fernando Iikawa, Rudolph Hey, and Paulo V. Santos — Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin, Germany

The manipulation and transport of spins are critical steps towards the realization of novel, functional devices for information processing, quantum computing, and quantum cryptography. Recently, we have demonstrated that the piezoelectric field induced by a surface acoustic wave (SAW) can be applied to increase the lifetime of photogenerated spins and transport them in semiconductor quantum wells (QWs) [1]. One of the limitation of the SAW-induced spin transport is the rather slow acoustic propagation velocity, which requires very long spin lifetimes for large (i.e., several tens of μm) transport lengths. In this work, we demonstrate spin transport lengths approaching 20 μm in GaAs/(Al,Ga)As QWs grown along the [110] direction. The longer lifetimes and transport lengths under the SAW fields are attributed to the simultaneous quenching of the excitonic [2] and D'yakonov-Perel (DP) spin relaxation mechanisms in (110) QWs [3]. We further show that the spins can be manipulated during transport by applying a magnetic field perpendicular to the carrier propagation direction, thus opening the way for applications in quantum information processing.

[1] T. Sogawa *et al.*, Phys. Rev. Lett. **87**, 276601 (2001)
[2] M. Z. Maialle *et al.*, Phys. Rev. **B47**, 15776 (1993)
[3] Y. Ohno *et al.*, Phys. Rev. Lett. **83**, 4196 (1999)

HL 3.9 Fr 12:45 TU P164

Hybrid ferromagnet/semiconductor nanostructures on a cleaved (110) InAs surface: spin-valve effect and extraordinary magnetoresistance — •Andreas Wittmann and Dirk Grundler — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstrasse 11, D-20355 Hamburg, Germany

We present a novel design for a ferromagnet/semiconductor hybrid transistor. For this, a ferromagnetic film is deposited on a cleaved InAs/InGaAs heterostructure incorporating a two dimensional electron system (2DES). As no Shottky barrier is present we obtain an excellent Ohmic interface contact with a measured resistance close to the Sharvin resistance.

To separate the FM layer on the cleaved edge into a source and a drain electrode we have used a shadow evaporation technique. This allowed us to tailor the separation length down to about 0.2 μm which was shorter than the mean free path in the 2DES. We have performed magnetotransport experiments and observe hysteretic spin–valve–like effects and a large positive magnetorestistance. We attribute the latter to the extraordinary magnetoresistance effect.

Currently we perform experiments on samples which are cleaved in situ right before evaporation. Source and drain are nanostructured by scratching the film with the tip of an atomic force microscope. This results in smaller separation lengths of the contacts. We present our latest results in this direction.

We acknowledge financial support by the DFG and the BMBF.

HL 3.10 Fr 13:00 TU P164

Magneto-transport in MnAs/GaAs:Mn paramagnetic-ferromagnetic hybrids grown by MOVPE and obtained by annealing of MBE-grown (Ga,Mn)As — •Shuangli Ye, Peter J. Klar, Wolfram Heimbrodt, Michael Lampalzer, Kerstin Volz, and Wolfgang Stolz — Department of Physics and Material Sciences Center, Philipps-University of Marburg, Germany

The MnAs/GaAs:Mn granular material consists of MnAs nanoclusters embedded in a GaAs:Mn matrix. The clusters are ferromagnetic or superparamagnetic (depending on size) at room temperature and compatibile with III-V heterostructures which makes them suitable for possible applications in magneto-optic or spintronic semiconductor devices. Here, we compare the physical properties of the two kinds of (Ga,Mn)As:MnAs paramagnetic-ferromagnetic hybrids prepared either by MOVPE directly or by annealing of (Ga,Mn)As alloys grown by low-temperature MBE. The size and the density of MnAs clusters and the distance between them depends strongly on the growth and annealing parameters. The magnetic properties of clusters determined by ferromagnetic resonance measurements as well as the magneto-transport properties measured in the temperature range from 2 to 300 K in fields up to 10 T will be compared for hybrids fabricated by the two methods. The correlation between the magnetic properties of the ferromagnetic clusters and the paramagnetic matrix with the transport mechanisms will be discussed.

HL 4 Quantenpunkte und -drähte: Optische Eigenschaften I

Zeit: Freitag 10:45–13:30 Raum: TU P-N201

HL 4.1 Fr 10:45 TU P-N201

Influence of well width fluctuations on the binding energy of excitons, charged excitons and biexcitons in GaAs-based quantum wells — •A. Filinov[1], M. Bonitz[1], C. Riva[2], F. Peeters[2], Y. Lozovik[3], A. Bracker[4], and D. Gammon[4] — [1]Institute for Theoretical Physics and Astrophysics, Christian-Albrechts-University Kiel, 24098 Kiel — [2]Departement Fysica, Universiteit Antwerpen, Universiteitsplein 1, B-2610 Antwerpen, Belgium — [3]Institute of Spectroscopy RAS, Moscow region, 142190 Troitsk, Russia — [4]Naval Research Laboratory, Washington DC 20375, USA

The binding energies of electron-hole bound states in quantum wells (QWs) are higher than in bulk, because of the enhanced Coulomb interaction between confined carriers. Besides, there is an active discussion about the influence of disorder (due to the surface defects or charged donors). In the present talk we present theoretical results obtained from first principle Path Integral Monte Carlo simulations. In particular, the influence of quantum well-width fluctuations on the binding energy of excitons, trions and biexcitons in GaAs/Al_xGa_{1-x}As and ZnSe based quantum wells and dots (QD) is analyzed in detail. The results show good quantitative agreement with available experimental data [1], including recent measurements of localized trions in ensemble and individual QDs [2].

[1] A.V. Filinov, C. Riva, F.M. Peeters, Yu.E. Lozovik, and M. Bonitz, Phys. Rev. B 70, 35323 (2004); [2] A.S. Bracker, E.A. Stinaff, D. Gammon, A.V. Filinov, et. al., submitted to Phys. Rev. B 2004.

HL 4.2 Fr 11:00 TU P-N201

Resonante Ramanstreuung in einzelnen InGaAs/GaAs-Quantenpunkten — •Rico Schwartz, Daniel Schwedt und Heinrich Stolz — Universität Rostock, Institut für Physik, AG Halbleiterphysik, Universitätsplatz 3, 18051 Rostock

Es wird über Photolumineszenzuntersuchungen an selbstorganisierten $In_{0,6}Ga_{0,4}As$/GaAs-Quantenpunkten [1] berichtet. Die Anregungsenergie wurde in einem Bereich von etwa 35 bis 55 meV oberhalb der Emission aus dem Grundzustand der Exzitonen variiert und für jede Anregungsenergie wurde ein Photolumineszenzspektrum aufgenommen. In diesen Spektren findet man neben exzitonischer Emission auch Linien, die durch Streuung am longitudinal optischen Quantenpunktphonon ($E_{LO-QP} = 33,5$ meV) oder am longitudinal optischen GaAs-Phonon ($E_{LO-GaAs} = 36,4$ meV) hervorgerufen werden. Fallen die Emissionslinien von Exziton und Quantenpunkt-Phonon energetisch zusammen, kommt es zu resonanter Verstärkung des Streuprozesses. Die Linienbreite der Resonanz ($\Delta E = 0,8$ meV) ist erheblich größer als die Summe der Linienbreiten von Exziton und Phonon, was auf eine starke Exziton-

Phonon-Kopplung im Halbleiterquantenpunkt hinweist.

[1] A. Kuther, M. Bayer, A. Forchel, A. Gorbunov, V. B. Timofeev, F. Schäfer, and J. P. Reithmaier, Phys. Rev. B 58, R7508 (1998)

HL 4.3 Fr 11:15 TU P-N201

Carrier dynamics in single quantum dots and implications on single-photon emission — •Thomas Aichele[1], Val Zwiller[2], and Oliver Benson[1] — [1]Humboldt-Universität zu Berlin — [2]ETH Zürich, Schweiz

Sources for the generation of single photon light states within a defined time interval and with a high extraction efficiency are important devices for a large range of experiments in quantum optics and applications in optical quantum technology [1,2]. In our experiment we study the photoluminescence (PL) of single InP quantum dots [3]. Measurements of the intensity correlation demonstrate the non-classical nature of the PL from a single quantum dot. Moreover, deviations from the simple form of a pure anti-bunching dip reveal peculiar features of the carrier dynamics in quantum dots. We studied bunching and anti-bunching as a function of optical excitation parameters. The origin of the observed effects and their implications on quantum information processing applications are discussed with the help of Monte Carlo simulations.

[1] T.Aichele, V.Zwiller and O.Benson, New J. Phys 6, 90 (2004)
[2] T.Aichele, G.Reinaudi and O.Benson, to appear in PRB (2004)
[3] V.Zwiller, T.Aichele, W.Seifert, J.Persson and O.Benson, APL 82,1509 (2003)

HL 4.4 Fr 11:30 TU P-N201

Recombination rates of excitons and biexcitons in quantum dots — •Michael Wimmer[1], John Shumway[2], and S. V. Nair[3] — [1]Institut für Theoretische Physik, Universität Regensburg — [2]Department of Physics and Astronomy, Arizona State University — [3]Centre for Advanced Nanotechnology, University of Toronto

The properties of interacting electron-hole pairs in a quantum dot are strongly affected by quantum correlations. Important examples include binding energies as well as radiative decay rates. Measurements on the biexciton recombination rate in different material systems lie in the theoretically predicted range of one to two times the rate of single exciton recombination [1].
Recently, configuration interaction (CI) studies have shown that the radiative decay rates depend strongly on the quantum dot size [2]. However, our studies indicate that energy and recombination rates do not converge simultaneously in CI calculations, leading to a systematic underestimation of the decay rate. We have developed a path integral Monte Carlo (PIMC) technique that does not suffer from this problem.
This technique is applied to realistic three-dimensional models of self-assembled quantum dots for different materials. We find that radiative recombination rates of typical dots lie in the cross-over regime between strong and weak confinement and compare these results with experiment.
References:
[1] C. Santori *et al.* PRB **65**, 073310 (2002), G. Bacher *et al.* PRL **83**, 4417 (1999), R. Thompson *et al.* PRB **64**, 201302 (2001)
[2] S. Corni *et al.* PRB **67**, 045313 (2003)

HL 4.5 Fr 11:45 TU P-N201

Electron and hole storage in InAs/GaAs quantum dots — •Witlef Wieczorek[1], Till Warming[1], Martin Geller[1], Viktor M. Ustinov[2], Alexey Zhukov[2], and Dieter Bimberg[1] — [1]Institut für Festkörperphysik, TU Berlin — [2]Ioffe Physico-Technical Institute RAS, St. Petersburg, Russia

Semiconductor quantum dots (QDs) with their possibility to confine single carriers representing one quantum bit of information are possible candidates for future memory devices. The potential of inhomogeneously broadened, self-organized QDs for parallel optical storage is demonstrated by spectral hole burning experiments. We investigate different MBE-grown InAs/GaAs quantum dot structures in order to store either holes or electrons as memory carriers. We demonstrate storage of electrons in QDs: By laser excitation a homogeneously broadened ground state of the QDs is charged leading to a spectrally shifted absorption due to few particle effects in the QDs. This is seen in a photocurrent spectrum as a red shifted, negatively charged Trion relative to the ground state. Storage of electrons opens the opportunity to do spin polarized measurements which are interesting for memory applications and quantum computing. Parts of this work are funded by the European SANDiE NoE, contract no. NMP4-CT-2004-500101 and SFB296 of DFG.

HL 4.6 Fr 12:00 TU P-N201

Optischer Gewinn in Quantenpunkten — •Michael Lorke, Torben R. Nielsen, Jan Seebeck, Paul Gartner und Frank Jahnke — Institut für Theoretische Physik, Universität Bremen

Für Laseranwendungen auf Basis von Halbleiter-Quantenpunkten ist die Kenntnis des optischen Gewinns in solchen Strukturen erforderlich. Für ein System, in dem die lokalisierten Quantenpunktzustände energetisch unterhalb eines Kontinuums von zweidimensionalen Benetzungsschichtzuständen liegen, werden optische Gewinnspektren am Beispiel des InGaAs-Materialsystemes vorgestellt und ihre Abhängigkeit von der Ladungsträgerdichte untersucht.

Im Rahmen einer mikroskopischen Theorie wird der Einfluß der Vielteilchenkorrelationen der Ladungsträger durch Coulomb-Wechselwirkung und Elektron-Phonon-Wechselwirkung auf die Gewinnspektren untersucht. Beiträge zur Coulomb-Überhöhung, zum Dephasieren und zur Energierenormierung werden diskutiert.

Während eine Auswertung der Vielteilchenkorrelationen im Rahmen der Markov-Näherung den optischen Gewinn stark unterschätzt, erhalten wir durch die Einbeziehung von Effekten jenseits der Markov-Näherung einen deutlich höheren optischen Gewinn. Desweiteren ist es wichtig, die Elektron-Phonon-Wechselwirkung auf der Basis von Quantenpunkt-Polaronen zu beschreiben.

HL 4.7 Fr 12:15 TU P-N201

Quantenkinetische Beschreibung von Polaronen in Halbleiter-Quantenpunkten — •Jan Seebeck, Torben R. Nielsen, Paul Gartner und Frank Jahnke — Institut für Theoretische Physik, Universität Bremen

Optoelektronische Anwendungen von Halbleiter-Quantenpunkten erfordern schnelle Streuprozesse der Ladungsträger. Für niedrige Ladungsträgerdichten liefert die Elektron-Phonon-Wechselwirkung den dominierenden Beitrag, der für selbstorganisiert gewachsene Quantenpunkte (QD) mit lokalisierten Zuständen, die energetisch unterhalb eines Kontinuums von delokalisierten Zuständen einer Benetzungsschicht (WL) liegen, untersucht wird.

In einfachen störungstheoretischen Rechnungen, die auf Fermi's Goldener Regel basieren, sind bei der Wechselwirkung mit LO-Phononen diejenigen Streukanäle blockiert, deren Übergangsenergien nicht der LO-Phonon-Energie entsprechen (Phonon Bottleneck). Wir stellen eine quantenkinetische Beschreibung des wechselwirkenden Vielteilchen-Systems vor, wobei die Ladungsträger als Polaronen behandelt werden. Unter Verwendung der spektralen Eigenschaften der QD- und WL-Polaronen werden die quantenkinetischen Gleichungen gelöst und speziell der Ladungsträgereinfang (WL→QD) sowie die Ladungsträgerrelaxation (QD→QD) für Fälle betrachtet, bei denen im Bild freier Zustände energieerhaltende Streuprozesse nicht möglich sind. Die quantenkinetische Beschreibung liefert dabei sogar für das schwach polare Materialsystem InGaAs/GaAs Streuzeiten von wenigen Pikosekunden.

HL 4.8 Fr 12:30 TU P-N201

Dynamics of spontaneous emission from quantum dots in microcavities — •J. Wiersig[1], T. Aschenbrenner[1], N. Baer[1], M. Lorke[1], P. Gartner[1], F. Jahnke[1], M. Benyoucef[2], P. Michler[2], M. Schwab[3], H. Kurtze[3], M. Bayer[3] und A. Forchel[4] — [1]Institut für Theoretische Physik, Universität Bremen, 28334 Bremen — [2]Universität Stuttgart — [3]Universität Dortmund — [4]Universität Würzburg

Controlling the spontaneous emission from semiconductor quantum dots by optical microcavities is important for many applications [1] such as microlasers and single-photon sources. Starting from a fully quantum mechanical theory for the microscopic dynamics of photons, electrons and holes in the coupled system of quantum dots, wetting layer, and microcavity we study the spontaneous emission dynamics. Numerical simulations for (In,Ga)As quantum dots embedded in a three-dimensional micropillar cavity show an enhancement of spontaneous emission due to the Purcell effect as the pillar diameter is varied from 6 to 2 micrometer. The computed time-resolved photoluminescence intensity shows a clear nonexponential decay in agreement with experimental data.

[1] P. Lodahl et al., Nature 430, 654-657 (2004)

HL 4.9 Fr 12:45 TU P-N201

Rekombinationsdynamik lokalisierter Exzitonen in einzelnen InGaN-Quantenpunkten — •Thomas Stempel, Matthias Dworzak, Axel Hoffmann, Lars Reissmann, André Strittmatter und Dieter Bimberg — Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin

Die Photolumineszenz (PL) von InGaN/GaN-Heterostrukturen zeigt ein spezifisches zeitliches Verhalten, das durch ein nichtexponentielles Abklingen und eine zeitliche Rotverschiebung des Lumineszenzmaximums gekennzeichnet ist. Für diese seit langem bekannten Effekte wurde bisher die Abschirmung interner elektrischer Felder verantwortlich gemacht. Zeit- und ortsaufgelöste PL-Untersuchungen an nur wenige nm dicken InGaN-Schichten zeigen jedoch, dass hier die Rekombinationsdynamik nicht aus Abschirmungseffekten resultiert. Stattdessen stellen diese Strukturen bei tiefen Temperaturen Quantenpunkt-Ensembles hoher räumlicher Dichte dar. Die Umverteilung von Ladungsträgern innerhalb des Ensembles von schwächer zu stärker lokalisierenden Quantenpunkten (QP) führt zur beobachteten Rotverschiebung. Das nichtexponentielle Abklingen dagegen resultiert aus der Überlagerung der Abklingkurven einzelner QP-Zustände mit einer breiten Verteilung der Exziton-Lebensdauern.

HL 4.10 Fr 13:00 TU P-N201

Exciton Dephasing in Quantum Dot Molecules — •Egor Muljarov and Roland Zimmermann — Institut für Physik der Humboldt-Universität zu Berlin, Newtonstr. 15, D-12489 Berlin

A microscopic theory of optical transitions in a multilevel excitonic system with linear coupling to acoustic phonons is developed. The cumulant expansion for the linear and four-wave mixing polarizations is generalized to a multilevel system and allows us to calculate the full time dependence and the spectral lineshape of the polarization. In particular, the broadening of zero-phonon lines is evaluated directly. It is shown that in quantum dot molecules real phonon-assisted transitions between exciton states dominate the dephasing, while virtual transitions are of minor importance. The latter are the only source of dephasing in uncoupled quantum dots [1]. Exciton dephasing rates calculated for a few lowest optical transitions depend strongly on interdot distance (tunnelling), electron-hole Coulomb interaction, and asymmetry of the double-dot potentials.

[1] E. Muljarov and R. Zimmermann, Phys. Rev. Lett. **93**, Nov. 2004.

HL 4.11 Fr 13:15 TU P-N201

Investigation of the optical mode structure in pillar microcavities — •N. Baer[1], J. Wiersig[1], P. Gartner[1], F. Jahnke[1], M. Benyoucef[2], S.M. Ulrich[2], P. Michler[2], and A. Forchel[3] — [1]Institute for Theoretical Physics, University of Bremen — [2]University of Stuttgart — [3]University of Würzburg

Due to the wide range of application a detailed understanding of the mode structure in microresonators is desirable. For planar structures, such as VCSELs, the often used 2×2 - transfer-matrix technique is sufficient to describe the experimental results. For pillar structures, however, the transverse confinement becomes essential and this simple approach is no longer applicable.

In a theory-experiment comparison we study the influence of the transverse mode confinement for decreasing pillar diameter on the emission properties of semiconductor quantum dots in micropillars [1]. The mode structure is determined from the solution of vector Maxwell equations for the 3d geometry. For pillar diameters large compared to the light wavelength, results of the mode spectrum obtained from a vectorial transfer-matrix approach [2] agree well with experiments. For smaller diameter the cavity quality is reduced due to less efficient confinement of the modes in the transverse direction. This effect cannot be accounted for in a transfer matrix approach and alternative methods, e.g., mode calculations based on Green's functions techniques are needed. Results show a decreasing transverse mode confinement for smaller pillars diameter.

[1] Benyoucef et al., New J. Phys. **6**, 91 2004
[2] D. Burak and R. Binder, IEEE J. Quantum Electron. **33**, 1205 (1997)

HL 5 Grenz- und Oberflächen

Zeit: Freitag 10:45–11:45 Raum: TU P-N202

HL 5.1 Fr 10:45 TU P-N202

Simulations of electrical force spectra obtainable on semiconductive surfaces — •F. Müller, A.-D. Müller, and M. Hietschold — Chemnitz University of Technology, Institute of Physics, Solid Surfaces Analysis Group, 09107 Chemnitz

The electrical forces between a metallic tip and a semiconductive surface, as detected in Electrical Force Microscopy (EFM), have been studied for various geometries and substrate properties with the finite element simulation tool FEMLab in two and three dimensions. The electrical force components and their second derivative with respect to the bias have been calculated in dependence on the distance and the tip diameter, because this information is directly comparable with electrical force measurements. The lateral resolution achievable with electrical measurements and its dependence on the substrate properties and the tip geometry are derived and explained quantitatively.

HL 5.2 Fr 11:00 TU P-N202

Analyse des strukturellen Übergangs zwischen c-Si/a-Ge: Theorie und Anwendung — •Karsten Thiel[1], Nikolai Borgardt[2], Boris Plikat[3], Tore Niermann[1] und Michael Seibt[1] — [1]IV. Physikalisches Institut der Universität Göttingen und SFB 602, Friedrich-Hund-Platz 1, 37077 Göttingen — [2]Moscow Inst. of Electronic Technologie, 124498 Moscow, Russland — [3]Infineon Technologies, Regensburg

Der strukturelle Übergang zwischen amorphen und kristallinen Materialien wird auf der Basis der hochauflösenden Transmissionselektronenmikroskopie (HRTEM) mittels einer Methode, die die Mittelung der Abbildungen entlang der Grenzfläche beinhaltet, am System c-Si/a-Ge untersucht. Diese gemittelten Abbildungen können unter Verwendung einer zweidimensionalen Verteilungsfunktion, die auf der amorphen Seite durch die mittlere atomare Dichte an der Grenze und auf der kristallinen Seite durch die bekannten Positionen der Atome beschrieben wird, mittels konventioneller Multi-Slice-Verfahren simuliert werden.

Neben der theoretischen Beschreibung werden auch Fragen der praktischen Anwendung diskutiert, wie die Frage der lateralen Auflösung dieses Ansatzes sowie die Frage nach signifikanten Unterschieden in den Verteilungsfunktionen unterschiedlicher Abbildungs- bzw. Mittelungsbereiche.

Durch das kontinuierliche Verschieben des Mittelungsbereiches entlang der Grenzfläche und Variation der lateralen Grösse ist es desweiteren möglich, Informationen über den Verlauf des Übergangs entlang dieser Grenze zu erhalten.

[1] N.I. Borgardt et al., Ultramicroscopy **90** (2002), 241.
[2] N.I. Borgardt et al., Phys. Rev. B **70** (2004), 195307.

HL 5.3 Fr 11:15 TU P-N202

Interatomic bond-order potentials for modelling the growth of semiconductor films — •Ralf Drautz[1], Duc Nguyen-Manh[2], Dewey A Murdick[3], Xiaowang Zhou[3], Brian Gillespie[3], Haydn N G Wadley[3], and David G Pettifor[1] — [1]Department of Materials, University of Oxford, Oxford, UK — [2]Theory Modelling Department, Culham Science Centre/UKAEA, Abingdon, UK — [3]School of Engineering and Applied Science, University of Virginia, Charlottesville VA, USA

Interatomic potentials for simulating the growth of semiconductor films must be able to describe bond breaking and remaking naturally within their remit. In this talk we outline the derivation of interatomic bond-order potentials (BOPs) for sp-valent systems by two well defined approximations within density functional theory. The resulting BOPs include a systematic variation of the bond order with band filling as well as environment dependent screening and are therefore applicable to sp-valent systems in general. As an example, we will discuss simulations of the growth of Si thin films.

HL 5.4 Fr 11:30 TU P-N202

Band alignment in $CuIn_5S_8$ / CuI heterostructures — •Igor Konovalov, Liudmila Makhova, and Rüdiger Szargan — Universität Leipzig, Wilhelm-Ostwald-Institut für Physikalische und Theoretische Chemie, Linnéstr. 2, 04103 Leipzig

Being a typical n-type semiconductor, $CuIn_5S_8$ spinel has a band gap of 1.5 eV. We studied the valence band alignment at the interface between $CuIn_5S_8$ and the typical p-type transparent semiconductor CuI using X-ray photoelectron spectroscopy. Single crystalline $CuIn_5S_8$ was cleaved in-situ and CuI sublimating from a Knudsen cell at 360 °C resulted in a deposition rate of 0.3 Å/min. The band discontinuity was found to include a minor cliff for the minority holes of about 0.1 eV. In non-epitaxial heterojunctions, band alignment with a cliff generally enhances the interface recombination current mechanism through the junction due to the narrowing of the band gap at the interface for the cross-interface recom-

bination involving the interface states. However, the cliff height found here is significantly smaller than that observed in $AgIn_5S_8$ / CuI heterojunctions before. This trend is in correspondence with the larger band gap of $AgIn_5S_8$ and with the doping pinning rule in its application to sulfidic semiconductors close to the equillibrium.

HL 6 Optische Eigenschaften

Zeit: Freitag 10:45–13:00 Raum: TU P-N229

HL 6.1 Fr 10:45 TU P-N229

Dependence on Well Width of the Exchange Instability in Dilute 2D Electron Gases — •Paula Giudici[1], Alejandro R. Goñi[1,2], Christian Thomsen[1], Maik Hauser[3], and Karl Eberl[3] — [1]Institut für Festkörperphysik, PN5-4, Hardenbergstr. 36, 10623 Berlin — [2]Institut de Ciència de Materials de Barcelona, Campus de la UAB, 08193 Bellaterra, Spain — [3]MPI für Festkörperfoschung, Heisenbergstr. 1, 70569 Stuttgart

High-mobility two-dimensional electron gases (2DEG) realized in modulation-doped GaAs single quantum well (SQW) structures are particularly suitable for studies of the many-body behavior of dilute electron systems. Recently, we have shown that a 2DEG undergoes a first-order phase transition when the first-excited subband becomes populated. Furthermore, the occurrence of a spontaneous breakdown of the spin symmetry was predicted, leading to the formation of a ferromagnetic phase. The existence of the spin instability was confirmed by PL and inelastic light scattering experiments at low effective temperatures of the electron gas. In this work we investigate the dependence of the phenomenology of the exchange instability on the SQW-width. For this purpose we studied the emission spectra of three SQW samples which differ only in the well width (20, 25 and 30 nm). The renormalization energy of the spin-polarized phase presents a clear trend for the studied QW widths. This dependence on well thickness indicates that the strength of the exchange interactions is a function of the confinement of the electron wave functions.

HL 6.2 Fr 11:00 TU P-N229

Quantentheorie der inkohärenten Thz-Emission wechselwirkender Plasmen in Gasen und Halbleitern — •Marten Richter, Stefan Butscher, Martin Schaarschmidt und Andreas Knorr — Institut für Theoretische Physik, AG Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Hardenbergstraße 36 PN 7-1, 10623 Berlin

Die Spektren der spontanen Emission im Terahertzbereich wechselwirkender Plasmen wird theoretisch untersucht. Zunächst wird ein laserinduziertes Elektronen-Ion Plasma betrachtet, in dem die Beiträge der durch Elektron-Ion- und Elektron-Molekül-Streuungen ermöglichten Übergängen innerhalb des Kontinuums der freier Elektronen betrachtet werden. Dieser Emissionsmechnismus wird dann auf Elektronenplasmen in einem Halbleiterquantenfilm-Subband übertragen, wo die Beiträge der Elektron-Phonon-Wechselwirkung Übergänge zwischen den Kontinuumszuständen der Elektronen ermöglichen.

HL 6.3 Fr 11:15 TU P-N229

Quantenkinetik von Halbleiter Intersubband Ünergängen. — •Stefan Butscher, Jens Förstner, Ines Walmüller und Andreas Knorr — Institut für theoretische Physik, Nichtlineare Optik und Quantenelektonik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

Der Einfluss der Quantenkinetik der Elektron-Phonon Wechselwirkung auf die optischen Eigenschaften von Intersubband Übergängen [1] in GaAs/GaAlAs Halbleiter Quantenfilmen wird untersucht. Im Bereich der linearen Optik wird die Ausbildung von Polaronresonanzen diskutiert [2]. Bei nichtlinearen Anregung zeigen sich Gedächtniseffekte der Wechselwirkung und die Verletzung der Energieerhaltung insbesondere bei Subbändern mit einer Energielücke unterhalb der Phonon Energie.

[1] I.Waldmüller et al, Phys.Rev.B 69,205310 (2004)
[2] S.Butscher et al, phys. stat. sol. (b) 241, R49-R51 (2004)

HL 6.4 Fr 11:30 TU P-N229

Leuchtet ein Halbleiter bei Zimmertemperatur ohne Anregung? — •Stefan Hanna und Alois Seilmeier — Physikalisches Institut, Universität Bayreuth, 95440 Bayreuth

Liegt ein Halbleiter im thermischen Gleichgewicht vor, muss eine Rekombinationsrate existieren, die der thermischen Generationsrate von Elektron-Loch-Paaren gleich ist. Generell dominiert bei Zimmertemperatur die strahlungslose Rekombination. Nach dem Kirchhoffschen Strahlungsgesetz ist allerdings wegen der Absorption des Halbleiters auch eine bandkantennahe Strahlungsemission zu erwarten. Es stellt sich die Frage, ob diese strahlende Interband-Rekombination auch bei Zimmertemperatur als Lichtemissionsspektrum nachzuweisen ist. Dazu werden undotierte Halbleiterproben definiert auf erhöhte Temperaturen von ca. 100°C gebracht, um deren Emission gegen die thermische Umgebungsstrahlung diskriminieren zu können. Das Lumineszenzspektrum wird über ein Gitterspektrometer und ein CCD-Element gemessen. Man beobachtet Spektren, die ein Maximum nahe der Bandkante ähnlich einem Photolumineszenzspektrum aufweisen und die unter Verwendung des Planckschen Strahlungsgesetzes und des Absorptionsspektrums der Probe verstanden werden können. Untersucht wird insbesondere die Emission kommerziell verfügbarer halbleiterdotierter Gläser im nahen infraroten Spektralbereich. Weiterhin werden Resultate für die Volumenhalbleiter GaAs und InP vorgestellt.

HL 6.5 Fr 11:45 TU P-N229

Photoleitungsspektroskopie an InAlAs/InAs/InAlAs/GaAs-Halbleiterstrukturen im Bereich der GaAs-Reststrahlenbande — •N. Mecking, K. Bittkau, Y.S. Gui, Ch. Heyn, D. Heitmann und C.-M. Hu — Institut für angewandte Physik, Universität Hamburg, Jugiusstraße 11, 20355 Hamburg

Wir haben das ferninfrarote Photoleitungsspektrum eines 2DES in einem InAs-Quantenwell zwischen zwei In(0.75)Al(0.25)As-Schichten untersucht. Dieses System ist als MBE-Struktur auf GaAs aufgewachsen. Aufgrund der niedrigen effektiven Elektronenmasse von InAlAs (hier: 0.033 me) ist es möglich die Position der Zyklotronresonanz des 2DES bei Magnetfeldern von ca. 10 T im Bereich der GaAs-Reststrahlenbande (ca. 250 - 300 cm-1) zu beobachten. Obwohl das 2DES 1400 nm vom GaAs-Substrat entfernt ist, weicht das Photoleitungsspektrum in diesem Bereich jedoch sehr stark von der einfachen Lorentzform der Zyklotronresonanz ab. Daher haben wir das elektromagnetische Feld der ferninfraroten Strahlung in unserem Multischichtsystem berechnet und auf diese Weise durch Vergleich mit dem so gewonnenen Absorptionsspektrums des 2DES gezeigt, dass die Abweichung vom Lorentzprofil durch Interferenzeffekte verursacht wird [1]. Zusätzlich können wir anhand des berechneten Profils auch noch ein scharfes Minimum bei der InAs-LO-Phonon-Energie als Polaronkopplungseffekt zwischen den Elektronen und LO-Phononen identifizieren. Dagegen sehen wir keinen Hinweis für einen Kopplungseffekt zwischen Elektronen und TO-Phononen.

[1] K. Bittkau, N. Mecking, Y.S. Gui, Ch. Heyn, D. Heitmann and C.-M. Hu, Phys. Rev. B. (submitted)

HL 6.6 Fr 12:00 TU P-N229

Polariton Propagation in Semiconductor Heterostructures — •Stefan Schumacher[1], Gerd Czycholl[1], Frank Jahnke[1], Iryna Kudyk[2], Ilja Rückmann[2], and Jürgen Gutowski[2] — [1]Institut für Theoretische Physik, Universität Bremen — [2]Institut für Festkörperphysik, Universität Bremen

A microscopic theory for linear and nonlinear polariton propagation is presented. Based on the dynamics controlled truncation (DCT) formalism a $\chi^{(3)}$-theory for the relevant density matrix elements is introduced. The theory incorporates both, coherent optical nonlinearities and propagation effects for spatially inhomogeneous semiconductor heterostructures.

Propagation effects are investigated in a regime, where the coherent material polarization as well as the optical fields are strongly influenced by the boundaries of the system. Ambiguities due to additional boundary condition (ABCs) are avoided by a direct solution of the quantum mechanical problems for the exciton and biexciton motion within the sample boundaries together with Maxwell's equations.

Linear and nonlinear transmission spectra in the coherent optical regime are analyzed for different excitation conditions. A direct theory-experiment comparison is given for a series of ZnSe/ZnSSe heterostructures. In contrast to the linear regime exciton-exciton Coulomb interaction turns out to strongly couple spectrally well-separated polariton states in nonlinear optics.

HL 6.7 Fr 12:15 TU P-N229

Resonanzfluoreszenz von Quantenfilmexzitonen: homogene vs. inhomogene Linienverbreiterung — •Daniel Schwedt[1], Heinrich Stolz[1], Hyatt M. Gibbs[2] und Galina Khitrova[2] — [1]Institut für Physik, Universität Rostock, Universitätsplatz 3, D-18051 Rostock — [2]Optical Sciences Center, The University of Arizona, Tucson, Arizona 85721-0094, USA

Die spektrale Linienform der Lumineszenz aus Quantenfilmen (QW) hängt stark von der Wachstumsunordnung an den Grenzflächen der Schicht zum Barrierenmaterial ab. Dies resultiert in einer Verteilung der Resonanzenergien (inhomogene Linienbreite) und in einer Ausrichtung der Übergangsdipole der Exzitonen. Für GaAs-QWs lassen sich die anregten Exzitonen bei geringen Anregungsdichten gut als ungeordnete Ensemble aus Dreiniveausystemen beschreiben [1]. Um die allgemeine Gültigkeit dieses Modells zu prüfen, haben wir Resonanzfluoreszenzexperimente an einem 8 nm breiten InGaAs-QW durchgeführt und vergleichen diese mit Modellrechnungen. Die Emission zeigt in diesem Fall eine starke Überlagerung von inhomogener und homogener Linienverbreiterung.
[1] D. Schwedt, Ch. Nacke, H. Stolz, S. Eshlaghi, D. Reuter and A. Wieck, phys. stat. sol. (b) **240**, 9 (2003).

HL 6.8 Fr 12:30 TU P-N229

Nonperturbative Theory of Exciton-Phonon Resonances in Semiconductor Absorption — •Karsten Hannewald and Peter Bobbert — Group Polymer Physics, Eindhoven Polymer Laboratories, Technische Universiteit Eindhoven, The Netherlands

We present a novel theory of exciton-phonon resonances, a commonly observed feature in near-band-gap semiconductor spectroscopy. Our results generalize the textbook absorption formula for a coupled atom/molecule-phonon system [1] to the case of semiconductors. The strength of our approach is the simultaneous inclusion of the dispersive single-particle band structures and charge-carrier Coulomb interactions while, at the same time, treating the electron-phonon interaction nonperturbatively [2]. Numerical studies for a simplified model crystal provide a proof-of-principle for the practical usefulness of our approach.
[1] G.D. Mahan, Many Particle Physics, (Plenum Press, London, 1990).
[2] K. Hannewald and P.A. Bobbert, submitted to Phys. Rev. Lett.

HL 6.9 Fr 12:45 TU P-N229

Exciton Diamagnetic Shift Reveals New Features in Disorder Statistics — •Michal Grochol, Frank Grosse, and Roland Zimmermann — Institut für Physik der Humboldt-Universität zu Berlin, Newtonstr. 15, 12489 Berlin, Germany

As the well-known near-field optical experiment [1] has shown, the diamagnetic shift varies among individual exciton lines in disordered quantum wells. Our calculations based on the full solution of the exciton Schrödinger equation in electron and hole coordinates [2] reveal a correlation between diamagnetic shift and wave function localization. A parallel computer code is developed to handle large scale simulations for different potential types. The diamagnetic shift average value and fluctuations as a function of the exciton transition energy are calculated. The relation between the underlying potential statistics and the diamagnetic shift is analyzed making the diamagnetic shift an experimental tool for investigating the underlying potential landscape.
[1] H. F. Hess, E. Betzig, T. D. Harris, L. N. Pfeiffer, and K. W. West, Science **264**, 1740 (1994).
[2] M. Grochol, F. Grosse, and R. Zimmermann, to appear in J. Lumin. (2004).

HL 7 Transporteigenschaften

Zeit: Freitag 10:45–13:00 Raum: TU P-N226

HL 7.1 Fr 10:45 TU P-N226

A Practical Scheme for Quantum Transport using Time-Dependent Density Functional Theory — •Stefan Kurth[1], Gianluca Stefanucci[2], Carl-Olof Almbladh[2], Angel Rubio[3], and Eberhard K.U. Gross[1] — [1]Institut für Theoretische Physik, FU Berlin, Berlin, Germany — [2]Solid State Theory, Lund University, Lund, Sweden — [3]Donostia International Physics Center, San Sebastian/Donostia, Spain

The Landauer formalism is a popular method to calculate the current of non-interacting electrons through a mesoscopic or nanoscopic system connected to two (or more) macroscopic electrodes in the steady-state. Here we present a *time-dependent* description of transport based on the time evolution of the non-interacting Schrödinger equation. We develop a numerical algorithm for the time propagation of extended states. For simple model systems, the scheme is used to compute the time-dependent current in response to an external dc or ac bias. As expected, for a dc bias the system evolves to a steady state. Using the algorithm in the framework of time-dependent density functional theory allows for the description of transport of *interacting* electrons beyond the Landauer formalism.

HL 7.2 Fr 11:00 TU P-N226

Electron localization in quantum networks — •Dario Bercioux[1,2], Michele Governale[3], Vittorio Cataudella[1], and Vincenzo Marigliano Ramaglia[1] — [1]Coherentia-INFN and "Federico II" University of Naples, I-80126, Italy — [2]Institut für Theoretische Physik, Universität Regensburg, D-93040, Germany — [3]NEST-INFM and Scuola Normale Superiore, Pisa, I-56126, Italy

Quantum networks are graphs of one-dimensional wires connected at nodes. For networks made up of quantum wires realized in semiconductor heterostructures, spin-orbit coupling due to the lack of inversion symmetry in the growth direction (Rashba effect[1]) plays an important role. We show that in particular quantum network extending in only one-dimension (chain of square loops connected at one vertex), Rashba effect gives rise to a electron localization phenomena [2]. This localization effect can be attributed to the spin precession due to the Rashba effect. Similar localization phenomena are observed in presence of magnetic field [3,4]. Both the effects are due to the strong interplay between the external fields and the geometry of the network. Here we present these effect in one- and two-dimensional cases showing that in special situation the interplay of magnetic field and Rashba effect completely destroys the localization effect.
[1] Yu A. Bychkov and E.I. Rashba, J. Phys. C: Solid State Phys. **17**, 6039 (1984). [2] D. Bercioux, M. Governale, V. Cataudella and V. Marigliano Ramaglia, Phys. Rev. Lett. **93**, 56802 (2004). [3] J. Vidal, R. Mosseri and B. Douçot, Phys. Rev. Lett. **81**, 5888 (1998). [4] C. Naud, G. Faini, and D. Mailly, Phys. Rev. Lett. **86**, 5104 (2001).

HL 7.3 Fr 11:15 TU P-N226

Magneto-transport measurements on evenly curved Hall bars — •Olrik Schumacher[1], Stefan Mendach[1], Matthias Holz[2], Holger Welsch[1], Christian Heyn[1] und Wolfgang Hansen[1] — [1]Institut für Angewandte Physik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg — [2]I. Institut für Theoretische Physik, Universität Hamburg, Jungiusstr. 9, 20355 Hamburg

We present transport measurements on evenly curved Hall bars integrated into InGaAs-microtubes. The method of self-rolling strained semiconductor double layers enables to build tubes with tuneable radii [1,2]. By the use of an optimized epitaxial layer design combined with a special lithographic procedure we are able to fabricate GaAs/InGaAs-microtubes containing a two-dimensional electron system (2-DES) in the tube walls. This opens up the possibility to perform transport measurements on evenly curved Hall bars with a strongly modulated magnetic field component perpendicular to the 2-DES plane. Transport measurements on such curved Hall bars with current direction along the curvature exhibit pronounced Shubnikow-de Haas oscillations which are found to be associated with the maximum perpendicular magnetic field component between the voltage contacts. Furthermore, we find a magnetic field inversion asymmetry depending on the perpendicular field component distribution along the curved Hall bar. For small magnetic fields we explain this asymmetry in classical terms using numerical simulations, for higher magnetic fields the Landauer Büttiker formalism is applied.
[1] V. Ya. Prinz et al., Physica E 6 (2000) 828-831
[2] O. G. Schmidt, K. Eberl, Nature 410 (2001) 168

HL 7.4 Fr 11:30 TU P-N226

Influence of N on the electron transport in (Ga,In)(N,As) probed by magnetotransport under hydrostatic pressure — •J. Teubert, P.J. Klar, W. Heimbrodt, K. Volz, and W. Stolz — Department of Physics and Material Sciences Center, Philipps-University of Marburg, Germany

Incorporation of small amounts of nitrogen into GaAs and (Ga,In)As results in considerable changes of the electronic properties of these materials. Whereas the optical properties are already extensively studied, there is only little knowledge about the effects of nitrogen incorporation onto the electronic transport behaviour of these III-V alloys. Magnetoresistance (MR) and Hall measurements at temperatures between 2 and 280 K and fields up to 10 T show large negative MR effects for n-type samples whereas p-type samples behave like conventional III-V alloys. We present first magnetotransport measurements under hydrostatic pressure up to 20 kbar for n-type (Ga,In)(N,As) samples. All the results can be explained qualitatively by the energetic and spatial disorder effects induced by N in the conduction band.

HL 7.5 Fr 11:45 TU P-N226

Admitances of quantum MIS (metal-insulator-semiconductor)-type structures — •Paul Racec[1,2] and Ulrich Wulf[3,1] — [1]IHP/BTU Joint Lab, Postfach 101344, 03013 Cottbus, Germany — [2]National Institute of Materials Physics, PO Box MG-7, 077125 Bucharest Magurele, Romania — [3]Brandenburgische Technische Universität Cottbus, Fakultät 1, Postfach 101344, 03013 Cottbus, Germany

We perform calculations of the charge-charge corelation function in open quantum nanostructures in the frame of random phase approximation. We use single particle wave-functions obtained in a separate static Hartee calculations. Full quantum-mechanical expressions for admitances of MIS (metal-insulator-semiconductor)-type nanostructures are given. The turnover frequency in the capacitance is associated with the lifetime of a quasi-bound state. Qualitative comparison with experimental data is also provided.

HL 7.6 Fr 12:00 TU P-N226

Quantenpunktelektronen als kontrollierbare Streuzentren für 2D-Elektronengase — •Marco Russ[1], Axel Lorke[1], Dirk Reuter[2] und Andreas D. Wieck[2] — [1]Laboratorium für Festkörperphysik, Universität Duisburg-Essen, Lotharstr. 1, 47048 Duisburg — [2]Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstr. 150, 44780 Bochum

AlGaAs-Heterostrukturen, die in einem geringen Abstand ein zweidimensionales Elektronengas und eine Lage selbstorganisierter InAs-Quantenpunkte enthalten, zeigen neben der grundsätzlich verringerten Beweglichkeit einige Besonderheiten in ihren Transporteigenschaften, deren Ursache noch nicht vollständig geklärt ist. Selbstorganisierte Quantenpunkte beeinflussen ihre Umgebung nicht nur durch strukturelle Effekte (Verspannung), sondern auch durch Wechselwirkungen mit den eingeschlossenen Elektronen, deren Zahl im Experiment in situ steuerbar ist. Hier werden Messungen im Temperaturbereich von 230mK-4,2K für verschiedene Dot-2DEG-Abstände vorgestellt, die eine Trennung dieser beiden Streumechanismen erlauben und quantitativ den Einfluss zusätzlicher Ladungen in der Quantenpunktschicht auf die Transporteigenschaften des zweidimensionalen Elektronengases beschreiben. Die Ergebnisse lassen sich unter der Annahme einer linearen Abhängigkeit der Beweglichkeit des 2DEG von der Ladung in der Quantenpunktschicht modellieren, für 6 Elektronen pro Quantenpunkt ergibt sich eine ladungsinduzierte Verringerung der Beweglichkeit von etwa 10%.

HL 7.7 Fr 12:15 TU P-N226

High frequency operation of monolithic GaAs/AlGaAs three terminal junctions — •Christian R. Müller, Lukas Worschech, Daniela Spanheimer, and Alfred Forchel — Technische Physik, Universität Würzburg, 97074 Würzburg

Non-linear transport characteristics of monolithic GaAs/AlGaAs three terminal junctions with junction lengths down to a few 10 nm were studied at room temperature and time dependent voltage variations up to 50 GHz. It is found that with increasing bias voltage applied to one branch, voltage sweeps at the other branch lead to a transistor operation with high gain up to $d\Delta V_{Out}/dV_g \sim 30$. We relate this novel type of operation to an accumulation of electrons in the junction in the strong non-linear regime, which in turn enhances the capactive coupling of the branches. The interplay of electron injection and gating leads to a pronounced peak in the input characteristics. We have studied the high frequency output of the device. Rectification of the input signal is still observed at frequencies up to 20 GHz.

HL 7.8 Fr 12:30 TU P-N226

Intrinsic feedback controlled bistability in an electron Y-branch switch — •David Hartmann, Lukas Worschech, Stefan Lang, Stephan Reitzenstein, and Alfred Forchel — Technische Physik, Universität Würzburg, 97074 Würzburg

Electron Y-branch switches (YBSs) controlled by four independent side-gates have been realized by electron beam lithography and wet etching in a modulation doped GaAs/AlGaAs heterostructure. Asymmetric gate bias allows the study of field effect in YBSs with only one branch exploited as swept gate controlling the channel between the other branch and the stem. Close to the onset limit of gate-current threshold the YBS shows an intrinsic pronounced switching bistability with no need of any external feedback. The input current-voltage characteristics can be tuned to a reversed and a non-reversed response with gain. We will discuss the role of different gate bias on the switching bistability. Different applications as nanoelectronic Schmitt-Trigger and complementary switching device are proposed and demonstrated.

HL 7.9 Fr 12:45 TU P-N226

Separating X-valley electrons in AlAs using quantum point contacts — •F. Erfurth, J. Moser, M. Bichler, D. Schuh, G. Abstreiter, and M. Grayson — Walter Schottky Institut, TU-Muenchen, 85748 Garching

We demonstrate the fabrication of one-dimensional (1D) AlAs electron systems used to distinguish between electrons from different conduction band valleys. Split gates are used to create a quantum point contact (QPC) by depleting two-dimensional (2D) electrons in a 15 nm wide quantum well ($n = 3 \times 10^{11}$ cm^{-2}, $\mu = 5.8$ m^2/Vs). In AlAs, the conduction band X-valley mass is anisotropic ($m_x = 0.19m_0$, $m_y = 1.1m_0$) and doubly degenerate. This degeneracy can be broken at a QPC depending on the QPC alignment relative to the crystal axes. The lateral confinement causes splitting into distinct mass subbands, and by shifting the 1D Fermi level, electrons from a specific valley can be selectively transmitted.
In our experiments we first use a magnetic field to break the valley degeneracy. At the quantum Hall filling factors of $\nu = 2$, $B = 6$ T we are able to separate edge channels into one transmitted valley and one reflected valley channel. At $\nu = 3$, $B = 4$ T ($\nu = 4$, $B = 3$ T) all three (four) channels of alternating valleys can be successively separated. This demonstrates the first successful use of 1D constrictions to distinguish between electrons from different valleys.

HL 8 III-V Halbleiter I

Zeit: Freitag 11:45–13:15 Raum: TU P-N202

HL 8.1 Fr 11:45 TU P-N202

Magnetic-Field-Induced Second Harmonic Generation in the Semiconductor GaAs — •Ingo Sänger[1], V.V. Pavlov[2], A.M. Kalashnikova[2], R.V. Pisarev[2], D.R. Yakovlev[1], and M. Bayer[1] — [1]Experimentelle Physik II, Universität Dortmund, 44221 Dortmund, Otto-Hahn-Str. 4, Germany — [2]A.F.Ioffe Physical Technic Academy of Sciences, 194021 St. Petersburg, Russia

Magnetic-field-induced signal of second harmonic generation (SHG) was found and investigated in GaAs semiconductor. This phenomenon arises due to the symmetry breaking that leads to new nonlinear optical contributions. A series of narrow SHG lines was observed in the spectral range from 1.52 to 1.77 eV that we attribute to magneto-excitons and Landau-level quantization of the band energy spectrum. Model calculations reveal a nonlinear magneto-optical spatial-dispersion as a dominant mechanism that comes together with the electric-dipole term.

HL 8.2 Fr 12:00 TU P-N202

Generalised Wannier Functions: An accurate and efficient way to construct ab-initio tight-binding orbitals — •Matthias Wahn[1,2] and Jörg Neugebauer[1,2] — [1]Fritz-Haber-Institut, Faradayweg 4-6, 14195 Berlin-Dahlem — [2]Max-Planck-Institut für Eisenforschung GmbH, Max-Planck-Straße 1, 40237 Düsseldorf

The tight-binding approximation (TB) provides an efficient and physically transparent basis set. Commonly, the corresponding orbitals and matrix elements are constructed starting from a minimum number of free or confined atomic orbitals. A problem with this approach is that it provides only an approximate basis set for which the completeness is hard to control. Generalized Wannier functions (GWF) [1] provide a minimum basis set while conserving the completeness of the original basis set and provide thus an interesting option. We have therefore implemented the generation of GWF in our plane wave pseudopotential code SFHIngX and checked the efficiency (number of non-vanishing matrix elements) and accuracy (compared to the original band structure) for various III-V semiconductors (GaAs, GaN, InN) and different exchange correlation functionals (LDA, EXX). Based on these results we show that the commonly applied localization criterion (spread function) is not sufficient but that a careful choice of the GWF allows a dramatic improvement of the efficiency.

[1] Nicola Marzari and David Vanderbilt, Phys. Rev. B 56, 12847 (1997).

HL 8.3 Fr 12:15 TU P-N202

Landé g factor of donor bound and free electrons in bulk GaAs — •Stefanie Döhrmann, Daniel Hägele, and Michael Oestreich — Universität Hannover, Institut für Festkörperphysik, Abteilung Nanostrukturen, Appelstr. 2, 30167 Hannover

We have measured the low temperature electron Landé g factor g^* in weakly n-doped bulk GaAs. The g factor is precisely determined by means of spin quantum beats which are measured by time resolved photoluminescence spectroscopy using a synchroscan streakcamera for detection. We discuss the dependence of g^* on excitation excess energy, influence of nuclear spins, excitation density and magnetic field. Two different regimes are identified and attributed to donor bound and free electrons, respectively. We find deviations of the g factor from the generally accepted value of -0.44.

HL 8.4 Fr 12:30 TU P-N202

Characterization and MOVPE growth of InP:Mn and GaN:Mn — •Alex Philippou, Stefan Weeke, Bert Raehmer, Markus Pristovsek, and Wolfgang Richter — Institute of Solid State Physics, TU-Berlin, Hardenbergstrasse 36, Berlin

Magnetic semiconductors are a promising research field for next generation device physics. In this work the metallorganic vapour-phase growth of Mn doped InP and GaN will be reported. The surface topology was analyzed by atomic force microscopy. Clearly the onset of cluster formation could be seen. X-ray diffraction on superlattices was used for estimating the amount of incorporated Mn to be ≈ 3 %. The magnetic and electronic properties were characterized with temperature and field dependent hall measurements and photoluminescence.

HL 8.5 Fr 12:45 TU P-N202

Strukturelle Einflüsse auf die Rekombinationsdynamik in InGaAsN-Quantenfilm-Strukturen — •Radowan Hildebrand[1], Matthias Dworzak[1], Till Warming[1], Axel Hoffmann[1], Massimo Galluppi[2], Lutz Geelhaar[2], Henning Riechert[2], T. Remmle[3] und Martin Albrecht[3] — [1]Instut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin — [2]Infineon Technologies AG, Corporate Research Photonics, 81739 München — [3]Institut für Kristallzüchtung, Max-Born-Str. 2, 12489 Berlin

Der Einbau von Stickstoff in InGaAs-Strukturen und die damit verbundene Verschiebung der Bandlücke in den infraroten Spektralbereich eröffnete dem quaternären Materialsystem InGaAsN seine Anwendung als aktive Schicht in Quantenfilm-Laser-Strukturen für den Spektralbereich zwischen 1,3 und 1,55 μm. Ziel gegenwärtiger Untersuchungen ist eine Optimierung der optischen Eigenschaften dieser Strukturen. Dazu wurden einzelne InGaAsN-Schichten mittels MBE bei verschiedenen Wachstumstemperaturen hergestellt und unterschiedlichen thermischen Ausheilverfahren unterzogen. Strukturelle Untersuchungen mittels hochauflösender Transmissionselektronenmikroskopie zeigen einen Übergang von reinen Quantenfilmen zu inselartigen Strukturen. Wie zeitaufgelöste und temperaturabhängige Photolumineszenzuntersuchungen beweisen, wird die Relaxation und Rekombination optisch angeregter Ladungsträger durch deren Lokalisierung und Umverteilung bestimmt.

HL 8.6 Fr 13:00 TU P-N202

Spinrelaxationszeiten in p-GaAs durch spinsensitive Sättigung der Intersubband-Absorption — •Petra Schneider[1], J. Kainz[1], S.D. Ganichev[1], S.N. Danilov[1], U. Rössler[1], W. Wegscheider[1], D. Weiss[1], W. Prettl[1], V.V. Bel'kov[2], M.M. Glazov[2], L.E. Golub[2] und D. Schuh[3] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg — [2]A. F. Ioffe Physico-Technical Institute, 194021 St. Petersburg, Rußland — [3]Walter Schottky Institut, TU München, 85748 Garching

Die Spinrelaxationszeiten von Löchern in p-leitenden GaAs/AlGaAs Quantentrögen, die durch spinsensitive Sättigung der Absorption von Ferninfrarot-Laserstrahlung gewonnen wurden, werden präsentiert. Die Sättigung der Intersubband-Absorption wird bei der Einstrahlung von zirkular polarisiertem Licht hauptsächlich durch die Spinrelaxation bestimmt. Das Sättigungsverhalten ist für verschiedene Quantentrogbreiten und in einem großen Temperaturbereich untersucht worden. Die Spinrelaxationszeiten wurden aus den gemessenen Sättigungsintensitäten mit Hilfe von theoretisch berechneten Absorptionskoeffizienten bestimmt. Unsere Ergebnisse zeigen, dass für dieses Material der dominierende Relaxationsprozess der D'yakonov-Perel'-Mechanismus ist. Text

HL 9 Hauptvortrag Ohno

Zeit: Freitag 14:15–15:00 Raum: TU P270

Hauptvortrag

HL 9.1 Fr 14:15 TU P270

Ferromagnetic III-V Semiconductors Spintronics — •Hideo Ohno — Research Institute of Electrical Communication, Tohoku University and ERATO, JST

Ferromagnetic III-V semiconductors offer a variety of new possibilities by combining semiconducting properties with magnetic cooperative phenomena [1]. Because of the hole-mediated ferromagnetism, one can turn on and off ferromagnetic phase isothermally and reversibly without changing temperature through electric field control of carrier concentration in a temperature range close to the transition temperature TC [2]. At lower temperatures, one can electrically modify coercive fields at which magnetization reversal takes place [3]. We have thus shown that in a class of ferromagnetic materials, magnetic properties can be electrically controlled just like conductivity of semiconductors can be altered by electric field effect. We have also shown that electrical current driven domain wall motion in a lithographically defined area of ferromagnetic III-V semiconductor structures occurs at current density much lower than the metallic counterparts [4]. The results of current induced magnetization reversal in nanoscale magnetic tunnel junctions in these material systems will also be reported [5].

[1] H. Ohno, Science, 281, 951 (1998).
[2] H. Ohno et al., Nature, 408, 944 (2000).
[3] D. Chiba et al., Science, 301, 943 (2003).
[4] M. Yamanouchi et al., Nature, 428, 539 (2004).
[5] D. Chiba et al., to appear in Phys. Rev. Lett.

HL 10 Spintronik II

Zeit: Freitag 15:00–16:30 Raum: TU P270

HL 10.1 Fr 15:00 TU P270

Elektrische Spininjektion über ferromagnetische Kontakte in LEDs im remanenten Zustand — •N.C. Gerhardt[1], S. Hövel[1], M.R. Hofmann[1], F.-Y. Lo[2], D. Reuter[2], A.D. Wieck[2], E. Schuster[3] und W. Keune[3] — [1]AG Optoelektronische Bauelemente und Werkstoffe, Ruhr-Universität Bochum, Bochum — [2]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Bochum — [3]Laboratorium für Angewandte Physik, Universität Duisburg-Essen, Duisburg

Bei der Spininjektion in Halbleiter-LEDs wurden in den letzten Jahren beeindruckende Erfolge erzielt. Spininjektion in spinoptische Bauelemente über ferromagnetische Kontakte war bisher aber nur mit hohen externen Magnetfeldern möglich. Diese Felder von 1-2 Tesla waren erforderlich, um die Magnetisierung der Kontaktschichten für den optischen Nachweis senkrecht auszurichten.

Wir demonstrieren in diesem Vortrag Spininjektion in GaAs ohne externes Magnetfeld aus dem remanenten Zustand. Hierzu verwenden wir ein Fe/Tb-Multischichtsystem mit senkrechter magnetischer Anisotropie als Spininjektionskontakt auf einer LED-Struktur mit einem 15nm breiten (GaIn)As-QW in der aktiven Zone. Spininjektion aus Remanenz wird über eine Polarisationsanalyse der Elektrolumineszenz bis zu einer Temperatur von 260K zweifelsfrei nachgewiesen.

Wir danken der DFG für die Unterstützung im Rahmen des SFB 491.

HL 10.2 Fr 15:15 TU P270

Dynamics of semiconductor hole systems with effective spin 3/2 — •R. Winkler — Institut für Festkörperphysik, Universität Hannover

Recently, the spin degree of freedom of the charge carriers in semiconductors has become the subject of great interest because of possible novel applications in the field of spintronics. While electrons in the conduction band have spin 1/2, the holes in the valence band of semiconductors like GaAs are characterized by an effective spin 3/2. The dynamics of these hole systems is governed by a strong spin-orbit interaction within the space of spin 3/2 states [1] which gives rise to a splitting of heavy and light hole states in 2D systems. A detailed understanding of hole systems is very important in the context of ferromagnetic semiconductors like GaMnAs where the ferromagnetism is mediated by the spin 3/2 holes in the valence band. We study the spin dynamics of hole systems at magnetic field $B = 0$ and $B > 0$. It is shown that spin 3/2 hole systems behave very different from spin 1/2 electron systems [2]. We discuss possible applications in the field of spintronics.

[1] R. Winkler, *Spin-Orbit Coupling Effects in 2D Electron and Hole Systems* (Springer, Berlin, 2003).
[2] R. Winkler, Phys. Rev. B **70**, 125301 (2004).

HL 10.3 Fr 15:30 TU P270

Spinabhängige Polarisation eines optisch gepumpten VCSELs — •S. Hövel[1], N.C. Gerhardt[1], M.R. Hofmann[1], J. Yang[2], D. Reuter[2] und A.D. Wieck[2] — [1]AG Optoelektronische Bauelement und Werkstoffe, Ruhr-Universität Bochum, Geb. IC 2/156, 44780 Bochum — [2]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Geb. NB, 44780 Bochum

Durch Injektion spinpolarisierter Elektronen in LEDs können derzeit bei Raumtemperatur nur Polarisationsgrade der Emission erreicht werden, die für spin-optoelektronische Anwendungen zu gering sind. Nichtlinearitäten an der Schwelle oberflächenemittierender Mikroresonatorlaser (VCSELs) ermöglichen dagegen eine entscheidende Verstärkung der Polarisationseffekte.

Wir zeigen, dass die Ausgangspolarisation eines optisch gepumpten VCSELs dabei nicht nur in Art und Weise der Eingangspolarisation folgt sondern auch mit einem höheren Polarisationsgrad als die Pumpstrahlung. Aus kleinen Polarisationsgraden der Pumpstrahlung resultieren somit hohe Polarisationsgrade der VCSEL-Emission. Mäßige Spin-Injektionseffizienzen lassen somit für einen elektrisch gepumpten VCSEL hohe Ausgangspolarisationen erwarten.

Wir danken der DFG für die Unterstützung im SFB 491.

HL 10.4 Fr 15:45 TU P270

Spin-orbit coupling and anisotropy of spin splitting — •Jens Könemann[1], D. K. Maude[2], and R. J. Haug[1] — [1]Inst. f. Festkörperphysik, Uni Hannover, Appelstrasse 2, D-30167 Hannover, Germany — [2]High Magnetic Field Laboratory, CNRS, 25 Avenue des Martyrs, BP 166, F-38042 Grenoble cedex 9, France

In our work we investigate the anisotropy of spin splitting of electrons in quantum dots with respect to different configurations of an applied magnetic field and compare it to the effective Land-factor. We explain our results by an interplay between spin-orbit coupling and quantum dot confinement of the electrons [1]. The spin splitting data for both samples display an anisotropy, i. e. the spin splitting caused by the out-of-plane field (with respect to the quantum well plane) is systematically larger than what is created by the in-plane field. In sample A (strong spatial confinement) we observe for the in-plane field orientation a smaller slope of the linear spin-splitting than for the out-of-plane-magnetic field orientation. In contrary, we find in sample B (weak confinement) the same slope of the splitting for both field orientations, but the out-of-plane field orientation of the spin-splitting dependence has a constant energy offset compared to the spin splitting in the in-plane field orientation. We will show that the anisotropy in spin splitting can be traced back to the spin-orbit coupling effects in the lateral electron motion inside the quantum well and that its values in both samples can be related to the same spin-orbit coupling characteristics.

[1] J. Könemann *et al.*, cond-mat/0409054

HL 10.5 Fr 16:00 TU P270

Local carrier induced ferromagnetisms in a II-VI dilute magnetic semiconductor. — •Charles Gould[1], Anatoliy Slobodskyy[1], Pawel Hawrylak[2], Fanyao Qu[2], Taras Slobodskyy[1], Peter Grabs[1], Daniel Supp[1], Georg Schmidt[1], and Laurens Molenkamp[1] — [1]Universität Würzburg (EP3), Am Hubland, D-97074, Würzburg, Germany — [2]Institute for Microstructural Sciences, National Research Council of Canada, Ottawa, Ontario K1A 0R6, Canada

We present transport measurements on an all-II-VI semiconductor tunneling structure consisting of a ZnBeMnSe barrier embedded with CdSe self assembled quantum dots. The zero magnetic field I-V characteristic exhibits many resonant peaks which are identified with tunneling through individual quantum dots. When a magnetic field is applied, the resonant peaks split following the Brillouin-like giant Zeeman splitting of the barrier. Given that there is no Mn in the dots, and the effect of the giant Zeeman splitting on the barrier height has negligible effect on peak position, this confirms that the individual electron levels in the quantum dots couple to the Mn system in the barrier.

More surprising is the observation that the splitting between pairs of states of opposite spin remains finite in the absence of magnetic field. This is explained by in a model taking into account both the antiferromagnetic direct Mn-Mn coupling and the carrier mediate ferromagnetic interaction caused by the presence of unpaired electron spins in the dot. The model confirms that the carriers in our system induce a local ferromagnetic interaction of the Mn ions in the vicinity of the current carrying dot.

HL 10.6 Fr 16:15 TU P270

Very Large Tunneling Anisotropic Magnetoresistance in (Ga,Mn)As based tunnel structures. — •Christian Rüster[1], Charles Gould[1], Tomas Jungwirth[2], Jairo Sinova[3], Gisela Schott[1], Karl Brunner[1], Georg Schmidt[1], and Laurens Molenkamp[1] — [1]Physikalisches Institut (EP3), Universität Würzburg, Würzburg, Germany — [2]Institute of Physics ASCR, Praha 6, Czech Republic — [3]Department of Physics, Texas A and M University, USA

We previously reported the discovery of tunneling anisotropic magnetoresistance, which manifests itself as spin-valve like behaviour in a normal-metal/insulator/ferromagnetic-semiconductor tunneling device, and results from a combination of the anisotropic density of states in the (Ga,Mn)As with respect to the magnetization direction, and a two-step magnetization reversal process in the material.

We now reports on the very large amplification of this effect in a fully epitaxial (Ga,Mn)As/GaAs/(Ga,Mn)As structure. In addition to raising questions about previous reports in the literature interpreting of spin valve behaviour in (Ga,Mn)As based structures as traditional tunneling

magnetoresistance akin to that in metals, the effect reported here also exhibits several novel spintronics features: (i) Both normal and inverted spin-valve signals in a single device; (ii) a large non-hysteretic magnetoresistance for perpendicular magnetic fields; (iii) A sensitivity to the direction of the external magnetic field; (iv) Enormous amplification of the effect at low bias and temperatures to the point of behaving as a true on-off current switch.

HL 11 II-VI Halbleiter I

Zeit: Freitag 15:00–16:30 Raum: TU P164

HL 11.1 Fr 15:00 TU P164

Optische und strukturelle Eigenschaften von MgZnO/ZnO-Hetero- und -Doppelheterostrukturen — •Susanne Heitsch, Gregor Zimmermann, Holger Hochmuth, Gabriele Benndorf, Heidemarie Schmidt, Michael Lorenz und Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, D-04103 Leipzig

MgZnO-Dünnfilme, MgZnO/ZnO-Heterostrukturen und -Doppelheterostrukturen (DHS) wurden auf a-Saphir-Substraten mittels Pulsed Laser Deposition (PLD) abgeschieden. In Photolumineszenz (PL)-Untersuchungen bei 2 K beobachtet man eine Blauverschiebung der Bandlücke des MgZnO mit steigendem Mg-Gehalt. AFM-Untersuchungen zeigen die Rauigkeit der MgZnO-Barriereschichten auf, deuten jedoch auch auf ein gleichmäßiges Wachstum der ZnO-Schichten auf allen auftretenden Facetten des MgZnO hin. PL-Untersuchungen an Heterostrukturen beweisen die gute optische Qualität des auf MgZnO abgeschiedenen ZnO. Für MgZnO/ZnO/MgZnO-DHS mit nominellen Quantengrabendicken von ≤ 6 nm ist in PL-Spektren bei 2 K eine deutliche Intensivierung der vom ZnO herrührenden PL gegenüber dickeren DHS beobachtbar. Temperaturabhängige Messungen zwischen 4.4 und 300 K zeigen, dass die dabei dominierende Rekombination freien Exzitonen zuzuschreiben ist, deren Emissionsenergie durch Confinement-Effekte um bis zu 50 meV gegenüber Bulk-Material blauverschoben ist.

HL 11.2 Fr 15:15 TU P164

Combining quasiparticle energy calculations with exact-exchange density-functional theory for II-VI compounds and group-III-nitrides — •Patrick Rinke[1], Abdallah Qteish[2], Jörg Neugebauer[3], Christoph Freysoldt[1], and Matthias Scheffler[1] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin — [2]Department of Physics, Yarmouk University, Irbid - Jordan — [3]Department of Theoretical Physics, University of Paderborn, Paderborn

We present a systematic *ab initio* study of the electronic structure for selected II-VI compounds and group III nitrides in the zinc-blende structure with special emphasis on the role played by the semicore d-electrons. We show that applying density-functional theory (DFT) in the exact-exchange (EXX) approach [1] leads to an improved description of the d-electron hybridisation compared to the local-density approximation (LDA). Moreover we find that it is essential to use the newly developed EXX pseudopotentials [2] in order to treat core-valence exchange consistenly.

In combination with quasiparticle energy calculations in the GW approximation we achieve very good agreement with available photoemission data. Since the DFT energies and wavefunctions serve as input for the GW calculation we conclude that for these materials EXX constitutes the better groundstate.

[1] M. Städele *et al*, Phys. Rev. Lett. **79** 2089 (1997)
[2] M. Moukara *et al*, J. Phys.: Condens. Matter **12** 6783 (2000)

HL 11.3 Fr 15:30 TU P164

Quadrupole Interaction in Semiconductors with Wurtzite Lattice: DFT-Theory and Experiments — •Sepp Unterricker[1], Veaceslav Samokhvalov[2], Frank Schneider[1] und Marc Dietrich[3] — [1]Institut für Angewandte Physik, TU Bergakademie Freiberg, D-09596 Freiberg — [2]AMD Dresden — [3]Deutsche Solar AG Freiberg

Quadrupole coupling constants as determined by methods like NMR, Mössbauer spectroscopy and PAC (perturbed angular correlations) can be calculated by modern methods of solid state theory from the electronic charge density distribution. In the presented contribution binary semiconductors with wurtzite structure are investigated. The calculations were performed with the WIEN97 code. In a first step accurate displacement parameters u were determined by the minima of total energies and the zero crossing of atomic forces. For host probes the theoretical electric field gradients reflect the experiments well. Especially by the PAC-method cases with impurity probes, e.g. doping atoms, can be measured also. The calculation of such configurations is more expensive because the elementary cell has to be enlarged and atomic relaxations to be considered.

HL 11.4 Fr 15:45 TU P164

Whispering Gallery Moden in hexagonalen Zinkoxid Mikro- und Nanoresonatoren — Th. Nobis, A. Rahm, E. M. Kaidashev, M. Lorenz, M. Grundmann, •Th. Nobis, A. Rahm, E. M. Kaidashev, M. Lorenz und M. Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Linnéstr. 5, D-04103 Leipzig

In den vergangenen Jahren wurden Whispering Gallery Resonatoren, in deren Innern das Licht durch Totalreflexion umläuft, intensiv untersucht. Deren typische laterale Abmessungen liegen im Mikroregime bei $D \gg 1\ \mu m$. Die Nanophotonik erfordert jedoch immer kleinere Kavitäten. Deshalb präsentieren wir in diesem Beitrag orts- und polarisationsabhängige Lumineszenzuntersuchungen an hexagonalen Zinkoxidsäulen und -nadeln, deren Dimensionen bis zu $D \simeq \lambda/n \simeq 200$ nm reichen. Die für ZnO-Bulkmaterial typische grüne Lumineszenz der Nanokristalle weist hierbei charakteristische Peakserien auf. Mittels eines einfachen Ebene-Wellen-Modells können diese Peakserien durch Whispering Gallery Moden (WGM) eines hexagonalen Resonators erklärt werden. Ferner kann an einer einzelnen ZnO Nanonadel systematisch die Blauverschiebung der WGM bei kleiner werdenden Resonatordurchmessern beobachtet und somit direkt der Übergang vom Mikro- ins Nanoregime verfolgt werden. Beim Annähern an die Nadelspitze erkennt man die Anregung von WGM bis zur Modenzahl $N = 1$.

HL 11.5 Fr 16:00 TU P164

Empirical Pseudopotential Calculation of $Zn_{1-x}Mg_xO$ ($0 \leq x \leq 1$) — •Daniel Fritsch, Heidemarie Schmidt, Rüdiger Schmidt-Grund, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften

We have investigated the electronic properties of the ternary alloy $Zn_{1-x}Mg_xO$ ($0 \leq x \leq 1$) by means of the Empirical Pseudopotential Method (EPM). Making use of transferable ionic model potential parameters we obtained the band dispersions of wurtzite ZnO and rocksalt MgO that compare to low-temperature experimental data, thereby validating the transferability of the used EPM parameters. Those transferable parameters are a good starting point for EPM calculations of the ternary alloy ZnMgO by means of the Virtual Crystal Approximation (VCA). We present the calculated band structures of $Zn_{1-x}Mg_xO$ for $0 \leq x \leq 1$ where the alloy dependent crystal modification is wurtzite for $x \leq 0.6$ and rocksalt for $x \geq 0.7$. For a better comparison with room-temperature experimental studies we weighted the EPM parameters with temperature dependent Debye-Waller factors by means of a model introduced by Brooks and Yu.

The obtained room-temperature band structures are discussed with respect to electronic band-to-band transitions leading to critical points in the dielectric function of $Zn_{1-x}Mg_xO$ measured by spectroscopic ellipsometry in the energy range from 0.75 eV up to 9 eV.

HL 11.6 Fr 16:15 TU P164

First-Principles Study on the Role of Oxygen Interstitials in Zinc Oxide — •Paul Erhart, Karsten Albe, and Andreas Klein — TU Darmstadt, Institut für Materialwissenschaft, Petersenstraße 23, 64287 Darmstadt

The electronic and optic properties of zinc oxide are to a large extent controlled by intrinsic and extrinsic defects. Therefore, a detailed understanding of its defect physics is essential for successful defect engineering. In the past a number of first-principles studies has dealt with intrinsic point defects in zinc oxide. While these studies have essentially confirmed the importance of oxygen vacancies and zinc interstitials, the role of oxygen interstitials has been insufficiently explored. We have performed a careful study of numerous oxygen interstitial configurations based on

density-functional theory calculations within the local density approximation. The charge state determines which configuration is energetically preferred: (1) if the defect is negatively charged, the most stable conformation is a split-interstitial which can be regarded as a strongly distorted tetrahedral interstitials; (2) on the other hand, if the oxygen interstitial is neutral or positively charged it assumes a dumbbell-like configuration in which two oxygen atoms share a site. This defect is characterized by a strong oxygen-oxygen bond which gives rise to its particular stability. Thanks to the oxygen-dimer-like structure it is able to compensate positive surplus charges in a manner that its formation energy remains almost constant as its charge state changes from neutral to doubly positive and thus is a potential donor under oxygen-rich conditions.

HL 12 Quantenpunkte und -drähte: Optische Eigenschaften II

Zeit: Freitag 15:00–16:30 Raum: TU P-N201

HL 12.1 Fr 15:00 TU P-N201

Biexciton Rabi oscillations in a single InGaAs/GaAs quantum dot — •Stefan Stufler[1], P. Ester[1], A. Zrenner[1], P. Machnikowski[2], V. M. Axt[2], T. Kuhn[2], and M. Bichler[3] — [1]Universität Paderborn, Warburger Straße 100, D-33098 Paderborn, Germany — [2]Institut für Festkörpertheorie, Westfälische Wilhelms-Universität, 48149 Münster, Germany — [3]Walter Schottky Institut, Technische Universität München, Am Coulombwall, D-85748 Garching, Germany

We report coherent control of the ground state biexciton in a single InGaAs/GaAs quantum dot. Excitation is achieved by resonant two-photon absorption of ps laser pulses. The occupancy of the quantum dot then is measured via the photocurrent. We observe Rabi oscillations which, in contrast to single-exciton oscillations, are not purely sinusoidal in excitation amplitude. This behavior is due to the two-photon excitation process. The experimental data show good qualitative agreement to theoretical curves derived for the assumption that sequential creation of the individual excitons is negligible. We have furthermore investigated the phase stability of coherent superposition states by quantum interference experiments. The observed dephasing times are only slightly shorter than those in according single exciton measurements. We thus are able to prove the feasibility of quantum gates based on the biexciton energy renormalization.

HL 12.2 Fr 15:15 TU P-N201

Absorption and Emission Spectroscopy on a Single Charge-Tunable Quantum Dot — •Martin Kroner[1], Alexander Högele[1], Stefan Seidl[1], Richard J. Warburton[2], Brian D. Gerardot[3], Pierre M. Petroff [3], and Khaled Karrai[1] — [1]Center for NanoScience and Department für Physik, Ludwig-Maximilians-Universität, Munich, Germany — [2]Department of Physics, Heriot-Watt University, Edinburgh, UK — [3]Materials Department, University of California, Santa Barbara, California 93106, USA

We have recently reported resonant interband absorption in the excitonic ground state of a single self-assembled InAs/InGaAs quantum dot [1]. The resonant interband transitions are observed directly as a reduction in the transmission signal when the exciton energy is tuned into resonance with a narrow band laser. This fairly new high-resolution laser spectroscopy technique profits from coherent creation of excitonic states in a single quantum dot, hence providing information about the oscillator strength as well as the lifetime. The excitonic state in the dot can be tuned from neutral to charged, simply by applying a gate voltage, as the dots are embedded in a field effect structure [2]. We measured absorption as well as photoluminescence spectra of the same quantum dot. Comparing these datasets reveals new insight into the electronic states of a quantum dot.

[1] A. Högele et al., Physica E 21 (2004); A. Högele et al., to appear in PRL (2004). [2] R. J. Warburton et al., Nature 405 (2000).

HL 12.3 Fr 15:30 TU P-N201

Heterodyne Four-Wave Mixing on Single Excitonic States — •Brian Patton[1], Wolfgang Langbein[2], and Ulrike Woggon[1] — [1]Experimentelle Physik IIb, Universität Dortmund, Otto-Hahn-Straße 4, 44221 Dortmund — [2]School of Physics and Astronomy, Cardiff University, Cardiff, Wales, UK

Coherent optical spectroscopy on excitonic states allows insights into the underlying physics and opens up the possibility of manipulation of individual quantum states. Non-degenerate four-wave mixing and pump-probe spectroscopy are currently the main techniques. Instead, we use a novel heterodyne four-wave mixing technique which, by spectral interference with a reference signal, allows us to recover both the amplitude and phase of the third-order nonlinear polarisation of the single state. High-NA imaging of the sample allows the recovery of the resonant transient nonlinearity of single localized excitons. Furthermore, the knowledge of the phase of our signal allows subsequent analysis in both time and frequency domains. We have also narrowed the excitation to a single state and used a strong pump pulse to allow us to coherently drive the polarisation of the individual exciton by a desired angle in the Bloch sphere. We analyse the observed Rabi oscillations in the exciton polarisation with regard to the polarisation decay of the transition and we were able to rule out excitation induced dephasing as the source for observed deviations in the behaviour of the oscillations from the ideal 2-level system.

HL 12.4 Fr 15:45 TU P-N201

Demonstration of Phonon Bottleneck in Single Quantum Dot Molecules — •Ruth Oulton[1], Gerhard Ortner[1], Hannes Kurtze[1], Matthias Schwab[1], Dmitri Yakovlev[1], Manfred Bayer[1], Simon Fafard[2], Zbig Wasilewski[2], and Pawel Hawrylak[2] — [1]Experimentelle Physik II, Universität Dortmund, D-44221 Dortmund, Germany — [2]Institute for Microstructural Sciences, National Research Council, Ottawa, K1A 0R6, Canada

The dependence of emission intensity from the tunnel split exciton states in InAs/GaAs quantum dot molecules on their energy separation is studied. Even at the smallest excitation powers luminescence from both states appears in the spectra, when the splitting is smaller than the optical phonon energy. When the splitting becomes larger, emission from the antibonding states is observed only when the systems are optically pumped resulting in Pauli-blocking effects. This demonstrates the existence of an acoustic phonon relaxation bottleneck.

HL 12.5 Fr 16:00 TU P-N201

8-band k·p-theory for Wurtzite Crystals: Electronic Structure of InGaN Quantum Dots — •Momme Winkelnkemper, Andrei Schliwa, Robert Seguin, Sven Rodt, and Dieter Bimberg — Institut für Festkörperphysik, Technische UniversitätBerlin

We present an 8-band **k·p**-model for the calculation of single particle states in wurtzite-type semiconductor quantum dots. Special attention is paid to the influence of pyro- and piezoelectric effects since they have a large impact on electron and hole states, the oscillator strength, as well as the Coulomb interaction within few-particle states like excitons, biexcitons, trions, etc. To calculate all these effects (a) the classical 8-band **k·p**-model is extended to include strain as well as piezoelectric effects similar to the treatment of cubic semiconductors and pyroelectric effects and (b) a configuration interaction method is employed to account for all the few-particle effects like direct Coulomb interaction, exchange and correlation. Finally our results are compared to recent experimental results obtained by cathodoluminescence measurements on single InGaN quantum dots.

Parts of this work are funded by Sfb 296 of DFG and SANDiE Network of Excellence of the European Commission, contract number NMP4-CT-2004-500101.

HL 12.6 Fr 16:15 TU P-N201

Direct Observation of Controlled Coupling in an Individual Quantum Dot Molecule — •Emily C. Clark, H. J. Krenner, M. Sabathil, A. F. Kress, D. Schuh, M. Bichler, G. Abstreiter, and J. J. Finley — Walter Schottky Institut and Physik Department, TU Muenchen, Am Coulombwall 3, D-85748 Garching, Germany

The realization of robust and scalable hardware for quantum information processing is one of the most challenging goals of solid-state physics. Excitons in semiconductor quantum dots (QDs) represent a particularly attractive quantum bit because they can be coherently manipulated using ultrafast laser pulses.

We report the direct spectroscopic observation of quantum coupling in individual quantum dot molecules (QDMs) and its manipulation using static electric fields. We performed photoluminescence spectroscopy on single pairs of stacked, self assembled InGaAs/GaAs QDMs which were

embedded in a n-i Schottky junction. A clear anti-crossing of spatially direct (e,h in same QD) and indirect (e,h in different QDs) excitonic states is observed as the electric field along the QDM axis is tuned. At the anticrossing the electron component of the wavefunction hybridizes into bonding and antibonding states split by the tunnel coupling energy of 1.6 meV. Comparison with realistic calculations, which include strain, piezo-electric and Coulomb effects, indicate a wetting layer separation of 11.9 nm. This is in very good agreement with the nominal growth separation of 10 nm. See: cond-mat/0410206

HL 13 III-V Halbleiter II

Zeit: Freitag 15:00–16:30 Raum: TU P-N202

HL 13.1 Fr 15:00 TU P-N202

Electronic structure and band alignment of GaIn(N)As/GaAs quantum wells determined by surface photovoltage and electroreflectance measurements — •M. Hetterich[1], A. Grau[1], M. Galluppi[2], L. Geelhaar[2], and H. Riechert[2] — [1]Institut für Angewandte Physik and Center for Functional Nanostructures (CFN), Universität Karlsruhe, D-76131 Karlsruhe, Germany — [2]Infineon Technologies AG, Corporate Research Photonics, D-81730 München, Germany

GaIn(N)As/GaAs is a material system with many applications in near infrared optoelectronics. However, in particular for nitrogen-containing quantum wells (QWs) the exact band alignment and conduction band dispersion are still controversial. In this contribution we combine in a first step contactless electroreflectance (ER) spectroscopy with surface photovoltage (SPV) measurements to determine the unstrained valence band offset of GaInAs/GaAs QW structures. While ER enables sensitive measurements even of weak optical transitions between quantized electron and hole states, the advantage of SPV experiments is, that they provide a more direct access to the band offset than many other techniques. Thus, the number of free fit parameters (and their range) used in the theoretical modelling of our ER spectra can be reduced substantially, leading to better defined results. In a second step we extend our SPV studies to GaInNAs/GaAs QWs. To model the non-parabolic conduction band structure due to the presence of nitrogen we use an effective numerical procedure based on the band anti-crossing (BAC) model. Through a fit to our experimental data the band alignment as well as the BAC model parameters E_{N} and C_{NM} can be determined.

HL 13.2 Fr 15:15 TU P-N202

Unusual Segregation of Antimony into InP in MOVPE — •Martin Leyer[1], Stefan Weeke[1], Frank Brunner[2], Markus Pristovsek[1], Markus Weyers[2], and Wolfgang Richter[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin, Hardenbergstraße 36 — [2]Ferdinand-Braun-institut für Höchstfrequenztechnik, 12489 Berlin, Gustav-Kirchhoff-Str. 4

The GaAsSb/InP material system has promising advantages for an InP based DHBT (Double Heterostructure Bipolar Transistor) regarding bandstructure alignment and base sheet resis-tance. The optimization of the GaAsSb/InP interface is a critical issue since Antimony segregation is observed disturbing the formation of an abrupt interface. In order to investigate Sb segregation using Metalorganic Vapor Phase Epitaxy (MOVPE), InP surfaces where exposed to TMSb and afterwards overgrown with InP. The growth was monitored in situ with RAS (Reflec-tance Anisotropy Spectroscopy) and spectroscopic ellipsometry. Secondary Ion Mass Spec-troscopy (SIMS) was used to analyse the Sb content. The incorporation of Sb showed an unex-pected temperature dependence in the range from 500°C to 600°C. In SIMS a second Sb con-taining layer appeared on top of the Sb exposed layer after a certain thickness. This could be explained by the existence of a quasi-liquid InSb surface phase above the InSb melting tem-perature of 527°C.

HL 13.3 Fr 15:30 TU P-N202

Photoluminescence Measurements on $GaAs_{1-x}N_x$ Quantum Wells — •B. Rähmer, F. Poser, M. Pristovsek, and W. Richter — Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin

It is well known that the fundamental bandgap energy of $GaAs_{1-x}N_x$ shifts into the infrared spectral region with increasing nitrogen content x. This makes $GaAs_{1-x}N_x$ an interesting material for light emitting devices with emission wavelengths from 1.3 μm to 1.55 μm . However, the underlying mechanism of the bandgap shift is still not fully understood.

Here we study the temperature dependent photoluminescence (PL) of MOVPE grown 5-fold $GaAs_{1-x}N_x$/GaAs super lattices for samples with x ranging between 1% and 5%. The N content x is determined by XRD and correlated to the PL data.

The annealing behavior was studied for one $GaAs_{1-x}N_x$/GaAs sample with 4% nitrogen. A blue shift of the PL emission with increasing annealing temperature as described in the literature was not observed but the PL intensity shows a significant increase.

HL 13.4 Fr 15:45 TU P-N202

Exchange reactions of As and N on GaAs surfaces — •R. Ehlert[1], S.J. Simon[1], F. Poser[1], N. Esser[2], P. Vogt[1], and W. Richter[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin — [2]Institute for Analytical Science, Dept. Berlin, Albert-Einstein Str. 9, 12489 Berlin

$GaAs_{1-x}N_x$ is a promising material for light emitting devices operating in a spectral range from 1.3 -1.55 μm . Understanding the nitrogen incorporation mechanisms in $GaAs_{1-x}N_x$ is crucial for optimization of growth conditions.

We present comparative in-situ RAS studies of $GaAs_{1-x}N_x$ under MOVPE condition and in UHV for samples with a nitrogen content of up to 5 % . Samples are grown in MOVPE by using TMGa, TBAs and TBHy as precursors or prepared by nitridation of GaAs surfaces. Upon nitridation a change of RAS spectra from the GaAs(2×4) to the GaAsN (3×3)-like is observed. After growth the samples are capped with an amorphous As-capping layer, transferred to UHV and decapped by annealing. Alternatively, samples were prepared by nitridation of clean GaAs(001) surfaces using ammonia as a nitrogen source. RHEED, RAS, STM and SXPS are used to measure surface properties.

HL 13.5 Fr 16:00 TU P-N202

Influence of sapphire nitridation of MOVPE growth of InN — •C. Werner, M. Drago, M. Pristovsek, and W. Richter — TU-Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin

The growth of InN in MOVPE is a challenging issue. Subsequently, the quality of the available InN layers is poor and fundamental properties of this material (i.e. the value of the bandgap energy) are still under discussion. Therefore, there is a strong demand to improve the InN. Usually our InN epitaxy is a three step process, consisting of nitridation, nucleation layer (commonly low-temperature and defective) and thick InN layer growth. In this work we study the effects of different nitridation procedures on the quality of InN layers. With in-situ spectroscopic ellipsometry (SE) we are able to see the progress of nitridation and get an insight into the nitridation process. We expose sapphire to ammonia in either nitrogen or hydrogen carrier gas. Both, the resulting nitrided substrate and the InN layer grown on top are characterised ex-situ with atomic force microscopy and X-ray diffraction. We found that hydrogen as carrier gas during nitridation has a negative effect on the crystal quality.

HL 13.6 Fr 16:15 TU P-N202

Defect related optical transitions in AlN bulk crystals — •Martin Albrecht[1], Klaus Irmscher[1], Matthias Rossberg[1], Thilo Remmle[1], Jürgen Wollweber[1], and Axel Hoffmann[2] — [1]Institut für Kristallzüchtung, Max-Born-Strasse 2, 12489 Berlin — [2]Institut für Festkörperphysik, TU Berlin, Hardenbergstrasse 36 10623 Berlin

Optical transitions in epitaxial AlN layers and bulk crystals are in general dominated by a broad luminescence band ranging from 4eV - 2eV. This luminescence band has been attributed to a variety of point defects (e.g. N-vacancies, Al vacancies and interstitials, ON) or defect complexes (especially VAl - ON). Youngman and Harris showed, that a red shift of this band could be related to an increasing oxygen content. In this paper we study by means of optical spectroscopy, electro-paramagnetic resonance and transmission electron microscopy AlN bulk crystals grown by the sublimation method. The crystals were grown in the temperature range between 1900°C and 2100°C in BN crucibles. They are either hexagonal platelets or single crystalline boules of 12x3x2mm size grown

along the c-axis. We find defect related bands at 3.45 eV, 3.0eV, 2.0 eV and 1.6 eV. A detailed study based on temperature and excitation dependent cathodoluminescence, time resolved photoluminescence and photoluminescence excitation is performed to analyse the physical nature of the defect related optical transitions

HL 14 Heterostrukturen

Zeit: Freitag 15:00–16:15 Raum: TU P-N229

HL 14.1 Fr 15:00 TU P-N229

Route to Bose-Einstein condensation of excitons in coupled quantum wells — •Roland Zimmermann — Institut für Physik der Humboldt-Universität zu Berlin

Spatially indirect excitons in coupled quantum wells (CQW) exhibit extremely long radiative lifetimes and a strong mutual repulsion of dipolar character. In a recent experiment [1] with a lateral trap potential, a substantial blue shift (5 meV) of the exciton emission line combined with a narrow angular characteristic normal to the quantum well plane has been reported. We present first theoretical results to explain these novel findings. For the CQW we calculate both the direct and exchange potential which enter the spin-dependent exciton Hamiltonian [2] and apply a dynamical T-matrix approach for the exciton propagator. The calculated emission is blue shifted but spectrally broad due to exciton-exciton scattering. The angle-resolved emission exhibits a sharp spike, which is a direct manifestation of off-diagonal long range order evolving at low temperatures.

[1] D.W. Snoke et al., arXiv:cond-mat/0410298 (2004)
[2] S. Ben-Tabou de-Leon and B. Laikhtman, Phys. Rev. B **63**, 125306 (2001)

HL 14.2 Fr 15:15 TU P-N229

Time-resolved photoluminescence of type-I and type-II (GaIn)As/Ga(NAs) heterostructures — •J. D. Heber, K. Hantke, C. Schlichenmaier, A. Thränhardt, T. Meier, B. Kunert, K. Volz, W. Stolz, S. W. Koch, and W. W. Rühle — FB Physik und WZMW, Philipps-Universität Marburg, Renthof 5, 35032 Marburg

A set of $(Ga_{0.77}In_{0.23})As/Ga(N_xAs_{1-x})$ heterostructures is studied by time-resolved photoluminescence. Four samples with nitrogen concentrations from $x = 0.48\%$ up to $x = 2.2\%$ are investigated at different temperatures and excitation densities. The experiments clearly show that the heterostructure band offset is type-I for $x = 0.48\%$ and type-II for $x = 2.2\%$. The situation is more complex for $x = 0.72\%$ and $x = 1.25\%$, since these samples are close to the transition from type-I to type-II and since disorder also influences the recombination dynamics. The experimental findings are analyzed using a detailed microscopic theory. The agreement between experiment and theory is very good and confirms that the $x = 0.72\%$ sample is type-I and the $x = 1.25\%$ sample is type-II.

HL 14.3 Fr 15:30 TU P-N229

Controlled motion of long-living excitons in tunable potential landscapes — •Andreas Gärtner[1], D. Schuh[2], and J. P. Kotthaus[1] — [1]CeNS and Department für Physik der LMU, München — [2]Walter Schottky Institut, TU München

The experiments to learn more about externally controlling the dynamics of long-living excitons are carried out in epitaxially grown heterostructures at temperatures below 4K. They contain two GaAs quantum wells (QWs) separated by a thin AlGaAs tunnel barrier. Lithographically patterned superficial gate structures allow the application of electrical fields tunable over a wide range.

An electron-hole pair generated optically usually relaxes quickly into a short-living excitonic state. However, in our QW samples spatially indirect excitons can be induced by an external electrical field: the exciton's constituents are located in adjacent QWs coupled by the tunnel barrier [1]. Experimentally we observe excitonic life times > 100 ns.

The excitonic energy can be controlled externally by applying electrical fields (quantum confined stark effect). Using adequately patterned metal gate structures various lateral excitonic potential landscapes $E_{\mathrm{exc}}(\mathbf{r}, t)$ can be formed causing a force $\mathbf{F} \propto \nabla E_{\mathrm{exc}}$ on an exciton [2]. We experimentally demonstrated excitonic drift over distances of several μm in temporally and spatially varying excitonic potential landscapes.

We also create traps for such long-living excitons by introducing additional superficial SiO_2 patters.

[1] Butov *et al.*, Nature **417**, 47 (2002)
[2] Zimmermann *et al.*, Phys. Rev. B **56**, 13414 (1997)

HL 14.4 Fr 15:45 TU P-N229

TE- and TM-polarization resolved spectroscopy on quantum wells under normal incidence — •M. Schardt[1,2], A. Winkler[1,2], G. Rurimo[2], S. Quabis[2], S. Malzer[1,2], G. Leuchs[2], and G. H. Döhler[1,2] — [1]Institute of Technical Physics I — [2]Max-Planck research group, Institute of Optics, Information and Photonics, University Erlangen-Nuremberg, Germany

We present TE- and TM-polarization resolved photocurrent measurements on quantum well pin diodes under normal incidence.
Usually, optical experiments performed in such a geometry yield information only about transitions involving in-plane (p_x- and p_y-) components of the hole wave functions because of the in-plane (TE-) polarization of the light. The lost information on transitions sensitive to the p_z components can be recovered by focussing a radially polarized laser beam through a microscope-objective with high numerical aperture (NA ≥ 0.9) [1]. With our setup, the electrical field vector at the focal tail has a significant component along the optical axis (TM-polarization!) which enables excitation of transitions sensitive to p_z components also. Experimental evidence of this feature has been performed by exploiting the selection rules for e-hh and e-lh transitions in a quantum well structure. We present a comparison of our recorded spectra with theoretical predictions obtained from simple geometric optics assumptions.

[1] S. Quabis et al., Optics Communications 179 (2000) 1-7

HL 14.5 Fr 16:00 TU P-N229

Atomically flat (110) GaAs interfaces by in-situ annealing — •Elisabeth Reinwald, Robert Schuster, Christian Gerl, Hans-Peter Tranitz, and Werner Wegscheider — Universität Regensburg, Institut für Experimentelle und Angewandte Physik, 93040 Regensburg

The growth of (110) GaAs using the cleaved-edge overgrowth method requires low substrate temperatures and high arsenic overpressure. These growth conditions are typically responsible for high surface and interface roughness. An in-situ annealing step reduces the roughness and large atomically flat surfaces can be achieved [1]. The deviation from an integer monolayer thickness results in characteristic islands or pits. The annealing step can be used to improve the quality of two-dimensional electron gases on (110) GaAs. Such high quality samples are necessary for creating a two-dimensional electron gas modulated in two perpendicular directions. In order to achieve this kind of modulation we use a superlattice modulation together with anodic oxidation with an atomic force microscope tip.

[1] M. Yoshita, H. Akiyama, L.N. Pfeiffer, K.W. West, Jpn. J. Appl. Phys. 40, L252 (2001)

This project is supported by the BMBF (01BM918).

HL 15 Elektronentheorie

Zeit: Freitag 15:00–16:00 Raum: TU P-N226

HL 15.1 Fr 15:00 TU P-N226

Orbital functionals in current-density-functional theory — •Nicole Helbig, Stefan Kurth, and Eberhard K.U. Gross — Freie Universität Berlin, Arnimalle 14, 14195 Berlin

The ab-initio treatment of many-electron systems in strong magnetic fields is still a challenging task. Current-density-functional theory (CDFT) is an option whose theoretical foundation was layed down many years ago. However, the application of this formalism has been hesitant because all electron-gas-based (LDA-type) approximations of the CDFT exchange-correlation functional have serious pathologies which make them awkward or impossible to use in practical calculations. As an alternative we have developed a CDFT version of the optimized effective potential (OEP) method which allows for the use of explicitly orbital-dependent functionals in the context of CDFT. We will present the derivation of these equations and will show results for a quantum dot in external magnetic fields.

HL 15.2 Fr 15:15 TU P-N226

Eine Methode zur Berechnung der Temperaturabhängigkeit der Fermi Energie in intrinsischen Halbleitern — •Rudolf Zeller — Institut für Festkörperforschung, Forschungszentrum Jülich, 52425 Jülich

Die Lehrbuchformel $E_F(T) = (E_V + E_L)/2 + 3kT/4 \ln(m_V/m_L)$ für die Fermi Energie als Funktion der Energiekanten und effektiven Massen von Leitungsband (L) und Valenzband (V) beruht auf der Näherung parabolischer Bänder und der Näherung $kT << E_L - E_V$. Aus gerechneten Bandstrukturen lassen sich die effektiven Massen nur sehr schwierig ermitteln und es ist nicht klar, für welchen Temperaturbereich die Näherungen gelten. Es wird eine Methode vorgestellt, wie man ohne diese Probleme $E_F(T)$ direkt aus der integrierten Zustandsdichte bestimmen kann, indem man diese Zustandsdichte als Funktion der komplexen Energie-Variablen betrachtet und ihre analytischen Eigenschaften ausnutzt. Die Methode wurde auf das Beispiel von GaN in Zinkblendestruktur angewendet und es werden Ergebnisse gezeigt, die im Rahmen der Dichtefunktionaltheorie mittels der tight-binding Korringa-Kohn-Rostoker Greenfunktionsmethode berechnet wurden.

HL 15.3 Fr 15:30 TU P-N226

kp parameters of wurtzite GaN — •Sviatoslav Shokhovets[1], Gerhard Gobsch[1], and Oliver Ambacher[2] — [1]Institute of Physics, TU Ilmenau, PF 100565, 98684 Ilmenau — [2]Center for Micro- and Nanotechnologies, TU Ilmenau, PF 100565, 98684 Ilmenau

Using a so-called A-set of parameters describing the six highest valence bands (VBs) and an assumption of a nonparabolic conduction band (CB) we calculated the imaginary part of the dielectric function in the vicinity of the fundamental absorption edge of wurtzite GaN. Both interband optical transitions and excitonic effects were included. Comparison to experiment yields the momentum matrix element, the electron effective mass, the size of the CB nonparabolicity, and parameter F related to the influence of remote bands. We estimate effects on the values determined owing to discrepancies between the reported A-sets of VB parameters, as well as optical anisotropy and possible anisotropy of the electron effective mass and present a set of self-consistent kp parameters which provides a parameterisation of the band structure of wurtzite GaN in the framework of an 8x8 Hamiltonian.

HL 15.4 Fr 15:45 TU P-N226

Diskretisierung von Mehrband-k·p-Schrödingergleichungen für mehrdimensionale Halbleiternanostrukturen — •Till Andlauer, Alex Trellakis und Peter Vogl — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching

Wir präsentieren eine systematische Untersuchung der Mehrband-k·p-Methode für beliebig orientierte, null- bis dreidimensionale Nanostrukturen in Ortsraum-Diskretisierung. Es ist bekannt, dass diese Methode zu unphysikalischen Lösungen führen kann, wie z.B. artifizielle Bandlücken-Zustände im Inneren von Halbleitern oder fälschlich gebundene Zustände an Grenzflächen verschiedener Materialien. Wir zeigen, dass man durch geeignete Reskalierung von Materialparametern im Hamilton, durch richtige Anordnung der Differenzial-Operatoren und der ortsabhängigen Materialgrößen in den Hamilton-Matrixelementen sowie durch passende Wahl des Diskretisierungsverfahrens diese Mängel beheben kann. In diesem Zusammenhang haben wir ein Diskretisierungsschema des Einhüllenden-Funktions-Formalismus entwickelt, das es ermöglicht, die Hamiltonmatrix unabhängig von der räumlichen Dimension, der Geometrie und Orientierung der Nanostruktur, sowie der Zahl der Basiszustände zu konstruieren.

HL 16 Poster Ia

Zeit: Freitag 16:30–19:00 Raum: Poster TU E

HL 16.1 Fr 16:30 Poster TU E

Weak Localization and Spin Splitting in Inversion Layers on p-type InAs — •Christopher Schierholz, Toru Matsuyama, Ulrich Merkt, and Guido Meier — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstrasse 11c, 20355 Hamburg, Germany

We have examined the magnetoconductivity of quasi two-dimensional electron systems in inversion layers on p-type InAs single crystals. Pronounced features of weak localization and antilocalization at low and beating patterns in SdH oscillations at high magnetic fields are observed. The low field data is almost perfectly described by the theory of Iordanskii, Lyanda-Geller and Pikus [1]. With this we obtain the spin splitting and the Rashba parameter of the ground electric subband as a function of the electron density [2]. In addition we determine the spin splitting and the Rashba parameter from the high field data by FFT analysis. The dependence of the Rashba parameter on the total carrier density is found to differ for low and high fields: the low field results agree well with band-structure calculations by Lamari [3]. The high field results are of the same order of magnitude but show a quite different dependence on the electron density and thus a strong deviation from the theoretical predictions.

[1] S. Iordanskii, Y. Lyanda-Geller, and G. Pikus, JETP Lett. **60**, 206 (1994).
[2] C. Schierholz, T. Matsuyama, U. Merkt, and G. Meier, Phys. Rev. B **70**, (December 15th, 2004).
[3] S. Lamari, Phys. Rev. B **67**, 165329 (2003).

HL 16.2 Fr 16:30 Poster TU E

Spin-Orbit Interaction in two- and one-dimensional InAs Heterostructures — •Sebastian von Oehsen, Christopher Schierholz, Guido Meyer, Toru Matsuyama, and Ulrich Merkt — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Germany

In spintronic devices like the spin transistor [1] the spin of the electron is controlled within a one-dimensional channel by the Rashba effect [2]. InAs heterostructures have a strong and tunable spin-orbit interaction and are thus an interesting material for such a device.

We investigate spin-orbit interaction in modulation-doped InAs heterostructures with two-dimensional electron systems by two transport experiments. First, the tunability of spin-orbit interaction is investigated in a two-dimensional channel: in low fields weak antilocalization is observed and analyzed according to Ref.[3], in high fields beating patterns of Shubnikov-de Haas oscillations are recorded. For the second experiment the heterostructures are laterally confined. With these quantum point-contacts we aim at the determination of the influence of spin-orbit interaction on the quantized conductance of a one dimensional channel.

[1] S. Datta and B. Das, Appl. Phys. Lett. **56**, 665 (1990)
[2] M. Governale and U. Zülicke, Phys. Rev. B **66**, 073311 (2002)
[3] S. Iordanskii, Y. Lyanda-Geller, and G. Pikus, JETP Lett. **60**, 206 (1994)

HL 16.3 Fr 16:30 Poster TU E

GaAs-based multi-terminal devices in lateral spin-valve geometry — •T. Last[1], M. Wahle[1], S.F. Fischer[1], U. Kunze[1], D. Reuter[2], and A.D. Wieck[2] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum, D-44780 Bochum — [2]Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum

Essential for the detection of spin accumulation in a lateral ferromagnet(FM)-semiconductor(SC) spin-valve structure is the resistance-matching between the FM/SC contact resistance and the resistance of the semiconductor channel. We present a multi-terminal lateral FM/SC tunnelling device based on a GaAs-heterostructure. A 50 nm moderately n-doped ($1x10^{16}/cm^3$) GaAs layer is grown on semi-insulating undoped GaAs. On top of the n-doped GaAs layer a 10.5 nm thick δ-doped ($1x10^{18}/cm^3$) layer is introduced to reduce the width of the Schottky-barrier and to provide tunnelling as the major spin injection mechanism at low voltages. Permalloy electrodes are optimized in terms of uniform magnetization at the FM/SC contact and suitable switching behaviour: widths 2.0 μm and 0.4 μm (length: 150 μm, thickness: 30 nm) separated by 0.2 μm. Up to now no spin blockade is observed. Further experiments are in progress towards optimization of the matching of the contact and channel resistances.

HL 16.4 Fr 16:30 Poster TU E

Optical spin injection from (Zn,Mn)Se into GaAs/(Al,Ga)As quantum wells — •Wolfgang Löffler, Daniel Tröndle, Thorsten Passow, Bruno Daniel, Miriam Kantner, Michael Hetterich, Michael Grün, Claus Klingshirn, and Heinz Kalt — Universität Karlsruhe (TH), Center for Functional Nanostructures (CFN) and Institut für Angewandte Physik, Wolfgang-Gaede-Str. 1, D-76128 Karlsuhe

The efficient injection of spin polarized charge carriers into semiconductor nanostructures is currently a field of intense research.

Using a confocal magneto-P technique we optically excite spin-polarized excitons in a semimagnetic (Zn,Mn)Se layer and detect the photoluminescence signal and its polarization state from a GaAs/(Al,Ga)As quantum well. The MBE-grown samples are placed in a magnetic cryostat at fields up to 14T and temperature T=4K. Comparing the measured circular polarization degrees of the photoluminescence signal in dependence of the excitation polarization we calculate the magneto-polarization, i.e. the degree of circular polarization induced by the magnetic field, which reaches values of up to 0.2. The actual injection efficiency is much higher but is to some extent masked by the fact that only 20% of the exciting light is absorbed within the (Zn,Mn)Se layer.

Currently we extend our work to electrical spin injection from doped (Zn,Mn)Se DMS layers into (In,Ga)As quantum wells.

HL 16.5 Fr 16:30 Poster TU E

Room temperature threshold reduction in vertical-cavity surface-emitting lasers by injection of spin-polarized electrons — J. Rudolph[1], S. Döhrmann[1], •T. Paprotta[1], D. Hägele[1], W. Stolz[2], and M. Oestreich[1] — [1]Institut für Festkörperphysik, Universität Hannover, Appelstraße 2, D-30167 Hannover, Germany — [2]Department of Physics and Material Sciences Center, Philipps University Marburg, Renthof 5, D-35023 Marburg, Germany

We experimentally demonstrate the reduction of the laser threshold of a commercial GaAs/(AlGa)As vertical-cavity surface-emitting laser (VCSEL) by optical injection of spin-polarized electrons at room temperature. A rate-equation model reproduces the measured reduction of 2.5% for injected electrons with 50% spin polarization. The model predicts a threshold reduction of more than 23% for 100% spin polarization in a VCSEL-structure with codoped 7.5 nm quantum wells and a reduction of 50% in otherwise identical VCSEL-structures grown on (110) substrate.

HL 16.6 Fr 16:30 Poster TU E

Electrical Searches of Spin Injection from Fe into GaAs-based Heterostructures — •Fang-Yuh Lo[1], E. Schuster[2], D. Reuter[1], W. Keune[2], J. Yang[1], and A. D. Wieck[1] — [1]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstraße 150, 44780 Bochum — [2]Laboratorium für Angewandte Physik, Universität Duisburg-Essen, Lotharstraße 1, 47048 Duisburg

We exploited the cleaved-edge overgrowth(CEO) method to have clean interfaces between Fe and GaAs-based heterostructures. Electrical measurements reveal a Schottky character for the Fe/heterostructures contact. For patterning the Fe film, we use focused ion beam(FIB) milling. We will discuss the fabrication of the spin-valve structure and their electrical characterization.

HL 16.7 Fr 16:30 Poster TU E

Towards Capture of Optically Induced Spin-Currents in Semiconductor Nanostructures — •Sangam Chatterjee[1], Wolfgang Rühle[1], and Klaus Köhler[2] — [1]Department of Physics and Material Science Center, Philipps-University Marburg, Renthof 5, 35032 Marburg, Germany — [2]Fraunhofer Institute for Applied Solid-State Physics, 79108 Freiburg, Germany

Coherent one and two photon excitation of semiconductors leads to spin-polarized currents due to quantum interference. Pure spin-currents without a net electron current are generated if the correct polarization geometry is chosen. The spin orientation and direction of these currents can be controlled by the relative phase of the two exciting fields [1]. Our goal is to detect these spin currents in an integrated device.

We have designed and grown a semiconductor nanostructure to demonstrate the capture of ballistic electrons in two different GaAs quantum wells. Experimental photoluminescence studies for different excitation and polarization geometries are presented and discussed.

[1] J. Hübner, W.W. Rühle et al., Phys. Rev. Lett. 90, 216601 (2003) and M. Stevens, A. Smirl et al., Phys. Rev. Lett. 90, 136603 (2003)

HL 16.8 Fr 16:30 Poster TU E

Steps towards the realization of ZnMnSe-InGaAs/GaAs SQW electrical spin injection LEDs — •M. Hetterich[1], J. Kvietkova[1], T. Passow[1], J. Lupaca-Schomber[1], B. Daniel[1], C. Klingshirn[1], W. Löffler[1], D. Tröndle[1], H. Kalt[1], D. Litvinov[2], and D. Gerthsen[2] — [1]Institut für Angewandte Physik and Center for Functional Nanostructures (CFN), Universität Karlsruhe, D-76131 Karlsruhe, Germany — [2]Laboratorium für Elektronenmikroskopie and CFN, Universität Karlsruhe, D-76128 Karlsruhe, Germany

Recently, techniques to spin-polarize electrons and inject them into semiconductor structures have attracted large attention as one of the key elements for a future spin-based (opto-) electronics. In the devices we want to study, semimagnetic ZnMnSe is used as a spin aligner and the spin-polarized electrons are injected into an InGaAs/GaAs quantum well (QW) LED. As the first step towards this aim we have fabricated surface-emitting InGaAs/GaAs QW p-i-n diodes using MBE and optical lithography. Bright electroluminescence (EL) could be obtained from these LEDs in the whole temperature range from 5-300 K. We have therefore moved on to add the n-doped ZnMnSe:Cl spin aligner, which is grown in a different system. A thin As layer is used to protect the sample from oxidation during transport to the II-VI chamber. This protective layer can easily be desorbed thermally, before the ZnMnSe growth is initiated. Indeed, TEM investigations prove the III-V/II-VI interface to be of good quality. Bright EL of these spin LEDs could already be obtained for T=5-300 K. Polarization-resolved magneto-EL measurements to determine the spin injection efficiency are currently under way.

HL 16.9 Fr 16:30 Poster TU E

A Spin-Mechanical Device for Detection and Control of Spin Current by Nanomechanical Torque — •Stefan Kettemann[1], Pritiraj Mohanty[2], Guiti Zolfagharkhani[2], and Peter Fulde[3] — [1]1. Institut fuer Theoretische Physik, Uni Hamburg, Jungiusstrase 9, 20355 Hamburg — [2]Department of Condensed Matter Physics, Boston University, Boston — [3]Max Planck-Institut fuer Physik Komplexer Systeme, Dresden

We propose a spin-mechanical device to control and detect spin currents by mechanical torque[1,2]. We show that this spin flip torsion balance effect can be strongly enhanced in a nanomechanical device when a nanowire containing a FM-NM interface is grown on top of a suspended nano-electro-mechanical structure (NEMS). Thereby, the spin transport can be measured by the induced mechanical torque in the NEMS torsion device. The inverse is also true: a torque at the FM-NM interface produces a potential difference between the two metals. Accordingly, a spin current can be generated by applying an external torque. We perform a detailed analysis to show that such a device can be used to detect, control and induce spin current[2]. [1] P. Fulde and S. Kettemann, Ann. Phys. 7, 214 (1998). [2] P. Mohanty, G. Zolfagharkani, S. Kettemann, and P. Fulde, Phys. Rev. B 70, 195301 (2004)

HL 16.10 Fr 16:30 Poster TU E

Tunneling Through Single-Crystal GaAs(001) Barriers With Sputtered Fe-Contacts — •Jürgen Moser, Marcus Zenger, Peifeng Chen, Werner Wegscheider, and Dieter Weiss — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, D-93040 Regensburg

We investigate transport through epitaxial GaAs(001) barriers sandwiched between sputtered Fe-films. To realize a Fe/GaAs(001)/Fe sandwich we use the epoxy-bond-and-stop-etch-technique. To achieve different magnetic switching fields of the two sputtered Fe-layers at room temperature one of the Fe-layers is covered with Co. This layer acts as a pinning layer and leads to a high coercive field of one Fe-layer. Previous experiments have shown that tunneling is the dominant transport mechanism for these samples. A pretreatment of one GaAs surface with hydrogen plasma at RT and a small acceleration voltage to reduce the native oxide layer increases the TMR-Effect from 1.2 % to about 3 % at 4.2 K which corresponds to a spin-polarisation of about 12 % in the Jullière model. Temperature dependent measurements show a reduction of the TMR-Effect to about 0.3 % at 300 K. This reduction is much higher than expected by the temperature dependence of the magnetisation of iron.

HL 16.11 Fr 16:30 Poster TU E

Spin polarization in a T-shape conductor induced by strong Rashba spin-orbit coupling — •Masayuki Yamamoto[1], Tomi Ohtsuki[2], and Bernhard Kramer[1] — [1]I.Institut für Theoretische Physik, Universität Hamburg, Jungiusstraße 9, 20355 Hamburg, Germany — [2]Department of Physics, Sophia University, Kioi-cho 7-1, Chiyoda-ku, Tokyo 102-8554, Japan

We investigate numerically the spin polarization of the current in the presence of Rashba spin-orbit interaction in a T-shaped conductor as proposed by A.A. Kiselev and K.W. Kim (Appl. Phys. Lett. **78** 775 (2001)). The recursive Green function method is used to calculate the three terminal spin dependent transmission probabilities. We focus on single-channel transport and show that the spin polarization becomes nearly 100 % with a conductance close to e^2/h for sufficiently strong spin-orbit coupling. From the quantum dynamics of wave packets, we deduce that this is due to spin separation caused by quantum mechanical scattering at the junction. The influence of the disorder on the predicted effect is discussed.

HL 16.12 Fr 16:30 Poster TU E

Mesoscopic spin filtering effect in the nonuniform spin-orbit interaction — •Jun-ichiro Ohe[1], Masayuki Yamamoto[1], Tomi Ohtsuki[2], Junsaku Nitta[3], and Bernhard Kramer[1] — [1]Hamburg University — [2]Sophia University, Japan — [3]NTT Basic Research Lab. and CREST-JST, Japan

Novel spin filtering in two-dimensional electron systems with nonuniform spin-orbit interactions (SOI) is numerically investigated. The strength of SOI is modulated perpendicular to the charge current. A spatial gradient of effective magnetic field due to the nonuniform SOI causes the Stern-Gerlach type spin separation. The direction of the polarization is perpendicular to the current and parallel to the spatial gradient. Almost 100 % spin polarization can be realized even without any external magnetic field and ferromagnetic contacts. The spin polarization persists even in the presence of randomness.

HL 16.13 Fr 16:30 Poster TU E

Spin-dependent localization effects in GaAs:Mn/MnAs granular paramagnetic-ferromagnetic hybrids at low temperatures — •C. Michel[1], C. Thien[1], S. Ye[1], P.J. Klar[1], W. Heimbrodt[1], S.D. Baranovskii[1], P. Thomas[1], and B. Goldlücke[2] — [1]Department of Physics and Materials Science Center, Philipps-University of Marburg, Germany — [2]MPI for Computer Science, Saarbrücken, Germany

We compare the magneto-transport in paramagnetic-ferromagnetic GaAs:Mn/MnAs granular hybrids and paramagnetic GaAs:Mn reference samples. The differences in the hole transport between the two systems at low temperatures arise due to carrier localization effects at the cluster–matrix interface in the hybrids. The localization is caused by a Schottky barrier formation at the interface as well as spin-dependent shifts of the hole bands caused by the stray field of the ferromagnetic clusters. The application of an external magnetic field leads to a delocalization of the carriers and thus a negative magneto-resistance effect. These effects can be simulated using a network model approach.

HL 16.14 Fr 16:30 Poster TU E

Weak anti-localization in InGaAs/InP quantum wires — •Vitaliy A. Guzenko, Thomas Schäpers, and Jens Knobbe — Institute of Thin Films and Interfaces (ISG1) and CNI - Center of Nanoelectronic Systems for Information Technology, Research Centre Jülich, 52425 Jülich

The Rashba effect is a promising candidate for spin manipulation in future spintronic devices. The strength of the Rashba effect is dependent on the choice of material. Thus determination of the spin-orbit coupling parameter is of importance. Observation of the weak anti-localization allows one to determine the Rashba coupling parameter if other techniques are not applicable.

We report on the magnetotransport properties of the quasi one-dimensional InGaAs/InP structures. 160 wires of the well defined width, connected in parallel, were prepared by etching the heterostructure, containing a two-dimensional electron gas. Gate dependent as well as temperature dependent measurements were performed, in order to determine the Rashba coupling parameter from the enhanced conductance due to weak anti-localization. The results were compared to the values obtained by analysing the beating pattern of the Shubnikov–de Haas oscillations.

HL 16.15 Fr 16:30 Poster TU E

Magnetotransport through nanoscale constrictions in ferromagnetic (001)-(Ga,Mn)As — •Markus Schlapps, Matthias Döppe, Tobias Feil, Matthias Reinwald, Werner Wegscheider, and Dieter Weiss — Universität Regensburg

Transport through small GaMnAs islands, separated by nanoscale constrictions from wider GaMnAs contacts, have recently shown interesting transport behaviour [1]. These constrictions act as pinning sites for domain walls and have so far shown spin-valve like effects with resistance changes $\Delta R/R \approx 1\%$ for constrictions on the order of 100 nm.

Here we show that $\Delta R/R$ is strongly temperature and current dependent and can be as high as 100% for 100 nm wide constrictions. The dependence on current, temperature and constriction width will be discussed.

[1] C. Rüster et al: PRL **91**, 216602 (2003)

HL 16.16 Fr 16:30 Poster TU E

Spin-orbit induced spin-polarized conductances in Y-shaped devices — •Kai Dittmer, Jun-Ichiro Ohe, and Bernhard Kramer — I.Institut für Theoretische Physik, Universität Hamburg, Jungiusstr. 9, 20355 Hamburg, Germany

One of the most important open questions in spintronics is the effective injection of spins into certain devices, e.g. the spin-transistor of Datta and Das [1]. The most simple appearing way is the injection via a ferromagnetic contact. One of the major obstacles in this approach is the current mismatch at the interfaces between the metallic contact and the semiconducting device. Using semiconducting ferromagnets is one way to circumvent this problem, but another problem with ferromagnets is the direct control of the ferromagnetic domains at the interface regions, and a third problem might be the influence of the magnetic stray fields penetrating the device.

As is well known in mesoscopics, spin-orbit interaction together with uncontrolled(impurity-) scattering results in the spin-dephasing of Dyakonov and Perel. Now, can spin-orbit interaction be used to produce spin-polarized currents, just like an inverse Dyakonov-Perel effect? The answer is yes [2], and we would like to propose with the Y-shaped spin-filter a possible device.

[1] S. Datta and B. Dat, Appl. Phys. Lett. **56**, 665 (1990)
[2] A. A. Kiselev and K. W. Kim, J. Appl. Phys **94**, 4001 (2003)

HL 16.17 Fr 16:30 Poster TU E

novel type of commensurability oscillations in haxagonal superlattices — •Stefan Meckler[1], Thomas Heinzel[1], Ulf Gennser[2], and Giancarlo Faini[2] — [1]IPkM, Heinrich-Heine-Universität, Univesitätsstr. 1, 40225 Düsseldorf, Germany — [2]LPN-CNRS, Route de Nozay, 91460 Marcoussis, France

Transport experiments on latteral superlattices in two-dimensional electron gases that show pronounced magneto-oscillations are reported. They originate from stable orbits around one or several antidots. In hexagonal lattice structures, we observe a novel type of classical commensurability peaks at high magnetic fields. These peaks are most prominent for large antidot diameters of about 70-90% of the lattice period. Using semiclassical simulations based on a billiard model, the observed oscil-

lations can be attributed to stable orbits bouncing between neighboring antidots. This interpretation is backed by the observation of Aharonov-Bohm type oscillations with a correspondingly large period at the observed resonances.

HL 16.18 Fr 16:30 Poster TU E

Ab initio impact ionization rate in GaAs, GaN, and ZnS — •Angelika Kuligk, Niels Fitzer, and Ronald Redmer — Universität Rostock, Institut für Physik, 18051 Rostock

We have performed ab initio band structure calculations for GaAs, GaN, and ZnS within density functional theory (DFT) using an exact exchange formalism with a local density approximation (EXX-LDA) for correlations. The wave-vector dependent microscopic impact ionization rate (IIR) is determined for these materials. A strong asymmetry of the IIR as well as a pronounced influence of the band structure is found. We compare these results with scattering rates obtained from band structures calculated with the empirical pseudopotential method (EPM). We present also energy-averaged impact ionization rates which can be applied in Monte Carlo simulations of high field electron transport.

HL 16.19 Fr 16:30 Poster TU E

In-plane tunneling spectroscopy of low-dimensional electron systems in a GaAs/AlGaAs heterostructure — •J.-L. Deborde[1], S. F. Fischer[1], U. Kunze[1], D. Reuter[2], and A. D. Wieck[2] — [1]Werkstoffe and Nanoelektronik, Ruhr-Universität Bochum — [2]Angewandte Festkörperphysik, Ruhr-Universität Bochum

The use of tunneling spectroscopy between low-dimensional electron systems is of great interest to observe spectral features such as band-structure effects or electron mode coupling. Using atomic force microscope (AFM) lithography, we produced a smooth potential barrier in a GaAs/AlGaAs heterostructure allowing in-plane tunneling in a two-dimensional electron gas (2DEG) as electrodes. The application of a bias across the barrier revealed Fermi-edge effects in the tunneling spectrum. Considering this AFM fabricated tunneling barrier, we aim to implement an in-plane electron directional coupler. Devices consisting of two parallel quantum wires (QWs) separated by a tunneling barrier were prepared by means of a combination of electron beam lithography and AFM lithography techniques. The electron density inside each one-dimensional electron waveguide (1DEWG) is controlled by in-plane gates whereas the height of the potential barrier is tuned by an electron-beam evaporated Schottky top gate. The conductance of the 1DEWGs show steps quantized with $2e^2/h$ as characteristic of one-dimensional transport. Experiments are expected to reveal tunnel coupling between the two 1DEWGs.

HL 16.20 Fr 16:30 Poster TU E

Ballistic rectification processes in crossed electron-waveguide devices — •Michael Knop[1], Ulrich Wieser[1], Ulrich Kunze[1], Dirk Reuter[2], and Andreas D. Wieck[2] — [1]Lehrstuhl für Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum, Germany — [2]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Germany

We investigate ballistic rectification processes in nanoscale four-terminal field effect devices with broken symmetry. The electron-waveguide injection leads are oppositely attached to a 200-400 nm wide and 2.5 μm long central channel which provides voltage probes. The angle between the injection leads and the central channel is varied between 30° and 90°. The devices are fabricated by a mix-and-match process combining high-resolution electron-beam and conventional photo lithography from a GaAs/AlGaAs heterostructure. The conductance characteristics of the injection leads show quantized conductance. Dc measurements in three-terminal configuration, one voltage probe remains unused, show ballistic rectification due to different mode population in the injection leads. In the four-terminal configuration we observe a rectification signal arising from the inertia ballistic motion of the injected electrons.

HL 16.21 Fr 16:30 Poster TU E

Ballistic transport in nanoscale Si/SiGe cross-bars — •Sorin Poenariu[1], Ulrich Wieser[1], Ulrich Kunze[1], and Thomas Hackbarth[2] — [1]Lehrstuhl für Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum, D-44780 Bochum — [2]DaimlerChrysler Forschungszentrum Ulm, Wilhelm-Runge-Strasse 11, D-89081 Ulm

Starting from a high-mobility modulation-doped Si/SiGe heterostructure we prepare nanoscale field effect devices in order to study ballistic transport phenomena at T= 4.2 K. The transport channel is defined by a four-terminal ballistic cross-bar. Different symmetric and asymmetric geometries are realized with respect to the width and length of the current leads. We use a mix-and-match process which combines high resolution electron-beam lithography with calixarene and optical lithography with standard photoresist. The resulting resist pattern is transferred into the heterostructure by a low-damage CF_4/O_2 plasma process. For small current injection the four-terminal I-V-characteristic shows a negative bend resistance due to the ballistic motion of electrons. The influence of a top gate voltage on the I-V-characteristic is analyzed for different geometries. A second evidence of ballistic transport is a pronounced negative differential conductance (NDC) which is found in two-terminal I-V-characteristics of cross-bars and quasi one-dimensional wires. This NDC is attributed to phonon emission of electrons in the hot-electron regime.

HL 16.22 Fr 16:30 Poster TU E

Herstellung und Charakterisierung von vertikal geschichteten, niedrig-dimensionalen Ladungsträgersystemen — •C. Werner, D. Reuter und A.D. Wieck — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum

Wir haben durch einen kombinierten Wachstums- und Implantationsprozess vertikal geschichtete, niedrig-dimensionale Ladungsträgersysteme in einer $Al_{0,33}Ga_{0,67}As/GaAs/Al_{0,33}Ga_{0,67}As/GaAs/Al_{0,33}Ga_{0,67}As$-Quantentopfstruktur hergestellt. Dabei wird mit Molekularstrahlepitaxie (MBE) zunächst ein Teil der Probe gewachsen und nach einem Ultrahochvakuum (UHV) Transfer in eine fokussierte Ionenstrahl (FIB) Anlage der Dotierstoff für das untere Ladungsträgersystem durch FIB eingebracht, bevor der Wafer nach UHV-Rücktransfer in der MBE-Anlage mit der Quantentopfstruktur fertig gestellt wird. Dies bietet - durch Wahl eines geschickten Implantationslayouts in Verbindung mit einer Strukturierung durch nasschemisches Ätzen - die Möglichkeit, die Ladungsträgersysteme getrennt zu kontaktieren. Bisher wurden zwei relativ weit voneinander entfernte Elektronengase erzeugt. Diese wurden zunächst getrennt vermessen und im Anschluss ihre Wechselwirkung untereinander untersucht.

HL 16.23 Fr 16:30 Poster TU E

Mikroskopische Transportmodelle für die Ladungsträgerdynamik in ZNS:Mn MISIM-Strukturen — •Karsten Meyer, Thomas Raker und Tilmann Kuhn — Institut für Festkörpertheorie, Wilhelm-Klemm-Str. 10, 48149 Münster

Wir untersuchen im Rahmen eindimensionaler mikroskopischer Modelle wie dem Drift-Diffusions und dem hydrodynamischen Transportmodell die Bistabilität der Ladungsübertragung in Wechselspannungsbetriebenen ZnS:Mn MISIM-Strukturen als Funktion von Amplitude und Frequenz der Treiberspannung. Es zeigt sich, dass dieses Phänomen in der Struktur der Gleichungen begründet ist und damit nicht kritisch vom funktionalen Verlauf des Stoßionisationskoeffizienten abhängt. So werden sowohl bei der Verwendung des üblichen, von Howard, Sahni und Alt vorgeschlagenen Verlaufs, als auch bei einer an experimentellen Ergebnissen angepassten Form breite bistabile Bereiche gefunden. Eine Erweiterung des Drift-Diffusions Modells auf zwei räumliche Dimensionen liefert Strukturbildungsphänomene wie sie auch im Experiment beobachtet werden.

HL 16.24 Fr 16:30 Poster TU E

Magnetic Focusing in Ballistic Hall-Bar Geometries — •Tobias Feil, Werner Wegscheider, and Dieter Weiss — Universität Regensburg

We investigate magnetotransport in Hall-bar geometries with dimensions much smaller than the electron mean free path at low temperatures. For the experiments we used GaAs/AlGaAs heterojunctions with low-temperature mobilities of 600 m^2/Vs and a corresponding mean free path of 45 μm.

Hall-bars with typically 4 μm wide mesas and potential probe separation of 4 μm were defined by electron beam lithography and dry etching. By driving a constant current along the Hall-bar we observe, as a function of a perpendicular magnetic field, pronounced oscillations in the longitudinal voltage drop, with a periodicity given by the magnetic focus condition:

$2nR_C = L \quad , \quad n = 1, 2, 3, ...$

with the cyclotron radius R_C and the contact separation L.

The resistance minima of the oscillations are well below the Drude resistance at low temperatures.

HL 16.25 Fr 16:30 Poster TU E

New approach to resonant transmission in nanostructures — •Oleg Kidun[1], Jamal Berakdar[1], and Natasha Fominykh[2] — [1]MPI für Mikrostrukturphysik, Halle, Germany — [2]Institute of Physics, St. Petersburg State University, St. Petersburg, Russia

We explore the resonant transmission probability in artificially fabricated nanosystems such as semiconductor quantum wells or quantum dots. We introduce the concept of spatially varying conductance and provide determining equations for this quantity. The theory resembles the well-known variable phase method [1-2], applied for 3D systems. Application of the suggested approach for particular nanostructures and a comparison of the theoretical results with experimental measurements are presented and discussed.

[1] F. Calogero, Variable Phase Approach in Potential Scattering, AP, NY (1967)

[2] O. Kidun, N. Fominykh, J. Berakdar, J. Phys. A 35, 9413 (2001)

HL 16.26 Fr 16:30 Poster TU E

Beam splitter Design using mixed phase space cavities — •Oliver Bendix, Antonio Mendez-Bermudez, and Ragnar Fleischmann — MPI für Strömungsforschung und Fakultät Physik der Universität Göttingen

We propose the construction of electronic/electromagnetic beam splitters using two-dimensional multi-lead waveguides. A prototype two-lead waveguide is locally deformed in order to produce a ternary incomplete horseshoe (proper of mixed phase space). Due to dynamical tunneling to phase space resonant islands the appearance of quasibound states (QBS) is induced. Then, we attach transversal leads to the waveguide on the deformation region in positions *along* the QBS, where the horseshoe is only slightly perturbed. We show that such QBS pump into the transversal leads giving rise to beam splitters. This assumption is based on the investigations due to classical Poincarè Maps [1] and quantum-mechanical Scattering Wave Functions (its Husimi Representation).

[1] J. A. Méndez-Bermúdez, G. A. Luna-Acosta, P. Šeba, and K. N. Pichugin, Phys. Rev. B **67**, 161104(R) (2003).

HL 16.27 Fr 16:30 Poster TU E

Bindungsspezifität von Peptiden auf Halbleiteroberflächen — •Karsten Goede[1], Michael Bachmann[2], Wolfhard Janke[2] und Marius Grundmann[1] — [1]Institut für Experimentelle Physik II — [2]Institut für Theoretische Physik, Universität Leipzig, Deutschland

Hybride Systeme aus anorganischen Halbleitern und Bio-Molekülen bilden einerseits ein gut zugängliches Modellsystem für das Studium des fundamental wichtigen Prozesses der molekularen Selbstanordnung, andererseits könnten sie vielfältige praktische Anwendungen finden als Bio-Sensoren oder in einer zukünftigen Nano-Bio-Elektronik. In diesem Beitrag zeigen wir, daß der mittels AFM-Messungen bestimmte Adhäsionskoeffizient von Clustern verschiedener Peptide mit ähnlicher Sequenz auf diversen Halbleiteroberflächen sowohl abhängig ist von der Elektronegativität der Oberflächenatome und ihrer räumlichen Anordnung als auch von der Art und Abfolge der Seitenketten in den Aminosäuren des Peptids [1]. Weiterhin können wir zeigen, daß eine geringe Adhäsion einhergeht mit der Ausbildung besonders großer und besonders weicher Cluster. Ausgehend von diesen empirischen Befunden werden Simulationen der Peptidfaltung vorgestellt, und der Weg zu einer theoretischen Modellierung der Peptid-Adhäsion auf Oberflächen wird diskutiert.

[1] K. Goede, P. Busch, M. Grundmann, Nano Lett., im Druck, Jahrgang 4, Ausgabe 11 (2004).

HL 16.28 Fr 16:30 Poster TU E

Die elektrische Aktiverung von Dotieratomen in SiC — •A. Mattausch, M. Bockstedte und O. Pankratov — Lst. für Theoretische Festkörperphysik, Universität Erlangen-Nürnberg, Staudtstr. 7, 91058 Erlangen

Die elektrische Aktivierung und Löslichkeit von Dotieratomen ist der limitierende Faktoren auf dem Weg zu hochdotierem SiC. In Stickstoff-dotierten Proben konnte eine vollständige elektrische Aktivierung nur für eine Dotierung unterhalb einer Grenzkonzentration von $2\text{-}5{\cdot}10^{19}\,\mathrm{cm}^{-3}$ erreicht werden [1,2]. Dagegen konnte Phosphor bis zu Konzentrationen von $10^{20}\,\mathrm{cm}^{-3}$ bei nahezu vollständiger Aktivierung implantiert werden [1]. Um das Verhalten dieser Dotieratome zu verstehen haben wir ihre elektrische Aktivierung und ihre Löslichkeit mittels *ab initio* Methoden untersucht. Wir finden, dass Phosphor als flacher Donator hauptsächlich auf dem Silizium-Untergitter eingebaut wird, während Stickstoff ausschließlich Kohlenstoff-Plätze besetzt. Die elektrische Aktivierung beider Donatoren wird im thermodynamischen Gleichgewicht nicht durch Kompensation begrenzt, sondern durch die Bildung von Präzipitaten beim Phosphor und durch Passivierung beim Stickstoff. Für die Stickstoffpassivierung ist die oberhalb einer kritischen Stickstoffkonzentration von $2{\cdot}10^{19}\,\mathrm{cm}^{-3}$ dominierende Bildung von Stickstoff-Leerstellen-Komplexen verantwortlich.

[1] M. Laube *et al.*, J. Appl. Phys **92**, 549 (2002).

[2] D. Schulz *et al.*, Mater. Sci. Forum **338-342**, 87 (2000).

HL 17 Poster Ib

Zeit: Freitag 16:30–19:00 Raum: Poster TU F

HL 17.1 Fr 16:30 Poster TU F

Untersuchung von strukturierten II-VI-Halbleiter-Nanopartikeln in unterschiedlicher Umgebung — •R. Lewinski[1], S. Dembski[1], A. Hoffmann[1], A. Gabriel[1], C. Graf[1], R Neder[2], M. Grimm[1], B. Langer[1] und E. Rühl[1] — [1]Institut f. Physikalische Chemie, Universität Würzburg, Am Hubland, 97074 Würzburg — [2]Institut f. Mineralogie und Kristallstrukturlehre, Universität Würzburg

Die elektronischen und strukturellen Eigenschaften von schichtweise aufgebauten II-VI-Halbleiter-Nanopartikeln wurden untersucht. Die Nanopartikel lassen sich mit einer neuartigen Methode chemisch modifizieren, so dass sie in größeren Partikeln einbettbar sind bzw. auf der Oberfläche von Metallkolloiden deponierbar werden. Dadurch sind die strukturellen Eigenschaften der Partikel in unterschiedlicher lokaler Umgebung untersuchbar. Die Kristallstruktur der Partikel wurde mit hochauflösender Elektronenmikroskopie und Röntgendiffraktometrie charakterisiert. Experimente zur Variation der Partikelumgebung wurden in einer Partikelfalle durchgeführt, die eine berührungsfreie Speicherung von Einzelpartikeln zulässt. Die Untersuchung der lokalen elektronischen Struktur erfolgte durch elementspezifische Anregung mit weicher Röntgenstrahlung.

HL 17.2 Fr 16:30 Poster TU F

Untersuchung makroskopischer Lumineszenzausbreitung in ZnO — •Manuel Decker, Heiko Priller, Robert Hauschild, Heinz Kalt und Claus Klingshirn — Institut für Angewandte Physik, Universität Karlsruhe (TH)

Bei der Untersuchung mehrerer ZnO Volumenproben beobachten wir bei T=100K neben der bandkantennahen UV-Photolumineszenz (PL) und dem grünen Emissionsband, verursacht von Sauerstoffleerstellen, zusätzlich noch eine orangene PL-Bande, deren ungewöhnliches zeitliches Verhalten genauer untersucht wird. Diese PL unterscheidet sich von der Lumineszenz in den anderen Spektralbereichen dadurch, dass diese sich langsam vom Anregungsspot über mehrere Millimeter zum Rand der Volumenprobe hin ausbreitet. Nach Abschalten der Laseranregung klingt diese PL im gesamten Kristall gleichmäßig ab. Das Transportphänomen kann durch ein 2d-Diffusionsmodell gut beschrieben werden. Durch Simulation der zeitlichen Dynamik und Vergleich mit den Messdaten wurden Mobilität und Zerfallszeit zu $\mu = 46cm^2/Vs$ respektive $\tau = 0.1s$ bestimmt. Als Interpretation werden ein thermisch aktivierter Hopping Prozess oder ein Elektron- bzw. Lochtransport in Störstellenbändern diskutiert.

HL 17.3 Fr 16:30 Poster TU F

Quadrupole Interaction in Some Spinel Type Ternary Semiconductors — •Veaceslav Samokhvalov[1], Jens Kortus[2], Frank Schneider[3], and Sepp Unterricker[3] — [1]AMD Dresden — [2]MPI für Festkörperforschung Stuttgart — [3]Institut für Angewandte Physik, TU Bergakademie Freiberg, D-09596 Freiberg

An extended group of ternary semiconductors AB_2C_4 (e.g. $CdCr_2Se_4$, $CdIn_2S_4$, $ZnAl_2S_4$) crystallize in the lattice of normal spinel. At the B- and C-sites large electric field gradients (efg) exist. Such efg can be calculated by modern ab-initio methods like the WIEN97 code. A comparison between experiment and theory can judge the quality of calculated

charge density distributions. With the PAC-method efg with impurity probes can be determined also. By the calculation of such systems beside accurate anion parameters u the relaxation of the neighbours has to be taken into account. This requires a unit cell of 56 atoms at least.

HL 17.4 Fr 16:30 Poster TU F

Hall effect measurements on ZnO thin films — •Matthias Brandt, Holger von Wenckstern, Susanne Heitsch, Gabriele Benndorf, Holger Hochmuth, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnestrasse 5, 04103 Leipzig

We have investigated the free carrier concentration and the Hall mobility of ZnO thin films in a wide temperature range. The thin films are grown by pulsed laser deposition on a-plane sapphire substrates. We have investigated four different kinds of samples: nominally undoped ZnO, nominally undoped ZnO grown on a MgO buffer layer, Al or Ga doped samples, and Al or Ga doped samples deposited in a MgO buffer layer. The dominating scattering mechanisms and the dominating donor levels are determined and discussed. Further we investigated the optical properties of the thin films using photoluminescence measurements. The obtained results are compared to temperature dependent Hall data of state of the art single crystals.

HL 17.5 Fr 16:30 Poster TU F

Influence of the incorporation of group V elements on the electrical properties of ZnO thin films — •Holger von Wenckstern, Susanne Heitsch, Gabriele Benndorf, Daniel Spemann, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstrasse 5, 04103 Leipzig

We have grown ZnO thin films by pulsed laser deposition on sapphire substrates. The samples were doped with N or with P in order to investigate the change in electrical conductivity compared to nominally undoped samples. For that we have used ZnO targets containing different amounts of e.g. P_2O_5 or e.g. Zn_3N_2. The electrical properties are related to the content of the group V acceptors. A number of samples is also investigated by photoluminescence measurements and new features in the recombination spectrum are correlated with the incorporation of N or P. The changes of the electrical properties after annealing the thin films at temperatures higher than 700°C are also reported.

HL 17.6 Fr 16:30 Poster TU F

Brechungsindex von kubischem $Mg_xZn_{1-x}O$ — •Anke Carstens[1], Rüdiger Schmidt-Grund[1], Bernd Rheinländer[1], Mathias Schubert[1], Holger Hochmuth[1], Michael Lorenz[1], Craig M. Herzinger[2] und Marius Grundmann[1] — [1]Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig — [2]J. A. Woollam Co., Inc. 645 M Street, Suite 102, Lincoln, Nebraska, 68508, USA

$Mg_xZn_{1-x}O$ ist attraktiv für Anwendungen als aktives Material in optoelektronischen Bauelementen, in Bragg-Reflektoren und als Material für optische Bauteile im UV-Bereich. Spektroskopische Ellipsometrie wurde im Spektralbereich von 0,75 eV bis 9,5 eV auf $Mg_xZn_{1-x}O$-Dünnfilme angewendet, die mittels PLD (pulsed laser deposition) auf c-orientierten Al_2O_3 Substraten abgeschiedenen worden waren.

Der Brechungsindex wurde an Proben mit verschiedener Mg-Konzentration ($0.67 \leq x \leq 1$) im Spektralbereich zwischen 0,75 eV und 0,9EG(x) mit einer Genauigkeit von typisch ±0,02 bestimmt. Einflüsse der Oberflächenrauhigkeit wurden mittels verallgemeinerter Ellipsometrie (Mueller-Matrix-Analyse) untersucht und in die Brechungsindex-Analyse einbezogen.

HL 17.7 Fr 16:30 Poster TU F

FIR-MIR Fourier transform spectroscopy of $Zn_{1-x}Mn_xSe$ epilayers grown by molecular-beam epitaxy — •K. C. Agarwal, B. Daniel, C. Klingshirn, and M. Hetterich — Institut für Angewandte Physik and Center for Functional Nanostructures (CFN), Universität Karlsruhe, D-76131 Karlsruhe, Germany

$Zn_{1-x}Mn_xSe$ is one of the most widely studied diluted magnetic semiconductors (DMS). Recently, DMS like $Zn_{1-x}Mn_xSe$ have been demonstrated to be useful as spin aligners, important ingredients for possible spin-based opto-electronic devices. In this contribution, we present the results of our investigations of n-doped and undoped ZnMnSe epilayers grown by molecular beam epitaxy (MBE) on GaAs(001) substrate. From plasma edge reflection studies of n-doped $Zn_{1-x}Mn_xSe$ epilayers ($0 \leq x \leq 0.13$), the carrier density dependent electron effective mass and transport properties are determined for different Mn contents. In addition, FIR investigations of undoped $Zn_{1-x}Mn_xSe$ epilayers were used to study the temperature dependence of phonons and the high frequency dielectric constant in this material for various Mn contents ($0 \leq x \leq 0.78$).

HL 17.8 Fr 16:30 Poster TU F

Wachstum und Charakterisierung zweidimensionaler ZnO:Al Nanoblätter und Nanowände durch Al2O3-unterstützte Carbothermale Verdampfung — •A. Rahm[1], G.W. Yang[2], M. Lorenz[1], Th. Nobis[1], J. Lenzner[1], G. Wagner[3] und M. Grundmann[1] — [1]Universität Leipzig, Institut für Experimentelle Physik II, D-04103 Leipzig, Deutschland — [2]State Key Laboratory of Optoelectronic Materials and Technologies, School of Physics and Engineering, Zhongshan University, Guangzhou 510275, P. R. China — [3]Universität Leipzig, Institut für Mineralogie, Kristallographie und Materialwissenschaft, D-04103 Leipzig, Deutschland

Mit Hilfe eines Al2O3 unterstützten carbothermalen Verdampfungsprozesses wurden freistehende zweidimensionale ZnO Nanoblätter und honigwabenähnlich verbundene Nanowände zusammen mit Nanodrähten auf goldbedeckten a-Saphir bzw. GaN/Si(111) Substraten gewachsen. Röntgendiffraktionsmessungen haben ergeben, dass die ZnO(0001) und die ZnO(10-11) Orientierung bei den Nanoblättern vorherrschend sind. Transmissionselektronenmikroskopie (TEM), Elektronenverlustspektroskopie (EDX), sowie Rasterelektronenmikroskopie (SEM) wurden zur weiteren strukturellen Charakterisierung verwendet und wir beweisen damit, dass ein Vapor-Liquid-Solid (VLS) Wachstum stattfindet. Temperaturabhängige Kathodolumineszenzmessungen zeigen Donator-Akzeptor-Paar-Übergänge, sowie gebundene Excitonen mit einer Halbwertsbreite von 2.1 meV bei 10K.

HL 17.9 Fr 16:30 Poster TU F

Eignung von ZnO-Nanosäulen als Laseremitter — •Holger Lange[1], Robert Hauschild[1], Joachim Zeller[1,2], Rainer Kling[3], Andreas Waag[4], Claus Klingshirn[1] und Heinz Kalt[1,2] — [1]Universität Karlsruhe (TH) — [2]Center for Functional Nanostructures, Karlsruhe — [3]Universität Ulm — [4]TU-Braunschweig

ZnO-Nanosäulen zeigen selbst bei Raumtemperatur Laseremission und stehen nicht nur deshalb im Mittelpunkt reger Forschungsbemühungen. In diesem Beitrag werden mit Hilfe von numerischen Simulationen (Finite-Elemente-Methode, approximative 3D-Geometrie) die Resonatoreigenschaften von ZnO-Nanosäulen berechnet. Der Einfluss von Geometrieparametern und Substrateigenschaften auf den Q-Faktor wird untersucht.
Im experimentellen Teil werden mit Hilfe spektroskopischer Methoden Alterungseffekte analysiert. Für Nanosäulen und Nanokristallite werden die Lumineszensspektren von frisch präparierten und gealterten Proben mit unter verschiedenen Parametern getemperten Proben verglichen.

HL 17.10 Fr 16:30 Poster TU F

Room-temperature cathodoluminescence of n-type ZnO thin films grown by PLD in N_2, N_2O, and O_2 background gas. — •M. Lorenz[1], H. Hochmuth[1], T. Nobis[1], J. Lenzner[1], G. Zimmermann[1], M. Diaconu[1], H. Schmidt[1], H. von Wenckstern[1], A. Schön[2], D. Schenk[2], and M. Grundmann[1] — [1]Universität Leipzig, Fakultät für Physik und Geowissenschaften, 04103 Leipzig, Germany — [2]El-Mul Technologies Ltd., Soreq, Yavne 81104, Israel

Epitaxial ZnO thin films were grown by pulsed laser deposition (PLD) in N_2, or N_2O, or O_2 background gas on MgO buffered a-plane sapphire substrates. The excitonic room temperature cathodoluminescence (CL) intensity, the carrier concentration and the Hall mobility show well defined maxima for films grown at PLD gas pressures of ca. 1 mbar N_2, N_2O, and O_2. However, despite the comparable high CL intensities of the ZnO films grown in the three different background gases, their surface roughness varied considerably. Films with rough surface show a broadening and splitting of the room temperature CL peak into maxima at 3.21 and 3.26 eV which could be due to either grain morphology or spatial variation of the electronic defect structure. Large-area PLD ZnO thin films were used to demonstrate scintillator device applications. Work supported partially (HS, MD) by the BMBF, FKZ 03N8708.

HL 17.11 Fr 16:30 Poster TU F

Transport of spin-polarized excitons in $Zn_{1-x}Mn_xSe$-based II-VI heterostructures — •B. Daniel, W. Löffler, D. Tröndle, C. Klingshirn, H. Kalt, and M. Hetterich — Institut für Angewandte Physik and Center for Functional Nanostructures (CFN), Universität Karlsruhe, D-76131 Karlsruhe, Germany

In order to study the transport of spin-polarized excitons through II-VI heterostructures in a magnetic field, polarization-resolved photoluminescence (PL) was measured on a series of different semiconductor heterostructures grown on GaAs by molecular beam epitaxy. To align the exciton spin, either ZnMnSe layers or short-period superlattices (ZnSe/MnSe or CdSe/ZnMnSe) were used. By measuring the PL shift of the latter as a function of the applied magnetic field, the effective g factor could be determined for the different structures. The circular emission detected proved that exciton spin polarization indeed took place. The heterostructures investigated consisted of a buffer layer (ZnSe), a quantum well (CdSe or ZnCdSe), a barrier (ZnSe) and a spin aligner layer (one of the above). In order to clarify the role of different contributions to the polarization degree of the quantum well PL polarization, a series of such structures was grown and investigated, varying in the Mn or Cd content of the spin aligner layer, the thickness of the barrier, and the Zn content in the quantum well. Additional information was deduced from experiments with different excitation wavelength.

HL 17.12 Fr 16:30 Poster TU F

Transport properties of n-doped $Zn_{1-x}Mn_xSe$ semimagnetic heterostructures — •B. Daniel, K. C. Agarwal, J. Lupaca-Schomber, J. Kvietkova, C. Klingshirn, and M. Hetterich — Institut für Angewandte Physik and Center for Functional Nanostructures (CFN), Universität Karlsruhe, D-76131 Karlsruhe, Germany

$Zn_{1-x}Mn_xSe$ alloys are promising candidates as spin aligners in optoelectronic spin devices. A series of n-doped $Zn_{1-x}Mn_xSe$:Cl samples with various compositions and doping concentrations has been grown by molecular beam epitaxy using elemental sources and $ZnCl_2$. To determine the carrier concentration and mobility as a function of temperature, Hall measurements in the van der Pauw geometry have been carried out on lithographically prepared clover leaf samples. Doping concentrations in the $10^{18}cm^{-3}$ range were observed in $Zn_{1-x}Mn_xSe$. With increasing Mn concentration a decrease in both the dopability and mobility was observed. Recently, we have also started further experiments concerning the investigation of $Zn_{1-x}Mn_xSe$/gold Schottky diodes and the magnetic field dependent tunnelling in $Zn_{1-x}Mn_xSe$/ZnSe structures.

HL 17.13 Fr 16:30 Poster TU F

Anionische Substitution in ZnMgTe — •Stefan Merita und Bruno K. Meyer — I.Physikalisches Institut JLU-Giessen, Heinrich-Buff-Ring 16, D-35392 Gießen

Wir untersuchen die Substituierbarkeit von Tellur durch Sauerstoff und Schwefel an polykristallinen Dünnschichten der Zusammensetzung $ZnTe_{1-x}(O,S)_x$ sowie $Zn_{1-y}Mg_yTe_{1-x}(O,S)_x$ und ihre Auswirkung auf die Bandkantenenergie und Kristallstruktur. Erste Versuche zur Dotierbarkeit des Materials mit Stickstoff werden präsentiert. Die Schichten werden über einen RF-Sputterprozess (Radiofrequenz, 13.56 MHz) hergestellt. Als Ausgangsmaterial dient ein ZnTe-Keramiktarget mit Auflagen von Mg-Folie, welches mit Argon als Prozessgas sowie variabler Zugabe von Sauerstoff bzw. Schwefelwasserstoff als Reaktivgas abgetragen wird. Die Resultate anschließender Temperaturbehandlung in unterschiedlicher Atmosphäre werden untersucht. Zur Analyse der Kristallstruktur wird Röntgenbeugung (XRD) verwendet, Bestimmung der Bandkantenenergie erfolgt mittels optischer Transmissionsmessung. Elektrische Materialeigenschaften (spezifischer Widerstand, Ladungsträgertyp, -dichte und -beweglichkeit) werden durch Hall-Messungen untersucht.

HL 17.14 Fr 16:30 Poster TU F

Guided growth of zinc oxide nano-pillars using self-organizing polymers for patterning the substrate with a catalyst — •Andre Langlois, Anton Reiser, Günther M. Prinz, Andreas Ladenburger, Martin Schirra, Rolf Sauer, and Klaus Thonke — Abteilung Halbleiterphysik, Universität Ulm, D-89069 Ulm

We have produced c-axis oriented zinc oxide nano-pillars via a vapor-liquid-solid process on a-plane sapphire substrates. The self-organizing properties of polymers are used to pattern the substrate surface with a catalyst to control the location of growth seeding. The dependence of the pillar thickness, height, and quality on the temporal growth temperature profile, source material, and oxygen supply during process is investigated. The catalyst pattern is analyzed by atomic force microscopy and high resolution scanning electron microscopy. The optical and crystalline properties of the asgrown nano-pillars are investigated by scanning electron microscopy, high resolution X-ray diffraction, photoluminescence spectroscopy, cathodoluminescence spectroscopy, and Raman spectroscopy.

HL 17.15 Fr 16:30 Poster TU F

Magneto-Photoluminescence and Raman study of zinc oxide nano-pillars — •Günther M. Prinz[1], Anton Reiser[1], Andre Langlois[1], Xinmin Cao[1], Andreas Ladenburger[1], Marek Potemski[2], Wolfgang Limmer[1], Rolf Sauer[1], and Klaus Thonke[1] — [1]Abt. Halbleiterphysik, Universität Ulm, D-89069 Ulm — [2]Grenoble High Magnetic Field Laboratory, 25 Av. de Martys, BP166

For optical characterization of zinc oxide nano-pillars grown on a-plane sapphire we used low-temperature Magneto-Photoluminescence(PL) and Raman spectroscopy. The g-Factors for electrons and holes were calculated based on Magneto-PL data. We observe similar donors and splittings as in ZnO bulk material. From splitting patterns recorded in Faraday and Voigt configuration we estimate the alignment degree of the pillars perpendicular to the a-plane of the substrate. Using Raman measurements we were able to calculate the strain parallel to the c-axis of the nano-pillars [1]. These results are consistent with high resolution x-ray diffraction data measured for comparison.

[1] Th. Gruber et al, J. Appl. Phys. 96(1) 289 (2004)

HL 17.16 Fr 16:30 Poster TU F

Optical phonons and infrared dielectric functions of hexagonal and cubic MgZnO thin films — •C. Bundesmann, M. Schubert, A. Rahm, D. Spemann, H. Hochmuth, E. M. Kaidashev, M. Lorenz und M. Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstraße 5, D-04103 Leipzig, Germany

Infrared spectroscopic ellipsometry (IRSE) and Raman scattering is applied to study the phonon modes and infrared dielectric functions of $Mg_xZn_{1-x}O$ thin films, which are grown by pulsed laser deposition on c-plane and r-plane sapphire. X-ray diffraction reveals a hexagonal structure for the $Mg_xZn_{1-x}O$ thin films with $x \leq 0.53$, whereas a cubic structure is found for the $Mg_xZn_{1-x}O$ thin films with $x \geq 0.67$. The cubic $Mg_xZn_{1-x}O$ thin films show a one mode behavior, where the TO and LO phonon modes shift linearly with x.[3] The hexagonal c-plane oriented $Mg_xZn_{1-x}O$ thin films on c-plane sapphire show two modes each for polarizations $E \perp c$ and $E||c$.[1,2] The phonon mode behavior with x can be described by the modified random element isodisplacement model.[4] Furthermore, generalized IRSE is applied to a-plane MgZnO thin films on r-plane sapphire, which allows to access the full set of infrared dielectric tensor parameters.[5] For the a-plane MgZnO thin films three phonon modes each for polarizations $E \perp c$ and $E||c$ are detected.

[1] C. Bundesmann et. al, Appl. Phys. Lett. 81, 2376-2378 (2002).
[2] R. Schmidt et. al, Proc. 26th ICPS, Edinburgh, UK (2002).
[3] C. Bundesmann et. al, Appl. Phys. Lett. 85, 905-907 (2004).
[4] J. Chen and W. Z. Shen, Appl. Phys. Lett. 83, 2154 (2003).
[5] C. Bundesmann et. al, Thin Solid Films 455-456C, 161-166 (2004).

HL 17.17 Fr 16:30 Poster TU F

Phonon and free-charge-carrier properties in — •Tino Hofmann[1], Bruno Daniel[2], Kapil Chandra Agarwal[2], Michael Hetterich[2] und Mathias Schubert[1] — [1]Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Universität Leipzig, Linnéstraße 5, 04103 Leipzig — [2]Institut für Angewandte Physik, Universität Karlsruhe, Wofgang-Gaede-Straße 1, 76131 Karlsruhe

$Zn_{1-x}Mn_xSe$ is a potential spin aligner in spintronic devices. We determine the free-charge-carrier effective mass m of doped n-type $Zn_{1-x}Mn_xSe$:Cl grown by molecular beam epitaxy using magnetooptic generalized ellipsometry at far-infrared wavelengths ($100-650\ cm^{-1}$) and external magnetic fields $B = \pm 3$ T. A clear decrease of $m(Zn_{1-x}Mn_xSe, x > 0)$ compared with m(ZnSe) is observed. We furthermore report on the composition dependent MnSe- and ZnSe-like phonon mode frequencies for the composition range from $x = 0$ to 0.2.

HL 17.18 Fr 16:30 Poster TU F

Evidence for an electrically conducting layer at the native zinc oxide surface — •Oliver Schmidt[1], Arnd Geis[1], Peter Kiesel[1], Noble Johnson[1], Andreas Waag[2], and Gottfried Döhler[3] — [1]Palo Alto Research Center, 3333 Coyote Hill Rd., Palo Alto, CA 94304, USA — [2]University of Braunschweig, Institute for Semiconductor Technology, Hans-Sommer Str. 66, 38106 Braunschweig — [3]University of Erlangen, Institute for Technical Physics I, Erwin Rommel-Str. 1, 91058 Erlangen

Measurements of the electrical properties of high-resistivity zinc oxide (ZnO) are strongly influenced by the sample ambient. Temperature-dependent Hall-effect measurements were performed on Li- and Cu-doped bulk crystals in both air and vacuum. Repeating the measurements under a given test ambient produced stable results. Changing the ambient systematically changed the measured results. We explain this behavior in terms of a surface conducting channel that exists in vacuum but is destroyed upon exposure to air. We propose that the surface conducting layer is eliminated in air due to changes of the surface condition (i.e., molecular adsorption from the gas phase and/or surface reconstruction mechanisms).

HL 17.19 Fr 16:30 Poster TU F

Analysis of a conducting channel at the ZnO surface using MOS structures — •Arnd Geis[1], Oliver Schmidt[1], Peter Kiesel[1], Noble Johnson[1], Andreas Waag[2], Andrey Bakin[2], and Gottfried Döhler[3] — [1]Palo Alto Research Center, 3333 Coyote Hill Rd., Palo Alto, CA 94304, USA — [2]University of Braunschweig, Institute for Semiconductor Technology, Hans-Sommer Str. 66, 38106 Braunschweig — [3]University of Erlangen, Institute for Technical Physics I, Erwin Rommel-Str. 1, 91058 Erlangen

The electrical properties of high-resistivity zinc oxide (ZnO) are strongly influenced by the sample ambient. Bulk samples that have been high resistive in ambient air can be reversibly transferred into a high conducting state under vacuum.

As an explanation we proposed a conducting electron channel at the ZnO surface. Under vacuum this channel appears upon annealing. Exposure to ambient air destroys the channel. The channel is evident only for samples showing a high bulk resistivity, and it seems to be the "natural"state of the ZnO surface.

We have investigated a variety of surface passivation layers and coatings in order to preserve or avoid the surface conducting channel under either environment. Appropriate coatings that preserve the surface conducting channel have been used for fabrication of MOS structures. We investigated the nature of the conducting channel by modulating the free carrier concentration at the surface. Our findings are important with regard to MOSFET devices based on ZnO.

HL 17.20 Fr 16:30 Poster TU F

Direct writing of two-dimensional electron gases by focused ion beam implantation doping of inverted GaAs/AlxGa1-xAs-heterostructures — •Christof Riedesel, Dirk Reuter, and Andreas D. Wieck — Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universtitätsstr. 150, D-44780 Bochum

We use molecular beam epitaxy (MBE) overgrowth of focused ion beam (FIB) implanted AlxGa1-xAs to fabricate laterally patterned two-dimensional electron gases (2DEGs) [1,2]. In this contribution we present directly written 2DEGs with sub-micron resolution. By choosing a line as implantation pattern and thus receiving a narrow lateral doping profile with an approximate width of the FIB-diameter, narrow electronic channels can be fabricated. Due to the additional lateral confinement of the 2D electrons in such a narrow channel the magnetotransport shows characteristic features which can be used to evaluate the electronic width of the channel. So far a minimal electronic channel width of 360 nm has been achieved. Financial support of the German Federal Ministry of Education and Research via grant No. 01BM908/6 is gratefully acknowledged.

[1] D. Reuter, C. Riedesel, P. Schafmeister, C. Meier, and A.D. Wieck, Appl. Phys. Lett. 82 (2003) 481.

[2] C. Riedesel, D. Reuter, and A.D. Wieck, Physica E 21, 592-596 (2004).

HL 17.21 Fr 16:30 Poster TU F

Anharmonic potentials for quantum dot atoms. — •Joseph Ambrose Pagaran and Stephan Fritzsche — Universität Kassel, Institut für Physik, D–34132 Kassel, Germany

Most model potentials that describe how electrons are confined in quantum dot atoms are based on harmonic potentials [1]. However, these model potentials are too simple and often lead to incorrect electronic structure of the system. As alternative model potentials, we propose a one-parameter family of anharmonic potentials following the work of Luban et al. [2] but generalized to three-dimensions. This family of potentials is obtained using the so-called intertwining method [3]. Because this family of potentials has a single parameter, which can be later fitted to the observed energy levels of the system, it may be more appropriate to describe the electron motion in realistic dots. In practice, realistic model potentials are usually derived using numerical methods.

[1] S. Reimann and M. Manninen, Rev. Mod. Phys. 74 (2002) 1283.
[2] M. Luban et.al., Appl. Phys. Lett. 54 (1989) 1997.
[3] J.O. Rosas-Ortiz, J. Phys. A: Math. Gen 31 (1998) L507.

HL 17.22 Fr 16:30 Poster TU F

Magneto transport measurements on overgrown cleaved edge heterostructures in hallbar-geometry — •Markus Lermer, Elisabeth Reinwald, Werner Wegscheider, and Dieter Weiss — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg

We present new methods to pattern and characterise overgrown cleaved edge (CE) heterostructures. By means of a novel sandwich technique a typically $6\mu m$ wide hallbar can be created on the edge of the less than $100\mu m$ wide cleavage-plane. The two-dimensional electron system (2DES) on the CE-plane is contacted by low resistive ohmic finger-contacts. This 4-point geometry allows for the first time direct measurement of the Hall- and longitudinal resistivity components of the 2DES on the cleavage plane. Due to the underlying superlattice the system is density modulated in a direction parallel to the current flow, and shows pronounced magneto resistance oscillations, which can be assigned to the various Fermicontours of a 1D- modulated system. The wet chemical transfer of linepatterns, e-beam written in self assembled monolayers, creates an additional modulation perpendicular to the current flow, so that a 2D-modulated electron system with small unit cell can be realised.

HL 17.23 Fr 16:30 Poster TU F

Defect analysis at the a-Si:H/c-Si heterojunction — •Abdelazize Laades, Lars Korte, Karsten v. Maydell, Christian Schubert, Klaus Kliefoth, Manfred Schmidt, and Walther Fuhs — Hahn-Meitner-Institut Berlin, Silizium-Photovoltaik, Kekuléstr. 5, D-12489 Berlin

Ultrathin undoped hydrogenated amorphous silicon (a-Si:H) layers (thickness $\approx$ 10 nm) were deposited by plasma-enhanced chemical vapor deposition on p-doped crystalline silicon wafers. The density of states at the a-Si:H/c-Si(p) interface was investigated by field-dependent surface photovoltage (FD-SPV) and photoluminescence (PL) techniques. Photoelectron yield spectroscopy (PEYS) has been applied to determine the density of states $N(E)$ within the ultrathin a-Si:H films.

By means of FD-SPV, the energetic distribution of the interface trap density $D_{\rm it}(E)$ could be determined. However, at room temperature the measurement is strongly influenced by recharging effects in a-Si:H. This effect can be reduced by cooling the sample down to 100 K.

$D_{\rm it}(E)$ consists of a continuum with a characteristic curvature extending towards the band edges. The minimum of $D_{\rm it}(E)$ is as low as 2×10^{11} eV^{-1}cm^{-2} at mid-gap. This demonstrates the excellent passivation of the silicon surface by a-Si:H. Applying PEYS, the Fermi energy and the gap state distribution (density of dangling bonds at mid-gap and Urbach energy of the tail states) in the a-Si:H film were measured. We will discuss the complex relationship between the values of $N(E)$ and $D_{\rm it}(E)$ measured with both methods.

HL 17.24 Fr 16:30 Poster TU F

Diamagnetic Shift of localized excitons in GaAs/AlGaAs Quantum Wells — •M. Erdmann[1], M. Wenderoth[1], R.G. Ulbrich[1], S. Malzer[2], and G. Döhler[2] — [1]IV. Physikalisches Institut der Universität Göttingen,Friedrich-Hund-Platz 1, 37077 Göttingen — [2]Institut für technische Physik, Universität Erlangen-Nürnberg, Erwin-Rommel-Straße 1, 91058 Erlangen

We have performed Magneto-Micro-Photoluminescence (μPL) experiments on GaAs/AlGaAs quantum wells. Emission spectra with spectral resolution of 70 μeV were obtained using a scanning μPL microscope with lateral resolution of 500 nm. A magnetic field of up to 12 T was applied perpendicular to the quantum wells. The disorder potential of the quantum well interfaces leads to a localization of excitons [1]. We find

that with increasing emission energy the diamagnetic shift of individual localized states increases by approximately a factor of 2. We discuss our results with regard to recent calculations of Grochol and Grosse [2].
[1] A. Zrenner et al., Phys. Rev. Lett. 72 (1994) 3382
[2] M. Grochol, F. Grosse, Proc. ICPS, Flagstaff 2004

HL 17.25 Fr 16:30 Poster TU F

Global view on the electronic properties of two-electron anisotropic quantum dots — •Panagiotis Drouvelis[1], Peter Schmelcher[1,2], and Fotis Diakonos[3] — [1]Theoretische Chemie, Universität Heidelberg, Im Neuenheimer Feld 229, D-69120 Heidelberg, Germany — [2]Physikalisches Institut, Philosophenweg 12, Universität Heidelberg, D-69120 Heidelberg, Germany — [3]Department of Physics, University of Athens, GR-15771 Athens, Greece

A detailed investigation of the effects of the interaction and anisotropy on the electronic structure and dynamical properties of two-electron quantum dots is being performed. For a circular quantum dot the system is integrable and the pure symmetry spectrum shows level clustering. The introduction of anisotropy serves as a rapid path to chaos for the classical dot with severe impact on the spectrum, thereby showing widening and interaction of the clusters. For particular anisotropic configurations the spectra show level clustering and one specific case turns out to be integrable. The parity symmetries of the corresponding integral of motion lead to singlet-triplet degeneracies. The developed numerical method also allows for a statistical analysis of the energy levels, which show deviations from the standard predictions. For predominantly chaotic phase spaces the results converge to the Wigner surmise. For very strong anisotropies, i.e., for the wire-like limit, the dynamical properties comprise the complete regime from softly interacting to kicked oscillators while the quantum counterpart exhibits intriguing patterns in the spectral sequence of level spacings.

HL 17.26 Fr 16:30 Poster TU F

All-electron GW code based on FP-(L)APW+lo — •Xinzheng Li, Ricardo Gomez-Abal, and Matthias Scheffler — Fritz-Haber-Institut der Max-Planck-Geselschaft, Faradayweg 4-6, Berlin

In the last years, the GW approximation (GWA) with input from density functional theory (DFT) has allowed for realistic and accurate treatment of the excited state properties of several systems, providing quasiparticle energies, lifetimes and dielectric functions. In most of the existing codes, pseudopotential DFT calculations are used as input and the self energy is computed for the valence states only, which corresponds to the assumption that the core-core and core-valence contributions to the self-energy can be well approximated by DFT. While this assumption is valid in many cases, there are still some others in which these two contributions show discrepancy with the DFT calculations and need to be computed within the GWA. The development of an all-electron GWA calculation is then necessary to include a larger range of materials.

We present a description of an all-electron GW code based on the FP-(L)APW+lo method. The optimized basis used for the matrix representation of nonlocal operators allows the inclusion of core and semicore states on the same footing with a reasonable computational cost. Preliminary results for Silicon are shown.

HL 17.27 Fr 16:30 Poster TU F

Investigation of Schottky diodes in high magnetic fields — •Matthias Schmidt, Holger von Wenckstern, Rainer Pickenhain, Michael Ziese, Pablo Esquinazi, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnestrasse 5, 04103 Leipzig

We report on investigations of Schottky diodes in magnetic fields ranging from 0 to 9 T. The contacts are realized on n-GaAs by thermal evaporation of Ni or Au. The diodes are characterized by current-voltage, capacitance-voltage, and admittance measurements. These measurements are done for temperatures between 10 K and 300 K in dependence on the applied magnetic field. The scope of this contribution is to determine the influence of the ferromagnetic Schottky contact realized with Ni on the interface properties compared to the diamagnetic contact realized with Au.

HL 17.28 Fr 16:30 Poster TU F

Modeling the electrical properties of interfaces obtained via UHV wafer bonding — •Alin Mihai Fecioru, Stephan Senz, and Ulrich Michael Gösele — Max-Planck-Institut für Mikrostrukturphysik, 06120 Halle

Si-Si and Si-GaAs interfaces were obtained by ultrahigh vacuum (UHV) wafer bonding. The electrical properties were characterized by temperature dependent current-voltage (I-V) measurements and deep level transient spectroscopy (DLTS). We compared various models for such interfaces with experimental results. First, the anti-serial Schottky barrier is used to model the band bending at the interfaces, and the proposed mechanism is the thermionic emission over the barrier, which is valid only when the mean free path of the carriers is large compared to the width of the depletion layer. A second approach is based on the drift-diffusion model, which yields analytical results only when the full-depletion approximation is assumed. Since the agreement between the experimental data and the calculated values are generally poor, we suggest an approach where an incomplete trap filling model is implemented into the Poisson equation together with an impact ionization contribution for high electrical fields.

HL 17.29 Fr 16:30 Poster TU F

Dotierelementabhängigkeit der Rauigkeit von elektronischen Grenzflächen in GaAs — •Sebastian Landrock, Nikos Jäger, Knut Urban und Philipp Ebert — IFF-IMF Forschungszentrum Jülich 52425 Jülich

Es wurden die Schichtdicke sowie die Rauigkeit und Korrelationslänge der elektronischen Grenzflächen von MBE gewachsenen GaAs-p-n-Schichtsystemen mittels Querschnitts-Rastertunnelmikroskopie untersucht. Für die p-dotierten Bereiche wurden zwei verschiedene Dotierelemente verwendet. Dabei zeigte sich, dass bei den mit Be dotierten Proben die Rauigkeit kleiner ist als bei einer C-dotierten Probe. Insbesondere ließ sich nur eine Komponente der Rauigkeit finden, welche durch die Abschirmung der geladenen Dotieratome hervorgerufen wird. Die zuvor gefundene Rauigkeitskomponente aufgrund einer Clusterung der C-Dotieratome liegt nicht in den Be dotierten Proben vor. Darüberhinaus sind die Be-dotierten Schichten -nicht jedoch die C-dotierten Schichten- deutlich verbreitert, was auf eine Diffusion der Be-Atome schließen lässt. Wir zeigen, dass die durch Diffusion bewirkte Aufreihung der Dotieratome an den Grenzflächen für die geringere Rauigkeit der p-n-Grenzflächen verantwortlich ist.

HL 17.30 Fr 16:30 Poster TU F

Scanning Tunneling Microscopy of Substitutional Phosphorus Atoms on different Lattice Sites in the Si(111)-(2×1) Surface — •J. K. Garleff[1], M. Wenderoth[1], R. G. Ulbrich[1], C. Sürgers[2], and H. v. Löhneysen[2] — [1]IV. Physikalisches Institut, Universität Göttingen, D-37077 Göttingen — [2]Physikalisches Institut and DFG Center for Functional Nanostrcutures (CFN), Universität Karlsruhe, D-76128 Karlsruhe

Substitutional phosphorus (P) atoms ($N_D \approx 6 \times 10^{18} cm^{-3}$) at the Si(111)-(2×1) surface were investigated by scanning tunneling microscopy (STM). The samples were prepared by *in situ* cleavage under ultra-high vacuum (UHV) conditions. The measurements were performed at low temperature (8 K) in a custom build STM. The P atoms were identified by their well-known characteristic voltage-dependent contrast [1]. At -0.5 V, the STM image exhibits an additional anisotropic protrusion that extends up to 10 nm along the individual π-bonded chains affected by the P atom. Four site-specific contrast patterns induced by the presence of P are observed in agreement with the four non-equivalent lattice sites for substitutional P atoms at the Si(111)-(2×1) surface [2]. The individual features are attributed to the local electronic properties of P atoms at the different lattice sites.
[1] T. Trappmann, C. Sürgers, and H. v. Löhneysen, Europhys. Lett. **38**, 177 (1997)
[2] K. C. Pandey, Phys. Rev. Lett. **47**, 1913 (1981)

HL 17.31 Fr 16:30 Poster TU F

Conductivity and preparation of nanowires — •F. Kost[1], T. Kolb[1], A. Pucci[1], M. Jalochowski[2], V. Hnatyuk[2,3] und G. Fahsold[1] — [1]Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität, 69120 Heidelberg, Germany — [2]Institute of Physics, Maria Curie-Sklodowska University, 20031 Lublin, Poland — [3]European College of Polish and Ukrainian Universities, 20029 Lublin, Poland

The investigation of metal nanowires is feasible with infrared-spectrometric experiments, which allow analysing these wires in a non-contact mode. Since the wires can be treated as antennas, they show resonances in the mid infrared range. Hence, by measuring the infrared- transmission spectra of nanowires, one can determine various characteristics of the wire. In this regard, size-effects in their

conductivity are of special interest. On the basis of model calculations, the measured transmission spectra give information on the dynamic conductivity of the nanowires [1]. In collaboration with the Group of M. Jalochowski (Lublin), we prepare metal nanostructures by evaporating lead on regularly stepped silicon surfaces. Thereby, solid-like nanowires of Pb align parallel to the step edges of the silicon due to self-organization processes. The diameter of such produced single crystalline wires ranges from about 1nm up to few ten nanometers [2].

[1]G. Fahsold and A. Pucci, Adv. in Solid State Physics, Vol. 43, ed. by B. Kramer (Springer, 2003) 833.

[2]M. Jalochowski, M. Strozak, R. Zdyb, Applied Surface Science 211 (2003) 209-215.

Supported by DFG (SPP 1165).

HL 17.32 Fr 16:30 Poster TU F

Classical Analysis of Trajectories in an Open Quantum Dot — •Roland Brunner[1], R. Meisels[1], F. Kuchar[1], M. Elhassan[2], J. Bird[3], and K. Ishibashi[4] — [1]Department of Physics, University of Leoben, Austria — [2]Department of Electrical Engineering, Arizona State University, USA — [3]Department of Electrical Engineering,University at Buffalo The State University of New York — [4]Semiconductor Laboratory, RIKEN, Saitama, Japan

Transport in sub-micron semiconductor structures is an important topic of low-dimensional electron physics. Among other possibilities small structures can be realized in the form of electron billiards, e.g. quantum dots, when the electron mean free path is larger than the region to which the electrons are confined. Then and for low currents, the transport can be described classically by the ballistic motion of single electrons. In this work, we address the question of stable trajectories in open quantum dots and their contribution to prominent structure in the low-field magnetoresistance. We present a classical model which allows to vary the confinement potential, deviations from circular symmetry, the entrance angle of the electrons (focussing), and the number of dots in series. We show in which regions of entrance angles backscattering peaks in the low-field magnetoresistance occur. We find that a smooth (parabolic) confinement potential describes the experimental magnetoresistance traces significantly better than a hard wall potential. For the backscattering regions we calculate the trajectories in a single open quantum dot and observe that all of them are regular and not chaotic.

HL 17.33 Fr 16:30 Poster TU F

Time-resolved THz-spectroscopy of Graphite — •Florian Schapper, Tobias Kampfrath, Luca Perfetti, Christian Frischkorn, and Martin Wolf — Fachbereich Physik der Freien Universität Berlin, Arnimallee 14, 14195 Berlin

We excite graphite with short laser pulses centered at 775 nm and subsequently probe its in-plane optical properties with mid-infrared pulses in a frequency range of about 8 to 28 THz. The field-resolved sampling of the probe pulses allows for the determination of the transient dielectric function of the sample. It contains a Drude-like response and a contribution induced by the blocking of direct optical transition. We are able to extract the temporal evolution of the electronic temperature, plasma frequency, and Drude current relaxation rate. Our results give evidence for the generation of hot optical phonons, which contribute strongly to a striking increase of the Drude relaxation rate by more than 100% during the first picosecond after excitation.

We present first results on shaping mid-infrared pulses by shaping the visible generation pulses.

HL 17.34 Fr 16:30 Poster TU F

Elektrische Transportmessungen in MeV dotierten Diamant-Substraten — •V.A. Tchernychev, T. Vogel und J. Meijer — Zentrale Einrichtung für Ionenstrahlen und Radionuklide, Ruhr-Universität Bochum

Um die Leitfähigkeit von IIa-Diamantsubstraten zu untersuchen, wurde Bor unter verschiedenen Implantationstemperaturen und Konzentrationen mit 2 MeV implantiert. Nach einem Ausheil- und Ätzprozess wurden an den Proben Hall Effekt- Messungen in einem Temperaturbereich von T=20-500°C zur Bestimmung der Ladungsträgerkonzentration und der Beweglichkeit durchgeführt. Die Proben mit Dotierungsgrößen von $10^{15}/cm^2$ zeigten insgesamt einen starken Abfall der Beweglichkeit bei niedrigen Temperaturen, obwohl das Leitfähigkeitsverhalten nur eine geringfügige Änderung zeigte. Als Ursache ist allgemein akzeptiert, dass der freie Ladungsträgerstrom in diesem Temperaturbereich durch Hopping ersetzt wird. Dieser parasitäre Strom zeigt offensichtlich keinen oder nur einen geringen Halleffekt. In der Literatur wird dieses Verhalten aber bislang kontrovers diskutiert; unklar scheint ebenfalls zu sein, ob und in welcher Form Hopping-Leitfähigkeit eine magnetische Induktion erzeugt. Dieser Beitrag soll das gefundene Transportverhalten verschiedener Diamantproben diskutieren und die Ergebnisse mit bekannten Modellvorstellungen vergleichen.

HL 17.35 Fr 16:30 Poster TU F

Optical and electronic properties of nitrogen-doped ultrananocrystalline diamond thin films — •Philipp Achatz, Jose-Antonio Garrido, and Martin Stutzmann — Walter Schottky Institut, Technische Universität München, Am Coulombwall, 85748 Garching, Germany

Ultrananocrystalline diamond thin films have recently attracted renewed interest, mainly due to the appearance of a very high n-type conductivity induced by the addition of nitrogen during growth. It has been shown that ultrananocrystalline diamond films can be deposited over large areas with a surface roughness down to 10nm, n-type conductivity up to 200 Ω-1cm-1 , and with electrochemical and mechanical properties very similar to the case of single crystalline diamond films. In this paper, we present our work on the characterization of the electronic, optical and structural properties of N-doped ultrananocrystalline diamond films grown on Si, quartz and diamond substrates. The mechanism of the high conductivity and the change of the electronic structure resulting from the incorporation of nitrogen will be discussed based on Hall effect, temperature dependent conductivity, and photocurrent measurements. Raman and X-ray diffraction experiments have been carried out to asses the structural properties of the ultrananocrystalline diamond films.

HL 17.36 Fr 16:30 Poster TU F

Einfluss der räumlichen Dispersion auf die Lumineszenz von Halbleitern — •Frithjof Meinke und Klaus Henneberger — Universität Rostock, FB Physik, 18051 Rostock

Wir untersuchen den Einfluss der räumlichen Dispersion auf die Lumineszenz eines Halbleiterplättchens in der Nähe der 1s-Energie des Exzitons. Wir folgen einem Modell, das trotz makroskopischer Beschreibung zusätzliche Randbedingungen vermeidet [1] und auf relativ einfache Weise erlaubt, die Lumineszenztheorie ohne Berücksichtigung der räumlichen Dispersion [2] um den Effekt der räumlichen Dispersion zu erweitern. Die retardierte Photon-Greensfunktion für diesen Fall lässt sich übersichtlich als Matrix schreiben und dient der Berechnung der Lumineszenz. Die Polarisationsfunktion des Halbleiters wird im interessierenden Frequenzbereich durch das Oszillatormodell genähert und ihr Übergang zum Vakuum geschieht durch die dielektrische Approximation. Der Unterschied der neuen Lumineszenzspektren gegenüber denen ohne räumliche Dispersion liegt etwa in der Größenordnung des Unterschieds bei Reflexionsspektren. Bedeutsam wird die Mitnahme der räumlichen Dispersion bei der Berechnung der Lumineszenz eines exzitonischen Bose-Einstein-Kondensats.

[1] PRL **80** 2889 (1998)
[2] PRL **76** 1820 (1996)

HL 17.37 Fr 16:30 Poster TU F

Photoluminescence properties of ZnO nanowires at low temperatures — •Lars Wischmeier[1], Tobias Voss[1], Ilja Rückmann[1], Sandra Börner[2], and Wolfgang Schade[2] — [1]Institut für Festkörperphysik, Universität Bremen, P.O. Box 330440, D-28334 Bremen — [2]Institut für Physik und Physikalische Technologien, Technische Universität Clausthal, Leibnizstrasse 4, D-38678 Clausthal-Zellerfeld

Zincoxide nanowires are promising building blocks for miniaturized optoelectronic devices operating in the blue to UV spectral region. Here, the optical properties of such wires with diameters < 200 nm were investigated at low temperatures. The nanowires were grown by a chemical vapor transport and condensation technique on a sapphire substrate.

The photoluminescence (PL) of the nanowire ensemble was measured as a function of temperature (4 - 100 K) and excitation density (up to 7.0 MW/cm^2). From the excitation density dependent measurement the P band resulting from the exciton-exciton collision shows a super-linear increase with slope values of ≈ 1 at low densities (< 0.7 MW/cm^2) and > 2 at higher densities. For a further emission peak originating from the radiative recombination of donor-bound excitons a linear increase was obtained. The temperature dependence of the shift of the emission energy was in good agreement with the empirical Varshni formula.

In addition results of first micro-PL studies of few to single ZnO nanowires with a spatial resolution on a sub-micrometer scale are presented.

HL 17.38 Fr 16:30 Poster TU F

Konzentrische a-Si/SiO_x Bragg-Reflektoren — •Rüdiger Schmidt-Grund[1], Tobias Gühne[2], Bernd Rheinländer[1], Volker Gottschalch[2], Helmut Herrnberger[2], Thomas Nobis[1] und Marius Grundmann[1] — [1]Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig — [2]Universität Leipzig, Fakultät für Chemie und Mineralogie, Linnéstr. 3, 04103 Leipzig

Laterales Bragg-Confinement von Mikroresonator-Lichtemittern erhöht das Verhältnis der Zahl der axial resonanten Moden zur Zahl der spontan emittierten lateralen Moden. Hoch reflektierende Si/SiO_x-Bragg-Reflektoren eignen sich gut zur Verbesserung des optischen Confinements in mikro-strukturierten Resonatoren. Auf Mikro-Glasstäbe mit Durchmessern von 5 bis 5000 μm wurden sowohl a-Si- und SiO_x-Einzelschichten als auch a-Si/SiO_x-Bragg-Reflektoren für den Wellenlängenbereich von 500 nm bis 1000 nm mit kleiner Paarzahl N (typisch N = 4,5) mittels PECVD (plasma-enhanced chemical vapor deposition) konzentrisch abgeschieden. Die Schichtdicken und das Reflexionsvermögen wurden mittels räumlich aufgelöster spektroskopischer Ellipsometrie und Mikro-Reflexion untersucht. Das aus der ellipsometrischen Analyse berechnete Reflexionsvermögen wurde mit demjenigen verglichen, welches mittels Mikro-Reflexion bestimmt wurde. Es wurde ein Zusammenhang zwischen Mikro-Glasstab-Durchmesser und Abscheiderate der Materialien gefunden. Für die Bragg-Reflektoren auf Mikro-Glasstäben wurden maximale Reflexionsvermögen über 96% erreicht. Für alle azimutalen Richtungen wurde eine Bragg-Bande im gleichen Wellenlängenbereich erzielt.

HL 17.39 Fr 16:30 Poster TU F

Laser-induced absorption changes in Cu_2O — •Tibor Fleck, Michael Jörger, and Claus Klingshirn — Institut fürAngewandte Physik, Universität Karlsruhe (TH), D-76128Karlsruhe

It is already known that a high density of 1s-excitons in the yellow series of Cu_2O leads to a density-dependent absorption change, i.e. increasing bleaching of np states with increasing density. To gather more information about e.g. the lifetime of the para-excitons we monitor the differential absorption spectra (DAS) for different excitation conditions ($\hbar\omega_{exc}$, P_{exc}) and delay times after pulsed ns-excitation with excimer- or dye-laser of our naturally grown Cu_2O samples.
Different $\hbar\omega_{exc}$ between the phonon-assisted 1s-absorption and excitation high above the band gap including resonant excitation of the np-states with P_{exc} up to the destruction threshold of the samples were chosen. The delay time between pump and probe ranges from time resolved ns-regime to time-integrated μs→ms-regime (the latter with a time resolution of $\approx$ 4μs). Some of the problems arising with DAS of small absorption changes and their interpretation are discussed.
We compare these results with true 3d numerical simulations of the diffusion equation including the excitonic lifetime as well as surface recombination and exciton creation efficiency.

HL 17.40 Fr 16:30 Poster TU F

Exzitonische Effekte in optischen Spektren von Volumenkristallen: Implementierung der Bethe-Salpeter-Gleichung für PAW Pseudopotentiale — •Patrick Hahn, Wolf-Gero Schmidt, Kaori Seino, Jürgen Furthmüller und Friedhelm Bechstedt — Computational Materials Science Group, FSU Jena, Max-Wien-Platz 1, 07743 Jena

Die optischen Spektren von Gruppe-IV Halbleitern (Si, Diamant, SiC), III-V-Halbleitern (InN,AlN,InP,GaP,GaAs) sowie von hexagonalem Eis werden parameterfrei berechnet und systematisch bez. des Einflusses von Vielteilcheneffekten untersucht, um physikalische Trends zu identifizieren. Die Berechnung der Spektren erfolgt in drei Schritten, beginnend mit der Dichtefunktionaltheorie in LDA- oder GGA-Näherung. Die Lösung der Kohn-Sham-Gleichung für den Grundzustand erfolgt mit einem Ebenen-Wellen-Code (VASP) unter Nutzung von „projector augmented wave “ (PAW) Pseudopotentialen. Darauf aufbauend beziehen wir Quasiteilchenkorrekturen im Rahmen der GWA und den Einfluß der Elektron-Loch-Wechselwirkung durch die Lösung der Bethe-Salpeter-Gleichung mit in die Rechnung ein. Dies führt zu einer hervorragenden Übereinstimmung mit dem Experiment. Physikalische und chemische Trends des Umfangs der Elektron-Loch-Wechselwirkung werden im Detail diskutiert.

HL 17.41 Fr 16:30 Poster TU F

Characterization of vertical-cavity surface-emitting laser structures by modulation spectroscopy — •C. Karcher, B. Metzger, P.J. Klar, and W. Heimbrodt — Department of Physics and Material Sciences Center, Philipps-University of Marburg, Germany

In recent years, various modulation spectroscopic methods have been successfully applied for characterizing vertical-cavity surface-emitting laser (VCSEL) structures. In particular, photomodulated reflectance (PR) and contactless electroreflectance spectra yield useful information about the coupling between the quantum wells in active region of the device and the cavity. Corresponding line shape models for describing the resonance behavior between quantum well exciton and cavity have been developed. An aspect which has not been addressed is the dynamics of the modulation process in VCSEL structures and its dependence on the resonance between cavity and exciton. These effects can be studied in the frequency domaine by monitoring the quadrature PR signal as a function of modulation frequency. We studied these effects in an InGaAs/GaAs/AlAs VCSEL structure as a function of cavity detuning using modulation frequencies in the range of 1 HZ to about 100 KHz and using various modulation laser wavelengths.

HL 17.42 Fr 16:30 Poster TU F

Anomalous temperature-dependence of free-charge-carrier concentration in modulation-doped $Al_xGa_{1-x}As$/GaAs quantum well superlattices studied by far-infrared magnetooptic Mueller-matrix ellipsometry — •Tino Hofmann[1], Claas von Middendorff[1], Gunnar Leibiger[2] und Mathias Schubert[1] — [1]Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Universität Leipzig, Linnéstraße 5, 04103 Leipzig — [2]Fakultät für Chemie und Mineralogie, Halbleiterchemie, Universität Leipzig, Linnéstraße 3, 04103 Leipzig

A study of the temperature-dependent free-charge-carrier properties in modulation-doped $Al_xGa_{1-x}As$:Si/GaAs (L, $x = 0.45$) superlattices is presented. Two different samples with quantum well lengths $L = 18$ nm and $L = 4$ nm are investigated using magnetooptic generalized ellipsometry at far-infrared wavelengths ($100 - 650 cm^{-1}$) at external magnetic fields $B = \pm 3$ T and temperatures ranging from $T = 10$ to 293 K. The model analysis allows independent determination of the free-charge-carrier parameters density N, mobility μ and effective mass m within the wells dispensing with the need for electrical contacts. Beside a weak anisotropic mobility behavior, a strong increase of the quantum-well free-charge-carrier density with decreasing temperature is observed for $L = 4$ nm in contrast to the sample with $L = 18$ nm where the free-charge-carrier density decreases as expected. A simple rate model successfully describes this behavior as a steady state of three condensation processes.

HL 17.43 Fr 16:30 Poster TU F

Fabrication of high-Q microdisks with embedded InAs quantum dots — •F. Wilde, T. Kipp, Ch. Heyn und D. Heitmann — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg

Optical microdisks resonators have recently gained interest since their whispering gallery modes (WGMs) combine high Q-factors with small mode volumes [1] and thus giving the opportunity to study light confinement and light-matter interaction in various aspects. Especially a microdisk containing only one quantum dot which matches a WGM frequency and is spatially located in the antinode of the WGM would be of great interest [2].

We have fabricated large arrays of GaAs microdisks with embedded InAs quantum dots (QDs) using laser-interference lithography and a two-step etching process [3]. Our aim is to fabricate microdisks with decreasing densities of QDs so that eventually there is only one QD per microdisk. We report about the optimization of the preparation process in particular the etching which causes sidewall roughness and predominantly limits the Q-factor of a WGM. The samples are characterized by microphotoluminescence.

[1] B. Gayral *et al.*, Appl. Phys. Lett. **75**, 1908 (1999)
[2] P. Michler *et al.*, Appl. Phys. Lett. **77**, 184 (2000)
[3] K. Petter *et al.*, Appl. Phys. Lett. **81**, 592 (2002)

HL 17.44 Fr 16:30 Poster TU F

Size dependent excitation energies of valence band plasmons in Si and SnO_x nanoparticles — •H Nienhaus, V Kravets, A Lorke, H Wiggers, M Kennedy, and F E Kruis — Sonderforschungsbereich 445, Universität Duisburg-Essen, 47048 Duisburg

Si and SnO_x nanoparticles with diameters in the range between 3 and 30 nm were produced in the gas phase and deposited on Au and Pd thin films. Structure and chemical composition were characterized by electron microscopy and Auger electron spectroscopy, respectively. By use of low electron energy-loss spectroscopy, electronic excitations of energies between 5 and 25 eV in the particles have been investigated. The energies of the valence band plasmons in both, Si and SnO_x, particles exhibit a strong size-dependence. Shifts of a few eV are observed when the diameter of the particle is reduced. The variation of the energy is found to be inversely proportional to the particle diameter. There are no significant changes of the excitation energy when varying the oxygen content of the tin oxide particles. In addition, energy losses due to interband transitions and core level ionization do not change with particle size.

HL 17.45 Fr 16:30 Poster TU F

SILICON LIGHT EMITTING DIODES PREPARED BY ION IMPLANTATION OF PHOSPHOROUS AND BORON — •Yevgen Yeromenko[1], Tzanimir Arguirov[1,2], Martin Kittler[2], and Winfried Seifert[2] — [1]BTU Lehrstuhl Experimentalphysik II — [2]IHP/BTU Joint Lab

The further progress in microelectronic technology requires, among others one more efficient and noise free way of transferring signals between the parts within a chip. A solution for substituting the currently used conductor interconnects is looked up in the optics: the use of optical interconnects. One aspect in the way to establish a viable optical communication in a chip is the development of efficient light emitter on silicon basis, compatible with currently used CMOS technology.

Here we report on light emitters, prepared by ion implantation. Boron or phosphorous are implanted in moderately doped n or p type silicon wafers and the wafers are subsequently annealed. In this way p-n junctions are formed. We study the influence of sample preparation conditions (implantation dose and energy, annealing type) over the room temperature silicon band edge luminescence from the diodes.

We observed efficient room temperature electroluminescence by forward biasing the diodes at typical for the microelectronics operating voltages - below 2V. The luminescence shows anomalous temperature behavior - its intensity becomes stronger with increasing the temperature.

HL 17.46 Fr 16:30 Poster TU F

Luminescence of Ge/Si heterostructures with miniband realized by Sb doping — •Vadim Talalaev, George Cirlin, Alexander Tonkikh, Nikolay Zakharov, and Peter Werner — Max-Planck-Institut, Weinberg 2, 06120 Halle (Saale)

The structure and emission properties of Ge/Si quantum dot superlattices (QDSLs) grown by molecular beam epitaxy are studied. In our particular system, an unusual large conduction band offset is formed by Sb doping of the Si spacer layers. Thereby, this heterostructure has a quantum well (QW) system for the electrons. The Arrhenius analysis of photoluminescence spectrum and a strict dependence of the activation energy versus spacer thickness indicate the existence of the electron state in this QWs. Related to this energy level, we measure the electroluminescence with a external efficiency 4E-4 at 1.55 um up to room temperature. We demonstate that such high luminescence efficiency is related to the formation of a conduction miniband due to tunneling of electrons between adjacent QWs and to the transition to quasi-direct excitons in Ge/Si QDSL. Miniband width (15-35 mev) and conduction band offset (110 mev) are calculated assuming different effective masse of electron state density for the Si QWs and Ge barriers as well. The details and limitations of the miniband concept are discussed.

HL 17.47 Fr 16:30 Poster TU F

Deposition von Si- und Ho-Ionen in $GaAs/Al_xGa_{1-x}As$ Heterostrukturen mittels fokussierter Ionenimplantation — •Sinan Ünlübayir, Dirk Reuter, Alexander Melnikov und Andreas D. Wieck — Lehrstuhl für angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum

Durch Anlegen einer Gegenspannung an den Probentisch einer Anlage zur fokussierten Ionenimplantation (FIB) ist es möglich, eine Vielzahl von Ionensorten auf Energien von typ. 50 eV abzubremsen. Aufgrund der geringen Ionenenergie werden für den Depositionsprosses nur geringe Kristallschäden erwartet, da die Eindringtiefen theoretisch nur von der Größenordnung einer Monolage sind. Eine III/V-Molekularstrahlepitaxie (MBE)-Anlage ist direkt mit der FIB-Anlage verbunden. Dies erlaubt es, den MBE-Prosses zu unterbrechen und durch diese Ionendeposition lokale Fremdatome einzubringen. Als Anwendungsbeispiel diskutieren wir die Deposition von Ho in das zweidimensionale Elektronensystem in einer $GaAs/Al_xGa_{1-x}As$-Heterostruktur, Ho dotierten InAs Quantenpunkten sowie mittels Si-Deposition dotierten $GaAs/Al_xGa_{1-x}As$-Heterostrukturen. Mittels Magnetotransportmessungen und Photolumineszenz wurde der Einfluß der eingebrachten Atome auf die elektrischen und optischen Eigenschaften untersucht.

HL 17.48 Fr 16:30 Poster TU F

Elektrische Charakterisierung von (Ga,Mn)As — •Safak Gök[1], Hartmut Zabel[2] und Andreas Wieck[1] — [1]Angewandte Festkörperphysik, Ruhr-Universität Bochum — [2]Experimentalphysik/Festkörperphysik, Ruhr-Universität Bochum

An ferromagnetische (Ga,Mn)As-Proben, die mit der Molekularstrahlepitaxie (MBE)-Technik hergestellt wurden, wurden Magnetotransportmessungen durchgeführt. Wir zeigen das Verhalten des Magnetowiderstandes und des Hallwiderstandes in Abhängigkeit von Temperatur. Unterhalb der Curie-Temperatur (76K) zeigen die Proben einen sehr starken negativen Magnetowiderstand. Bei höheren Temperaturen wird der Magnetowiderstand kleiner und wir beobachten auch ein Bereich mit positivem Magnetowiderstand für B=0T. Unserer Ziel ist ähnliche magnetische Halbleiter ortsaufgelöst herzustellen. Wir benutzen fokusierte Ionenstrahlen, um in das GaAs-Gitter magnetische Ionen einzubauen. Die ersten Ergebnisse bezüglich der Morphologie und Zusammensetzung der implantierten Bereiche werden vorgestellt.

HL 17.49 Fr 16:30 Poster TU F

MOVPE growth of $B_xGa_{1-x}P$ alloys on (001) GaP substrates — •Volker Gottschalch[1], Gunnar Leibiger[1], Jens Bauer[1], and Gabi Benndorf[2] — [1]Universität Leipzig, Institut für Anorganische Chemie, Linnéstraße 3, 04103 Leipzig — [2]Universität Leipzig, Institut für Experimentelle Physik II, Linnéstraße 5, 04103 Leipzig

Only a few data are available on the boron incorporation in $A^{III}B^{V}$ compounds. Epitaxial growth of $B_xGa_{1-x}As$ and $B_xGa_{1-x-y}In_yAs$ alloys on GaAs have been studied. We have studied the boron incorporation in GaP because of their optoelectronic properties and the potential application to optoelectronic devices. We report on the metal-organic vapourphase epitaxy growth of $B_xGa_{1-x}P$ alloys on (001) GaP substrates using the precursors triethylboron, trimethylgallium and phosphine. The mole fraction of Boron in the epitaxial layer was varied from x = 0 to 0.03. The growth behaviour of single layers and strained quantum well structures was studied. The influence of the growth conditions on layer deposition, boron incorporation, interface quality, and optical properties of bulk-like and quantum well structures is discussed and compared with the Nitrogen incorporation in GaP.

HL 17.50 Fr 16:30 Poster TU F

(InGa)As Laserbauelemente (1,2 μm) mit vergütetem Resonator — •Tobias Gühne[1], Volker Gottschalch[1], Gunnar Leibiger[1], Helmut Herrnberger[2], Jaro Kovač[3], Jaro Kovač jr.[4], Rüdiger Schmidt-Grund[5] und Bernd Rheinländer[5] — [1]Universität Leipzig, Institut für Anorganische Chemie, Linnéstraße 3, 04103 Leipzig — [2]Leibniz-Institut für Oberflächenmodifizierung e.V., Permoserstr. 15, 04303 Leipzig — [3]Slowakische Technische Universität, Fakultät für Mikroelektronik, Ilkovicova 3, SK 81219 Bratislava — [4]International Laser Center, Ilkovicova 3, SK 81219 Bratislava — [5]Universität Leipzig, Institut für Experimentelle Physik II, Linnéstraße 5, 04103 Leipzig

Die Darstellung und der Einfluss von a-Silizium- und Siliziumoxid-Schichten als Spiegel- und Antireflektionsschichten für Laserdioden (1,2 μm) wurde untersucht. Alle Laserstrukturen wurden mittels MOVPE auf (001)-GaAs gezüchtet. Das aktive Gebiet besteht aus einer Doppelquantengrabenstrukur von $Ga_{0,63}In_{0,37}As$, eingebettet in GaAs. Als Mantelschichten dienen zwei $Al_{0,35}Ga_{0,65}As$ Schichten. Mittels PECVD wurden die Laserriegel auf den Spaltflächen vergütet. Auf einer Resonatorfläche wurde ein 5,5-facher Braggspiegel aus Silizium und Siliziumoxid abgeschieden. Durch diese Vergütung wird nahezu die gesamte Lichtintensität über die Frontfläche emittiert, welche ihrerseits mit einer SiO_x-Schicht versehen in ihrer Reflektivität gemindert wurde. Die Auswirkungen auf den differentiellen Quantenwirkungsgrad, die Schwellstromdichte und die Strahlgüte wurden untersucht.

HL 17.51 Fr 16:30 Poster TU F

MOVPE-Darstellung freistehender $A^{III}B^{V}$-Nanodrähte — •Jens Bauer[1], Volker Gottschalch[1], Helmut Herrnberger[2] und Gerald Wagner[2] — [1]Universität Leipzig, Institut für Anorganische Chemie, Linnéstraße 3, 04103 Leipzig — [2]Leibniz-Institut für Oberflächenmodifizierung e.V., Permoserstr. 15, 04303 Leipzig

Halbleitende Nanostrukturen bilden die Grundlage für neuartige optoelektronische Bauelemente. Dabei nehmen freistehende Nanodrähte eine Hauptrolle ein, da Heterostrukturen integriert werden können und die Morphologie der Nanodrähte eine einfache Kontaktierung erlaubt. Im Bereich einiger Nanometer lassen sich Quanteneffekte ausnutzen. Im Beitrag werden die Arbeiten zur Darstellung freistehender $A^{III}B^{V}$-Nanodrähte mittels Metallorganischer Gasphasenepitaxie (MOVPE) in einem „bottom-up"-Prozess vorgestellt. Die Grundzüge des Nanodrahtwachstums beruhen auf dem für Elementhalbleiter bekannten „vapor-liquid-solid" (VLS)-Wachstumsprozess, der für $A^{III}B^{V}$-Halbleiter und die MOVPE einiger Modifikationen bedarf. Es werden Untersuchungen zur Substratpräparation mit Goldpartikeln vorgestellt und der Einfluss von Wachstumsparametern (Temperatur, Partialdrücke, Wachstumszeit) auf die Realstruktur diskutiert. Schließlich wird auf erste Ergebnisse zur physikalischen Charakterisierung der Nanodrähte eingangen.

HL 17.52 Fr 16:30 Poster TU F

Magneto-optical spectroscopy and thermal annealing effects in GaInNAs / GaAs quantum well structures and bulk GaAsN — •A. Grau, P. Feinäugle, W. Löffler, H. Kalt, and M. Hetterich — Institut für Angewandte Physik and Center for Functional Nanostructures (CFN), Universität Karlsruhe, D - 76131 Karlsruhe, Germany

As a promising material system for the realization of near infrared optoelectronic devices GaInNAs / GaAs gained more and more importance, but still many material parameters are not well known.

In earlier investigations we used photoreflectance (PR) and photoluminescence excitation (PLE) spectroscopy in order to get more information about the band alignment and conduction band dispersion in GaInNAs-based quantum well structures as a function of compositions and well width. In this contribution we present the results of extended studies using magneto-photoluminescence (MPL) and magneto-absorption of GaInNAs / GaAs multiple quantum well structures. From the theoretical modelling of our MPL measurements we are able to obtain values for the reduced effective exciton mass and the electron effective mass. As expected a strong increase in the electron effective mass due to the presence of nitrogen is found, in good agreement with theory and our earlier PLE and PR results.

Additionally, we studied the effect of thermal annealing on the photoluminescence (PL) of GaAsN bulk samples in terms of intensity, line width and energy shift of the PL peak.

HL 17.53 Fr 16:30 Poster TU F

Studies of the local vibrational N-mode in III-N-V dilute nitrides by Raman spectroscopy — •M. Güngerich, P.J. Klar, W. Heimbrodt, B. Kunert, K. Volz, and W. Stolz — Department of Physics and Material Sciences Center, Philipps-University of Marburg, Germany

The local environment of the nitrogen atom is of crucial importance for the global electronic structure changes of the III-V host, i.e. the strength of the local perturbation at the N-site due to the differences in size and electronegativity between the N atom and the anion it replaces determines the magnitude of the band structure changes. The phonons of the dilute nitrides exhibit a two-mode behaviour. A local N-mode is observed in addition to the host-like modes. The local N-mode is a useful probe of the local N-environment. We study the frequency of the N-related mode in various III-N-V alloys, i.e. GaNAs, GaNSb, GaNP, at ambient pressure and at hydrostatic pressures up to 20 GPa yielding information about the Ga-N bond strength in a wide range of lattice constants.

HL 17.54 Fr 16:30 Poster TU F

Investigation and modelling of the temperature-dependent electronic states in GaNAs and GaInNAs/GaAs quantum well structures — •M. Hetterich[1], A. Grau[1], T. Passow[1], A.Yu. Egorov[2], and H. Riechert[2] — [1]Institut für Angewandte Physik and Center for Functional Nanostructures (CFN), Universität Karlsruhe, D-76131 Karlsruhe, Germany — [2]Infineon Technologies AG, Corporate Research Photonics, D-81730 München, Germany

Recently, GaInNAs/GaAs has evolved to one of the most promising material systems for the realization of optoelectronic devices operating in the near infrared spectral range. However, many aspects of its electronic structure are still under debate.

In our contribution we investigate the temperature-dependent conduction band structure of GaNAs and GaInNAs/GaAs MQWs with high In concentration using photoreflectance (PR) spectroscopy. The band structure is described using the well-known band anti-crossing (BAC) model. For the BAC wavefunction in general GaInNAs heterostructures we have derived special boundary conditions which are applied to calculate the bound states in the quantum well samples. From the modelling of our experimental data we obtain information about the BAC Hamiltonian parameters. Both the energy of the nitrogen level E_N and the coupling parameter C_{NM} in the Hamiltonian are found to decrease with increasing temperature. The anti-crossing interaction between E_N and the conduction band leads to a significantly reduced temperature dependence of the band-gap compared to nitrogen-free material.

HL 17.55 Fr 16:30 Poster TU F

Magneto-gyrotroper photogalvanischer Effekt in Halbleiter-Quantentrögen — •Wolfgang Weber[1], V.V. Bel'kov[2], S.D. Ganichev[1], E.L. Ivchenko[2], S.A. Tarasenko[2], S.N. Danilov[1], Petra Schneider[1], S. Giglberger[1], M. Olteanu[1], P. Tranitz[1], W. Wegscheider[1], D. Weiss[1] und W. Prettl[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg — [2]A. F. Ioffe Physico-Technical Institute, 194021 St. Petersburg, Rußland

Der Magneto-gyrotrope photogalvanische Effekt wurde in (001)- und (110)-orientierten Zinkblendestruktur basierten Quantentrögen unter optischer Anregung im Terahertz Frequenzbereich sowohl experimentell, als auch theoretisch untersucht. Die verwendeten Anregungsfrequenzen verursachen Intrasubband-Übergänge im Elektronenband. Ein parallel zur Probenebene ausgerichtetes Magnetfeld erzeugt Photoströme sowohl bei polarisierter als auch bei unoplarisierter Anregung. Im allgemeinen überlagern sich der spingalvanische Effekt, der durch zirkular polarisiertes Licht verursacht wird, und der magneto-gyrotrope Effekt, der durch unpolarisierte Anregung verursacht wird. Wir zeigen, daß die beiden Effekte im Falle zweier spezieller Geometrien separabel sind.

HL 17.56 Fr 16:30 Poster TU F

Ultrahigh vacuum direct bonding of III-V semiconductors at room temperature after cleaning with hydrogen ion — •Nasser Razek[1], Axel Schindler[1], Volker Gottschalch[2], and Bernd Rauschbach[1] — [1]Leibniz-Institut für Oberflächenmodifizierung e. V., Permoserstr. 15, D-04318 Leipzig, Germany — [2]Unversität Leipzig, linnestr.3 04103 Leizig, Germany

Direct wafer bonding of GaAs were carried out in an ultrahigh vacuum. The wafer surfaces GaAs were cleaned by bombardment of low energy a mass separated hydrogen of ions 300 eV with current density ~ 4.5 $\mu A/cm^2$ at temperature 150 °C. After cleaning at room temperature, the wafers were connected face to face. At contact, the interface formed spontaneously over the whole wafer area without any application of mechanical pressure. Then, the bonded wafers were annealed in UHV or at low temperature <200 °C to improve the bonding at the interface over the large wafer areas. The samples interface has been investigated by infrared transmission pictures and cross-sectional transmission electron microscopy. The electrical characteristic of the bond interface has been investigated by current-voltage (I-V) measurement.

HL 17.57 Fr 16:30 Poster TU F

Optical orientation of electron spins in GaAs quantum wells — •Stefan Pfalz[1], Roland Winkler[1], Tobias Nowitzki[1], Dirk Reuter[2], Andreas Wieck[2], Daniel Hägele[1], and Michael Oestreich[1] — [1]Universität Hannover, Institut für Festkörperphysik, Abteilung Nanostrukturen, Appelstraße 2, 30167 Hannover, Germany — [2]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstraße 150, 44780 Bochum, Germany

We present a detailed experimental and theoretical analysis of the optical orientation of electron spins in GaAs/AlAs quantum wells. Using time and polarization resolved photoluminescence excitation spectroscopy, the initial degree of electron spin polarization is measured as a function of excitation energy for a sequence of quantum wells with well widths between 63 Å and 198 Å. The experimental results are compared with an accurate theory of excitonic absorption taking fully into account electron-hole Coulomb correlations and heavy-hole light-hole coupling. We find in wide quantum wells that the measured initial degree of polarization of the lu-

minescence follows closely the spin polarization of the optically excited electrons calculated as a function of energy. This implies that the orientation of the electron spins is essentially preserved when the electrons relax from the optically excited high-energy states to quasi-thermal equilibrium of their momenta. Due to initial spin relaxation, the measured polarization in narrow quantum wells is reduced by a constant factor that does not depend on the excitation energy.

HL 17.58 Fr 16:30 Poster TU F

Spin dependent bleaching of the optical absorption in GaAs-QWs — Stefan Pfalz, Roland Winkler, Daniel Hägele, •Michael Römer, and Michael Oestreich — Universität Hannover, Institut für Festkörperphysik, Abteilung Nanostrukturen, Appelstraße 2, 30167 Hannover

The initial degree of spin polarization for optically excited electron-hole pairs in GaAs quantum wells is studied using time and polarization resolved photoluminescence spectroscopy. We observe a dramatic decrease of initial spin polarization with increasing excitation power. We argue that this decrease can be attributed to a spin dependent phase space filling. Optically created electrons and holes can partially block the creation of additional carriers, an effect known as bleaching of the optical resonance. This effect is spin dependent and effective as long as electrons and holes have not undergone a scattering event. A rate equation model yields good agreement with our experimental findings.

HL 17.59 Fr 16:30 Poster TU F

Parasitäre Moden in GaN Doppelheterostruktur Laserdioden — •Holger Fischer[1], Ulrich T. Schwarz[1], Thomas Schödl[1], Markus Pindl[1], Georg Feicht[1], Michael Furitsch[2], Andreas Leber[2], Andreas Miler[2], Alfred Lell[2] und Volker Härle[2] — [1]Institut für Angewandte und Experimentelle Physik, Universitätsstr. 31, 93053 Regensburg, Germany — [2]OSRAM Opto Semiconductors GmbH, Wernerwerkstr. 2, 93049 Regensburg, Germany

Wir untersuchen die Auswirkungen parasitärer Moden auf das Verstärkungsspektrum und auf das Fernfeld von (Al,In)GaN Laserdioden. Als Substratmaterial wird für diese Laserdioden entweder SiC oder GaN verwendet, das Substrat hat also gleichen oder höheren effektiven Brechungsindex als der Wellenleiter. Die Lasermode kann sich dadurch abhängig von der Wellenlänge ins Substrat ausbreiten. Im Verstärkungsspektrum beobachten wir deshalb Oszillationen der Verstärkung im Transparenzbereich der Diode. Auch die Auswirkungen auf das Fernfeld der Laserdioden haben wir durch Messungen untersucht. Wir können desweiteren durch Messungen des Nahfelds die parasitären Moden direkt nachweisen. Rechnungen nach der 1-dimensionalen Transfermatrixmethode zeigen gute Übereinstimmung zwischen Theorie und Experimenten. Ein besseres Verständnis der Entstehung und Auswirkungen der parasitären Moden soll dazu beitragen, die Laserstrukturen zu verbessern und die Ausbildung parasitärer Moden zu unterdrücken.

HL 17.60 Fr 16:30 Poster TU F

Molekular-Strahl-Epitaxie von Mn dotierten GaN Schichten — •Martin Kocan, Martin Roever, Dong-Du Mai, Marco Bertelli, Tore Niermann, Jörg Malindretos, Jan Zenneck, Michael Seibt und Angela Rizzi — IV. physikalischer Institut, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

Theoretische Arbeiten sagen für den magnetisch verdünnten Halbleiter GaN:Mn ferromagnetische Eigenschaften mit einer Curie Temperatur von über 300 K vorher. Das macht dieses Materialsystem interessant für 'Spin-Elektronik' Anwendungen. Die verfügbaren experimentellen Daten bestätigen zum Teil die Existenz einer ferromagnetischen Ordnung oberhalb von Raumtemperatur, sind bisher jedoch nicht konsistent genug, um die Frage nach den zugrunde liegenden Mechanismen zu beantworten. In diesem Beitrag wird die Untersuchung von GaN:Mn Strukturen vorgestellt. Die GaN:Mn Schichten wurden mittels einer MBE (Molekular-Strahl-Epitaxie) Anlage mit einer Uni-Bulb(TM) Plasma-Quelle hergestellt. Das Wachstum erfolgte auf einem p-Si(111) Substrat. Die GaN:Mn Schichten wurden bei unterschiedlichen Wachstumsbedingungen aufgewachsen. Unterschiedliche Mn Konzentration wurde in den Schichten gemessen. Die Oberflächenmorphologie wurde mit einem optischen Mikroskop und einem AFM (Atomic Force Microscopy) analysiert. Mit XRD (X-ray Diffraction) und TEM (Transmission Electron Microscope) konnte man die strukturellen Eigenschaften auf Ausscheidungen-Bildung untersuchen. Die magnetischen Eigenschaften zeigen sowohl paramagnetisches als auch ferromagnetisches Verhalten.

HL 17.61 Fr 16:30 Poster TU F

Scanning Tunneling Spectroscopy of Carbon and Zinc Acceptors in GaAs — •S. Loth[1], M. Wenderoth[1], T. C. G. Reusch[1], L. Winking[1], R. G. Ulbrich[1], S. Malzer[2], and G. Döhler[2] — [1]IV. Physikalisches Institut, Universität Göttingen, D-37077 Göttingen — [2]Institut für Technische Physik, Universität Erlangen-Nürnberg, D-91058 Erlangen

Carbon and zinc dopants embedded near in-situ cleaved {110} surfaces of GaAs were studied with low temperature UHV scanning tunneling spectroscopy (STS) at 8K. Both dopants are shallow substitutional acceptors, carbon on an As site and zinc on a Ga site. Laterally resolved STS measurements show conductivity at voltages well below 1V, localized at the dopant atoms. In the voltage interval from 0V to 1V the conductance above undisturbed surface regions vanishes. We employ a quantum-mechanical transport simulation to describe the tunnel current along a path perpendicular to the sample surface from the metallic tip to the bulk of the semiconductor. The comparison of the simulated spectra with the measured ones allows us to identify the transport mechanisms which contribute to the specific shape of the I(V) characteristics.

HL 17.62 Fr 16:30 Poster TU F

Optical and magnetic properties of rare earth implanted AlN — •G. Öhl[1], U. Vetter[1,2], M. Uhrmacher[1], C. Ronning[1], and H. Hofsäss[1] — [1]Georg-August-Universität, II. Physikalisches Institut, Friedrich-Hund-Platz 1, 37077 Göttingen — [2]Philipps-Universität, AG Oberflächenphysik, Renthof 5, 35032 Marburg

Rare earths (RE) in AlN already have been studied extensively. Nevertheless, as shown in recent studies e.g. on the system AlN:Gd [1,2], where single systems with moderate Lanthanide doses implanted were investigated - RE in AlN show very promising features, e.g. for the use as electroluminescent emitters.

In this study we investigated single (at high doses) and double systems of RE in AlN thin films grown on SiC. The RE were implanted at different energies and fluences giving a square implantation profile. RBS analysis was performed to monitor the annealing behaviour of the implantation profile, while possible clustering of the metal ions was monitored by XRD measurements. Optical properties were investigated by means of temperature dependent time-resolved cathodoluminescence studies, life-time and energy-transfer studies were performed on selected radiative intra-4f electron transitions of the implanted lanthanide ions. In addition, magnetic properties of the RE implanted AlN will be discussed.

(1) U. Vetter et al., Appl. Phys. Lett. 83, 11 (2003) (2) J.B. Gruber, U. Vetter et al., Phys. Rev. B 69 (2004)

HL 17.63 Fr 16:30 Poster TU F

Structural and magnetic properties of Co-implanted ZnO films — •Numan Akdogan[1], Alexei Nefedov[1], Hartmut Zabel[1], and Hans-Werner Becker[2] — [1]Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany — [2]Ionenstrahlenphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany

The recently discovered class of ZnO-based dilute magnetic semiconductors (DMSs), which can be formed by doping $3d$ transition metal atoms in ZnO, offers an interesting combination of electrical, optical, and magnetic properties. Of special interest is the possibility to join aspects of semiconductor and magnetic effects to develop new device concepts. Furthermore, the band gap in ZnO is large enough (3.3 eV) to allow operation of such devices at room temperature. Moreover, according to suggestion of Dietl [1], the ZnO-based DMSs can order ferromagnetically at room temperature. In this contribution we report on structural and magnetic properties of Co-implanted ZnO films. ZnO films were epitaxially grown sapphire substrates via rf-sputtering. Subsequentially the films were doped with Co-ions via ion implantation. The structural characterization was carried out using synchrotron radiation at the HASYLAB and the DELTA (Dortmund). The magnetic properties were investigated using x-ray resonant magnetic scattering (XRMS) at BESSY as well as MOKE and SQUID magnetometry. This work is supported by BMBF through the project 03ZAE8BO. N.A. acknowledges a fellowship through the International MPI Research School "SurMat".

1. T. Dietl et al, Science **287**, 1019 (2000).

HL 17.64 Fr 16:30 Poster TU F

Structural, optical and electrical properties of p-type transparent conducting $CuAlO_2$ thin films prepared by RF reactive sputtering — •Bin Yang, Bruno K. Meyer, Angelika Polity, Thorsten Krämer, and Baker Farangis — I. Physikalisches Institut, Justus-Liebig-Universität, Heinrich-Buff-Ring 16, 35392 Giessen, Germany

In recent years, p-type transparent conducting oxide compounds based on the delafossite structure have attracted much attention because of their potential in preparing novel transparent p-n junction for device applications. In this work, transparent conducting $CuAlO_2$ thin films have been deposited by RF reactive sputtering technique on glass and quartz substrates using CuAl alloy target in a mole ratio of 1:1. A study of structural, optical, and electrical properties was performed on the films, varying deposition parameters such as the substrate temperature and the oxygen partial pressure. The crystalline phase in the films was identified to be the delafossite structure by x-ray diffraction. The optical properties, such as the wavelength dependence of the transmittance and the band gap, were determined. The average transmittance is 55% in the wavelength range of 400-1100 nm and the band gap E_g ∼3.45 eV. Hall effect measurements confirmed the p-type nature of the semiconductors. The temperature dependence of the electrical conductivity of the $CuAlO_2$ thin films was measured.

HL 17.65 Fr 16:30 Poster TU F

Elektrische und optische Charakterisierung elektrochemisch abgeschiedener Zinkoxid/Farbstoff-Absorbermaterialien — •Jens Reemts, Jürgen Parisi und Achim Kittel — Abteilung Energie- und Halbleiterforschung, Institut für Physik, Universität Oldenburg, 26111 Oldenburg

Elektrochemische Farbstoff-Solarzellen verwenden zur Absorption von Licht und zum Transport der Ladungsträger kein klassisches Halbleitermaterial, sondern organische Farbstoffe, die an ein anorganisches Trägermaterial angelagert werden. Zinkoxid ist aufgrund seiner hohen Porosität und damit verbundenen großen Oberfläche neben TiO_2 ein vielversprechendes Material für solche Solarzellen. Ein großer Vorteil der Zinkoxidelektroden ist, dass die Farbstoff-Sensibilisatormoleküle direkt während der elektrochemischen Herstellung in das Trägermaterial eingebaut werden. Wir charakterisieren den Einfluss unterschiedlicher Farbstoffmaterialien und -konzentrationen auf die Oberflächenmorphologie mittels optischer und Rastersonden-Mikroskopie. Die elektrischen Eigenschaften dieser als Elektrode verwendeten Kompositschichten werden mit Hilfe von Strom/Spannungs-Messungen unter Beleuchtung und in Dunkelheit untersucht. Die spektrale Antwort der transversalen und lateralen Filmleitfähigkeiten wird unter Beleuchtung mit verschieden farbigen LEDs charakterisiert. Wir beobachten neben thermisch aktivierten Zuständen sehr lange Relaxationszeiten auf Änderungen der Beleuchtungsintensität mit unterschiedlichen Wellenlängen bei Messungen ohne Elektrolyten.

HL 17.66 Fr 16:30 Poster TU F

Two Photons photoemission from metastable continuum states of fullerens and nanoclusters — •Oleg Kidun[1], Jamal Berakdar[1], and Natasha Fominykh[2] — [1]MPI für Mikrostrukturphysik, Halle, Germany — [2]Institute of Physics, St. Petersburg State University, St. Petersburg, Russia

Using the variable phase approach [1-3]we developed a method for the investigation of the quasistationary states of fullerenes and nanoclusters. In particualr we explore the possibility of the two-photons photoemission from these states. The energy and the time behavior of two-photon photoionization probability is studied in details and illustrated by numerical results.

[1] F. Calogero, Variable Phase Approach in Potential Scattering, AP, NY (1967)

[2] V. Babikov, Method of the Phase Functions in Quantum Mechanics, Nauka, Moscow (1969)

[3] O. Kidun, N. Fominykh, J. Berakdar, J. Phys. A 35, 9413 (2001)

HL 17.67 Fr 16:30 Poster TU F

In-plane gate transistors realized by writing with focused-ion-beam implantation — •Mihai Draghici, Dorina Diaconescu, Dirk Reuter, and Andreas D. Wieck — Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstr. 150, 44780 Bochum

The focused-ion-beam (FIB) technique was used in past to directly write in-plane gate transistors [1]. Insulating regions are written by FIB implantation on $GaAs/Al_xGa_{1-x}As$ - heterostructure samples in order to define a narrow conducting channel and to electrically separate the gate electrode from the channel.

We present a new method where the conducting channel is defined by doping with FIB implantation (positive writing mode). Using a p-type $GaAs/Al_xGa_{1-x}As$ - heterostructure as base material, n-type conducting regions are realized by overcompensation doping with Si ions. This technique involves an additionally technological step, thermal annealing in order to activate the dopants but offers the possibility to integrate n- and p-conducting channels on the same wafer (similar to CMOS technique).

We discuss the dependence of electrical properties of the n- and p-type transistors on the channel dimensions and implantation doses.

[1] A. D. Wieck and K. Ploog, Appl. Phys. Lett. 56, 928 (1990).

HL 17.68 Fr 16:30 Poster TU F

Evaluation of active semiconductor structures by combined scanning thermo-elastic microscopy and finite element simulations — •Ralf Meckenstock[1], Dirk Dietzel[1], Sutharat Chotikaprakhan [1], Jean L.N. Fotsing[1], Josef Pelzl[1], and Simone Cassette[2] — [1]Exp. Phys. 3, Solid State Spectroscopy, Ruhr-University Bochum, D-44780 Bochum, Germany — [2]Thales Research and Technology France, F-91404 Orsay Cedex, France

The main objections of experimental and theoretical efforts of a common research work are the localization of the heat sources and the determination of the temperature peak rises in the hot region of nano-tailored semiconductor devices. Here we report on combined investigations of hot areas in a high power high electron mobility transistor (HEMT) using a scanning thermo-elastic microscope (SthEM) and finite element (FE) simulations of the problem. The sample was a AlGaN/GaN-HEMT grown on sapphire substrate, with a gold coating for improved thermal management.The thermo-elastic image reveals a hot line adjacent to the gate region as it is predicted by the finite element simulation. A rescaling of the estimated temperature amplitude obtained by the thermo-elastic measurements leads for conditions of the FE-simulations to a maximum temperature of about 200 °C in reasonable agreement with the simulation. Work performed in the frame of the EC-project MICROTHERM.

HL 17.69 Fr 16:30 Poster TU F

Relationship between Mn 3d electron hybridization and magnetic order in (GaMn)As dilute ferromagnetic semiconductors — •F. Kronast[1], R. Osyannikov[1], A. Vollmer[1], H.A. Dürr[1], W. Eberhardt[1], P. Imperia[2], D. Schmitz[2], G. Schott[3], K. Brunner[3], M. Sawicki[4], and L. Molenkamp[3] — [1]Bessy GmbH , Albert-Einstein-Str.15, 10439 Berlin — [2]Hahn-Meitner-Institut, Albert-Einstein-Str.15, 10439 Berlin — [3]Universität Würzburg, am Hubland, D-97074 Würzburg — [4]Institute of Physics, Polish Academy of Sciences, Warszawa, Poland

The hybridization of Mn 3*d* and Ga/As valence orbitals in $(Ga_{1-x}Mn_x)As$ films with x between 0.007 and 0.062 was studied using x-ray absorption techniques. The signature of Mn acceptor states responsible for long-range ferromagnetic order can be identified with x-ray magnetic circular dichroism at all Mn concentrations. An additional magnetically dead Mn species with a reduced number of 3*d* electrons is observed for 0.062 Mn. We provide evidence that this is due to Mn-Mn nearest neighbor pairs which bind valence holes and ultimately limit the size of the magnetic ordering temperature.

HL 18 Hauptvortrag Woggon

Zeit: Samstag 09:00–09:45 Raum: TU P270

Hauptvortrag HL 18.1 Sa 09:00 TU P270

Coupled quantum systems with quantum dots — •Ulrike Woggon — FB Physik, Universität Dortmund, Otto-Hahn-Str. 4, D-44227 Dortmund

We will present recent experiments with semiconductor quantum dots as being one part in a coupled quantum system. The coupling of quantum dots to another quantum state such as another quantum dot, confined photons or phonons is investigated by ultrafast spectroscopy. Nature and strength of the quantum mechanical coupling mechanism will be discussed for a few exemplary quantum systems containing quantum dots. We will discuss the distinctly different properties we can gain when two systems are coupled and we will show how the coupling can be controlled, either to maximum (exciton-photon coupling) or minimum coupling strength (exciton-phonon coupling). We will give an insight into fascinating new physical properties we can obtain when two quantum systems are coupled and outline their importance for both fundamental and applied physics.

HL 19 Hauptvortrag Zrenner

Zeit: Samstag 09:45–10:30 Raum: TU P270

Hauptvortrag HL 19.1 Sa 09:45 TU P270

Manipulations of a qubit in a semiconductor quantum dot — •Artur Zrenner[1], Stefan Stufler[1], Patrick Ester[1] und Max Bichler[2] — [1]Universität Paderborn, Warburger Str. 100, D-33098 Paderborn — [2]Walter Schottky Institut, Technische Universität München, Am Coulombwall, D-85748 Garching

Semiconductor quantum dots are zero-dimensional model systems with excellent optic and electric properties. In optical experiments on single self-assembled InGaAs quantum dots the excitonic ground state transition appears as an extremely narrow resonance of only a few μeV width. The resonant interaction with cw laser fields can be studied in detail by photocurrent spectroscopy, revealing the effects of nonlinear absorption and power broadening of the line width, as expected for a genuine two-level system. For the case of pulsed laser fields and in the absence of decoherence, the two-level system represents a qubit. Excitations with ps laser pulses result in qubit rotations, which can be evidenced in a quantitative way as Rabi oscillations in photocurrent experiments. Double pulse experiments further allow us to infer important system parameters like the decoherence time and the excitonic fine structure of the underlying two level system.

HL 20 Symposium: Single Photon Sources and Spectroscopy of Individual Quantum Systems

Zeit: Samstag 10:45–13:15 Raum: TU P270

HL 20.1 Sa 10:45 TU P270

Read-out and manipulation of single electron and nuclear spins and spin pairs — •J. Wrachtrup — University of Stuttgart, Stuttgart, Germany

Optically accessible defects in semiconductors with large band gap show a number of properties which make them interesting candidates for a controlled engineering of quantum states in solids [1]. The talk will concentrate on color centers in diamond. One of the particularly interesting defects, the nitrogen vacancy defect center, has an electron spin paramagnetic ground state. The fluorescence of this defect strongly depends on the spin state of the electron. Single defect centers can be isolated by optical microscopy. It was shown that the spin state of a single defect center can be determined by optical spectroscopy. Microwave and radiofrequency irradiation allows to manipulate single electron and nuclear spins (for example nitrogen and ^{13}C) [2,3]. One can create arbitrary spin quantum states, for example Bell states, and probe its dephasing behavior. The talk will describe similar experiments in which for example nanopositioned defect centers are entangled.

[1] F. Jelezko and J. Wrachtrup J. Phys: Cond. Mat. 16 (2004) R1089

[2] F. Jelezko, T. Gaebel, I. Popa, A. Gruber, and J. Wrachtrup Phys. Rev. Lett. 92 (2004) 076401

[3] F. Jelezko, T. Gaebel, I. Popa, A. Gruber, and J. Wrachtrup Phys. Rev. Lett. 93 (2004) 130501

HL 20.2 Sa 11:15 TU P270

Solid-state single-photon-sources for quantum cryptography — •H. Weinfurter[1], Ch. Wang[1], Ch. Braig[1], P. Zarda[1], and Ch. Kurtsiefer[2] — [1]Department für Physik, Ludwig-Maximilians-Universität, D-80799 München — [2]Department of Physics, National University of Singapore, Singapore 117542, Singapore

Color centers in diamond turned out to be simple and reliable sources of single photons. Based on confocal microscope set-up, these sources can be operated at room-temperature without any sign of bleaching. For example the N-V (nitrogen-vacancy) center was already used in experiments on the complementarity principle and for quantum cryptography. Its disadvantages, in particular the broad emission spectrum, can be avoided when using different centers studied more recently. The talk introduces the method of creating single photons and gives an overview of experiments applying these novel sources.

HL 20.3 Sa 11:45 TU P270

Optically initialization of single spins in semiconductor quantum dots — •Jonathan Finley , Miro Kroutvar, Dominik Heiss, Max Bichler, and Gerhard Abstreiter — Walter Schottky Institut and Department of Physics, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany

We will demonstrate the reversible transfer from optical polarization to the spin orientation of single carriers in semiconductor quantum dots. Following resonant excitation of the ground state exciton using circularly polarized light and selective charge separation in specially designed Schottky photodiode structures, we convert photon polarization into carrier spin orientation. After a time delay Δ t (=5ns to 1ms) the spin polarization of stored charges is tested by electrically neutralizing the dots and detecting the intensity and polarization state of the resulting electroluminescence signal. For electron storage samples, the EL is $>$ 80% circularly polarized at T = 1K with a helicity that directly reflects the optical excitation and vanishes following excitation with un-polarized light. Using such techniques, we have recently measured the electron spin T1 and its dependence on lattice temperature and magnetic field. It is shown to be extremely long ($>$25ms at 1K), decreasing with magnetic field with a clear B^{-5} exponent, demonstrating that spin flip at low temperatures is mediated by SO mixing of the Zeeman levels by single piezoelectric phonons. Electron spin dynamics will be contrasted with hole storage samples and prospects for optical single dot spin readout will be given.

HL 20.4 Sa 12:15 TU P270

Spectroscopy of single nanowire heterostructures — •V. Zwiller, M. Borgström, and A. Imamoglu — Institute of Quantum Electronics, ETH, 8093 Zürich, Switzerland

Quantum dots are often referred to as artificial atoms because of their atom like density of states, yielding sharp optical transitions. Unlike for atoms, quantum dots properties can be tailored by modifying their composition, shape and size. Devices based on single quantum dots enable new functionalities; one particularly exciting novel function is the generation of non classical light.

We will present results obtained on single GaAsP quantum dots grown in GaP nanowires. The wires were grown using 20 nm sized gold catalysts by the use of metal organic vapor phase epitaxy in the vapor liquid solid growth mode. Low temperature photoluminescence studies were performed on single wires under continuous and pulsed laser excitation. Previously we demonstrated single photon generation in several material systems: InAs quantum dots in GaAs were used to generate single photons at around 920 nm, InP quantum dots in GaInP at around 680 nm and CdSe dots in ZnSe were used for the green region. The potential of these novel quantum dots embedded in wires will be compared to the conventional Stranski Krastanow quantum dots.

HL 20.5 Sa 12:45 TU P270

Voltage-Controlled Optics of a Single Quantum Dot — •Khaled Karrai[1], Alexander Högele[1], Stefan Seidl[1], Martin Kroner[1], Richard J. Warburton[2], Brian D. Gerardot[3], and Pierre M. Petroff[3] — [1]Center for NanoScience and Department für Physik, Ludwig-Maximilians-Universität, Geschwister-Scholl-Platz 1, 80539 München, Germany — [2]School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh EH14 4AS, United Kingdom — [3]Materials Department, University of California, Santa Barbara, California 93106, USA

We show how the optical properties of a single semiconductor quantum dot can be controlled with a small dc voltage applied to a gate electrode. Using a newly developed high-resolution laser spectroscopy method we find that the transmission spectrum of the neutral exciton exhibits two narrow lines with about 2 micro-eV linewidth. The splitting into two linearly polarized components arises through an exchange interaction within the exciton. We show that choosing a gate voltage where the dot is occupied with an additional electron turns off the exchange interaction. In this regime, the negatively charged exciton has no dark states. Saturation spectroscopy demonstrates that the neutral and the negatively exciton behaves as a two-level system. Our experiments show that the remaining problem for preparing and manipulating excitonic quantum states in this system is possibly spectral fluctuation on a micro-eV energy scale.

HL 21 Spintronik III

Zeit: Samstag 10:45–13:00 Raum: TU P164

HL 21.1 Sa 10:45 TU P164

Spin lifetimes at GaAs (100) and (110) surfaces — •Jan-Peter Wüstenberg, Lijun Guo, Kevin Hiebbner, Hans-Christian Schneider, Michael Bauer, and Martin Aeschlimann — FB Physik, TU Kaiserslautern, Erwin-Schrödinger-Str., 67663 Kaiserslautern

Spin transport through a semiconductor/metal interface is an important obstacle in semiconductor-based spintronics. At semiconductor surfaces the Fermi-level pinning may cause a band bending that significantly affects the carrier and spin dynamics. The decay of the electron-spin polarization near different p-doped GaAs surfaces is investigated by means of time- and spin-resolved two photon photoemission (TR-2PPE). By measuring the spin and energy of electrons emitted from the different GaAs surfaces the (energy-dependent) spin-polarization decay times are determined. The experimental results are compared to bulk measurements (time-resolved magneto-optical Kerr effect) and theoretical results for spin-polarization decay within the Bir-Aronov-Pikus mechanism. It is found that the strength of the band bending at the surfaces directly influences the spin decay.

HL 21.2 Sa 11:00 TU P164

Strain-induced spin splitting determined from $B = 0$ spin precession, and spin lifetimes of drifting electrons in n-GaAs — •Markus Beck, Claus Metzner, Stefan Malzer und Gottfried H. Döhler — Institut für Technische Physik I, Universität Erlangen-Nürnberg, Erwin-Rommel-Str. 1, D-91058 Erlangen

In stationary Faraday rotation measurements, we observe the spin transport of photoexcited electrons in n-GaAs spatially resolved. The measured spatial distribution of spin polarization under transport conditions allows for the determination of spin lifetimes and their dependencies on the applied field, temperature and doping density. Externally applied strain results in a k-linear spin splitting, which causes spin precession on a length scale inversely proportional to the applied strain, independent of the electron drift velocity. Successively increasing the sample strain along [110] allows to determine the strain-induced spin splitting along [110] quantitatively. In accordance with the theoretical expectation, we observe no spin splitting along [100] for strain along [100]. We present the measured results together with calculations of the spin transport, which quantitatively explain the observed decrease of the spin lifetime with the applied field in terms of an increased electron temperature.

HL 21.3 Sa 11:15 TU P164

Diluted magnetic semiconductor resonant tunneling diodes as spin polarized current detectors. — •Anatoliy Slobodskyy[1], Charles Gould[1], Taras Slobodskyy[1], Peter Grabs[1], David Sánchez[2], Georg Schmidt[1], and Laurens Molenkamp[1] — [1]Physikalisches Institut der Universität Würzburg EP3, Am Hubland, D-97074 Würzburg, Germany — [2]Département de Physique Théorique, Université de Genève, CH-1211 Genève 4, Switzerland

We previously demonstrated spin dependent transport on all-II-VI resonant tunneling diodes (RTD) with a magnetic quantum well [1]. We now present new results on these structures, showing that they can be operated as spin detection devices. Current voltage characteristics of the samples were measured in magnetic fields (B) up to 16 T and temperature down to 40 mK. At intermediate fields, the B=0 spin degenerate resonance splits into spin-up and spin-down components following the Giant Zeeman splitting of the well material. At higher magnetic fields, a strong change in the relative amplitude of the spin-split resonances is observed. This results from an interplay between the Giant Zeeman splitting in the quantum well and normal Zeeman splitting in the injector. The Zeeman splitting of the bottom of the conduction band in the injector polarizes the current injected into the RTD, and this polarization is detected by the spin selectivity of the quantum well states. A straight forward model correctly describing the voltage, temperature, and magnetic field dependence of the device is presented.

[1] A. Slobodskyy, C. Gould, T. Slobodskyy, C.R. Becker, G. Schmidt, and L.W. Molenkamp, Phys. Rev. Lett. 90, 246601 (2003)

HL 21.4 Sa 11:30 TU P164

Magnetotransport experiments in (311)A-(Ga,Mn)As — •Matthias Döppe, Ursula Wurstbauer, Matthias Reinwald, Werner Wegscheider und Dieter Weiss — Institut für Experimentelle und Angewandte Physik, Universität Regensburg; D-93040 Regensburg

In recent years ferromagnetic semiconductors like (Ga,Mn)As have proved to be very interesting for spin injection experiments. By varying strength and angle of an applied in-plane magnetic field the magnetisation's easy axis can be obtained by employing the Giant Planar Hall Effect [1]. So far most experiments were carried out on (001)-(Ga,Mn)As heterostructures. Here we report on magnetotransport experiments on MBE-grown (Ga,Mn)As layers on (311)A-GaAs-surfaces. This type of material is interesting as it can host two-dimensional hole gases. We've investigated the magnetic anisotropy and the temperature dependence by magnetotransport experiments for magnetic fields applied in and out of plane. In contrast to (001)-(Ga,Mn)As our experiments show that the easy axis is not in-plane.

[1] H. X. Tang, R. K. Kawakami, D. D. Awschalom and M. L. Roukes, Phys. Rev. Lett. **90**, 107201 (2003)

HL 21.5 Sa 11:45 TU P164

Role of carrier lifetime and spin relaxation time for spin injection in an InGaAs detector — •L. Schreiber[1], K. Schmalbuch[1], N. Müsgens[1], B. Beschoten[1], G. Güntherodt[1], A. Kawaharazuka[2], M. Ramsteiner[2], J. Herfort[2], H.-P. Schönherr[2], and K. H. Ploog[2] — [1]2. Physikalisches Institut, RWTH Aachen, 52056 Aachen — [2]Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin

Spin injection from various ferromagnets into semiconductors through a Schottky barrier was demonstrated by circularly polarized light emitted from a spin LED [1,2]. It turns out that the spin injection efficiencies measured by the degree of optical polarization only weakly depends on the FM injection layer when using InGaAs/GaAs QW as a spin detector. This might be due to its shorter spin relaxation time compared to its carrier lifetime. Therefore, we determine both time constants in an In0.1Ga0.9As/GaAs p-i-n diode by time-resolved transmission and Faraday rotation.

Taking the ratio of both time constants into account as deduced from a rate equation model [1], we find that the injection efficiency at low temperatures (25 K) is a factor of 5 higher than expected from the optical polarization. Approaching 300 K, we observe a steep increase of the correction factor up to a value of 10. A weak dependency on the external bias is found in the range of light emission. BMBF FKZ 01BM160 and 13N8244

[1] M. Ramsteiner, J. Supercond. 16, 661 (03)
[2] A. Kawaharazuka et. al., APL 85, 3492 (04)

HL 21.6 Sa 12:00 TU P164

All optical probe of dynamic nuclear spin polarization in n-GaAs — •Klaus Schmalbuch, Lars Schreiber, Marcus Heidkamp, Bernd Beschoten, and Gernot Güntherodt — II. Physikalisches Institut, RWTH Aachen, Templergraben 55, 52056 Aachen

Nuclear spins are a candidate for solid-state implementation of a quantum computer, since they are localized and exhibit spin relaxation times in the order of seconds. Electron spins can be used to address and control nuclear spins by the hyperfine interaction. Therefore we investigated dynamic nuclear polarization in bulk n-GaAs in small magnetic fields using all-optical NMR. Electron spins are coherently pumped by a circularly polarized laser pulse. Their orientation is probed by time-resolved Faraday rotation. The shift of their precession frequency (Overhauser shift) is a measure of the optically induced local nuclear field.

The strongest nuclear fields are observed after pumping localized electron spin states of the donor bands with time constants of the order of seconds. In contrast, delocalized electron spins with long spin lifetimes couple only weakly to the nuclear system. Those states can thus be used for fast read-out of the nuclear fields by the Overhauser shift using resonant spin amplification. Tilting the sample with respect to the laser beams further enhances the dynamic nuclear polarization. With this technique, we observe nuclear fields of several 10 mT at an external field of 10 mT.

Supported by BMBF FKZ 01BM160

HL 21.7 Sa 12:15 TU P164

An all electrical detection of spin Rabi oscillation in crystalline silicon — •Christoph Boehme and Klaus Lips — Hahn-Meitner-Institut Berlin, Kekuléstr. 5, 12489 Berlin, Germany

P_b centers are paramagnetic bandgap states at the silicon to silicon dioxide interface which can be detected electrically with single spin sensitivity. Here, it is demonstrated, that the coherent spin motion of this defect can also be observed electrically with high sensitivity. The detection setup used is based on the direct measurement of spin-dependent photocurrents. When charge carriers localize at the P_b sites they form spin pairs that are pumped to high triplet densities due to their longer trapping time compared to singlet states. The triplet pairs coherently interconvert to singlets by means of electron spin resonance. This leads to oscillations of the charge carrier recombination rates and thus, by means of a charge measurement, the spin state can be read. The demonstration of this readout is accomplished by induction of a Rabi-oscillation on the localized spins. The sensitivity of this coherent readout experiment reached SNR$\approx \sqrt{n}/(10^6$spins); (n = shot number).

HL 21.8 Sa 12:30 TU P164

Anisotropy Analysis of GaMnAs on GaAs (001) and (311)A by Magnetotransport and Ferromagnetic Resonance — •Matthias Reinwald[1], Ursula Wurstbauer[1], Matthias Döppe[1], Christoph Bihler[2], Hans Huebl[2], Sebastian Gönnenwein[3], Martin Brandt[2], Dieter Weiss[1], and Werner Wegscheider[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg, Germany — [2]Walter Schottky Institut, Technische Universität München, 85748 Garching, Germany — [3]Kavli Institute of Nanoscience Delft, Faculty of Applied Sciences, Delft University of Technology, 2628 CJ DELFT, The Netherlands

$Ga_{(1-x)}Mn_xAs$ layers with manganese content x of about 2% have been grown by molecular beam epitaxy on GaAs (001) and (311)A substrates. Magnetotransport measurements with in-plane magnetic field show planar Hall effect, so that it is possible to study the angular dependence of the switching fields by rotating the sample in the field. In (001) samples, a correlation between these switching fields and the magnetic anisotropy with the easy axis parallel to the surface is observed. (311) oriented samples show a more complicated behaviour of the magnetic anisotropy, which is confirmed by ferromagnetic resonance experiments. The hard axis correlated with a strong uniaxial magnetic anisotropy along growth direction in case of the (001) samples is tilted out of the growth direction for the (311) samples, leading to a different behaviour of the planar Hall effect.

This work is supported by BMBF Verbundprojekt „Spinelektronik und Spinoptoelektronik in Halbleitern“

HL 21.9 Sa 12:45 TU P164

Pulsed electrical spin injection into III-V semiconductor heterostructures — •Nicolas Müsgens[1], Lars Schreiber[1], Georg Richter[1], Bernd Beschoten[1], Gernot Güntherodt[1], and Paul A. Crowell[2] — [1]II. Physikalisches Institut, RWTH Aachen, 52056 Aachen — [2]School of Physics and Astronomy, University of Minnesota, Minneapolis, Minnesota 55455, USA

The implementation of coherent electron spins into semiconductors and the full control of their quatum mechanical degrees of freedom may eventually enable quantum computational operations in solid state devices. Spin coherence in semiconductors has so far only been established and monitored by time-resolved all optical pump probe techniques. Here, we use a novel time-resolved technique, which offers to electrically create and inject coherent spin states into a spin light-emitting diode using ultrafast current pulses ($FWHM \sim 100$ ps). Both, transport and dephasing of the injected spin packets can be probed by phase-locked time-resolved Kerr rotation.

Supported by BMBF FKZ BM 160

HL 22 GaN: Präparation und Charakterisierung I

Zeit: Samstag 10:45–13:15 Raum: TU P-N201

HL 22.1 Sa 10:45 TU P-N201

Rare earth implantation in GaN - an alternative route to develop integrated, all-nitride light-emitting devices — •Katharina Lorenz[1], U. Wahl[1], E. Alves[1], T. Wojtowicz [2], P. Ruterana[2], S. Dalmasso[3], E. Nogales[3], R.W. Martin[3], K.P. O'Donnell[3], S. Ruffenach[4], and O. Briot[4] — [1]Instituto Tecnológico e Nuclear, Sacavém, Portugal — [2]SIFCOM, CNRS-ENSICAEN, Caen, France — [3]University of Strathclyde, Glasgow, U.K. — [4]GES, Université de Montpellier II, France

In the frame of the European research and training network RENiBEl (Rare Earth Doped Nitrides for High Brightness Electroluminescent Emitters) we study the doping of GaN by rare earth implantation. GaN epilayers grown by MOCVD were implanted with Er, Tm and Eu under different implantation conditions (varying fluence, temperature, energy). RBS/channeling was used to monitor the damage evolution in the Ga-sublattice after implantation and annealing and to establish the lattice site location of the implanted ions. The nature of structural defects was studied by transmission electron microscopy and the optical properties of the samples by room temperature cathodoluminescence. The introduced damage could be significantly reduced by implantation at high

temperature or by implanting through a thin AlN capping layer. Annealing was necessary for optical activation of the implanted samples. After annealing, sharp rare earth related emissions were observed. The emission intensity is highly dependent on the annealing temperature and best results were achieved for annealing up to 1300°C using an AlN capping layer to protect the surface from dissociation.

HL 22.2 Sa 11:00 TU P-N201

Formation of steps and vicinal surfaces on GaN (0001) surfaces: Implications on surface morphologies and surface roughening. — •Liverios Lymperakis and Jörg Neugebauer — Fakultät für Naturwissenschaften, Universität Paderborn, Fachbereich 6-Physik, D-33095 Paderborn

The most common and technologically most relevant growth direction of wurtzite GaN is normal to the {0001} basal plane. The morphology of these surfaces is known to be extremely sensitive to the growth conditions: Going from N-rich to more Ga-rich conditions a transformation of the morphology occurs accompanied by smoother surfaces and better film quality. Surface steps may act as nucleation and compensation centers and thus play a crucial role in these transformations. In order to get a microscopic understanding of these effects the energetics and geometry of possible step/vicinal surface configurations on (0001) wurtzite GaN surfaces have been studied employing density functional theory, a plane wave basis set, and pseudopotentials. We find that for growth under N-rich conditions steps/vicinal surfaces may spontaneously form on the surface. However, going to more metal-rich conditions we find the steps to be thermodynamically unstable against the formation of the laterally contracted bilayer structure. Based on our calculations we discuss and explain recent experimental observations on surface roughening and growth anisotropy of GaN surfaces.

HL 22.3 Sa 11:15 TU P-N201

Iron doped GaN as a potential material for spintronic devices — •Enno Malguth[1], A. Hoffmann[1], W. Gehlhoff[1], D. Azamat[1], O. Gelhausen[2], and M.R. Phillips[2] — [1]Institut für Festkörperphysik, TU Berlin, Hardenbergstr. 36, 10623 Berlin — [2]Microstructural Analysis Unit, University of Technology, Sydney, Australia

For the potential use of iron doped GaN as a material for spintronic applications it is of great importance to know the exact energetic position of the electronic states of the Fe ions in the bandgap. Another crucial issue is the charge state in which the iron is present. In order to investigate these issues a set of about 400μm thick freestanding HVPE grown GaN:Fe crystals with different Fe-concentration levels ranging from $2\times10^{16}cm^{-3}$ to $2\times10^{20}cm^{-3}$ were studied by means of photoluminescence (PL), transmission, photoluminescence excitation (PLE) and electron paramagnetic resonance (EPR). The fact that the samples are freestanding permitted to carry out the optical experiments polarising parallel and perpendicular to the c-axis. Fe^{2+}, Fe^{3+} and Fe related defect-complexes were found to be present depending on the iron concentration. For the former two term schemes could be derived including fine structure. A multiple splitting of all these states due to the distortion of the trigonal crystal field along the c-axis in c_{3v} symmetry was observed. Particularly for the $^5E \rightarrow ^5T_2$ transitions of the Fe^{2+} which until now were believed to be degenerate with the conduction band a complex absorption structure could be resolved. Knowing the predominant polarisations of each transition line the exact splitting of the electronic Fe-states in the trigonal crystal field could be pinpointed.

HL 22.4 Sa 11:30 TU P-N201

Lumineszenz von gewachsenen und geätzten GaN-Nanosäulen — •Nicolas Thillosen, Simone Montanari, Ralf Meijers, Raffella Calarco, Roger Steins, Nicoleta Kaluza, Hilde Hardtdegen und Hans Lüth — Institut für Schichten und Grenzflächen ISG1 und CNI - Center of Nanoelectronic Systems for Information Technology, Forschungszentrum Jülich, 52425 Jülich

Im Vergleich zu GaN-Schichten auf Si(111)-Substraten, wurde beobachtet, dass eindimensional gewachsene GaN-Nanosäulen eine stärkere UV-Lumineszenz zeigen und, dass die Säulen relaxiert sind. In diesem Beitrag werden die Photolumineszenz-Eigenschaften von in der MBE auf Si(111) gewachsenen GaN-Nanosäulen verglichen mit Säulen, welche durch reaktives Ionenätzen aus GaN-Schichten präpariert wurden. Die Herstellung der Schichten erfolgte sowohl mit MBE auf Si(111) als mit MOVPE auf Saphir. Aus der energetischen Lage des Donator-gebundenen exzitonischen Übergangs E_{DBX} konnte der Verspannungszustand bestimmt werden. Die Auswertungen ergeben, dass unabhängig vom ursprünglichen Verspannungszustand der GaN-Schichten und der Herstellungsmethoden der Säulen dieselbe Bandlücke gefunden wurde, die mit der des vollständig relaxierten GaN übereinstimmt.

HL 22.5 Sa 11:45 TU P-N201

Herstellung von c-$Al_xGa_{1-x}N$ Epitaxieschichten mit hohem Al-Gehalt — •Stefan Potthast, Jörg Schörmann, Donat Josef As und Klaus Lischka — Universität Paderborn, Fakultät für Naturwissenschaften, Department Physik, Warburger Strasse 100, 33095 Paderborn

Die kubischen III-Nitride besitzen ein grosses Potential für die Realisierung optoelektronischer und elektronischer Bauelemente durch eine hohe Variabilität der Bandlücke und fehlende spontane und piezoelektrische Polarisation. Für die Herstellung von Bauelementen ist das Abscheiden von $Al_xGa_{1-x}N$ Schichten mit vorher bestimmbarem Al-Gehalt von essentieller Bedeutung, da er in Multiquantentrogstruktren die Barrierenhöhe und damit die optischen Eigenschaften bestimmt. Dazu wurden $Al_xGa_{1-x}N$ Schichten mit einem Al-Gehalt von x=0 bis x=0.52 mittels plasmaunterstützter Molekularstrahlepitaxie hergestellt. Anschließend wurden die strukturellen und optischen Eigenschaften mit Röntgendiffraktometrie und Kathodolumineszenz ermittelt. Es konnte gezeigt werden, dass der Haftkoeffizient von Ga expontentiell mit dem Al-Gehalt abnimmt, wenn das Verhältnis der Bindungsenergien berücksichtigt wird. Bei Anwendung dieses Modells auf das Al/Ga-Flußverhältnis lassen sich $Al_xGa_{1-x}N$ Schichten mit x=0.52 herstellen, bei denen der Anteil der hexagonalen Phase unterhalb der Detektionsgrenze liegt.

HL 22.6 Sa 12:00 TU P-N201

Kubische $Al_xGa_{1-x}N$/GaN Bragg Spiegel für den grünen Spektralbereich — •Jörg Schörmann, Alexander Pawlis, Stefan Potthast, Donat Josef As und Klaus Lischka — Universität Paderborn, Fakultät für Naturwissenschaften, Department Physik, Warburger Strasse 100, 33095 Paderborn

Kubische Gruppe III-Nitride sind vielversprechende Materialien für die Herstellung optoelektronischer Bauelemente wie z.B. Resonant Cavity Light Emitting Diodes (RCLED's). Im Gegensatz zu den hexagonalen Materialien bilden sich in der kubischen Phase keine spontanen elektrischen Felder aus. Dies ist für die Realisierung niedrigdimensionaler Bauelemente von grosser Bedeutung. Bragg Reflektoren (DBR) sind wichtige Komponenten zur Realisierung von RCLED's. Der Brechungsindexunterschied zwischen AlN, GaN und deren ternären Verbindung AlGaN ist sehr gering. Um hohe Reflektivitäten zu erreichen ist daher ein hoher Al-Gehalt oder eine grosse Anzahl von Spiegelpaaren notwendig. Kubische $Al_xGa_{1-x}N$/GaN Bragg Spiegel wurden mittels plasmaunterstützter Molekularstrahlepitaxie auf 3C-SiC (001) Substraten hergestellt. Die Schichtdicken eines 15,5-fach DBR wurden für eine Bragg-Wellenlänge von 510nm dimensioniert. Die strukturellen Eigenschaften wurden mittels Röntgendiffraktometrie und Rasterkraftmikroskopie bestimmt. Die experimentellen Ergebnisse der Reflexionsmessung zeigen unter Berücksichtigung der Rauhigkeit eine gute Übereinstimmung mit den berechneten Daten.

HL 22.7 Sa 12:15 TU P-N201

The temperature dependence of the thermal expansion of GaN — •Claudia Roder, Sven Einfeldt, Stephan Figge, and Detlef Hommel — Institut für Festkörperphysik, Universität Bremen, Otto-Hahn-Allee, 28359 Bremen

In the case of epitaxial layers grown on foreign substrates the difference in the thermal expansion coefficients between the layer material and the substrate material governs the strain induced in the layer during cool-down from growth to room temperature. Since the strain determines various important parameters of GaN such as the bandgap, the accurate knowledge of the thermal expansion is essential not only from a physical point of view but also for device engineering. The thermal expansion of GaN bulk crystals was investigated in an extended temperature range from 12 to 1025 K. The lattice parameters a and c were measured by high-resolution x-ray diffraction. The temperature dependence of the derived thermal expansion coefficients along the a and c directions could be perfectly described over the entire temperature range within both the Debye model and the Einstein model for the lattice vibrations. Debye and Einstein temperatures were derived along the a and c axes, respectively.

HL 22.8 Sa 12:30 TU P-N201

Einfluss von N_2 als Trägergas für GaN Wachstum im invertierten Einlass — •Roger Steins, Hilde Hardtdegen, Nicoleta Kaluza, Martina v.d. Ahe, Zdenek Sofer und Yong Suk Cho — Center of Nanoelectronic Systems for Information Technology (CNI), Institut für Schichten und Grenzflächen, Forschungszentrum Jülich GmbH, 52425 Jülich

In der Literatur wird N_2 als Trägergas u.a. nachgesagt die Morphologie und die strukturellen Eigenschaften des GaN zu verschlechtern. Für die Anwendung in High Electron Mobility Transistoren bedarf es aber Oberflächen mit geringer Rauhigkeit und ausgezeichneter struktureller Qualität. In diesem Beitrag wurde der Einfluss von N_2 auf das Wachstum und die Schichteigenschaften systematisch untersucht. In einem AIX 200/4 RF-S Reaktor wurden Versuche bei verschiedenen Trägergasmischungen von H_2 und N_2 in der Hochtemperaturphase durchgeführt. Nukleation und Rekristallisation fanden in reiner Wasserstoffatmosphäre statt. Dabei musste sowohl der Gesamtfluss auf das Trägergasgemisch hin optimiert, als auch das Flussverhältnis und das V/III Verhältnis in der Gasphase variiert werden. Es wird gezeigt, dass sich trotz großer Mengen N_2 im Trägergas Schichten hoher Qualität abscheiden lassen.

HL 22.9 Sa 12:45 TU P-N201

Fermi level dependence of optical and magnetic properties in MOCVD-grown GaMnN — •Christoph Hums[1,2], M. Strassburg[2,3], M.H. Kane[3], A. Asghar[3], J. Senawiratne[2], M. Alevli[2], N. Dietz[2], C.J. Summers[3], I.T. Ferguson[3], and A. Hoffmann[1] — [1]Technische Universität Berlin,Institut für Festkörperphysik, 10623 Berlin, Germany — [2]Georgia State University, Department of Physics and Astronomy, Atlanta, GA 30302 — [3]Georgia Institute of Technology, Electrical and Computer Engineering / Materials Science and Engineering, Atlanta, GA 30332

Transition metal (TM) doped wide gap semiconductors such as GaN and ZnO are revealed as the most promising candidates for room temperature spintronics applications. The ferromagnetic behavior strongly depends on the TM concentration and the prevailing carrier type. MOCVD grown GaMnN epilayers with varying Mn-concentration and Si co-doping have been studied. The effect on Mn incorporation on the formation of defect states and impurity subbands inside the bandgap in GaN was monitored by optical spectroscopy. A broad absorption band detected around 1.5 eV is attributed to the presence of a Mn-induced subband. The intensity of the absorption band correlates with the Mn concentration and vanishes upon silicon co-doping. The magnitude of magnetization decreases as the Fermi level is increased and crashes at Si concentrations of $10^{20} cm^{-3}$. This strong Fermi level dependence of the magnetization can not result from phase segregation or ferromagnetic Mn-clusters.

HL 22.10 Sa 13:00 TU P-N201

Mikroskopische Lumineszenzeigenschaften von InGaN-MQWs auf Si(111) — •Stephan Tiefenau, Till Riemann, Jürgen Christen, Armin Dadgar und Alois Krost — Institut für Experimentelle Physik, Otto-von-Guericke-Universität, PF 4120, D-39016 Magdeburg

Wir stellen hoch-ortsaufgelöste Kathodolumineszenz (KL)-Untersuchungen an InGaN-Multiple Quantum Wells (MQWs) auf Si(111) vor, die Bedeutung als aktive Zone von Lichtemittern im UV- und sichtbaren Spektralbereich besitzen. Mikroskopische Fluktuationen der Quantenausbeute und des Indiumeinbaus werden dabei durch die Intensität bzw. Form lokaler KL-Spektren direkt abgebildet. Bei 800°C mittels MOVPE gewachsene MQWs zeigen ein Maximum der integralen Lumineszenz bei 440nm. Auf einer mikroskopischen Ortsskala unterhalb von 1μm gibt es jedoch lokale statistische Fluktuationen der spektralen Linienposition, und es treten relativ scharfe Linien (80meV) in Niederenergetischen bis jenseits von 500nm auf. Im Gegensatz dazu emittieren bei 840°C gewachsene MQWs zwei breite Lumineszenzlinien um 425nm und 470nm. Diese Linien treten auf einer Größenskala von 10μm räumlich komplementär auf und sind direkt mit der Oberflächenmorphologie korreliert. Der Einsatz von GaN, InGaN, oder InAlN als Barrierenmaterial sowie der Einfluss verschiedener Indium-Precursor wird diskutiert. Charakteristische Unterschiede zwischen den einzelnen QWs des MWQ werden durch die systematische Variation der QW-Anzahl herausgearbeitet.

HL 23 II-VI Halbleiter II

Zeit: Samstag 10:45–13:15 Raum: TU P-N202

HL 23.1 Sa 10:45 TU P-N202

EPR study on the valence state of 3d transition-metal ions in ZnO based diluted magnetic semiconductors — •Mariana Diaconu, Heidemarie Schmidt, Andreas Pöppl, Rolf Böttcher, Joachim Hönstsch, Holger Hochmuth, Michael Lorenz, and Marius Grundmann — Institut für Experimentelle Physik II, Fakultät für Physik und Geowissenschaften, Universität Leipzig, Linnéstrasse 3-5, 04103 Leipzig, Germany

In this paper we discuss theoretical and experimental results of electron paramagnetic resonance (EPR) for 3d transition-metal (TM) doped ZnO films, system belonging to a new class of materials called diluted magnetic semiconductors (DMS). Ferromagnetism at room-temperature was found on DMS, for example on Mn-alloyed ZnO films grown by pulsed laser deposition (PLD) [1,2]. For explaining the physical origin of the observed ferromagnetism, the valence state of 3d TM ions in ZnO has to be known.

For Mn-doped ZnO we performed EPR measurements on films obtained by PLD with Mn concentrations ranging from 0.1 to 10 at%. We observed the typical Mn^{2+} spectrum for low doping (0.1 at% Mn). For higher Mn-concentrations the hyperfine lines are not visible, but we see the fine-structure lines, broadened by dipole-dipole interactions. Onto these lines an intense broad single line was superposed. The broad single line, also found in Mn-alloyed nanostructures, is due to Mn ions in higher local concentrations. We modelled the EPR spectra and obtained the fine and hyperfine splitting parameters of Mn-alloyed ZnO.

[1] P. Sharma et al., Nature Materials **2** (2003), 673.
[2] M. Diaconu et al., submitted to Phys. Rev. B.

HL 23.2 Sa 11:00 TU P-N202

Electrical characterization of ZnO using Schottky contacts — •Holger von Wenckstern, Swen Weinhold, Rainer Pickenhain, Gisela Biehne, Holger Hochmuth, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstraße 5, 04103 Leipzig

We have investigated electron traps in ZnO thin films using admittance and deep level transient spectroscopy. The c-oriented ZnO thin films are grown epitaxially on a-plane sapphire by pulsed laser deposition. The Schottky contacts are realized by thermal evaporation of Ag or Pd. The ohmic contacts are realized by an eutectic mixture of indium and germanium. The properties of the contacts were investigated by current-voltage and capacitance-voltage measurement. For that, the diodes were investigated in a temperature range from 10 K to 330 K.

Thermal admittance spectroscopy was carried out between 10 and 330 K. Deep level transient spectroscopy (DLTS) was done in two different setups. In one of them the diodes were investigated between 10 and 300 K. The other allows investigations between 80 and about 500 K. Up to now we have identified by DLTS defects lying about 290 meV or 710 meV below the conduction band minimum, respectively.

HL 23.3 Sa 11:15 TU P-N202

Electron effective mass and transport properties of n-doped $Zn_{1-x}Mn_xSe$ epilayers studied by infrared reflection spectroscopy — •K. C. Agarwal, B. Daniel, C. Klingshirn, and M. Hetterich — Institut für Angewandte Physik and Center for Functional Nanostructures (CFN), Universität Karlsruhe, D-76131 Karlsruhe, Germany

Zn(Mn)Se is a diluted magnetic II-VI semiconductor material with a variety of potential applications in optoelectronic devices, e.g. light-emitting diodes and blue-green laser diodes as well as optoelectronic spin devices. For a full utilization of these materials, it is vitally important to have a solid knowledge of material parameters like the electron effective

mass and transport properties in these materials. In this contribution, we present the results of our studies on the slope electron effective mass as a function of doping concentration in n-doped $Zn_{1-x}Mn_xSe$:Cl epilayers ($0 \leq x \leq 0.13$). The doping concentration in our samples was determined using Hall measurements in the van-der-Pauw geometry. The electron-plasma frequency was extracted from experimental reflectivity data by making a Drude-Lorentz type multi-oscillator fit taking into account the effects of free charge carriers in doped semiconductors, background dielectric constant as well as the ZnSe-, MnSe- and GaAs-like phonons. In addition we also discuss the optical mobility and resistivity in these samples calculated from our determined fit parameters.

HL 23.4 Sa 11:30 TU P-N202

Morphology and electronic structure of MOMBE grown ZnO surfaces — •Stefan Andres, Tilo Plake, and Christian Pettenkofer — Hahn-Meitner-Institut, Glienicker Str. 100, 14109 Berlin

ZnO is deposited by metal organic molecular beam epitaxy (MOMBE) in an ultrahigh vacuum (UHV) system on various substrates such as Si(111), Al_2O_3, ZnO($10\bar{1}0$) and glass at temperatures between 200°C and 500°C. Films are investigated in-situ by low energy electron diffraction (LEED), photoelectron spectroscopy (PES) and scanning tunneling microscopy (STM). For deposition with the precursor system diethylzinc/water significantly lower OH admixtures were found in the O1s region by monochromated x-ray photoelectron spectroscopy (MXPS) in comparison to magnetron sputtered films. The surface electronic structure is investigated by angle resolved PES (ARPES) with respect to the admixture of hydrogen during film growth and subsequent annealing of the films. Thus the hydrogen incorporation into the film and the termination of the surface can be determined. For ZnO films on Al_2O_3 the electrical properties (doping and resistivity) are determined ex-situ and compared to the data obtained from the valence band spectra.

HL 23.5 Sa 11:45 TU P-N202

Strukturelle Eigenschaften des Donators Indium in nanokristallinem ZnO — •Th. Agne[1], V. Koteski[2], H.-E. Mahnke[2], H. Wolf[1] und Th. Wichert[1] — [1]Technische Physik, Universität des Saarlandes, D-66041 Saarbrücken — [2]Bereich Strukturforschung, Hahn-Meitner-Institut Berlin, D-14109 Berlin

Nanokristallite des II-VI Halbleiters ZnO wurden mit dem Donator Indium in einem relativen Konzentrationsbereich von 10^{-5}-10^{-3} dotiert und anschließend bei 473 K einer Hydrothermalbehandlung unterzogen, wobei sich eine mittlere Korngröße von ca. 11 nm einstellt.

PAC-Untersuchungen an der Sonde $^{111}In/^{111}Cd$ in hoch In-dotiertem nano-ZnO zeigen bis zu einer Konzentration von 10^{-4}, dass die ^{111}In-Atome auf Zn-Plätzen eingebaut werden. Bei dieser Konzentration zeigen sich aber auch zwei In-Defektkomplexe, die bei einer höheren In-Konzentration von 10^{-3} das PAC-Spektrum dominieren. Es konnte abgeschätzt werden, dass sich in ZnO Nanokristallen diese In-Defektkomplexe dann bilden, wenn sich mehr als ein In-Donator in einem Nanokristallit befindet. Die lokale Umgebung der In-Atome in hoch In-dotiertem ZnO Nanokristallen wurde auch mit der EXAFS-Methode untersucht. Die EXAFS-Messungen an der K-Kante der In-Dotieratome zeigen eine deutliche Aufweitung des Kristallgitters hin zur O_{NN}-Schale. Es wurde eine Abwesenheit von Zn_{NNN}-Atomen beobachtet, für die bis jetzt keine Erklärung gefunden werden konnte. Möglicherweise steht diese Beobachtung mit der Struktur der In-Defektkomplexe in Zusammenhang, die in den PAC-Experimenten beobachtet werden.

Gefördert durch die DFG im Rahmen des SFB277.

HL 23.6 Sa 12:00 TU P-N202

Optical Properties of Colloidal CdSe-Nanocrystals: Size, Shape and Temperature Dependence of Luminescence Dynamics. — •Oliver Schöps[1], E. Herz[2], M.V. Artemyev[3], C. Arens[4], N. Rousseau[4], D. Schikora[4], K. Lischka[4], and U. Woggon[1] — [1]Universität Dortmund, Institut für Physik, Experimentelle Physik IIb, Otto-Hahn-Strasse 4,D-44227 Dortmund — [2]Cornell University,Ithaca, NY — [3]Belarussian State University, Minsk — [4]Universität Paderborn

CdSe nanocrystals show enormous potential concerning their applications in photonic devices due to the size tunability of their emission wavelength and their high quantum yield. The wet chemical preparation allows the control of size and shape from spherical nanocrystals to elongated nanorods. Here the spectrally as well as temporally resolved photoluminescence (PL) data is analysed. Transitions between excitonic fine structure levels govern the population dynamics and therefore the PL decay times. With increasing size the nanorods' PL properties display a transition from a fully confined, zero dimensional to a one dimensional structure. We furthermore address the modification of the PL, when a novell overgrowth technique is applied to incorporate colloidal nanoparticles in a MBE grown ZnSe Matrix.

HL 23.7 Sa 12:15 TU P-N202

Elektrische Eigenschaften von $ZnO_{1-x}S_x : (H, Al)$ — •Thorsten Krämer, Angelika Polity, Changzhong Wang und Bruno K. Meyer — Justus-Liebig-Universität Gießen, 1. Physikalisches Institut, Heinrich-Buff-Ring 16, 35392 Gießen

Das Legierungssystem $ZnO_{1-x}S_x$ zeigt einen parabolischen Verlauf der Bandlücke bei variierender Zusammensetzung x zwischen den binären Endpunkten ZnO (Eg=3,3 eV) und ZnS (Eg=3,6 eV). Dieses Verhalten läßt sich mit $E_{ZnOS}(x) = xE_{ZnS} + (1-x)E_{ZnO} - bx(1-x)$ beschreiben, wobei der Bowingfaktor b für $ZnO_{1-x}S_x$ etwa 3 eV annimmt. Die Bandlücke kann also durch Wahl der Zusammensetzung Werte zwischen 3,6 eV und 2,6 eV annehmen. Durch ein Radiofrequenz-Sputterverfahren wurden dünne $ZnO_{1-x}S_x$-Schichten auf Saphir und Glas hergestellt und zur Erhöhung ihrer elektrischen Leitfähigkeit mit Aluminium und/oder Wasserstoff dotiert. Zur Bestimmung der Ladungsträgerdichte, der Beweglichkeit und des spezifischen Widerstandes wurden Halleffektmessungen in der van-der-Pauw Geometrie durchgeführt. 4-Punkt-Leitfähigkeitsmessungen konnten zur Überprüfung der Widerstandswerte herangezogen werden. Weiterhin werden Messungen der optischen Transmission vorgestellt.

HL 23.8 Sa 12:30 TU P-N202

Synthesis and Characterization of Co-doped ZnO Nanocrystals — •Niklas Volbers, Daniel Pfisterer, Joachim Sann, Bruno Meyer und Detlev Hofmann — I. Physikalisches Institut, Justus-Liebig-Universität-Giessen, Heinrich-Buff-Ring 16, D-35392 Giessen, Germany

Transition-metal doped ZnO is a promising candidate for transparent ferromagnetic semiconductors and its technical application will demand nanoscale structures. We have prepared Co-doped ZnO nanoparticles using a wet-chemical synthesis route. Recently, it was shown that nanocrystals prepared in a similar way show roomtemperature ferromagnetism [1]. We have studied the growth mechanism of the doped nanoparticles and the incorporation of Co into the nanocrystals. Compared to undoped nanocrystals the doping results in a reduced growth rate and reduced size of the nancrystals. The incorrporation of the Co dopant in the form of Co^{2+} substituting Zn is confirmed by the observation of the internal crystal field transitions in absorption and emission spectroscopy. It is in line with electron paramagnetic resonance experiments. However, no evidence for ferromagnetism is found so far. This is probably related to the small size of our nanocrystals (∼3nm), while ferromagnetism was observed for much bigger nanocrystals (>100 nm) [1].

[1] Schwartz et al.: Magnetic Quantum Dots: Synthesis, Spectroscopy, and Magnetism of Co^{2+}- and Ni^{2+}-Doped ZnO Nanocrystals. J. Am. Chem. Soc., 125: 13205-13218, June 2003.

HL 23.9 Sa 12:45 TU P-N202

Doping of group I acceptors in ZnO — •Joachim Sann, Arndt Zeuner, Niklas Volbers, and Bruno K. Meyer — I. Physikalisches Institut, Justus-Liebig-Universität-Giessen, Heinrich-Buff-Ring 16, D-35392 Giessen, Germany

We report on the optical properties of ZnO bulk crystals subjected to different treatments to study the incorporation of group I acceptors. Salts containing Sodium, Lithium or Potassium were used for diffusion into bulk ZnO at temperatures between 400 and 800 °C. The films were investigated by steady state and temperature-dependent photoluminescence (PL). In the case of Lithium (Na) we were able to introduce acceptors which give rise to a donor acceptor pair band around 3.05 eV. According to previous investigations the acceptor may be a pair defect which compensates the shallow Li (Na) donors but does not lead to p-type conduction. We compare our results with in-situ doped CVD grown ZnO epitaxial films.

HL 23.10 Sa 13:00 TU P-N202

Phosphordotierung in ZnO — •Christian Neumann[1], Joachim Sann[1], Ute Haboeck[2] und Bruno K. Meyer[1] — [1]I. Physikalisches Institut, Justus-Liebig-Universität-Giessen, Heinrich-Buff-Ring 16, D-35392 Giessen, Germany — [2]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin

Phosphor ist ein möglicher Kandidat für eine p-Dotierung von ZnO.

Wir berichten über den Einbau von Phosphor in mittels CVD epitaktisch abgeschiedenen ZnO-Dünnschichten sowie Diffusionsexperimenten an ZnO-Einkristallen. Röntgendiffraktometrie, temperaturabhängige Photolumineszenzmessungen im Bereich von 4 - 300 K sowie Ramanspektroskopie von 50 - 2750 cm^{-1} mit verschiedenen Anregungswellenlängen zeigen den Einfluß der Phosphordotierung im ZnO.

HL 24 Bauelemente

Zeit: Samstag 10:45–12:30 Raum: TU P-N229

HL 24.1 Sa 10:45 TU P-N229

Ultrafast carrier dynamics in an InAs quantum-dot amplifier emitting at 1.3 μm — •Sabine Dommers[1], Stephan Schneider[1], Ulrike Woggon[1], Paola Borri[2], Wolfgang Langbein[3], Thorsten Kettler[4], Matthias Lämmlin[4], and Dieter Bimberg[4] — [1]Universität Dortmund, Otto-Hahn-Str. 4, 44221 Dortmund, Germany — [2]School of Biosciences, Cardiff University, Main Building, Park Place, Cardiff CF10 3TL, UK — [3]Department of Physics and Astronomy, Cardiff University, 5 The Parade, Cardiff CF24 3YB, UK — [4]Institut für Festkörperphysik, TU Berlin, 10623 Berlin, Germany

InAs quantum-dot amplifiers (QDA) can show improved performances over well or bulk devices. The investigated QDA with a ground-state (GS) emission wavelength of 1.3 μm is appealing for optical communication technology. We measure the ultrafast carrier dynamics at the GS and the linewidth enhancement factor (LEF) α at room temperature. The QDA is a p-i-n narrow ridge waveguide structure with InAs quantum-dots in the active region. Using differential transmission spectroscopy, with heterodyne detection, absorption/gain and refractive index dynamics are studied. The LEF α is determined from measurements of the modal gain g and the refractive index Δn. Resonant to the GS the LEF α is 0.02 for low bias current and becomes zero or even negative for higher transition energies [1]. These results are promising for low chirp operation and supression of beam filamentation. We also find that the gain recovery dynamics is suitable for signal processing at high bit-rates with recovery time constants of some ps [2]. [1] S. Schneider et al. IEEE J. Q. El. 40, 1423 (2004) [2] P. Borri et al. IEEE J.Sel.Top. Q. El. 8, 984 (2002)

HL 24.2 Sa 11:00 TU P-N229

Measurement of overlay accuracy of E-beam generated patterns for the fabrication of vertical gate all-around transistors — •Jürgen Moers, Andre van der Hart, and Hans Lüth — Institute of Thin Films and Interfaces and Center for Nanoelectronic Systems for Information Technology, Forschungszentrum Jülich, D-52425 Jülich

The scaling of MOSFET devices will go on at least for the next 15 years. This downsizing will lead to severe short channel effects, which have to be answered by new device architectures. The most promising candidates for end of roadmap MOSFETs are multigate devices such as FINFET, triple-Gate FET or vertical gate all-around FET. All of these MOSFETs show a proper control of the electric field in the channel area. However, for all these advanced MOSFETs, different patterns have to be aligned with an overlay accuracy of a few ten nanometers.

In this work, we present an overlay accuracy measurement method based on optical moire pattern: In three adjacent areas two overlaying gratings of period p_1 and p_2 are defined in two lithography steps: In the first area, the gratings are both defined in the first step, in the second area they are completely defined in the second step and in the third area p_1 is defined in the first step and p_2 in the second step. The three arising moire patterns have a phase difference according to their alignment shift: While the difference between the first and the second is due to statistical errors during the lithography (normally very small), the phase difference to the third area is attributed to the overlay error and hence a clear measure of it. The method is applied to a vertical gate all-around MOSFET process and overlay errors can be measured with an accuracy of less than $4nm$.

HL 24.3 Sa 11:15 TU P-N229

Fabrication and characterization of a vertical resonant tunneling diode in the sub-100nm range — •Jakob Wensorra[1], Mihail Ion Lepsa[1], Klaus Michael Indlekofer[1], Arno Förster[2], and Hans Lüth[1] — [1]Institut für Schichten und Grenzflächen (ISG1) und Center of Nanoelectronic Systems for Information Technology (CNI), Forschungszentrum Jülich GmbH, 52425 Jülich — [2]Fachhochschule Aachen, Abteilung Jülich, Physikalische Technik, Ginsterweg 1, 52428 Jülich

With the help of electron beam lithography and using high resolution Hydrogen Silsesquioxan (HSQ) as mask material, vertical GaAs/AlAs resonant tunneling diodes (RTD) with lateral dimensions down to 50nm have been realized. For contacting the nanostructures, a novel non-alloyed ohmic contact on a very thin low-temperature-grown GaAs (LT-GaAs) top layer has been developed. By means of DC electrical measurements, the dependence of the I-V characteristics on the device dimension has been analyzed. Here, the electronic transport properties are strongly influenced by the lateral depletion region, which defines the vertical conductive channel within the device. In the I-V characteristics, a clearly pronounced region of negative differential conductance has been observed at room temperature, down to 50nm lateral dimensions.

HL 24.4 Sa 11:30 TU P-N229

Investigation of Electrical and Optical Properties of BaxSr1-xO Gate Oxide MIS Structures — •OLIVER KERKER[1], JAN ZACHARIAE[2], FARRUKH MIRZA[1], RÜDIGER FERRETTI[1], and KARL HOFMANN[1] — [1]Institut für Halbleiterbauelemente und Werkstoffe, Universität Hannover, Appelstr.11a, 30167 Hannover — [2]Institut für Festkörperphysik, Universität Hannover, Appelstr.2, 30167 Hannover

This investigation focuses on MIS structures with the (amorphous or crystalline) high-k dielectrics BaxSr1-xO. These high-k dielectrics are highly hydrophilic and degrade by the formation of hydroxides. Different metal oxide and nitride films are investigated as diffusion barriers and gate electrodes which are deposited by reactive sputtering and PECVD. The thermodynamic and chemical stability and morphology after RTA treatments of complete MIS capacitors are characterized by electrical measurements like tunneling leakage current (I(V)) and by SEM. Complete MIS gate stacks are analyzed by spectroscopic ellipsometry for the determination of complex dielectric functions, thickness of films, refractive indices and optical band gaps. Diffusion barriers are characterized for qualitative compositional surface analysis by XPS and for band structure determination by EELS.

HL 24.5 Sa 11:45 TU P-N229

A novel photo-conductive detector for single photon detection — •R. Schmidt[1], M. Vitzethum[1], S. Malzer[1], P. Kailuweit[2], D. Reuter[2], A. Wieck[2], and G.H. Döhler[1] — [1]Technische Physik I, Universität Erlangen-Nürnberg — [2]Angewandte Festkörperphysik, Ruhr-Universität Bochum

We present the concept of an ultra sensitive photo-conducting detector that should be particularly suitable for single-photon detection. It basically represents a p-i-n diode and junction FET integrated into a single device. Extremely high detectivity can be achieved by reducing the electrically active area of the device to the intersection point of two narrow perpendicular doping stripes. Therefore the capacitance of the detector reaches values lower than 0.1 fF, whereas the optical detection area is not reduced. The buried bottom stripe is written by a Focussed ion beam (FIB) directly into GaAs and is then overgrown by the following MBE-layers. The top stripe can be easily defined by wet-chemical etching.

The extremely low capacitance of our device implies charging voltages in the mV-range per photo-generated electron hole pair, leading to a persistent increase in the top-channel current of up to 10 nA. First experimental results show that room temperature dark currents at a few volts reverse bias are in the low pA- and capacitances in the low fF-range. The expected large photo-conductive gain is observed.

HL 24.6 Sa 12:00 TU P-N229

MOSFETs with high-k dielectrics Al_2O_3 and Pr_2O_3 — •Bernhard Fabel, Michael Oswald, Martin Sterkel, and Walter Hansch — Institute for Technical Electronics, Technical University Munich, Arcisstr. 21, 80333 Munich, Germany

MOS devices were fabricated and characterized for optimisation of high-k materials properties and fabrication conditions and compared to reference MOSFETs with SiO_2 gate dielectric. In the reference MOSFETs SiO_2 ($d_{Ox} \approx 25\,\mathrm{nm}$) as gate dielectric and aluminium metal gate

were implemented and characterized. Approving the reproducibility of these devices the SiO_2 was replaced by the promising high-k candidates aluminium oxide Al_2O_3 and praseodymium oxide Pr_2O_3. Al_2O_3 was deposited by atomic layer deposition (ALD) at 300°C and 1 mbar. Pr_2O_3 was evaporated in ultra high vacuum in a molecular beam epitaxy (MBE) system at room temperature. Capacitance and conductance measurements were used to extract the following MOS parameters: dielectric constant ϵ_r, interface state density D_{it}, flatband voltage shift ΔV_{FB}. The breakthrough field E_{BD} could be determined by measuring the current density. MOSFETs transfer characteristics lead to the values of threshold voltage shift ΔV_{Th}, channel mobility μ, subthreshold swing S, I_{on} and I_{off} current. Due to the data of the reference devices, it is possible to evaluate the high-k device and material properties by comparing the extracted parameters.

HL 24.7 Sa 12:15 TU P-N229

A new opto-electronic device: A polarisation-sensitive, intensity-independent switch for $1.3\mu m$ — •Stefan Krämer[1], J. Spieler[1], S. Malzer[1], S. Neumann[2], W. Prost[2], F.J. Tegude[2], and G.H. Döhler[1] — [1]Technische Physik I, Universität Erlangen-Nürnberg — [2]Halbleitertechnik, Universität Duisburg

Under specific growth conditions the quaternary semi-conductor InGaAsP forms a monoatomic superlattice in $[111]_B$-direction, similar to some ternary materials. These ordered materials exhibit a strong absorption anisotropy for light polarised in [110] or [1-10] direction at near-bandgap photon energies. The quaternary InGaAsP, lattice-matched to InP, is particularly appealing for photonic device applications, as its bandgap can be adjusted to the standard wavelengths for optical communication ($1.3\mu m$ and $1.55\mu m$). We use the optical anisotropy for a polarisation-dependent opto-electrical switch. It consists of a strongly polarization dependent photo-FET-diode with ordered $1.3\mu m$ InGaAsP in the active region, which is grown on top of a polarization-independent reference-diode with disordered $1.5\mu m$ InGaAsP in the absorbing layer. The absorption layer thicknesses are designed such, that depending on polarisation the photocurrent in the reference diode is larger or smaller than in the photo-FET-diode. Accordingly, almost the whole voltage drops either on the photo-FET- or on the reference-diode, whence the n-channel conductance is either "off"or "on"depending on the polarisation. Switchting is observed for $100\text{nW} < P_{Laser} < 1.5\text{mW}$ with $I_{on} =$ 10mA, practically independent on the laser power. The switching contrast ranges between 3 and 7 orders of magnidude, depending on P_{Laser}.

HL 25 Si / Ge

Zeit: Samstag 10:45–12:45 Raum: TU P-N226

HL 25.1 Sa 10:45 TU P-N226

Grazing-Incidence Diffraction Strain Analysis of a Laterally patterned Si wafer treated by Focused Ge and Au Ion Beam Implantation — •J. Grenzer[1], L. Bischoff[1], and U. Pietsch[2] — [1]Forschungszentrum Rossendorf e.V., Institute of Ion Beam Physics and Materials Research,P.O.Box 51 01 19, D-01314 Dresden, Germany — [2]University of Potsdam, Institute of Physics, Am Neuen Palais 10, 14469 Potsdam, Germany

Strain analysis of a laterally patterned Si-wafer was carried out utilizing X-ray grazing-incidence diffraction performed at the ID10B at the ESRF. The lateral patterning was done by focused ion beam implantation using a AuGeSi alloy liquid metal ion source. Samples were prepared by either a 35 keV Au^+ ion beam (dose: $0.3, 2 \cdot 10^{14} cm^{-2}$) or by a 70 keV Ge^{++} ion beam (dose: $8 \cdot 10^{14} cm^{-2}$). It was shown that a periodical defect structure consisting of both implanted and not implanted stripes is created due to ion beam implantation. The induced strain distribution induced, however, shows no periodicity. This can be only explained by an overlap of the strain fields created in each implanted stripe.

We found a maximum strain for the Au implanted samples in a depth of about 20 nm ($\Delta a/a = -1, -3 \cdot 10^{-4}$ for the Au samples); for the Ge sample in a depth of $\approx 100nm$ ($\Delta a/a = -1.2 \cdot 10^{-4}$). At depths $500nm$ below the sample surface the strain of the Ge sample becomes smaller than the detection limit ($\Delta a/a < 2 \cdot 10^{-5}$). Using this technique we were able to create a buried Ge layer with a thickness of about 200 nm and an averaged Ge content of about 1%.

HL 25.2 Sa 11:00 TU P-N226

Doppelresonantes Raman Spektrum in Germanium — •M. Mohr, M. Machón, J. Maultzsch und C. Thomsen — Institut für Festkörperphysik, TU Berlin, Hardenbergstr. 36, 10623 Berlin

Das Raman Spektrum von Germanium zeigt eine schwache Mode unterhalb der optischen Phononen, deren Frequenz von der Energie der Anregung abhängt[1]. Diese Abhängigkeit ist je nach Orientierung der Probe verschieden. Wir haben diese Mode in Hinsicht auf Doppelresonanz[2] untersucht. Nach der resonanten Absorption von Licht wird das Elektron in einen realen Zustand gestreut, was zu einer zweifachen Verstärkung des Ramansignals führt. Die im Prozess beteiligten Phononen stammen nicht aus dem Γ-Punkt, daher können über die Phononendispersion Rückschlüsse gezogen werden. Wir untersuchen die Streuprozesse entlang Achsen hoher Symmetrie, diskutieren den Einfluss der Auswahlregeln für Elektron-Phonon-Streuung und vergleichen die Vorhersagen mit experimentellen Daten.
A
[1] D.J. Mowbray et al., Proc. 20th ICPS (World Scientific, 1990), 2017
[2] C. Thomsen und S. Reich, Phys. Rev. Lett. **85**, 5214 (2000)

HL 25.3 Sa 11:15 TU P-N226

Vacancy complexes with oversized impurities in Si and Ge — •K. Schroeder, H. Höhler, N. Atodiresei, R. Zeller, and P. H. Dederichs — Institut für Festkörperforschung, FZJ, 52425 Jülich

We examine the electronic and geometrical structure of impurity-vacancy complexes in Si and Ge. Within the framework of density-functional theory we use two complementary *ab initio* methods, the pseudopotential-PW method and the all-electron KKR method, to investigate the structure of vacancy complexes with 11 different *sp*-impurities. For Sn in Si, we confirm the split configuration (Sn on the bond center and two half vacancies on neighboring sites), and obtain good agreement with EPR data of Watkins[1]. We find that all impurities of the 5*sp* and 6*sp* series in Si and Ge prefer the split-vacancy configuration, with an energy gain of 0.5 to 1 eV compared to the substitutional complex. On the other hand, impurities of the 3*sp* and 4*sp* series form (slightly distorted) substitutional complexes. An exception from this rule is Al, which forms a split complex in Si and a strongly distorted substitutional complex in Ge. We find a strong correlation of these data with the size of the isolated impurities, defined via the lattice relaxations of the nearest neighbors.
[1] G. D. Watkins, Phys. Rev. B **12**, 4383 (1975)

HL 25.4 Sa 11:30 TU P-N226

Electronic and optical properties of capped Si and Ge nanocrystallites — •Luis Ramos, Jürgen Furthmüller, and Friedhelm Bechstedt — FSU Jena - IFTO, Max-Wien-Platz 1, D-07743 Jena, Germany

Quantum confinement (QC) in Si and Ge nanocrystallites (NC's) gives rise to new material properties interesting to applications such as data storage devices, photodetectors, and optoelectronics. The lattice mismatch of Si and Ge and the fact that $Si_{1-x}Ge_x$ is a highly miscible alloy for all concentrations x could prevent very sharp Si/Ge interfaces. However, a considerable progress in controlling the growth of Si/Ge heterostructures has been achieved and novel structures with embedded NC's can be synthetised.

In this work we present ab-initio pseudopotential plane-wave calculations for Si(Ge)-capped Ge(Si) free-standing NC's. We study their structural and electronic properties, optical absorption spectra, Stokes shifts, radiative lifetimes, and the space localization of the HOMO and LUMO. We verify that Si-(Ge-)capped Ge(Si) NC's have significant differences in their structures and the type-II character of a Si/Ge heterojunction. In certain cases the absorption spectra shows a compensation effect related to composition and QC effects. The results are compared to those of Si NC's capped with oxide shells.

HL 25.5 Sa 11:45 TU P-N226

Ripple structure of ion beam induced Si wafer — •Ullrich Pietsch[1], J. Grenzer[1], S. Hazra[2], T.K. Chini[2], and M.K. Sanyal[2] — [1]University of Potsdam, Institute of Physics, 14415 Potsdam, Germany — [2]Surface Physics Division, Saha Institute of Nuclear Physics, 1/AF Bidhannagar, Kolkata 700 064, India

Ion beam induced ripple formation in Si wafers was studied by atomic force microscopy (AFM) and non-destructive depth-resolved x-ray grazing incidence diffraction (GID). The formation of ripple structure at high doses (7̃x10 17 ions/cm2), starting from initiation at low doses (1̃x10 17 ions/cm2) of ion beam is evident from AFM, while that in the buried crystalline region below a partially crystalline top layer is evident from GID study. The GID technique reveals that these periodically modulated wave-like buried crystalline features become highly regular and strongly correlated as one increases the Ar ion beam energy from 60 keV to 100 keV. The vertical density profile obtained from the analysis of Vineyard profile shows that the density in the upper top part of ripples is decreased to about 15% of the crystalline density. The partially crystalline top layer at low dose, transforms to a completely amorphous layer for high doses and the top morphology was found to be conformal with the underlying crystalline ripple. On the other hand, the amorphous part of the damaged top layer is textured and scales with the ion dose. S. Hazra, T.K. Chini, M.K. Sanyal, J. Grenzer and U. Pietsch, Phys.Rev.B70 121307(R) 2004

HL 25.6 Sa 12:00 TU P-N226

X-ray Raman scattering at the Si L-edge of Si and amorphous SiO — •M. Volmer[1], C. Sternemann[1], J.A. Soininen[2], A. Hohl[3], G. Venko[4], S. Streit[1], and M. Tolan[1] — [1]Institut für Physik, Universität Dortmund, Deutschland — [2]Div. X-ray Physics, Dept. Physical Sciences, University of Helsinki, Finland — [3]Institute of Materials Science, Darmstadt University of Technology, Germany — [4]ESRF, Grenoble, France

We present measurements of the *Si* L-edge of polycrystalline *Si* and amorphous *SiO* using the x-ray Raman scattering technique (XRS). The momentum transfer dependence of XRS gives acces to additional monopole excitation channels for the high momentum transfer regime, where the dipole approximation is no longer valid. The *Si* L-edge spectra show clear momentum transfer dependence with respect to their total shape and will be compared to calculations using a Bethe-Salpeter equation-based approach including core-hole and lifetime effects. The *Si* L-edge of amorphous *SiO* exhibits distinct fine structure along with pronounced momentum-transfer dependence. These spectra will be discussed in terms of the interface-clusters mixture model for the structure of amorphous *SiO* on the basis of a disproportionation of *SiO* into *Si* and SiO_2.

HL 25.7 Sa 12:15 TU P-N226

Phosphorous donor wave function in strained silicon layers — •Hans Huebl[1], André Stegner[1], Martin S. Brandt[1], and Günther Vogg[2] — [1]Walter Schottky Institut, Technische Universität München, München, Germany — [2]Fraunhofer Institut - Zuverlässigkeit und Microintegration, München, Germany

The wave function of shallow donors such as phosphorous in silicon can be determined very accurately by electron spin resonance. In particular in the context of quantum computing, the manipulation of the donor wave function currently receives considerable attention. Here, we report on the influence of strain on the hyperfine interaction in P-doped Si. In contrast to previous experiments, where the effects of external strain on bulk Si:P were investigated, we use fully strained thin Si:P layers on virtual SiGe substrates grown by CVD where high Ge contents of up to 30% in the substrate allow much higher strains to be investigated. For detection of the spin resonance in these thin epilayers, electrically detected magnetic resonance is used. Si:P on relaxed $Si_{0.84}Ge_{0.16}$ has a hyperfine interaction of 25 G, which is reduced by 40% from the unstrained case, in excellent agreement with the extrapolation of the data obatined on bulk Si:P.

HL 25.8 Sa 12:30 TU P-N226

Ferromagnetic Mn–doped Ge — •Thomas Vallaitis, Mario Gjukic, Christian Jäger, and Martin S. Brandt — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany

Heavily manganese–doped germanium with a reported Curie temperature T_C of up to 116 K [Park *et al.*, Science **295** (2002), 651] is of interest as a potential material for spintronic applications. Samples have been grown on Ge(100) substrates by MBE with manganese concentrations ranging from 0.02 at.% up to 52 at.%, as determined by elastic recoil detection analysis and EDX. The substrate temperature was approx. 225 °C. Raman scattering and UV/VIS reflection measurements indicate a good crystalline quality of the epitaxial films up to a Mn concentration of 10 at.%, where the Ge TO Raman peak shows a FWHM of 5.4 cm^{-1}. Raman modes attributed to Mn–Mn vibrations as well as a low concentration of holes in Hall effect measurements indicate that clusters or intermetallic compounds are formed. SQUID magnetization measurements for samples with a Mn concentration of $3 - 20$ at.% clearly show the presence of several magnetic phases: (i) the ferromagnetic Mn_5Ge_3 with $T_C = 285$ K and (ii) a low–temperature phase with a remanence that disappears at 30 K.

HL 26 SiC

Zeit: Samstag 12:30–13:15 Raum: TU P-N229

HL 26.1 Sa 12:30 TU P-N229

Growth of oxynitrides on Si-rich 4H-SiC(0001) surfaces — •Patrick Hoffmann, Andriy Goryachko, and Dieter Schmeisser — BTU Cottbus, Angewandte Physik - Sensorik, Konrad-Wachsmann-Allee 17, 03046 Cottbus

Oxynitride layers are grown on 4H-SiC(0001) by a thermal treatment in N_2O. The nitrogen content is controlled by varying the growth conditions (N_2O pressure and substrate temperature) and the nitrogen incorporation is found to be stronger for higher substrate temperatures and lower N_2O pressures.

Excess carbon is generated due to SiC decomposition under such growth conditions (high temperature and low N_2O pressure) which leads to unwanted high interface state density and has to be avoided. Our approach is to prepare a Si-rich or even Si-covered SiC surface by Si evaporation. Upon oxidation in N_2O the additional silicon is expected to compensate the loss of silicon from the SiC while preparation.

The Si-rich SiC surface as well as the grown layers were investigated by photoelectron spectroscopy (XPS) for chemical analysis and by AFM/STM for analysis of the surface morphology. Concerning the chemical analysis we focus on the total nitrogen content, on the amount of silicon nitride Si_3N_4 and of silicon oxynitride SiO_xN_y, and on the existence of sub-oxides which build the interface between SiC and the oxynitride layers.

HL 26.2 Sa 12:45 TU P-N229

Dotieratom-Interstitials in 4H-SiC — •A. Mattausch, M. Bockstedte und O. Pankratov — Theoretische Festkörperphysik, Universität Erlangen-Nürnberg, Staudtstr. 7, 91058 Erlangen

Eine gebräuchliche Dotiermethode für SiC ist die Ionenimplantation. Sie hinterlässt jedoch Schäden, sodass ein Ausheilprozess für die Aktiverung der Dotieratome nötig ist. Hierbei nehmen die Dotieratome die gewünschten substitutionellen Plätze ein. Dies geschieht entweder über einen Leerstellen- oder einen Interstitial-Mechanismus, wobei sich gezeigt hat, dass der Leerstellenmechanismus z.B. für Bor kaum eine Rolle spielt [1,2]. Mit Hilfe einer DFT-basierten *ab initio*-Methode haben wir die Zwischengitter-Eigenschaften der gebräuchlichen Dotieratome Bor, Aluminium, Stickstoff und Phosphor in 4H-SiC untersucht. Es zeigt sich, dass sich die Ergebnisse für die Bor-Diffusion in 3C-SiC [2] auf 4H übertragen lassen. Für Aluminium wird die Diffusion über einen *kick-out*-Mechanismus vorhergesagt, wobei die *kick-in*-Barriere auf einen substitutionellen Si-Platz mit $E_m < 1$ eV sehr niedrig ist. Die n-Typ Dotieratome Stickstoff und Phosphor diffundieren beide mittels *split-interstitials*, bei denen zwei Atome sich einen Gitterplatz teilen. Bei Stickstoff findet die Diffusion dabei praktisch ausschließlich über das Kohlenstoff-Untergitter statt.

[1] K. Rüschenschmidt *et al.*, J. Appl. Phys. **96**, 1458 (2004).
[2] M. Bockstedte *et al.*, Phys. Rev. B **70**, 115203 (2004).

HL 26.3 Sa 13:00 TU P-N229

Bildung und Eigenschaften von Stapelfehlern in Stickstoff dotiertem 4H-SiC — •Klaus Irmscher, Martin Albrecht, Matthias Rossberg, Hans-Joachim Rost, Dietmar Siche und Günter Wagner — Institut für Kristallzüchtung, Max-Born-Straße 2, D-12489 Berlin

4H-SiC-Wafer, die aus Stickstoff dotierten ($> 2 \times 10^{19} cm^{-3}$) Einkristallen geschnitten und bei 1100°C getempert wurden, zeigen eine hohe Dichte planarer Defekte. Hochauflösende Transmissionselektronenmikroskopie zeigt, dass die erzeugten planaren Defekte aus sechs Si-C-Doppelschichten in kubischer Stapelfolge bestehen. Solch eine 3C-SiC-Lamelle kann durch das Gleiten zweier Shockleyscher Partialversetzungen in benachbarten Basisebenen entstehen und als Doppelstapelfehler (DSF) angesehen werden. Die durchgeführten Temperexperimente deuten darauf hin, dass die Oberfläche das Ursprungsgebiet der Partialversetzungen ist. Kürzlich wurde gezeigt, dass die elektronische Struktur von Stapelfehlern in SiC gut durch ein Quantentrogmodell beschrieben werden kann. Darauf wird hier zurückgegriffen, um die charakteristische Lumineszenz bei etwa 500 nm und die starke Anisotropie der elektrischen Leitfähigkeit zu erklären. Eine erhöhte Auflösung der Struktur der Lumineszenzbande konnte erreicht werden, indem auf einem Substratwafer mit DSFn eine niedrig dotierte Epitaxieschicht, in die sich die DSF fortsetzten, aufgebracht wurde. Das ermöglichte eine eindeutige Identifizierung der der Lumineszenzbande zugrunde liegenden Phononenstruktur. Neben den dominierenden Einphononen- werden auch Zwei- und Dreiphononenrepliken nachgewiesen.

HL 27 Störstellen / Amorphe Halbleiter

Zeit: Samstag 12:45–13:15 Raum: TU P-N226

HL 27.1 Sa 12:45 TU P-N226

Ab-initio Study of the Diffusion of Gallium and Arsenic in Silicon — •Ralf Meyer, Michel Côté, Laurent J. Lewis, and Normand Mousseau — Département de physique, Université de Montréal, C.P. 6128 succ. Centre-Ville, Montréal (Québec) H3C 3J7, Canada

We report results of ab initio calculations of the diffusion of Ga and As in crystalline silicon. In the first part of our work we have studied the possible defect configurations of the diffusing atoms in the crystal lattice. In order to do this, we have performed ab initio total-energy calculations based on the pseudopotential approach and the local density approximation with a planewave basis set. In the second part of our study, we have determined possible diffusion paths of the defect atoms in the silicon matrix. Here, we have employed the activation relaxation technique [1] in combination with the self-consistent charge density functional tight-binding method [2] for the calculation of energies and forces.
[1] N. Mousseau and G. T. Barkema, Phys. Rev. Lett. **77**, 4358 (1996).
[2] M. Elstner et al., Phys. Rev. B **58**, 7260 (1998).

HL 27.2 Sa 13:00 TU P-N226

Charge trapping in SiO2 layers implanted with rare earths and Ge ions — •Slawomir Prucnal[1], Jiaming Sun[2], Xiangqian Cheng[3], and Wolfgang Skorupa[4] — [1]s.prucnal@fz-rossendorf.de — [2]J.Sun@fz-rossendorf.de — [3]xqcheng@fz-rossendorf.de — [4]w.skorupa@fz-rossendorf.de

Metal-oxide-silicon (MOS) structures containing different rare earth and germanium ions exhibit strong luminescence from 300 to 1540 nm. It is very interesting from the viewpoint of the formation of silicon-based light-emitting devices. The different behaviour of charge trapping in Ge, Tb, Gd and Eu enriched SiO2 layer was studied under constant current regime. High-frequency (100 kHz) capacitors-voltage (C-V) characteristics exhibit a strong dependence of the charge trapping on the type of elements implanted into the SiO2 layer. The increase of the Eu concentration up to 3 percent leads to a shift of the C-V characteristics towards negative voltage in comparison with fresh samples, which reveals positive charge trapping. The capture cross section and the concentration of the different type of charge traps can also be strongly influenced by changing the annealing temperature and annealing time.

HL 28 Hauptvortrag Hägele

Zeit: Samstag 14:15–15:00 Raum: TU P270

Hauptvortrag HL 28.1 Sa 14:15 TU P270

Electron spin relaxation in semiconductors — •Daniel Hägele, Stefanie Döhrmann, Jörg Rudolph, and Michael Oestreich — Universität Hannover, Institut fürFestkörperphysik, Abteilung Nanostrukturen, Appelstr. 2,D-30167 Hannover

Magnetoelectronics in metals has led to breakthroughs in computer hard disk technology, non-volatile magnetic memory (MRAM). MRAM technology also offers prospects for integrating magnetologic. Semiconductor spinelectronics on the other hand is still in its infancies. This new electronics seeks to combine the exceptional advantages of magnetoelectronics with the highly developed semiconductor technology. Long spin lifetimes are a prerequisite for spintronics to work. Therefore, a detailed understanding of spin relaxation mechanisms is required to develop design rules for spintronic devices with optimized spin lifetimes. Recently, suppression of the prominent Dyakonov-Perel spin relaxation mechanism has been found in heterostructures with special orientation of crystal axes making them prime candidates for spintronic applications at room temperature. We show experimentally that spin lifetimes in such structures depend critically on spin orientation. In GaAs quantum wells grown on (110) oriented substrate the spin lifetime of spins oriented in the plane is found to be dramatically reduced by a factor of ten compared to spins along the growth direction. For wide quantum wells a novel electron spin relaxation mechanism due to intersubband scattering is identified that limits the spin lifetime at elevated temperatures also in the direction of longest spin lifetimes [1].
[1] S. Döhrmann *et al.*, Phys. Rev. Lett. **93**, 147405 (2004)

HL 29 Spintronik IV

Zeit: Samstag 15:00–16:15 Raum: TU P270

HL 29.1 Sa 15:00 TU P270

Preferred sites and valence states of transition metals in spintronic $ZnGeP_2$ — •Wolfgang Gehlhoff[1], Dmitri Azamat[1], Axel Hoffmann[1], and Nikolaus Dietz[2] — [1]Institute for Solid State Physics, Technical University Berlin, Germany — [2]Department of Physics and Astronomy, Georgia State University, Atlanta, USA

The quest for room-temperature ferromagnetic semiconductors resulted in a recent interest in transition metal (TM) doped ternary pnictides $A^{II}M^{IV}X_2^V$. The site preference and valence states for the different TM and their interaction with native defects play an important role in the discussion of the origin of the ferromagnetism [1, 2]. However, there are only few experimental data for the ternary pnictides [3]. For low Mn-doped samples the characteristic Mn^{2+} EPR spectra for isolated Mn^{2+} on group II site are observed. In higher doped $ZnGeP_2$ we observed the formation of Mn-Mn pairs. In addition, we could detect new TM defects in unintentionally doped $ZnGeP_2$.Without illumination of the samples we observed two iron-related spectra. The first one is identified as the spectrum of Fe^{2+} ($3d^6$) incorporated on the Zn site with S=2 and a large zero-field splitting. The second one arises from Fe^{3+} ($3d^5$) with S=5/2 and substitute for Ge site. Under illumination we observed the spectrum from Fe^+ on Zn site. The strongest Cr-related spectrum is caused by Cr^{4+} on Ge site.
[1] P. Mahadevan and A. Zunger, Phys. Rev. Lett. **88**, 047205 (2002)
[2] T. Kamatani and H. Akai, Phase Transitions **76**, 401 (2003)
[3] W. Gehlhoff, D. Azamat, A. Hoffmann, Materials Science in Semiconductor Processing, Vol.6 (2003) pp. 379-383

HL 29.2 Sa 15:15 TU P270

Spin-orbit coupling parameters for electrons and holes in III-V semiconductors — •R Scholz[1], J.-M. Jancu[2], E.A. de Andrada e Silva[2,3], and G.C. La Rocca[2] — [1]Institut für Physik, Technische Universität Chemnitz, Chemnitz, Germany — [2]Scuola Normale Superiore and INFM, Piazza dei Cavalieri 7, Pisa, Italy — [3]Instituto Nacional de Pesquisas Espaciais, 12201 Sao Jose dos Campos, Sao Paulo, Brasil

Multi-band $\mathbf{k}\cdot\mathbf{p}$ Hamiltonians depend on both momentum and spin-orbit coupling parameters whose values turn out to be crucial for the spin splittings and the anisotropy of both conduction and valence bands. We report on a precise determination of the $\mathbf{k}\cdot\mathbf{p}$ parameters required for an effective 14-band bulk Hamiltonian for III-V semiconductors [1] by using an improved tight-binding (TB) model [2]. The TB calculations are performed in an $sp^3d^5s^*$ nearest neighbor model including spin-orbit coupling, where the optimized parameters reproduce the experimental band energies all around the Brillouin zone. The 14-band model is obtained from a Löwdin renormalization of the 40-band TB Hamiltonian and a subsequent Taylor series expansion around Γ. Our new values for the off-diagonal spin-orbit splitting between the Γ_4 valence and conduction states and for the k^3 Dresselhaus spin splitting of the conduction band are compared to previous results. The differences between the TB band structure and the $\mathbf{k}\cdot\mathbf{p}$ expansion define the range of applicability of the latter, indicating requirements for experimental tests of the theory.
[1] P. Pfeffer and W. Zawadzki, Phys. Rev. B **53**, 12813 (1996).
[2] J.-M. Jancu, R. Scholz, F. Beltram, and F. Bassani, Phys. Rev. B **57**, 6493 (1998).

HL 29.3 Sa 15:30 TU P270

Experimenteller Nachweis von strominduzierter Spinorientierung in Quantentrogstrukturen — •S.D. Ganichev[1], S. N. Danilov[1], S. Giglberger[1], Petra Schneider[1], V. V. Bel'kov[2], L. E. Golub[2], W. Wegscheider[1], D. Weiss[1] und W. Prettl[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg — [2]A. F. Ioffe Physico-Technical Institute, 194021 St. Petersburg, Rußland

Es wurde experimentell nachgewiesen, daß ein elektrischer Strom in niederdimensionalen Systemen zu einer stationären Spinpolarisation der freien Ladungsträger führt [1]. Mikroskopisch betrachtet ist dieser Effekt die Konsequenz aus der Spin-Bahn-Kopplung, die die Spinentartung der Ladungsträger im k-Raum aufhebt, und der spinabhängigen Relaxation. Dieser Effekt wurde bereits vor über 20 Jahren theoretisch von Aronov und Lyanda-Geller vorhergesagt [2]. Direkte Inter-Subband-Übergänge in p-GaAs Multi-Quantentrögen wurden durch Terahertzstrahlung eines optisch gepumpten cw FIR-Lasers mit 118 μm bei Raumtemperatur angeregt. Diese strominduzierte Spinpolarisation führt zu Faradayeffekt und Dichroismus. [1] S.D. Ganichev et.al., cond-mat/0403641. [2] A.G. Aronov and Yu.B. Lyanda-Geller, JETP Lett. **50**, 431 (1989).

HL 29.4 Sa 15:45 TU P270

Experimentelle Bestimmung der Rashba- und Dresselhaus-Beiträge zur Spin-Bahn-Wechselwirkung — •Stephan Giglberger[1], S. D. Ganichev[1], V. V. Bel'kov[2], L. E. Golub[2], E. L. Ivchenko[2], Petra Schneider[1], W. Wegscheider[1], D. Weiss[1] und W. Prettl[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg — [2]A. F. Ioffe Physico-Technical Institute, 194021 St. Petersburg, Rußland

Das relative Verhältnis der Rashba- und Dresselhausterme, durch welche die Spin-Bahn-Wechselwirkung in Halbleiter Quantentrogstrukturen beschrieben wird, konnte zum ersten mal in n-leitenden GaAs Quantentrögen direkt gemessen werden [1]. Mit einem optisch gepumpten, gepulstem FIR - Laser wurden mit 148 μm bei Raumtemperatur indirekte Übergänge durch Drude-Absorption induziert und die Winkelabhängigkeit des spingalvanischen und zirkular photogalvanischen Effektes gemessen. Das Verhältnis der Rashba- und Dresselhaus-Koeffizienten kann direkt aus diesem Experiments bestimmt werden und bedarf keinerlei durch die Theorie berechneten Größen. [1] S.D. Ganichev et.al., Phys.Rev.Lett. **92**, 256601-1 (2004).

HL 29.5 Sa 16:00 TU P270

Spin dynamics of electrons in n-doped InAs quantum dots. — •Alex Greilich, Irina Yugova, Sergej Verbin, Evgenij Zhukov, Matthias Schwab, Dmitrij Yakovlev, and Manfred Bayer — Experimentelle Physik II, Universität Dortmund, D-44221, Germany

We have studied the carrier spin dynamics in n-doped InAs quantum dots (QDs) and have compared it with the one from undoped reference dots. The measurements are time-resolved and was done with mode locked Ti:Sa laser (frequency 76MHz, 1-ps pulse duration) and the signal was detected either by a streak camera or by pump and probe time-resolved Faraday rotation. T_2 and T_1 times in n-doped QDs were considerably longer than in undoped QDs. The dependence of these times on temperature, magnetic field and excitation power was measured and analyzed.

HL 30 II-VI Halbleiter III

Zeit: Samstag 15:00–16:30 Raum: TU P164

HL 30.1 Sa 15:00 TU P164

Characterisation of vapor transport grown ZnO bulk crystals — •Detlev M. Hofmann[1], Joachim Sann[1], Daniel Pfisterer[1], Angelika Polity[1], Valentin Laguta[1], Albrecht Hofstaetter[1], Bruno K. Meyer[1], Thomas Frank[2], Gerhard Pensl[2], R. Tena-Zaera[3], J. Zuninga-Perez[3], and Vincente Munioz Sanjose[3] — [1]I. Physikalisches Institut, Justus-Liebig-Universität, Heinrich-Buff-Ring 16, 35392 Giessen, Germany — [2]Institut für angewandte Physik, Universität Erlangen-Nürnberg, Staudtstr. 7, Gebäude A3, 91058 Erlangen, Germany — [3]Dpto. Fisica Aplicada y Electromagnetismo, co. Dr. Moliner n°50, 46100 Burjassot Valencia, Spain

The samples were as grown, or treated in post growth annealing experiments at temperatures between 900°C and 1200°C in vacuum, O_2 or Zn atmospheres. Samples annealed in Zn atmosphere are redish and become transparent after O_2 annealing. In luminescence experiments we find deep emission bands related to the oxygen vacancies and to residual copper, in the excitonic range several donor bound excitons are observed. The energy positions of the excitons are similar to the H-related and the Al-related donor bound excitons and that of I_7. The presence of residual donors is confirmed by EPR and ENDOR. DLTS shows that the traps commonly labeled E3 (E_{CB} - 430 meV) and E4 (E_{CB} - 530 meV) are in the material and that E4 increases after the Zn anneal. The results are used to construct a level scheme of the centers in the material in order to explain the optical and electrical properties. This work was financially supported by the EU-SOXESS-network.

HL 30.2 Sa 15:15 TU P164

Luminescence bands in acceptor doped ZnO — •Daniel Pfisterer[1], Joachim Sann[1], Frank Leiter[1], Arndt Zeuner[1], Christian Neumann[1], Bruno K. Meyer[1], Detlev M. Hofmann[1], and Nikolaj Romanov[2] — [1]I. Physikalisches Institut, Justus-Liebig-Universität, Heinrich-Buff-Ring 16, D-35392 Giessen — [2]A.F. Ioffe Physico-Technical Institute, RAS, 194021 St. Petersburg, Russia

We have used electron paramagnetic resonance (EPR) and optically detected magnetic resonance (ODMR) to characterise various ZnO samples doped with group I acceptors (Li, Na) or the group V nitrogen acceptor, as well as ZnO powders thermally treated in nitrogen atmosphere. For the group I acceptors the PL response of the ODMR shows that Li and Na cause deep luminescence bands. The spectra are compared to the emission caused by oxygen vacancies. An omnipresent resonance at g = 2.006 is related to an emission at 1.65 eV and is likely to be caused by Zn-vacancies. The isolated nitrogen acceptors (N^-) are found to quench the donor acceptor pair recombination at 3.26 eV.

HL 30.3 Sa 15:30 TU P164

High reflectivity semiconductor bragg-mirrors for II - VI microcavities — •N. Rousseau, C. Arens, A. Pawlis, D. Schikora, and K. Lischka — Universität Paderborn, Department Physik, Warburger Strasse 100, 33095 Paderborn

ZnSe/ZnMgSe distributed Bragg reflectors in the green spectral range have been grown on GaAs (1 0 0) substrates by molecular beam epitaxy. It has been studied the influence of the number of stacks on the reflectivity and on the roughness for a given concentration of the Zn-

MgSe alloy (15%). Optical and structural properties were investigated using reflectance, HRXRD, RHEED, and photoluminescence. A calculation based on the transfer matrix model was applied to the design of these II−VI DBRs. ZnSe/ZnMgSe DBRs containing between 13 and 32 stacks of alternated quarter-wavelength layers were obtained. As a result of growth optimization, a maximum reflectance of 81% at 510nm was measured for 32 pairs of ZnSe/Zn(0.85)Mg(0.15)Se.

HL 30.4 Sa 15:45 TU P164

Temperature-dependency of the fundamental band-gap properties of (0001)ZnO thin films — •Nurdin Ashkenov, Rüdiger Schmidt-Grund, Daniel Fritsch, Wolfram Czakai, Mathias Schubert, Holger Hochmuth, Michael Lorenz und Marius Grundmann — Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Universität Leipzig, Linnéstraße 5, 04103 Leipzig, Germany

We report on the temperature dependencies of the fundamental band-to-band transition energies, amplitudes and broadenings of (0001)ZnO thin films grown on (0001)Al_2O_3 substrate by Pulsed Laser Deposition. Spectroscopic ellipsometry (SE) data are measured at temperatures between 300 K and 830 K, and are supplemented by the photoluminescence data between 4.4 K and 300 K. SE data are analyzed by using model dielectric function approaches augmented by excitonic contributions. The increase of the valence band splitting upon temperature is indicative for a change of the crystal-field-splitting parameter. For ZnO, the phonon dispersion must be considered appropriately in order to model the temperature dependence of the fundamental band-to-band transition energy. We obtain strong contributions due to optical phonons at elevated temperatures, whereas acoustic phonons dominate the electron-phonon coupling at low temperatures. The experimentally determined bandgap energies are compared with those calculated by the Empirical Pseudopotential Method.

HL 30.5 Sa 16:00 TU P164

Room-temperature ferromagnetism in Mn-alloyed ZnO — •Heidemarie Schmidt[1], Mariana Diaconu[1], Holger Hochmuth[1], Michael Lorenz[1], Gabriele Benndorf[1], Daniel Spemann[1], Annette Setzer[1], Pablo Esquinazi[1], Andreas Pöppl[1], Holger von Wenckstern[1], Karl-Wilhelm Nielsen[2], Rudolf Gross[2], Herbert Schmid[3], Werner Mader[3], Gerald Wagner[4], and Marius Grundmann[1] — [1]Universität Leipzig, Fakultät für Physik and Geowissenschaften, 04103 Leipzig, Germany — [2]Walther-Meißner-Institut für Tieftemperaturforschung, 85748 Garching, Germany — [3]Rheinische Friedrich-Wilhelm Universität Bonn, 53117 Bonn, Germany — [4]Universität Leipzig, Institut für Mineralogie, Kristallographie und Materialwissenschaft, 04275 Leipzig, Germany

Following [1] we prepared textured, soft ferromagnetic Mn-alloyed ZnO thin films by pulsed laser deposition at low growth temperatures around 500°C and ambient oxygen partial pressures larger than 0.1 mbar for future spintronics applications. The homogeneity and intrinsic nature of magnetic domain formation can be probed by magnetic force microscopy. At 300 K the saturation magnetization and coercive field of optimized films amount to 0.013 emu/g and 234 Oe, respectively. Atomic force microscopy and SQUID measurements reveal that the grain size for large coercive fields in 1 μm thick Mn-alloyed ZnO films ranges between 130-160 nm. The existence of a critical grain size in textured ferromagnetic films can be explained on the basis of Brown's micromagnetic model. [1] P. Sharma et al., Nature Materials **2**, 673 (2003).

HL 30.6 Sa 16:15 TU P164

Thermische Dissoziation von gebundenen Exzitonenkomplexen in ZnO — •S. Giemsch, F. Bertram, S. Petzold, Th. Hempel, J. Christen, A. Dadgar und A. Krost — Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg, PF 4120, D-39016 Magdeburg

Die thermische Dissoziation von gebundenen Exzitonenkomplexen wurde in MOCVD gewachsenen ZnO Schichten mittels temperatur- und anregungsdichteabhängigen, sowie zeitaufgelösten Photolumineszenzmessungen (PL) untersucht. Der bandkantennahe Bereich des PL-Spektrums bei T=4.2 K besteht aus scharfen exzitonischen Linien (freies und gebundene Exzitonen: FX, I2/I3, I8, I9) sowie deren Zweielektronensatelliten (TES). I8 (FWHM < 1.6 meV) dominiert deutlich das Spektrum. In temperaturabhängigen PL-Messungen werden thermisch aktivierte Lumineszenzprozesse beobachtet, die zu zusätzlichen Linien (z.B. Band-Störstelle) bei höherer Temperatur führen. Die Bindungsenergien der beobachteten Exzitonen und Störstellen wurde bestimmt. Es finden sich teilweise erhebliche Unterschiede zu den in der Literatur gefundenen Werten. Die Relaxations- und Rekombinationskinetik wird mit zeitaufgelösten ps-PL-Messungen detailliert untersucht.

HL 31 GaN: Bauelemente

Zeit: Samstag 15:00–16:30 Raum: TU P-N201

HL 31.1 Sa 15:00 TU P-N201

Optimierung InGaN-basierter grüner LEDs — •D. Fuhrmann[1], G. Klewer[1], C. Netzel[1], N. Riedel[1], G. Ade[2], P. Hinze[2], U. Rossow[1] und A. Hangleiter[1] — [1]TU Braunschweig, Inst. f. Techn. Phys., 38106 Braunschweig; d.fuhrmann@tu-bs.de — [2]Physikalisch Technische Bundesanstalt, 38116 Braunschweig

Nitridbasierte grüne LEDs zeigen im Vergleich zu blauen LEDs deutlich geringere interne Quanteneffizienzen (IQE). Ursache dafür sind das grössere piezoelektrische Feld, damit verbunden eine geringere Oszillatorstärke sowie Probleme beim In-Einbau in die notwendigen In-reichen InGaN-Schichten. Mittels MOVPE wurden $In_xGa_{1-x}N$/GaN DQW-Strukturen mit Emissionswellenlängen λ_{Peak} zwischen 450 und 530nm hergestellt. Der In-Einbau wurde dabei durch die Wachstumstemperatur T_{QW} gesteuert. Geringere T_{QW} führen zu einem erhöhten In-Einbau, und damit zu höheren λ_{Peak}. Bei 2nm breiten QWs konnte durch Absenken der Temperatur von 800°C auf 760°C λ_{Peak} von 450nm auf 510nm verschoben werden. Eine weitere Absenkung der Temperatur führte zur Bildung von In-clustern, sodass die weitere Erhöhung von λ_{Peak} nur mit breiteren QWs möglich war. AFM, TEM und REM zeigen die gute strukturelle Qualität aller Proben. PL-Messungen zeigen eine Verringerung der Intensität sowie eine Verbreiterung der QW-Emission mit steigendem λ_{Peak}. Ebenso kommt es zur Verringerung der IQE, bestimmt mittels temperatur-und leistungsabhängiger PL. Dennoch findet man IQE≥30% für λ_{Peak}=530nm (Vergleich: λ_{Peak}=460nm, IQE≥70%). Elektrische Messungen („on wafer") liefern Werte von 2,5mW bei 20mA (λ_{Peak}=460nm) und lassen auch für grüne LEDs hohe Ausgangsleistungen erwarten.

HL 31.2 Sa 15:15 TU P-N201

Mode dynamics in (Al,In)GaN laser diodes — •Markus Pindl[1], Ulrich T. Schwarz[1], Michael Furitsch[2], Andreas Leber[2], Alfred Lell[2], and Volker Härle[2] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, D-93040 Regensburg, Germany — [2]OSRAM Opto Semiconductors GmbH, Wernerwerkstr. 2, 93049 Regensburg, Germany

Stable and well defined optical modes in laser diodes (LDs) are of major interesst in the design of (Al,In)GaN lasers. Improper geometric properties of the waveguide can cause the appearance of higher lateral modes, unstable modes, mode filamentation, and beam-steering. A stable fundamental mode operation is essential for sophisticated applications like laser printers or optical data storage. We used a self-built scanning near-field microscope (SNOM) to investigate the mode behaviour of the LDs. To analyze the temporal dynamics, the SNOM has a time resolution of 5 ns. The SNOM measurements show the near-field of the optical mode

directly on the facet of the LDs. To investigate effects like beam-steering, we also measured lateral cuts in the x/z plane directly in the middle of the propagating beam in a distance of 0 μm − 20 μm to the laser facet. We found that the LDs suffer form filamentation, mode hopping, and beam-steering if the ridge width of the waveguide is wider than 2 μm. The cuts of the propagating beam in the x/z plane show a tilting and, in some cases, also a splitting of the beam. Because the cuts of the propagating beams show not only the near-field of the optical mode, but also how the mode propagates in the free space, one can find informations about the phase in the near-field of the LD.

HL 31.3 Sa 15:30 TU P-N201

Facet degradation of GaN heterostructure laser diodes — •Thomas Schoedl[1], Ulrich T. Schwarz[1], Volker Kümmler[2], Michael Furitsch[2], Andreas Leber[2], Andreas Miler[2], Alfred Lell[2], and Volker Härle[2] — [1]Institut für Angewandte und Experimentelle Physik, Universitätsstr. 31, 93053 Regensburg, Germany — [2]OSRAM Opto Semiconductors GmbH, Wernerwerkstr. 2, 93049 Regensburg, Germany

We investigated the degradation of cleaved facets of (Al,In)GaN laser diodes on SiC substrate in different atmospheres. We found that operation in water-free atmospheres with sufficient oxygen shows a slow degradation. Operation in atmospheres with water vapor show a fast degradation and an oxidation on the facet. We provide a simple model to describe the development of this damage, which is a permanent damage to the laser diode and can't even be removed by heating the laser diode up to 200°C. If the laser diode is operated in pure nitrogen, we find a thick deposition on the facet, which shows high absorption. This deposition can be removed by either high optical output powers or by operation in atmospheres with sufficient oxygen. We also explain the influence of these coatings to the degradation behavior and see this coatings as the reason for unstable kinks in the L–I–characteristics during operation.

HL 31.4 Sa 15:45 TU P-N201

GaN basierte Lichtemitter – Vergleich von Homo- und Heteroepitaxie — •S. Figge, J. Dennemarck und D. Hommel — Institut für Festkörperphysik, Universität Bremen

GaN basierte optoelektronische Bauelemente werden meist mittel Heteroepitaxie auf Substraten wie Saphir hergestellt, die Gitterfehlanpassung führt jedoch selbst mit Techniken wie lateralem Überwachsen zu hohen Versetzungsdichten. Bisher existiert aber keine Wachstumsmethode zur Herstellung von Volumenkristallen zur Waferproduktion. Dieser Engpass kann umgangen werden, indem dicke GaN-Schichten auf Saphir mittels Hydrid-Gasphasenepitaxie (HVPE) gewachsen werden.

In diesem Vortrag werden Laserstrukturen, die parallel auf Saphir- und HVPE-GaN-Substraten mittels metallorganischer Gasphasenepitaxie hergestellt wurden, auf ihre optischen und elektrischen Eigenschaften hin verglichen. Beide Strukturen wurden als Index-geführter Laser prozessiert, wobei die Struktur auf GaN-Substrat mit einem Rückseitenkontakt ausgeführt wurde. Es zeigt sich in der Photolumineszenz, dass die Intensität der Quantentröge auf GaN-Substrat um über eine Größenordnung stärker ist. Während die Strom-Spannungs-Kurven auf beiden Substraten vergleichbar sind, kann die Struktur auf GaN-Substrat bei wesentlich höheren Strömen betrieben werden, da die Wärme durch das GaN Substrat besser extrahiert werden kann. Es zeigte sich außerdem, dass die Facetten auf GaN Substrat durch Spalten der Struktur erzeugt werden können.

HL 31.5 Sa 16:00 TU P-N201

AlInN-basierte elektronische und optoelektronische Bauelemente — •Armin Dadgar[1], Martin Neuburger[2], Fabian Schulze[1], Jürgen Bläsing[1], André Krtschil[1], Hartmut Witte[1], Annette Diez[1], Mike Kunze[3], Ingo Daumiller[3], Erhard Kohn[2] und Alois Krost[1] — [1]Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg, Postfach 4120, 39016 Magdeburg — [2]University of Ulm, Department of Electron Devices and Circuits, Albert-Einstein-Allee 45, 89081 Ulm — [3]MicroGaN GmbH, Albert-Einstein-Allee 45, 89081 Ulm

Für elektronische (FET) und optoelektronische (RCLED, VCSEL) Bauelemente ist die Verwendung von AlInN aufgrund der Möglichkeit, dieses gitterangepaßt auf GaN zu wachsen, äußerst interessant. So sind von Al-reichen AlInN Schichten bei Verwendung in FETs hohe Polarisationsladungen aufgrund der hohen spont. Polarisation an der Grenzfläche zum GaN zu erwarten. Tatsächlich zeigen AlInN/GaN gegenüber AlGaN/GaN FETs deutlich höhere 2D Ladungsträger- ($> 2x10^{13} cm^{-3}$) und Leistungsdichten (>4.4 W/mm). Durch die Veränderung der Verspannung des AlInN kann dabei der Anteil der piezoel. Polarisation so gewählt werden, daß sie die in diesem Material sehr starke spont. Polarisation verstärkt oder abschwächt, was sich in den 2D Trägerdichten widerspiegelt. Für Braggreflektoren ist dieses Material durch die Möglichkeit, verspannungsarm und somit im Gegensatz zum AlGaN/GaN System rißfrei zu wachsen, sehr interessant. Wir zeigen rißfreie 40-fach AlInN/GaN Braggreflektoren mit hohen Reflektivitäten und diskutieren anhand von 10-fach Reflektoren den Einfluß der Prozeßführung auf die Reflektivität.

HL 31.6 Sa 16:15 TU P-N201

Dynamic properties of blue (Al,In)GaN laser diodes — •Ulrich T. Schwarz[1], Markus Pindl[1], Michael Furitsch[2], Andreas Leber[2], Andreas Miler[2], Alfred Lell[2], and Volker Härle[2] — [1]Institut für Angewandte und Experimentelle Physik, Universitätsstr. 31, 93053 Regensburg, Germany — [2]OSRAM Opto Semiconductors GmbH, Wernerwerkstr. 2, 93049 Regensburg, Germany

While remarkable progress is being reported on blue laser diode lifetime and output power, information on dynamic properties of those laser diodes are rare. For most applications a kink-free operation up to several ten milliwatt optical output power is as critical as is the quality of the far-field intensity distribution. For direct modulation, i.e. pulsed operation, carrier dynamics and thermal budget will critically influence stability of the optical output power and beam pointing stability. We demonstrate how to measure simultaneously the temporal evolution of near-field and far-field of blue laser diodes. From this information we extract the phase dynamics that causes beam steering. The importance of the carrier dynamics for beam instabilities is expressed in the relatively high value of the antiguiding factor of InGaN quantum wells, which was predicted in simulations including many-body effects and which was measured by means of the Hakki-Paoli method of gain spectroscopy.

HL 32 Halbleiterlaser I

Zeit: Samstag 15:00–16:30 Raum: TU P-N202

HL 32.1 Sa 15:00 TU P-N202

GaSb-basierte Halbleiter-Diodenlaser im externen Resonator für den Wellenlängenbereich um 2 μm — •Eva Geerlings[1], Marcel Rattunde[1], Johannes Schmitz[1], Gudrun Kaufel[1], Joachim Wagner[1] und Hans Zappe[2] — [1]Fraunhofer-Institut für Angewandte Festkörperphysik, Tullastraße 72, 79108 Freiburg — [2]Institut für Mikrosystemtechnik, Universität Freiburg, Georges-Köhler-Allee 102, 79110 Freiburg

GaSb-basierte Typ-I Halbleiterlaser, die im Wellenlängenbereich um 2 μm emittieren, können in der Medizintechnik in der nicht-invasiven Diagnostik z.B. zur Messung des Blutzuckerspiegels von Diabetes-Patienten, eingesetzt werden. Für dieses Messverfahren, das auf spektroskopischer Sensorik beruht, sind breit durchstimmbare Diodenlaser nötig.

Um einen breiten Durchstimmbereich realisieren zu können, werden die Diodenlaser in einen externen Resonator, der auf der Littrow - Konfiguration basiert, betrieben. Verwendet wurden indexgeführte schmale Rippenwellenleiter-Laser mit hochreflektierend/antireflektierend beschichteten Facetten. In dieser Arbeit werden wesentliche Parameter, die den maximalen Durchstimmbereich beeinflussen, analysiert. Speziell wurde der Einfluß der Gitterreflektivität sowie des Kopplungsfaktors zwischen internem und externem Resonator auf den Durchstimmbereich untersucht. Es konnte ein maximaler Durchstimmbereich von 130 nm erreicht werden, wobei der Laser zwischen 2.21 μm und 2.34 μm quasikontinuierlich betrieben werden kann.

HL 32.2 Sa 15:15 TU P-N202

Tuning of the emission wavelength in mid-infrared quantum-cascade micro-lasers by controlling the cavity length — •S. Höfling[1], P. Eugster[1], J. Seufert[2], J. Koeth[2], J.P. Reithmaier[1], and A. Forchel[1] — [1]Technische Physik, Universität Würzburg, Würzburg — [2]nanoplus, Nanosystems and Technology GmbH, Gerbrunn

The fabrication and investigation of edge-emitting quantum-cascade (QC) lasers and micro-lasers with monolithically integrated deeply etched semiconductor-air Bragg-mirrors based on GaAs is reported. We observe a reduction of the threshold current density by 25 % and an increase of the operation temperature by 23 K to 315 K for 800 μm by employing Bragg-mirrors. Devices with ultra-short cavities of about 100 μm (36 times the wavelength) operate up to 260 K. At 80 K, these devices show threshold currents as low as 0.63 A and output levels up to 56 mW. In these devices, longitudinal single mode operation with output levels exceeding 7.7, 5.6 and 2.8 mW was measured at 180, 200 and 240 K, respectively. This can be attributed to the limited gain bandwidth of QC lasers and the large mode spacing in these devices, which is proportional to the square of the wavelength. We demonstrate that tuning of the emission wavelength is feasible by controlling the cavity length and thereby selecting the spectral position of the Fabry-Perot modes. The tuning range of the low excitation modes of devices, whose cavity lengths vary in steps of 1 μm (from 98 to 105 μm), is about 180 nm, centered at 9.18 μm.

HL 32.3 Sa 15:30 TU P-N202

Quantenpunktlaser auf InP mit einer Verstärkungsbandbreite von über 250 nm — •Andre Somers, Stefan Deubert, Wolfgang Kaiser, Johann Peter Reithmaier und Alfred Forchel — Technische Physik, Universität Würzburg, Würzburg

Für viele Anwendungen besteht ein starkes Interesse an einem größeren spektralen Verstärkungsbereich, als herkömmliche Quantenfilmlaser liefern können. Aufgrund der statistischen Größenverteilung von Quantenpunktstrukturen auf InP ist die Bandbreite bereits deutlich vergrößert. Durch spezielle Schichtdesigns ist es möglich die Bandbreite bis über 250 nm zu steigern. Damit kann der gesamte langwellige Telekommunikationsbereich zwischen 1.4 und 1.65 μm mit einer Schichtstruktur abgedeckt werden, z.B. für optische Verstärker (SOAs) oder abstimmbare Laser mit externer Kavität (ECLs). Die in diesem Beitrag präsentierten Laser zeigen verschiedene Ansätze, mit denen eine solche Bandbreite auf InP realisiert wurde. Um dies zu erreichen wurde die Abhängigkeit der Emissionswellenlänge von der Quantenpunktdicke ausgenutzt. Durch die Kombination von verschiedenen Quantenpunkt- und Barrierendicken in einer aktiven Zone ist es möglich die Verstärkung über einen großen spektralen Bereich zu verteilen. Für die Bestimmung der spektralen Bandbreite wurde die Streifenmethode angewandt.

HL 32.4 Sa 15:45 TU P-N202

Laser emission from ultra-small single quantum-well pillar microcavities — •M. Benyoucef[1], P. Michler[1], J. Wiersig[2], F. Jahnke[2], M. Kamp[3], and A. Forchel[3] — [1]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany — [2]Institut für Theoretische Physik, Universität Bremen, Postfach 330440, 28334 Bremen, Germany — [3]Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

High efficiency and low threshold semiconductor lasers can be achieved through control of spontaneous emission in microcavities [1]. The spontaneous and stimulated emission of pillar microcavities with different lateral diameters (1-4 μm) were investigated by low temperature (T = 4 K) micro-photoluminescence spectroscopy. The pillar microcavity structures consist of an active region of an InGaAs single quantum-well. A GaAs cavity is sandwiched between the bottom and top distributed Bragg reflectors (DBRs), which consist of 22- and 20-period of AlAs/GaAs layers, respectively.

In this work, we report the observation of lasing with low thresholds (12 mW/cm2) and large spontaneous emission factors (β) from optically-pumped small pillar microcavities. For a 1.5 μm diameter pillar, a linewidth of about 0.17 nm is measured bellow the laser threshold, however, above the laser threshold, the linewidth decreases to a value about 0.08 nm and then is approximately constant for higher excitation powers. Using a rate equation model, we estimate the β values. Furthermore, calculated mode structures of the microcavity lasers will be presented.

[1] F. M. Matinaga et al., Appl. Phys. Lett. 62, 443 (1993).

HL 32.5 Sa 16:00 TU P-N202

Nichtlineare Prozesse in Zwei-Farben Halbleiterlasern — •Stefan Hoffmann, Xiao Luo und Martin Hofmann — AG Optoelektronische Bauelemente und Werkstoffe, Ruhr-Universität Bochum, IC2/156, D-44780 Bochum

In den letzten Jahren konnte gezeigt werden, dass Zwei-Farben Halbleiterlaser ein wichtiges Instrument zur Generation von Dauerstrich Terahertzstrahlung bei Raumtemperatur sind. Dabei wurde zudem deutlich, dass diese Systeme aufgrund der Nichtlinearität im Halbleiter eine interessante Dynamik aufweisen. Wir analysieren Vierwellenmischen zwischen den zwei Wellenlängen des Lasers und die direkte Abstrahlung der Differenzfrequenz im Terahertzbereich im Hinblick auf mögliche Anwendungen. Insbesondere wird das Leistungs- und Bandbreitenpotential der direkten Emission diskutiert und anderen Konzepten zur Erzeugung von Terahertzstrahlung gegenübergestellt, die auf einer externen Photomischung beruhen.

HL 32.6 Sa 16:15 TU P-N202

405nm-Laserdioden auf Bulk-GaN-Substraten — •C. Rumbolz, A. Leber, M. Furitsch, A. Avramescu, A. Miler, G. Brüderl, A. Lell und V. Härle — OSRAM Opto-Semiconductors GmbH, Wernerwerkstr. 2, 93049 Regensburg

Gängiges Verfahren zur Herstellung von opto-elektronischen Bauteilen im InAlGaN-Materialsystem ist die Heteroepitaxie auf SiC- oder Saphir-Hilfssubstraten. Aufgrund der Gitterfehlanpassungen zwischen Substrat und Epitaxie weisen die aufwachsenden Schichten hohe Defektdichten ($\sim 10^9 \mathrm{cm}^{-2}$) auf. Trotz nichtstrahlender und spontaner Rekombination an diesen Defekten erreichen bei OSRAM OS gefertigte Ridgelaser auf SiC-Substrat Rekordschwellstromdichten von nur 5,6kA/cm^2 und Steilheitsbestwerte von 0,9W/A. Dennoch werden bei cw-Alterungen mit 10mW optischer Ausgangsleistung nur Lebensdauern knapp über hundert Stunden erreicht. Um bessere Laserparameter und längere Lebensdauern zu erreichen wurden Ridgelaser zur Defektreduzierung auf GaN-Substraten hergestellt. Gezeigt werden erste Ergebnisse dieser defektreduzierten Bauteile($<10^7 \mathrm{cm}^{-2}$), die im Vergleich zu SiC-Dioden signifikant bessere Laserparameter mit Schwellstromdichten von 3,3kA/cm^2 und Steilheiten bis 1,5W/A aufweisen. Diese erlauben geringe elektrische Verlustleistungen während den Alterungsuntersuchungen. Die Alterungsraten gegenüber SiC-Dioden reduzieren sich auf ein Viertel. Mit Alterungsraten unter 0,1mA/h werden bei 10mW optischer Ausgangsleistung cw-Lebensdauern von mehreren hundert Stunden erzielt.

HL 33 Kohlenstoff/Diamant

Zeit: Samstag 15:00–16:00 Raum: TU P-N229

HL 33.1 Sa 15:00 TU P-N229

The Influence of Line Tension on the Shape of Epitaxially Grown Silicon Nanowires — •Volker Schmidt, Stephan Senz, and Ulrich Gösele — Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany

Silicon nanowires grown epitaxially via the vapor-liquid-solid mechanism show a larger diameter at the base of the nanowire, which can not be explained by an overgrowth of the nanowire alone. By considering the equilibrium condition for the contact angle of the droplet, the Neumann quadrilateral relation, a quasi-static model of epitaxial nanowire growth is derived. It is found that a change of the contact angle of the droplet is responsible for the larger diameter of the nanowire base so that the expansion has to be considered a fundamental aspect of epitaxial vapor-liquid-solid growth. By comparison of experimental results with theoretical calculations, an estimate for the line tension is obtained. In addition, the growth model predicts the existence of two different growth modes. Only within a certain range of line tension values the mode corresponding to ordinary nanowire growth is realized, whereas nanowire growth stops at relatively small height if the line tension exceeds an upper boundary. An approximate analytic expression for the upper boundary as a function of the surface tensions is given.

HL 33.2 Sa 15:15 TU P-N229

Mechanismen der epitaktischen Nukleation von Diamant auf Iridium — •Matthias Schreck, Thomas Bauer, Stefan Gsell und Bernd Stritzker — Uni Augsburg, Institut für Physik, 86135 Augsburg

Mittels Gleichspannungs-unterstützer Keimbildung im Mikrowellenplasma können epitaktisch orientierte Diamantkeime auf der Oberfläche von Iridium erzeugt werden. Die strukturellen Eigenschaf-

ten der abgeschiedenen Nukleationsschichten wurden mittels x-ray absorption near edge structure (XANES), elastic recoil detection (ERD), Rasterkraftmikroskopie (AFM) und Hochauflösungs-Transmissionselektronenmikroskopie (HREM) untersucht. Es zeigt sich, dass die Keime in einer ca. 0,6 nm dicken Kohlenstoffschicht an der Oberfläche des Iridium vorliegen müssen. Lateral findet man drastische Variationen in der Keimdichte (Domänenbildung). Die zugrunde liegenden Rückkopplungsprozesse und die möglichen Mechanismen der Keimbildung werden im Vortrag diskutiert.

HL 33.3 Sa 15:30 TU P-N229

Homoepitaktische Abscheidung von Diamant mit hohen Wachstumsraten — •Thomas Bauer, Matthias Schreck, Hadwig Sternschulte und Bernd Stritzker — Uni Augsburg, Institut für Physik, 86135 Augsburg

Homoepitaktisches Wachstum mittels Chemischer Gasphasenabscheidung (CVD) kann Diamantkristalle mit höchster kristalliner und elektronischer Qualität liefern [1]. In der vorliegenden Arbeit wurde das CVD-Wachstum auf Typ Ib-Einkristallen (aus der Hochtemperatur-Hochdruck-Synthese) bei hohen Wachstumsraten von bis zu 30 μm/h untersucht. Auf nominell (001)-orientierten Oberflächen bildete sich bei den typischen Wachstumsbedingungen von 10% CH_4 in Wasserstoff, einem Gasdruck von 200 mbar und Substrattemperaturen von 1200^{o}C eine hohe Dichte von nichtepitaktischen Kristalliten. Durch Verwendung von Substraten mit off-axis-Winkeln zwischen 3^o und 7^o konnten diese komplett unterdrückt werden. Hochauflösungsröntgenbeugungsmessungen ergaben Halbwertsbreiten der Rockingkurven von $< 0,01^o$. Die Linienbreiten der Ramanspektren sind mit 1,62 cm^{-1} vergleichbar mit denen der besten IIa-Einkristalle.

[1] J. Isberg et al. Science 297 (2002) 1670.

HL 33.4 Sa 15:45 TU P-N229

Wachstum von epitaktischen Diamantschichten auf Silizium mittels Iridium/Metalloxid-Pufferschichten — •Stefan Gsell, Thomas Bauer, Johannes Goldfuss , Matthias Schreck und Bernd Stritzker — Uni Augsburg, Institut für Physik, 86135 Augsburg

Epitaktische Schichten aus Strontiumtitanat ($SrTiO_3$) und Yttria-stabilisiertem Zirkonoxid (YSZ) wurden mittels Molekularstrahlepitaxie (MBE) bzw. gepulster Laserablation (PLD) auf Si(001) aufgebracht. Sie dienten als Unterlage für die nachfolgende Deposition von einkristallinen Iridiumschichten. Die Charakterisierung der Proben erfolgte mit Hilfe von Röntgentexturmessungen, Rasterelektronenmikroskopie und Ramanspektroskopie. Auf beiden Materialsystemen Ir/$SrTiO_3$/Si(001) und Ir/YSZ/Si(001) wurde mittels Gleichspannungs-unterstützer Keimbildung in einer Mikrowellenplasmaanlage Diamant epitaktisch abgeschieden. Mit Mosaizitätswerten unter 1^o sind diese Schichten um nahezu eine Grössenordnung besser als bei direkter Deposition von Diamant auf Silizium. Die vorliegenden Ergebnisse zeigen einen aussichtsreichen Weg für die Abscheidung großflächiger einkristalliner Diamantschichten auf.

HL 34 Neue Materialien

Zeit: Samstag 15:00–15:45 Raum: TU P-N226

HL 34.1 Sa 15:00 TU P-N226

Ferromagnetism in Fe-doped $ZnGa_2O_4$ semiconductor — •Tulika Maitra and Roser Valentí — Institut für Theoretische Physik, J. W. Goethe Universität, Robert-Mayer Str. 8, 60054 Frankfurt am Main, Germany

Motivated by the recent experimental observation of long range ferromagnetic order at a relatively high temperature of 200K in the Fe doped $ZnGa_2O_4$ semiconducting spinel, we propose a possible mechanism for the observed ferromagnetism in this system. We show how a double exchange model can be written down for this system and calculate the ground state phase diagram in this model for two cases, one where Fe is doped at the tetrahedral position and the other where it is doped at the octahedral position. We find that in both cases such a model can give rise to a stable ferromagnetic phase in a wide range of parameter space. The results for a single orbital are different from the degenerate two-orbital case in the limit of high Fe^{2+} concentration. The doubly-degenerate e_g orbitals and the hopping between them play a crucial role in stabilising the ferromagnetic phase in this limit. The case when Fe is doped in both the tetrahedral and the octahedral positions is also outlined.

HL 34.2 Sa 15:15 TU P-N226

Microchanneling Untersuchungen an mittels Ionenstrahlsynthese hergestellter ß-$FeSi_2$-Strukturen — •Ü. Dagkaldiran[1], D. Grambole[2], V. Herrmann[2], H.-U. Schreiber[1] und J. Meijer[1] — [1]Ruhr-Universität Bochum — [2]Forschungszentrum Rossendorf

Halbleitendes Eisendisilizid (ß-$FeSi_2$) ist immer öfter Gegenstand der heutigen Forschung. Der Verdacht, dass ß-$FeSi_2$ vermutlich einen direkten Bandübergang von 0,8 eV besitzt [1], macht ihn zu einem viel versprechenden Kandidaten für μ-LED's auf Silizium Basis. Monokristallines ß-$FeSi_2$ würde sogar die Möglichkeit für einen μ-Laser eröffnen.
Die Temperatur während der Ionenimplantation, die Ausheilschritte, die Energie des Ionenstrahls sowie die Dosis und die Stromdichte, Strukturgröße etc. sind entscheidende Prozessparameter für die Synthese solcher Strukturen, die aufeinander abgestimmt werden müssen.
Die Kombination der beiden Anlagen, der Hochenergie Ionen Projektor (HEIP) an Ruhr Universität Bochum und die μ-Channeling Anlage im Technologiezentrum Rossendorf, erlaubt die schnelle Herstellung und auch die Analyse der Strukturen. Die Strukturen wurden mit einer Ionenernergie von 800 keV hergestellt. Die Dosis wurde zwischen 1; 3 und 5x10^{17} Fe^+/cm^{-2} variiert. Die Temperature während der Implantation wurde zwischen 50 - 350 °C variiert. Die Untersuchung zeigte, dass die Ostwald Reifung von der Implantationtemperatur abhängt. Raman Messungen bestätigten die Synthese von ß-$FeSi_2$.

[1] N.E. Christensen; Phys. Rev. B42, 1990, p.7148-7153

HL 34.3 Sa 15:30 TU P-N226

Hydrogen in GaMnAs — •C. Bihler[1], H. Huebl[1], C. Noemeier[1], M. S. Brandt[1], S. T. B. Goennenwein[2], and W. Schoch[3] — [1]Walter Schottky Institut, Technische Universität München, 85748 Garchig, Germany — [2]Kavli Institute of Nanoscience Delft, Delft University of Technology, 2628 CJ Delft, The Netherlands — [3]Abteilung Halbleiterphysik, Universität Ulm, 89081 Ulm, Germany

The hole concentration in the ferromagnetic semiconductor GaMnAs can be adjusted independently from the concentration of Mn by post-growth incorporation of hydrogen. FTIR experiments have shown that Mn-As-H complexes are formed during hydrogenation. To obtain further information on the structural changes induced, we have performed X-ray diffraction experiments. Upon hydrogenation, the unstrained lattice constant of the GaMnAs epilayer increases by $\Delta a/a = 0.6 \times 10^{24}$ cm^3[H]. This increase is markedly lower than the corresponding increase in hydrogenated Si:B which suggests that H is built into GaMnAs on a lattice site such as the antibonding site. In addition, the effective indiffusion of hydrogen is determined via measurements of the ferromagnetic resonance of the thin films where the temperature- and time-dependence of the shift of the collective spin-wave mode upon hydrogenation and anneal is compared to the shifts found upon wet-chemical etching of the films.

HL 35 Hybride Systeme

Zeit: Samstag 15:45–16:30 Raum: TU P-N226

HL 35.1 Sa 15:45 TU P-N226

Sensitization of silicon thin films by dye molecules — •Christian Kelting[1], Ulrich Weiler[2], Thomas Mayer[2], Dieter Wöhrle[3], Ossamah Abdallah[4], and Derck Schlettwein[1] — [1]Institut für Angewandte Physik, Justus-Liebig-Universität Giessen, D-35390 Giessen — [2]FG Oberflächenforschung, FB Material- und Geowissenschaften, Technische Universität Darmstadt, D-64287 Darmstadt — [3]Institut für Organische und Makromolekulare Chemie, Universität Bremen, D-28334 Bremen — [4]Abteilung für Solare Energetik, Hahn-Meitner-Institut, D-14109 Berlin

The use of Si-dye hybrid materials in the intrinsic layer of thin film solar cells is expected to increase the light harvesting efficiency and hence also the conversion efficiency. En route to such materials phthalocyanine (Pc) molecules have been vapour-deposited on Si wafers (hydrogen terminated by HF etching), microcrystalline Si and amorphous Si prepared by a hot-wire CVD technique. Films from monolayer coverage up to 20 nm of unsubstituted (PcZn) and fluorinated zinc complexes of Pc were studied. The growth of these strongly absorbing materials was investigated by UV-Vis spectroscopy. After the alignment of the energy levels of PcZn and the fluorinated derivatives has been deduced from UPS studies the present measurements are focussed on photoconduction measurements at the films to study an injection of charge carriers from the excited dye molecules to Si.

HL 35.2 Sa 16:00 TU P-N226

Transmissionseigenschaften magneto-elektrischer Barrieren in Dysprosium-Halbleiter-Hybriden — •Nico Schulz[1] und Thomas Heinzel[2] — [1]Physikalisches Institut, Albert-Ludwigs-Universität, 79108 Freiburg, Germany — [2]IPkM, Heinrich-Heine-Universität, 40225 Düsseldorf, Germany

Magneto-elektrische Barrieren werden in einem zweidimensionalen Elektronengas einer Ga[Al]As-Heterostruktur durch eine Gate-Schichtstruktur definiert, die Dysprosium als ferromagnetische Komponente enthält. Der Barrierenwiderstand wird als Funktion des externen magnetischen Feldes, der Temperatur sowie der Elektronendichte untersucht. Das Verhalten des Barrierenwiderstandes als Funktion der Temperatur und der Ladungsträgerdichte ist qualitativ, allerdings nicht quantitativ, konsistent mit einem thermisch aktivierten Transportmechanismus. Durch Streuung unterstützte Transmission spielt dagegen eine untergeordnete Rolle. Weiterhin sind sowohl Curie-Temperatur als auch Koerzitivfeld der Dysprosium-Filme im Vergleich zum Volumenmaterial stark erhöht.

HL 35.3 Sa 16:15 TU P-N226

Mikro-Magnetolumineszenz-Spektroskopie an Ferromagnet-Halbleiter Hybridstrukturen — •S. Halm[1], F. Seifert[1], G. Bacher[1], H. Schömig[2], A. Forchel[2], J. Puls[3] und F. Henneberger[3] — [1]Werkstoffe der Elektrotechnik, Universität Duisburg-Essen, Bismarckstr. 81, 47057 Duisburg — [2]Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg — [3]Institut für Physik, Humboldt-Universität Berlin, Newtonstraße 15, 12489 Berlin

Hybridstrukturen aus mikroskopischen Ferromagneten und magnetischen Halbleitern sind ein vielversprechender Ansatz, um lokale Einschlusspotentiale für Ladungsträger eines definierten Spins im Halbleiter zu realisieren. Das Streufeld der Ferromagneten moduliert dabei die Bandlücke des magnetischen Halbleiters unter Ausnutzung des riesigen Zeeman-Effektes.
Wir präsentieren hochortsaufgelöste Magnetolumineszenz-Messungen an einem semimagnetischen $Zn_{0.77}Cd_{0.15}\mathbf{Mn}_{0.08}Se$-Quantenfilm, auf den sub-mikrometergroße metallische Ferromagnet-Draht- und Punktstrukturen aufgebracht wurden. Es lässt sich eine magnetfeld- und ortsabhängige Modulation des Photolumineszenz-Signales beobachten, die auf eine lokale spinabhängige Änderung der Bandlücke hinweist.

HL 36 Quantenpunkte und -drähte: Optische Eigenschaften III

Zeit: Montag 10:00–12:15 Raum: TU P164

HL 36.1 Mo 10:00 TU P164

Optically Programmable Electron Spin Memory Using InGaAs Quantum Dots — •Dominik Heiss, Miro Kroutvar, Yann Ducommun, Max Bichler, Dieter Schuh, Gerhard Abstreiter, and Jonathan J Finley — Walter Schottky Institut, TU Muenchen, Am Coulombwall 3, 85748 Garching, Germany

The spin of a single electron localized in a quantum dot (QD) in static magnetic fields provides a natural two level system that has been proposed to be suitable as a quantum bit [1].

We present a spin memory device which enables the preparation, storage and readout of electron spins. This device is based on charging of a sub-ensemble of a single layer of InGaAs self-assembled QDs with resonant optical excitation. These charges can be stored over microsecond timescales without any loss or interdot redistribution processes [2]. Using circular polarized excitation we are able to define the spin orientation of the stored electrons. This device allows us to investigate the temporal dynamics of localized spins in magnetic fields by varying the storage time. Our results reveal very long spin lifetimes T1, with a lower limit of 20ms at 4T and 1K. Analyzing the magnetic field dependence we identified the dominant spin-flip mechanism to be spin-orbit mixing of the Zeeman levels mediated by one-phonon scattering at low temperatures and high magnetic fields [3]. [1] Loss, DiVicenzo, Phys. Rev. A 57 (1998) [2] Kroutvar et al., Appl. Phys. Lett. 83 (2003) [3] Kroutvar et al., Nature 432 (2004)

HL 36.2 Mo 10:15 TU P164

Strong coupling in a quantum dot microcavity system — •Carolin Hofmann[1], Johann Peter Reithmaier[1], Grzegorz Sek[1,2], Andreas Löffler[1], Silke Kuhn[1], Stephan Reitzenstein[1], Leonid Keldysh[3], Vladimir Kolakovskii[4], Tom Reinecke[5], and Alfred Forchel[1] — [1]Technische Physik, Universität Würzburg, Am Hubland, D-97074 Würzburg — [2]Institute of Physics, Wrocław University of Technology, 50-370 Wrocław, Poland — [3]Lebedev Physical Institute, Russian Academy of Science, 119991 Moscow, Russia — [4]Institute for Solid State Physics, Russian Academy of Science, 142432 Chernogolovka, Russia — [5]Naval Research Laboratory, Washington, DC 20375, USA

Pronounced cavity quantum electrodynamics (cQED) effects are observed in a structure consisting of quantum dots embedded in a high quality micropillar cavity. cQED distinguishes between the weak and the strong coupling regime, depending on the coupling strength between the atom-like emitter and the electromagnetic modes of the cavity. Weak coupling corresponds to an irreversible process in which the quantum mechanical emitter-photon coupling leads to the well known Purcell-Effect. Strong coupling is related to a reversible energy exchange between the emitter and the cavity mode. It will be shown that high quality AlAs/GaAs micropillar cavities containing a low density GaInAs quantum dot layer allow one to observe weak as well as strong coupling effects in semiconductor structures. These studies have allowed the first observation of strong coupling characterized by vacuum Rabi splitting in a solid state system.

HL 36.3 Mo 10:30 TU P164

Photoluminescence studies of multi-modal self-assembled quantum dots under high hydrostatic pressure — •Christian Kristukat[1], Alejandro Rudolfo Goñi[2], Konstantin Pötschke[1], Andrei Schliwa[1], Dieter Bimberg[1], and Christian Thomsen[1] — [1]Technische Universität Berlin, Institut für Festkörperphysik, PN 5-4, Berlin, Germany — [2]ICREA Research Professor, Institut de Ciència de Materials de Barcelona, Campus de la UAB, 08193 Bellaterra, Spain

We have investigated the photoluminescence from self-assembled InAs/GaAs quantum dots at 2 K under high hydrostatic pressure up to 9 GPa. The spectra show up to nine peaks which are attributed to the ground-state exciton emission from groups of quantum dots which differ by entire monolayers. With increasing pressure all emission peaks shift to higher energy, exhibiting the typical behavior of direct $\Gamma - \Gamma$ transitions. Beginning at about 4.6 GPa the emission of the smallest dots first and then that of the bigger dots quenches successively. At 9 GPa all peaks have disappeared. This is due to the conduction band crossover of the GaAs X-point energy with the Γ-point ground state of the dots, at which the electron confinement is lost and the heterostructure becomes type-II in character. The pressure coefficient of the exciton recombination in the dots varies from 66 meV/GPa up to about 100 meV/GPa for the largest and the smallest dots, respectively, which is in average much smaller than that of bulk GaAs and InAs. The reason for that are possibly the change of the misfit strain and the elastic constants with pressure which affects the band gap and the pressure dependence of the barrier height, effective masses and dot size which determine the confinement energy.

HL 36.4 Mo 10:45 TU P164

Purcell effect in exciton and biexciton recombination in the same quantum dot in micropillar cavites — •Stephan Reitzenstein[1], Dimitri Krizhanovskii[1,2], Grzegorz Sek[1,3], Carolin Hofmann[1], Maxim Makhonin[1,2], Vladimir Kulakivskii[2], and Alfred Forchel[1] — [1]Technische Physik, Universität Würzburg, Am Hubland, D-97074 Würzburg — [2]Institute for Solid State Physics, Russian Academy of Science, Chernogolovka, 142432, Russia — [3]Institute of Physics, Wrocław University of Technology, 50-370 Wrocław, Poland

We report on the investigation of single and two exciton states of a single quantum dot (QD) embedded in the active layer of a high finesse (Q = 4500) GaAs/AlAs micropillar cavity. The microcavity structure is composed of 20 (23) repetitions of λ/4-GaAs/AlAs (69 nm/82 nm) layers in the top (bottom) Bragg reflector. The active layer in the λ-GaAs cavity contains self-assembled $In_{0.6}Ga_{0.4}As$ QDs (density ≈ 10^{10} cm^{-2}) placed at the antinode of the on-axis resonant fundamental mode of planar cavity. By tuning the QD exciton and the QD biexciton on resonance with the optical mode we observe a strong, but identical enhancement of the emission by a factor of about 30. By model calculations of the measured intensity dependences including sidewall losses we determine a Purcell factor of about 8 in both cases. This is fully consistent with the model for the Purcell factor, which relates the enhancement of the radiative recombination only with parameters of the cavity and not with the characteristics of the particular transition studied.

HL 36.5 Mo 11:00 TU P164

Shape and Order of Wavefunctions in Uncapped InAs/GaAs Quantum Dots — •A. Schliwa[1], T. Maltezopoulos[2], M. Morgenstern[3], R. Wiesendanger[2], and D. Bimberg[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin — [2]Institute of Applied Physics, University of Hamburg — [3]II. Inst. of Physics B, RWTH Aachen University

Recently it became possible to map the shape of electron wavefunctions in uncapped InAs/GaAs quantum dots (QDs) by using scanning tunneling spectroscopy (STS) [1]. These measurement revealed an anomalous order of the single particle states in most of the investigated QDs which triggered the here presented theoretical investigations based on the eight-band-$\mathbf{k}\cdot\mathbf{p}$ model.
The outer shape of the model-QD is specified by using the morphological data, recorded as a byproduct of the STS-method, whilst the composition profile has been treated as variable. Most of the measured QDs are elongated in $[1\bar{1}0]$ direction with a larger in-plane anisotropy-ratio at the QD-apex than at the bottom. Therefore the order of the wavefunctions is strongly affected by their position in the QD. The tip induced electric field favours a location at the QD-bottom whereas a high InAs concentration in the upper region makes a position in the QD-apex more favourable. In the first case we find the usual order of wavefunctions: s, p_x, p_y, d whereas in the other case the p_y -state moves behind the d-state.

[1] Maltezopoulos T., Bolz A., Meyer C., Heyn C., Hansen W., Morgenstern M., Wiesendanger R., Phys. Rev. Lett. 91, p.196804 (2003)

HL 36.6 Mo 11:15 TU P164

Single CdSe nanorods spectroscopy — •Tobias Selle[1], Nicolas Le Thomas[1], Mikhail Artemyev[2], and Ulrike Woggon[1] — [1]Experimentelle Physik II, Otto-Hahn Strasse 4, 44221 Dortmund, Germany — [2]Institute for Physico-Chemical Problems of Belarussian State University, Minsk 220080, Belarus

Colloidal CdSe(ZnS) core-shell nanorods (NR) are one-dimensional (1D) nanostructures emitting highly polarized light and therefore represent attractive nanocrystals for applications in advanced optical technologies as well as for fundamental research.

The polarization dependence of the excitonic emission lines is determined in bath-cryostat micro-photoluminescence experiments of single NRs. Taking into account the 1D symmetry of the emitter the observations are explained by a radius dependent change in the symmetry of the 1D-exciton ground state which transforms from a dark state into bright states below a critical radius of $R_{\mathrm{crit}} \approx 3.7$nm.

Furthermore the excitation intensity dependence of the spectral linshape is investigated at low temperature. The effect of the acoustic phonon and the charges in the surrounding will be discussed.

HL 36.7 Mo 11:30 TU P164

Stark shifts induced by internal and external electric fields in single colloidal semiconductor nanocrystals — •J. Müller[1], J. M. Lupton[1], A. L. Rogach[1], J. Feldmann[1], D. Talapin[2], and H. Weller[2] — [1]Photonics and Optoelectronics Group, Sektion Physik, LMU Munich, 80799 Munich, Germany — [2]Institute of Physical Chemistry, University of Hamburg, 20146 Hamburg, Germany

We study heterostucture nanocrystals consisting of an elongated CdS shell with a spherical CdSe core located at one end of the shell. The broken symmetry defines a spatial direction of surface charge movement towards and away from the emitting core. This leads to a change in the electric field induced Stark shift as the charges meander along the surface. We observe a universal correlation between the linewidth and the emission energy during spectral diffusion, allowing us to microscopically track the charges on a nanometer scale from 5 K up to room temperature [1]. The dependence of the fluorescence linewidth on the local electric field provides a novel probe of the nanocrystal nanoenviroment. Furthermore, application of external electric fields to single nanocrystals makes it possible to shift the emission wavelength through the Stark effect by up to 100 meV. [1] Müller et al., Phys. Rev. Lett. 93, 167402 (2004)

HL 36.8 Mo 11:45 TU P164

Untersuchung der elektronischen Zustände von Halbleiterquantenpunkten im Rahmen von Tight-Binding-Modellen — •Stefan Schulz und Gerd Czycholl — Institut für Theoretische Physik, Universität Bremen

Die optischen und elektronischen Eigenschaften von Halbleiterquantenpunkten sind stark abhängig von der Größe, Geometrie, Zusammensetzung als auch von den Einteilchenzuständen und der Coulomb-Wechselwirkung.

Die Einteilchenzustände und auch die Einteilchenenergien von Halbleiternanostrukturen werden hier mit Hilfe von Tight-Binding-Modellen untersucht. Diese Modelle bieten einen mikroskopischen Zugang zur Beschreibung von niederdimensionalen Strukturen.
Durch Anpassung an charakteristischen Eigenschaften der Bandstruktur der Volumenmaterialien werden die in den Tight-Binding-Modellen auftretenden Parameter bestimmt.

Es werden sowohl nitrid-basierte Halbleiterquantenpunkte als auch Nanostrukturen basierend auf II-VI-Materialien untersucht. Betrachtet werden hierbei unterschiedliche Modellgeometrien.
Im Rahmen dieser mikroskopischen Theorie wird insbesondere der Einfluß von Verspannungseffekten auf die elektronischen Einteilchenzustände untersucht.

HL 36.9 Mo 12:00 TU P164

Photolumineszenz– und Raman–Spektroskopie an Si–Nanopartikeln aus der Gasphase — •Stephan Lüttjohann[1], Cedrik Meier[1], Vasyl Kravets[1], Axel Lorke[1] und Hartmut Wiggers[2] — [1]Laboratorium für Festkörperphysik, UniversitätDuisburg–Essen, Lotharstraße 1, 47048 Duisburg — [2]Institut für Verbrennung und Gasdynamik,Universität Duisburg–Essen, Lotharstraße 1, 47048 Duisburg

Die optischen und phononischen Eigenschaften größenselektierter Si–Nanopartikel (3nm-60nm), hergestellt durch Pyrolyse von Silan in einem Niederdruck–Mikrowellenreaktor, werden mittels Photolumineszenz– und Raman–Spektroskopie untersucht.

Die Ramanspektren zeigen verschiedene Streumechanismen in den Partikeln, darunter auch Ramanprozesse höherer Ordnung. Explizit wird hier die $TO(\Gamma)$–Phononmode als Funktion der Partikelgröße untersucht. Es zeigt sich, dass die energetische Verschiebung der Linie hin zu kleineren Energien mit abnehmender Partikelgröße nicht vollständig durch ein Phonon–Confinement–Modell beschrieben werden kann.

Die experimentellen Photolumineszenzspektren zeigen eine klare Abhängigkeit der Emissionswellenlänge von der Größe der untersuchten Partikel (size effect). Auf diese Weise kann die Lumineszenz der Partikel im Bereich von λ=600nm–1000nm eingestellt werden. In der Temperaturabhängigkeit der Lumineszenz zeigt sich, dass mit abnehmender Temperatur das Lumineszenzmaximum kontinuierlich zu kleineren Wellenlängen verschiebt, während die Intensität der Lumineszenz zunächst zunimmt, dann aber, ab einer Temperatur von $T = 80K$ wieder drastisch abnimmt.

HL 37 Photonische Kristalle I

Zeit: Montag 10:00–12:15 Raum: TU P270

HL 37.1 Mo 10:00 TU P270

Enhanced light-matter interaction in semiconductor quantum wells embedded in one-dimensional photonic crystals — •Bernhard Pasenow[1], Matthias Reichelt[1], Tineke Stroucken[1], Torsten Meier[1], Stephan W. Koch[1], Armis R. Zakharian[2], and Jerome V. Moloney[2] — [1]Department of Physics and Material Sciences Center, Philipps University, Renthof 5, D-35032 Marburg — [2]Arizona Center for Mathematical Sciences, University of Arizona, Tucson, AZ 85721, USA

The development of photonic crystals has offered novel possibilities to improve the characteristics of optoelectronic devices such as light-emitting diodes and lasers. Here, we analyze the optical properties of semiconductor quantum wells embedded in one-dimensional photonic crystals using a microscopic theory. It is shown that the linear optical spectra of such structures exhibit signatures of non-perturbative light-matter coupling if the exciton is resonant with a field mode that occurs slightly below the optical gap. Due to light focusing and slow light propagation, optical gain enhancement is predicted, exceeding that of a homogeneous medium by more than one order of magnitude. If the structures are placed inside a microcavity, the gain increases superlinearly with the number of wells and for more than five wells exceeds the gain of a corresponding vertical-cavity surface-emitting laser.

[1] B. Pasenow, M. Reichelt, T. Stroucken, T. Meier, S.W. Koch, A.R. Zakharian, and J.V. Moloney, submitted.

HL 37.2 Mo 10:15 TU P270

Optical properties of semiconductor photonic-crystal structures: Spatially-inhomogeneous excitonic resonances and optical gain — •Torsten Meier, Matthias Reichelt, Bernhard Pasenow, Tineke Stroucken, and Stephan W. Koch — Department of Physics and Material Sciences Center, Philipps University, Renthof 5, D-35032 Marburg

Significant aspects of the light-matter interaction can be tailored in suitably designed systems consisting of semiconductor nanostructures and dielectric photonic crystals. Such effects are described by a microscopic theory which provides a self-consistent solution of the dynamics of the electromagnetic field and the material excitations. The theory is applied to investigate spatially-inhomogeneous excitonic resonances, which arise as a consequence of the modified Coulomb interaction in the vicinity of a structured dielectric medium [1-3]. It is demonstrated that these inhomogeneities lead to distinct modifications of the optical spectra [3].

[1] R. Eichmann, B. Pasenow, T. Meier, T. Stroucken, P. Thomas, and S.W. Koch, Appl. Phys. Lett. **82**, 355 (2003).
[2] T. Meier and S.W. Koch, in *Photonic Crystals - Advances in Design, Fabrication and Characterization*, Eds. K. Busch, S. Lölkes, R.B. Wehrspohn, and H. Föll, (Wiley-VCH, Berlin, 2004) pp. 43-62.
[3] M. Reichelt, B. Pasenow, T. Meier, T. Stroucken, and S.W. Koch, submitted.

HL 37.3 Mo 10:30 TU P270

Frequency-Selective Modification of the Radiation Pattern of Emitters in Photonic Crystals — •Michael Barth and Frank Cichos — Photonics and Optical Materials, Institute of Physics, Chemnitz University of Technology

We have studied the angle-dependent spontaneous emission of dye molecules in single, highly ordered domains of three-dimensional photonic crystals using a new microscopy setup. A strongly modified radiation pattern has been found for frequencies near the photonic stop band, including a highly directional four-fold intensity enhancement at its high-frequency edge. For the first time, the experimental observations are directly compared to numerical calculations of the angle-dependent local optical density of states. The excellent agreement between experiment and theory suggests, that the angular emission probability of the dye molecules is directly modified by the optical mode structure of the photonic crystal. This leads to a spectral and spatial redistribution of the emitted light without significant change of the radiative lifetime.

HL 37.4 Mo 10:45 TU P270

Ferroelectric Liquid Crystals as tunable optical stop-band materials — •Wolfgang Haase[1], Vladimir Bezborodov[2], Valery Lapanik[2], Fedor Podgornov[1], and Artisom Lapanik[1] — [1]Teschnische Universität Darmstadt, Eduard-Zintl-Institut für Anorganische und Physikalische Chemie, Petersenstr. 20, D-64287 Darmstadt, Germany — [2]Institute of Applied Physics Problems, Minsk 220064, Belarus

Ferroelectric Liquid Crystals (FLCs) have unique combination of optical and electrooptical properties (fast response time and periodically modulated structure) which makes them attractive for application as tunable stop band materials. As it was showed in our early works, the FLCs was successfully utilised for tuneable laser generation in dye-doped samples at the edge of the photonic band gap and its tunability due to temperature and the electric field was demonstrated. In the present report, we will demonstrate new type of the FLC mixtures with very high birefringence (around 0.3). These materials are based on phenyl and biphenyl pirimidines and a four ring chiral compound with high optical anisotropy. The combination of these components allowed us to have chiral SmC phase in wide temperature range, vary the helical pitch over the whole optical band as well as greatly increase its birefringence. In addition, these mixtures have excellent alignment properties (both for planar and for homeotropic orientation). The lasing properties of these mixtures doped with laser dyes (DCM, Rhodamine 590) will be discussed.

HL 37.5 Mo 11:00 TU P270

Photonic Crystal Based Spectroscopic Gas Sensors — •Torsten M. Geppert[1,2], Daniel Pergande[2], Andreas v. Rhein[2], Stefan L. Schweizer[2], Ralf B. Wehrspohn[2] und Armin Lambrecht[3] — [1]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle — [2]Universität Paderborn, Dept. Physik, Warburgerstr. 100, D-33098 Paderborn — [3]Fraunhofer-Institut für Physikalische Messtechnik, Heidenhofstr. 8, D-79110 Freiburg

Gas sensors are important for a broad range of technical fields. Among other types, spectroscopic gas sensors are a very general approach, applicable for the detection of a variety of different gases due to their high selectivity to specific absorption lines for each gas. A drawback of such systems is their relatively large size caused by the necessary size of the interaction volume of the dilute gas medium and the light. The use of 2D photonic crystals (PhCs), e.g. made of macroporous silicon, allows a dramatic decrease in size of of the interaction volume by exploitation of certain features of the PhC bandstructure such as a very low group velocity v_g. However, a low v_g leads to high reflection at the PhC interface, resulting in low transmission and therefore an unfavorable signal-to-noise-ratio. Investigations of different strategies to improve the transmission led to the development of a novel taper concept, the so-called *Anti-Reflection-Layer*. Its working principle is different from classical anti-reflection-coatings and based on mode-matching of the incoming plane wave and the Bloch-modes in the photonic crystal.

HL 37.6 Mo 11:15 TU P270

Zeitaufgelöste THz-Spekroskopie von Oberflächenplasmonpolaritonen auf Halbleitergitterstrukturen — •Martin Kuttge, Jaime Gomez Rivas, Peter Haring Bolivar und Heinrich Kurz — Institut für Halbleitertechnik, RWTH Aachen, Sommerfeldstrasse 24, 52074 Aachen

Das Gebiet der Plasmonik steht derzeit im Fokus einer Reihe physikalischer Arbeiten und technologischer Entwicklungen. Es umfasst die Untersuchung von Oberflächenplasmonpolaritonen (engl. Surface Plasmon Polaritons, SPPs), einer kollektiven Anregung von Ladungsträgern an der Grenzfläche zwischen einem Dielektrikum und einem Metall, und hat in den letzten Jahren zu einer großen Anzahl von Forschungsaktivitäten in Bereichen der Sensorik und der subwellenlängen Manipulation von Strahlung geführt. Die Beeinflussung der SPP-Propagationseigenschaften ist dabei von besonderem Interesse. Hierfür bieten periodische Halbleiterstrukturen eine Möglichkeit.
Wir haben zum ersten Mal zeitaufgelöste Messungen zur Erzeugung und Propagation von SPPs im THz-Frequenzbereich durchgeführt[1]. Die Verwendung von Halbleitern statt Metallen eröffnet zudem neue Möglichkeiten zur Kontrolle der SPP-Propagation. In weiteren Messungen haben wir gezeigt, dass eine periodische Strukturierung der Oberfläche die Propagation der SPPs für ein Band von Frequenzen beeinflussen kann[2].
[1] J. Saxler et al., Phys. Rev. B 69, 155427 (2004)
[2] J.G. Rivas et al. submitted to Phys. Rev. Lett.

HL 37.7 Mo 11:30 TU P270

Photonic crystals with negative refraction focus light beams below the diffraction limit — •Anton Husakou and Joachim Herrmann — Max Born Institute, Max Born Str. 2a, D-12489 Berlin, Germany

The resolution limit of all conventional optical devices is determined by the fact that all evanescent components of an electromagnetic wave are lost during propagation. It has been suggested that evanescent waves can be amplified by a slab with a negative refraction index leading to a subwavelength resolution of image. Up to now this superlensing effect was studied for imaging of sub-wavelength features. We show that a photonic crystal with negative refraction amplifying evanescent waves, combined with an aperture which creates seed evanescent waves, can focus light beams below the diffraction limit of half of the wavelength. We describe beam focusing both in the context of effective-medium theory as well as using the numerical solution for a realistic photonic crystal structure. We show that an input beam is focused to a spot with FWHM of 0.14λ in the case of effective-medium theory and 0.25λ for the realistic structure of a photonic crystal.

HL 37.8 Mo 11:45 TU P270

Light-emitting biological photonic crystals — •Melanie El Rharbi-Kucki and Thomas Fuhrmann-Lieker — Makromolekulare Chemie und Molekulare Materialien, FB Naturwissenschaften, Universität Kassel, Heinrich-Plett-Str. 40, 34109 Kassel

Biological nanostructures are widespread in nature. They are extremely diverse in material composition, structural complexity and function. In many animal phyla photonic crystal structures in the range of the wavelength of visible light are used to produce brilliant structural colours. Here we present one of the few examples of photonic crystal structures in plants. The silica cell wall of the centric diatoms Coscinodiscus granii and Coscinodiscus wailesii can be regarded as slab waveguide photonic crystals with hexagonal and square structure. The lattice constants of the photonic structures are in the dimension of the UV to NIR range. Light is the main energy source for diatoms and an essential factor giving information about the environment they are living in. We investigate the optical properties of the diatom shell with respect to the biological function and the possibility for technological application. To explore the control of absorption and emission of light by the photonic structures, various laser dye molecules were incorporated into the diatom shell by the use of an in vivo-technique. We give an overview on dye classes that are incorporated into the photonic crystal structure and present recent results on the microscopically resolved emission behaviour. This project is part of the DFG priority program on photonic crystals.

HL 37.9 Mo 12:00 TU P270

Trapping and manipulating dielectric nanoparticles on Photonic Crystals using an optical tweezer — •Oliver Benson and Franz Boczianowski — Humboldt-Universität zu Berlin

We perform a controlled experiment where we manipulate sub-micron particles (polystyrene beads and single cells) on Photonic Crystal (PC) structures in aqueous solution with an optical tweezer. The goal of the experiment is to investigate the potential of PC structures for (bio-)sensing applications. We introduce the setup and report on first tests where we trapped and manipulated dielectric particles from 10 μm down to 50 nm. The smaller particles were doped with dye molecules in order to establish optical detection and imaging via their fluorescence light. Additionally, we trapped biological specimen, such as single yeast and blood cells. As a very important result we could demonstrate that it is possible to trap and manipulate 500 nm particles close to the surface of a silicon PC structure which was immersed in water. The results are very promising for future experiments aiming towards sensing and ultra-sensitive force as will be discussed in this talk.

HL 38 Halbleiterlaser II

Zeit: Montag 10:00–12:15 Raum: TU P-N201

HL 38.1 Mo 10:00 TU P-N201

Auswirkungen der Alterung auf Rekombinationsdynamik und optische Verstärkung von GaN-basierten Laserdioden — •C. Netzel[1], S. Heppel[1], A. Hangleiter[1], S. Miller[2], M. Furitsch[2], A. Leber[2], A. Lell[2] und V. Härle[2] — [1]Institut für Technische Physik, TU Braunschweig — [2]OSRAM Opto Semiconductors, Regensburg

Die Entwicklung von GaN-basierten, blauen Halbleiterlaserdioden (LDs) ist inzwischen bis zur industriellen Produktion fortgeschritten. Die Erschließung des UV-Bereichs für LDs ist momentanes Forschungsziel. Ein Problem, das allgemein die Weiterentwicklung hemmt, sind Alterungsprozesse, bedingt durch hohe Wärmeentwicklung und/oder hohe Ströme in den Heterostrukturen. Untersuchungen dieser Alterungsprozesse mit leistungs- und temperaturabhängiger Photolumineszenz und optischen Verstärkungsmessungen werden hier vorgestellt. Elektrisch gealterte und ungealterte Laserstreifen ($\lambda \approx$400nm) wurden verglichen. Während die ungealterten Laser höhere Verstärkung und niedrigere Wellenleiterverluste im Fall hoher Ladungsträgerdichten aufweisen, zeigen die gealterten Strukturen bei niedrigen Ladungsträgerdichten höhere interne Quantenausbeuten. Um zu verifizieren, ob die Wärmeentwicklung während der Alterung für die Unterschiede verantwortlich ist, wurden Laserstrukturen über 24 Stunden bei unterschiedlichen Temperaturen geheizt und die optischen Messungen zwischen den Heizschritten verglichen.

HL 38.2 Mo 10:15 TU P-N201

Study of CdSe ridge waveguide quantum dot laser diodes emitting at 560 nm — •Arne Gust, Matthias Klude, Stephan Figge, and Detlef Hommel — Institute of Solid State Physics, University of Bremen, Otto-Hahn-Allee NW1, D-28359 Bremen, Germany

Lasing of CdSe quantum dot laser diodes at room-temperature around a wavelength of 560 nm in pulsed-mode was reported by our group. The LD structure has a separate confinement structure like common quantum well lasers. The active region consists of a fivefold stack containing nominally 1.9 monolayer CdSe per sheet separated by 3.5 nm ZnSSe spacer.

Electro-optical characteristics of different ridge and planar CdSe quantum dot laser diodes were compared. A reduction of the threshold current density by a factor of 4.7 for the ridge structure was obtained. This drastic change has to be associated to the reduction of current spreading inside the LDs. Furthermore, a significant slower degradation of CdSe quantum dot structures compared to common ZnSe-based quantum well structures was observed. Under pulsed condition in LED mode the quantum dot laser exhibits an operating time of 3200 h.
[1] M. Klude *et al.*, Electron. Lett. **37**, 1119 (2001).

HL 38.3 Mo 10:30 TU P-N201

Nichtgleichgewichtseffekte in Halbleiterlasern — •Angela Thränhardt[1], Sascha Becker[1], Stephan W. Koch[1], Jörg Hader[2] und Jerome V. Moloney[2] — [1]Fachbereich Physik und Zentrum für Materialwissenschaften, Philippsuniversität Marburg, Renthof 5, 35032 Marburg — [2]Arizona Center of Mathematical Sciences and Optical Sciences Center, University of Arizona, Tucson, Arizona 85721, USA

Die Relevanz von Nichtgleichgewichtseffekten in Halbleiterlaserstrukturen wie Lochbrennen und Erwärmung von Ladungsträgersystem und Gitter wird abhängig von den Strukturparametern diskutiert. Dazu werden die optischen Eigenschaften unter voller Berücksichtigung von Nichtgleichgewichtseffekten mikroskopisch berechnet. Wegen der großen numerischen Komplexität des mikroskopischen Modells wird zur Durchführung von Parameterstudien ein vereinfachtes Modell entwickelt, welches beispielsweise eine Betrachtung des Anschaltprozesses eines Lasers ermöglicht. Das Modell basiert auf den Maxwell-Halbleiterblochgleichungen und auf aus mikroskopischen Rechnung extrahierten *effektiven* Streuzeiten, benutzt keine phänomenologischen, d.h. nur experimentell zu ermittelnden Parameter und zeigt gute Übereinstimmung mit dem mikroskopischen Modell.

HL 38.4 Mo 10:45 TU P-N201

Elevated Temperture Performance of CEO Quantum Wire Cascade Emitter Devices — •Stefan Schmult, Thomas Herrle, Hans-Peter Tranitz, Matthias Reinwald, Christian Gerl, and Werner Wegscheider — Universität Regensburg, Institut für Experimentelle und Angewandte Physik, D-93040 Regensburg

Quantum Wire cascade devices emitting in the Mid-Infrared spectral region have been realised recently by employing the Cleaved Edge Overgrowth (CEO) technique [1,2]. The emission wavelength is about 9 μm with a maximum optical output power of 17 nW at a maximum operating temperautre of 20 K [3]. The limited temperature perfomance of the devices can be attributed to current leakage across the first growth step. We investigated the leak current temperature behavior of several first growth step heterostructures in dependence of their growth temperatures. The resulting emitter devices, operated up to 80 K, showed clear emission at around 10 μm. Polarisation dependent measurements of the emitted light have been carried out to analyse the electronic intersubband transitions between Quantum Wire states in the emitter devices. The talk describes the polarisation and temperature dependent characterisation of the emitter structures.

[1] S. Schmult, I. Keck, T. Herrle, W. Wegscheider, M. Bichler, D. Schuh and G. Abstreiter, Appl. Phys. Lett. 83, 2003. [2] S. Schmult, I. Keck, T. Herrle, W. Wegscheider, A.P. Mayer, M. Bichler, D. Schuh and G. Abstreiter, Physica E 21, 2004. [3] S. Schmult, T. Herrle, H.-P. Tranitz, M. Reinwald, W. Wegscheider, M. Bichler, D. Schuh and G. Abstreiter, to be published in Proceedings of ICPS 27, 2004.

HL 38.5 Mo 11:00 TU P-N201

Loss studies in T-shaped waveguides for the midinfraredspectral region — •Thomas Herrle, Stefan Schmult, Markus Pindl, Ulrich Schwarz, and Werner Wegscheider — Institut für Experimentelleund Angewandte Physik Universität Regensburg, 93040 Regensburg

Intersubband emitters with active regions of lower dimensionality have attracted a lot of interest in recent years, since basic theoretical considerations predict a decrease of non-radiative losses in lower dimensional systems. To this end experiments on active regions using quantum-dot systems [1, 2] and quantum-wire systems [3] instead of conventional coupled quantum-well systems have been published recently. Here we present loss studies for a T-shaped waveguide for the quantum-wire intersubband emitter device reported in [3]. We present how such a T-shaped waveguide structure can be optimized regarding the confinement factor and the waveguide losses due to free carrier absorption. These waveguide losses turn out to be reduced in the quantum-wire cascade structure compared to the underlying conventional quantum-well structure. The presented waveguide calculations are the basis for the realization of a quantum-wire intersubband laser for the midinfrared spectral region.

[1] N. Ulbrich, J. Bauer, G. Scarpa, R. Boy, D. Schuh, G. Abstreiter, S. Schmult, and W. Wegscheider, Appl. Phys. Lett. **83**, 1530 (2003)
[2] S. Anders, L. Rebohle, F. F. Schrey, W. Schrenk, K. Unterrainer, and G. Strasser, Appl. Phys. Lett. **82**, 3862 (2003)
[3] S. Schmult, I. Keck, T. Herrle, W. Wegscheider, M. Bichler, D. Schuh, and G. Abstreiter, Appl. Phys. Lett. **83**, (2003)

HL 38.6 Mo 11:15 TU P-N201

Study of homogeneity of local tilt distribution in thin film disk laser devices by means of spatially resolved white beam x-ray diffraction — •U. Zeimer[1], J. Grenzer[2,3], D. Korn[2], S. Döring[2], M. Zorn[1], and U. Pietsch[2] — [1]Ferdinand-Braun-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin — [2]Institut für Physik, Universität Potsdam, Am Neuen Palais 10, 14415 Posdam — [3]Forschungszentrum Rossendorf, Bautzner Landstraße 128, 01328 Dresden

Optically pumped semiconductor disc laser devices (SCDLs) consist of an AlAs/GaAs- Bragg grating with an InGaAs/InGaP multilayer stack on top as the active medium.

To study the homogeneity of the strain induced local tilt distribution of an SCDL device we have set up an experiment at the BESSY EDR beamline using an horizontal reflection geometry. The sample was mounted on a heatable sample holder. The (004) diffracted intensity was monitored by a CCD camera. First we have taken a topograph of the whole sample to identify the tilted regions. The tilted regions were studied in detail by scanning the sample mechanically through the x-ray beam with a footprint of 130 x 100μm^2.

A computer program was developed to track the individual diffracted spot position relatively to an average one and to determine its intensity and halfwidth. From these data local tilts and lattice parameters can be determined.

HL 38.7 Mo 11:30 TU P-N201

Degradation experiments of blue-violet laser diodes grown on SiC and GaN substrates — •M. Furitsch, A. Avramescu, A. Miler, S. Miller, A. Leber, C. Rumbolz, G. Brüderl, A. Lell, and V. Härle — OSRAM Opto Semiconductors GmbH, Wernerwerkstr. 2, 93049 Regensburg

GaN-based semiconductor laser diodes emitting around 405 nm are particularly interesting for storage systems with high capacity for post dvd applications and for high resolution industrial printing.

We developed edge emitting blue-violet laser diodes on SiC substrates, taking advantage of the very good electronically and thermally conductivity of SiC compared to sapphire used by other groups.

Our lasers on SiC substrate exhibit defect densities of $10^9\,\mathrm{cm}^{-2}$ and lifetimes of 120 h and 310 h at $P_{\mathrm{opt}} = 10\,\mathrm{mW}$ and 1 mW, respectively are demonstrated.

With GaN substrates now available, blue-violet laser diodes were grown using a slightly adapted epitaxial laser structure. Homo epitaxial growth on the new substrate shows improved laser parameters compared to hetero epitaxy on SiC or sapphire substrates.

We realized lasers on GaN substrate with considerably decreased defect densities of $< 10^7\,\mathrm{cm}^{-2}$ and we achieved lifetimes of several hundred hours at $P_{\mathrm{opt}} = 10\,\mathrm{mW}$. We show that due to the reduced defect density, less nonradiative recombination centers are generated and the lifetime increases.

HL 38.8 Mo 11:45 TU P-N201

Untersuchungen zum Stromrauschen und Photonenrauschen von Interband und Intersubband Halbleiterlasern — •Jens von Staden[1], Tobias Gensty[1], Wolfgang Elsässer[1] und Christian Mann[2] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, Schloßgartenstraße 7, 64289 Darmstadt — [2]Fraunhofer-Institut für Angewandte Festkörperphysik (IAF), Tullastraße 72, D-79108 Freiburg

Intersubband Quanten-Kaskaden-Laser (QCL) repräsentieren die jüngste Generation von Halbleiterlasern, die mittlerweile bedeutende Bauteile für die Gasanalytik im mittleren infraroten Spektralbereich (3,5 μm - 20 μm Wellenlänge) darstellen. Wir untersuchen die Intensitätsrauscheigenschaften von QCLn und vergleichen sie mit denen von Interband Diodenlasern (DL). Die untersuchten Laser sind beides Fabry-Perot Laser, die bei einer Wellenlänge von 850nm (DL) und 5 μm (QCL) emittieren. Wir charakterisieren das Intensitätsrauschen mit Hilfe des Relative Intensity Noise (RIN). Dabei zeigt sich, dass das RIN von QCLn ein anderes Skalierungsverhalten zeigt als RIN von DLn [1]. In diesem Beitrag diskutieren wir die Zusammenhänge zwischen dem Stromrauschen und dem Photonenrauschen bei DLn und QCLn.

[1] T. Gensty W. Elsäßer und Ch. Mann, eingereicht bei Phys. Rev. Lett. (2004).

HL 38.9 Mo 12:00 TU P-N201

cw-THz-Erzeugung durch Photomischen von externen Resonatormoden eines Breitstreifenlasers — •Saša Bakić[1], Icksoon Park[1], Ingo Fischer[1], Wolfgang Elsässer[1], Cezary Sydlo[2] und Hans Hartnagel[2] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, Schloßgartenstraße 7, D-64289 Darmstadt — [2]Institut für Hochfrequenztechnik, Technische Universität Darmstadt, Merckstraße 25, D-64283 Darmstadt

Mittlerweile bestehen mehrere Ansätze zur Realisierung einer Strahlungsquelle im THz-Frequenzbereich mit vielfältigen Anwendungsperspektiven in Spektroskopie und Medizin. Wir präsentieren Untersuchungen zu einer durchstimmbaren, kontinuierlichen THz-Strahlungsquelle durch Photomischen zweier longitudinaler Moden eines Breitstreifenlasers auf einer Mikrostrukturantenne. Die simultanen, longitudinalen Moden werden durch einen externen, mit einem Reflexionsgitter abstimmbaren Doppel-Resonator in Littman-Konfiguration erzeugt. Die generierte THz-Strahlung im Frequenzbereich von 0.25 bis 0.9 THz wird mit einem Fourier-Transform-Spektrometer und einem Bolometer spektral charakterisiert und nach ihren Polarisationseigenschaften analysiert. Darüber hinaus wird die Leistung der erzeugten THz-Strahlung in Abhängigkeit von der optischen Leistung untersucht.

HL 39 Quantenpunkte und -drähte: Transporteigenschaften I

Zeit: Montag 10:00–12:15 Raum: TU P-N202

HL 39.1 Mo 10:00 TU P-N202

Nonmonotonic charge occupation in double dots — •Jürgen König[1] and Yuval Gefen[2] — [1]Institut für Theoretische Physik III, Ruhr-Universität Bochum, 44780 Bochum, Germany — [2]Department of Condensed Matter Physics, The Weizmann Institute of Science, 76100 Rehovot, Israel

We study the occupation of two electrostatically-coupled single-level quantum dots with spinless electrons as a function of gate voltage. While the total occupation of the double-dot system varies monotonically with gate voltage, we predict that the competition between tunneling and Coulomb interaction can give rise to a nonmonotonic filling of the individual quantum dots. This non-monotonicity is a signature of the correlated nature of the many-body wavefunction in the reduced Hilbert space of the dots. We identify two mechanisms for this nonmonotonic behavior, which are associated with changes in the spectral weights and the positions, respectively, of the excitation spectra of the individual quantum dots. An experimental setup to test these predictions is proposed.
[1] J. König and Y. Gefen, cond-mat/0408691.

HL 39.2 Mo 10:15 TU P-N202

Kondo effect versus spin blockade — •D. Kupidura[1], M. C. Rogge[1], R. J. Haug[1], and W. Wegscheider[2] — [1]Institut für Festkörperphysik, Universität Hannover, D-30167 Hannover — [2]Angewandte und Experimentelle Physik, Universität Regensburg, D-93040 Regensburg

We report a competition between Kondo effect and spin blockade in a lateral quantum dot defined by local anodic oxidation on a GaAs/AlGaAs-heterostructure. We observe magnetically induced chessboard patterns in the conductance of our system what suggests Kondo correlations between electronic spins in the leads and an unpaired spin within the quantum dot. Thus the dot forms a spin singlet with the leads. Additionally we observe a spin blockade phenomenon, which is correlated with a spin polarization of the 2-dimensional leads in a magnetic field. This polarization destroys the spin up/spin down superposition of the Kondo singlet. Thus along with the onset of this spin blockade we find a suppression of the Kondo effect.

HL 39.3 Mo 10:30 TU P-N202

Transport through a quantum dot spin valve — •Matthias Braun[1], Jürgen König[1], and Jan Martinek[2] — [1]Theoretische Physik III, Ruhr-Universität Bochum, D-44780 Bochum — [2]Institut für Theoretische Festkörperphysik, Universität Karlsruhe, D-76128 Karlsruhe

We develop a theory of spin-dependent transport through a single-level quantum dot with strong Coulomb interaction, weakly coupled to ferromagnetic leads [1]. The theory explicitly allows for non-collinear lead magnetizations, as well as an externally-applied magnetic field.

We derive generalized rate equations for the dot's occupation and accumulated spin and discuss the influence of the dot's spin on the conductance of the device. The Coulomb interaction, generates an intrinsic source of spin precession, leading to negative differential conductance as well as a nontrivial dependence of the conductance on the angle between the lead magnetizations [1,2]. In addition, the applied magnetic field gives rise to the Hanle effect. We propose schemes [3] to observe these different precession mechanisms in transport experiments, and show, how to utilize them to determine the spin lifetime in the quantum dot.
[1] Matthias Braun et al., cond-mat/0404455 (2004)
[2] J. König et al., Phys. Rev. Lett. 90, 166602 (2003)
[3] Matthias Braun et al., cond-mat/0411xxx (2004)

HL 39.4 Mo 10:45 TU P-N202

Investigation of tunneling rates in quantum dots using a quantum point contact — •M. C. Rogge[1], C. Fricke[1], B. Harke[1], R. J. Haug[1], and W. Wegscheider[2] — [1]Institut für Festkörperphysik, Universität Hannover, D-30167 Hannover — [2]Angewandte und Experimentelle Physik, Universität Regensburg, D-93040 Regensburg

We present transport measurements on a coupled system including a quantum dot and a quantum point contact. We use a GaAs/AlGaAs heterostructure containing a two-dimensional electron system (2DES) 34 nm below the surface. The device is built using an atomic force microscope (AFM) for lithography. The lateral quantum dot and the quantum point contact are defined using local anodic oxidation (LAO). We investigate our device in a 3He/4He dilution refrigerator. We measure the transport through the quantum dot and at the same time use the quantum point contact as a charge detector. Thus we can still observe charge fluctuations on the dot in a regime, where the current through the dot is too low for transport measurements. In this regime we were able to investigate and compare the tunneling rates to source and drain leads. Thus we were able to find a symmetry line, on which the tunneling rates to both leads are equal. Keeping the tunneling rates symmetric, we were able to detect the change in charge induced by exited dot states in nonlinear measurements.

HL 39.5 Mo 11:00 TU P-N202

Investigation of spin blockade in a quantum dot using a quantum point contact as a charge detector — •C. Fricke[1], M. C. Rogge[1], B. Harke[1], F. Hohls[1], R. J. Haug[1], and W. Wegscheider[2] — [1]Institut für Festkörperphysik, Universität Hannover, D-30167 Hannover — [2]Angewandte und Experimentelle Physik, Universität Regensburg, D-93040 Regensburg

We show transport measurements in high magnetic field on a coupled system including a quantum dot and a quantum point contact. We use a GaAs/AlGaAs heterostructure containing a two-dimensional electron system (2DES) 34 nm below the surface. The lateral quantum dot and the quantum point contact (QPC) are defined by an atomic force microscope (AFM) using the local anodic oxidation (LAO). We perform our measurements in a 3He/4He dilution refrigerator with a superconductive magnet. Transport through the quantum dot and the quantum point contact are measured at the same time. We thereby use the QPC as a charge detector. Thus we can observe charge fluctuations on the dot with high sensitivity, even when the current through the dot is too low for transport measurements. At high magnetic field we observe spin blockade on the dot. In this regime charge redistributions due to the magnetic field lead to a change in the effective charge detected by the QPC.

HL 39.6 Mo 11:15 TU P-N202

Single electron quantum dots — •Daniel Schröer[1], Andreas K. Hüttel[1], Stefan Ludwig[1], Jörg P. Kotthaus[1], and Karl Eberl[2] — [1]CeNS und Sektion Physik, LMU München, Germany — [2]MPI f. Festkörperforschung, Stuttgart, Germany

We create lateral quantum dots by depleting the two-dimensional electron system of an AlGaAs/GaAs heterostructure using lithographically defined gold gates. An advantage of this lateral approach is the flexibility in number and geometry of leads and gates. Multiple quantum dots can be coupled capacitively or via tunnel barriers. The interdot coupling strengths and the number of electrons per dot are tunable by means of gate voltages. Here, we present measurements on a unique gate design that allows the definition of either a single or a double quantum dot in the

few electron limit. By gradually adjusting the gate voltages, we observe a smooth transition from a single dot to a double dot. We quantify the decreasing interdot tunnel coupling using low frequency transport spectroscopy for one and two electrons. The electron number is verified with an additional quantum point contact. Further on, indications of Kondo effect and higher order tunneling processes are investigated in both the single and double dot regime.

HL 39.7 Mo 11:30 TU P-N202

Electrostatically defined single gate quantum dots — •C. Rössler[1], A. K. Hüttel[1], S. Ludwig[1], J. P. Kotthaus[1], and W. Wegscheider[2] — [1]CeNS und Department für Physik der LMU, 80539 München — [2]Institut für Angewandte und Experimentelle Physik, Universität Regensburg, 93040 Regensburg

We perform transport measurements on quantum dots (QD) defined by means of negatively biased gate electrodes on top of a AlGaAs/GaAs heterostructure. The two–dimensional electron gas (2DEG) is only 37 nm below the surface of our δ–doped sample. Conductance measurements in the Coulomb blockade regime, for example on a QD defined by three gates, are strongly affected by temporal charge fluctuations. Our layout contains one complex shaped gate. If biased sufficiently, it divides the 2DEG into two electrically isolated areas. At lower bias voltage, the geometry of this gate results in a QD beneath it, even if all other gates are grounded. This has been reproduced on three different samples. Strikingly, the transport properties of the single gate dot are undisturbed by the fluctuations. We investigate this QD in its few electron limit. The coupling to the leads depends strongly on the gate voltage which is the only control parameter. In the regime of strong coupling, we observe Kondo signatures and investigate its temperature and magnetic field dependencies.

HL 39.8 Mo 11:45 TU P-N202

Spektroskopie von Vielteilchen-Wellenfunktionen in selbstorganisierten InAs-Quantenpunkten — •Oliver Wibbelhoff[1], A. Lorke[1] und D. Reuter[2] — [1]Laboratorium für Festkörperphysik, Universität Duisburg-Essen, Lotharstr. 17, D-47048 Duisburg, Germany — [2]Lehrstuhl für angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstr. 150, D-44780 Bochum, Germany

Wir verwenden frequenzabhängige Kapazitäts-Spannungs-Spektroskopie um die Tunnelwahrscheinlichkeit von Elektronen in Quantenpunkten zu messen, die in eine Feldeffekt-Transistor-Heterostruktur [1] eingebettet sind. Der Wechselspannungsfrequenz folgend, tunneln die Elektronen zwischen den selbstorganisierten InAs-Quantenpunkten und einem hoch dotierten Rückkontakt hin und her. Eine zusätzliche Gleichspannung ermöglicht es eine Anzahl von 0 - 6 Elektronen in die InAs-Insel zu laden. Durch Anlegen eines zur Tunnelrichtung senkrechten Magnetfeldes und Messung des resultierenden Tunnelstroms kann der Impuls der tunnelnden Elektronen variiert und so die Aufenthaltswahrscheinlichkeiten im k-Raum ausgetastet werden [2]. Für die niedrigsten Energiezustände zeigt sich eine gute Übereinstimmung mit dem Modell eines harmonischen Potenzials, sowie eine Formanisotropie der Inseln entlang der <110> Kristallachsen. Die Vielteilchen-Wellenfunktionen der höherenergetischen Zustände zeigen eine Feinstruktur, die auf komplexe elektronische Wechselwirkungen hinweist.

[1] H. Drexler et al., Phys. Rev. Lett. 73, 2252 (1994).
[2] A. Patanè et al., Phys. Rev. B 65, 165308 (2002).

HL 39.9 Mo 12:00 TU P-N202

Spektroskopie an Quantenringen — •Chr. Notthoff[1], A. Lorke[1], O.S. Wibbelhoff[1] und D. Reuter[2] — [1]Festkörperphysik, Universität Duisburg-Essen, Lotharstraße 1, 47048 Duisburg — [2]Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätststr. 150, 44780 Bochum

Die Dispersion der Eigenzustände von Elektronen und Exzitonen im Einschlußpotential von selbstorganisierten InAs-Quantenringen in einer GaAs-Matrix werden mittels Kapazitäts-Spannungs- und Photolumineszenz-Spektroskopie unter dem Einfluß eines äußeren Magnetfeldes untersucht.

Die Quantenringe sind in einer MISFET-Struktur eingebettet, um sie der Kapazitäts-Spannungs-Spektroskopie zugänglich zu machen. Im Gegensatz zu der diamagnetischen Dispersion der Elektroneneigenenergien in Quantenpunkten zeigen Quantenringproben eine Struktur in der Dispersion der Elektroneneigenenergien, die auf einen Übergang der Drehimpulsquantenzahl der Elektronenwellenfunktion mit wachsendem Feld hinweist. Durch den Vergleich der experimentell bestimmten Magnetfeldabhängikeit mit numerischen Modellrechnungen kann der elektronische Radius der Quantenringe bestimmt und mit dem aus AFM-Messungen ermittelten Radius verglichen werden.

Die Dispersion der Exzitonen im Magnetfeld wurde mittels Photolumineszenz-Spektroskopie bestimmt. Hier zeigt sich ebenfalls eine Struktur in der Dispersion, was für nicht geladene Exzitonen zunächst nicht zu erwarten ist, jedoch durch polarisierte Exzitonen erklärt werden kann.

HL 40 Preisträgervortrag Belzig

Zeit: Montag 12:30–13:15 Raum: TU P270

HL 40.1 Mo 12:30 TU P270

Quantum noise in mesoscopic systems — •Wolfgang Belzig — Department of Physics and Astronomy, University of Basel, Klingelbergstr. 82, 4056 Basel, Switzerland — Träger des Walter-Schottky-Preises

Full counting statistics aims at a complete characterization of the distribution of measurement outcomes. In my talk I will demonstrate how this concept allows to investigate quantum correlations in a variety of mesoscopic systems. Three examples will be discussed:

a) In analogy to Schottky's work on the current fluctuations in a vacuum diode, shot noise in superconducting contacts allows to identify the nature of the elementary charge transfer events.
b) The Coulomb interaction in complex quantum dots or molecules leads to a strongly correlated current statistics.
c) The density fluctuation statistics in a fermionic quantum gas reflects the crossover from a superfluid state to a molecular Bose-Einstein condensate.

HL 41 Hauptvortrag Soukoulis

Zeit: Montag 14:15–15:00 Raum: TU P270

Hauptvortrag HL 41.1 Mo 14:15 TU P270

Negative index materials: New frontiers in optics — •C. M. Soukoulis — Ames-Laboratory and Department of Physics and Astronomy, Iowa State University, Ames, IA 50011 — Research Center of Crete, FORTH, Heraklion, Crete, Greece

The possibility of negative refraction has brought about a reconsideration of many fundamental optical and electromagnetic phenomena. This new degree of freedom has provided a tremendous stimulus for the physics, optics and engineering communities to investigate how these new ideas can be utilized. Many interesting and potentially important effects not possible in positive refracting materials, such as near-field refocusing and sub-diffraction limited imaging, have been predicted to occur when the refractive index changes sign. In this talk, I will review our own work on negative refraction in metamaterials, and describe the possible impact of them as new types of optical elements. In particular, I will present theoretical and experimental results on engineered microstructures designed to have both e and m negative. Results for different polarizations and propagation directions will be presented. Recent results on microstructures operating at 100 THz will be also discussed. Finally, experimental and theoretical results for negative refraction and sub-wavelength resolution in 2D photonic crystals will be presented .

Work supported by US-DOE, DARPA, and EU (DALHM project).

HL 42 Symposium: Photonic Crystals

Zeit: Montag 15:00–18:00 Raum: TU P270

HL 42.1 Mo 15:00 TU P270

The Mid-field microscope: Development of a 50 nm resolution microscope based on surface plasmon effects — •Ian T. Young, Yuval Garini, and Margreet Docter — Department of Imaging Science & Technology, Faculty of Applied Sciences, Lorentzweg 1, Delft University of Technology, NL-2628 CJ Delft, The Netherlands

Ebbesen, Lezec and others have described a technique to achieve an extraordinary transmission of light through small holes (< 200 nm) in a thin metallic film. This phenomenon is thought to be due to photon-plasmon interactions in thin metallic films that contain a periodic structure (e.g. a set of holes). Three main features of this phenomenon are: 1) Larger transmitted intensity than predicted by quantum calculations; 2) Well-defined transmission spectrum, and; 3) Possibly a very small diffraction (about 3 degrees) of transmitted light, in contrast to conventional diffraction. We are constructing a nano-array illuminator consisting of a thin metallic film containing an array of nano-sized holes and a mechanical translation mechanism. This configuration will be used with conventional optics and a scientific CCD camera to achieve a new type of NSOM system that we refer to as a mid-field microscope. With this microscope we expect lateral resolution on the order of the hole diameter, 50 nm, a sample depth up to 1-2 microns, and partial confocality permitting high-resolution, high-speed, three-dimensional image acquisition.

HL 42.2 Mo 15:30 TU P270

Controlled coupling of a subwavelength dipole to a photonic crystal microcavity — •V. Sandoghdar, F. Koenderink, and B. Buchler — Laboratory of Physical Chemistry, Swiss Federal Institute of Technology, (ETH), 8093 Zürich, Switzerland

Recently there has been a remarkable progress in the design and fabrication of photonic crystal microcavities with very high quality factors and low volumes. This promises interesting experiments in various fields including Cavity Quantum Electrodynamics and integrated optics. We discuss the coupling between a photonic crystal microcavity and a subwavelength object, such as a single quantum emitter or a scanning probe tip. We show how the cavity modifies the radiative properties of an emitter and how a subwavelength particle modifies the spectral properties of the resonator.

HL 42.3 Mo 16:00 TU P270

Noise properties of supercontinua generated in photonic crystal fibers (PCFs) — •Harald R. Telle and Nils Haverkamp — Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

The generation of femtosecond supercontinua in PCFs results from the complex interplay of various nonlinear effects like self-phase-modulation, four-wave-mixing, fission of Raman solitons, wave-braking and so on. A similar complexity is expected for the noise properties of such white-light-sources. Experimental investigations of several modulation transfer functions of a typical PCF will be presented from which noise- and phase-coherence-properties of the generated spectra can be inferred. Possible effects of such fluctuations on practical applications like optical frequency metrology or heterodyne-CARS will be discussed.

HL 42.4 Mo 16:30 TU P270

Novel photonic quasicrystal geometries and waveguide designs for applications in dispersion engineering — •M. D. B. Charlton [1], M. E. Zoorob[2], G. J. Parker [1], N. Perney [3], M. C. Netti[2], P. Ayliffe[2], S. J. Cox [1], J. J. Baumberg [3], and J. S. Wilkinson [1] — [1]Dept of Electronics and Comp. Science, University of Southampton, SO17 1B — [2]Mesophotonics Ltd, 2 Venture Road, Chilworth Science Park, Southampton, SO167NP — [3]School of Physics and Astronomy, University of Southampton,Southampton SO17 1BJ, UK

After a review of previous work on 12-fold symmetric quasicrystals, I present more recent unpublished theoretical work on dispersion and localisation effects in novel quasicrystal geometries with higher symmetry order. Implications for applications will also be discussed. In addition, recent theoretical and practical work on loss reduction in planar photonic crystal slabs will be presented, addressing in particular the issue of etch depth.

HL 42.5 Mo 17:00 TU P270

Interaction between Photonic Gaps and Material Excitations in 1- and 2-Dimensional Structures — •Carl G. Ribbing[1], Herman Högström [2], and Andreas Rung[1] — [1]Dept. of Functional Materials, Swedish Defense Research Agency, Linköping, Sweden of Sensor Technology, Swedish Defence Research Agency, Linköping, Sweden — [2]Department of Engineering Sciences, The Ångström Laboratory, Uppsala, University, Box 534, 751 21 Uppsala, Sweden

Photonic gaps in periodic dielectric structures originate from diffraction and interference, and can be observed phenomenologically as total reflectance and zero emittance. Mathematically, the appearance of a gap coincides with the occurrence of an imaginary wave vector. This is characteristic also for homogenous materials with a negative dielectric function – typical for metals in the visible and infrared spectral regions. Investigations of so called metallodielectric crystals with new and interesting features were published in the later part of the 90's. In this contribution, the case of polaritonic, photonic crystals is discussed. In the infrared region, a group of compounds with ionic binding have Reststrahlen Bands within which the dielectric function is negative. This will give rise to the formation of *polaritonic* gaps that are narrow, in contrast to the metallodielectric case, and occur in a material that is an electric insulator. Depending on the detailed conditions, different features arise from the interaction between the *polaritonic* gap and the photonic gap (fixed by the choice of structure and lattice constant).

HL 42.6 Mo 17:30 TU P270

Sol-Gel Approaches to Photonic Crystal Systems — •Frank Marlow, Denan Konjhodzic, Helmut Bretinger , and Hongliang Li — Max-Planck-Institut für Kohlenforschung, Kaiser-Wilhelm-Platz 1, D-45470 Mülheim an der Ruhr

A prerequisite for an efficient "molding the flow of light" by photonic crystals is the molding of materials in desired nanostructures. Very often, conventional materials and processing techniques cannot fulfill the theoretical requirements for the materials and structures. Sol-gel methods enable the controlled introduction of porosity into the materials by the use of molecular or supramolecular templates. The porosity can be used for lowering the refractive index, for soft processing of the materials and for stress relaxation. Examples for this are ultra-low refractive index film used as supports for 2D photonic crystals, inverse opals with a skeleton-like unit cell filling and ferroelectric films with high transparency and good structuring possibilities. Detail results will be described on mesoporous silica films with a refractive index of 1.14 and on their use in 2D photonic crystals waveguide systems. The films are synthesized by a template-modified sol-gel process using triblock copolymers.[1] Furthermore, the structure tuning possibilities of inverse opals and their photonic properties will be investigated. Here materials with new possible bandgaps can be constructed.[2] Finally, first investigations of sol-gel processed ferroelectric PZT films will be shown. They can lead to switchable photonic crystals.

[1] M. Schmidt, G. Boettger, M. Eich, W. Morgenroth, U. Huebner, H. G. Meyer, D. Konjhodzic, H. Bretinger, F. Marlow, Appl. Phys. Lett. 85 (2004) 16.

[2] F. Marlow, W. Dong, ChemPhysChem 4 (2003) 549.

HL 43 GaN: Präparation und Charakterisierung II

Zeit: Montag 15:00–16:45 Raum: TU P164

HL 43.1 Mo 15:00 TU P164

Segregation von Dotieratomen in GaN — •M. Siebert, Th. Schmidt, J. I. Flege, S. Gangopadhyay, A. Pretorius, S. Einfeldt, S. Figge, D. Hommel und J. Falta — Institut für Festkörperphysik, Universität Bremen, Postfach 330 440, 28 334 Bremen

Im blauen Spektralbereich sind GaN-basierte Heterostrukturen von großer Bedeutung für die Anwendung in Laserdioden (LD) und Leuchtdioden (LED). In diesem Zusammenhang ist ein genaues Verständnis des Einbaus von Mg und Si, die als Dotieratome für p- bzw. n-Dotierung verwendet werden, notwendig. So wurde beobachtet, dass Mg-Dotieratome nicht homogen im GaN-Film verteilt sind, sondern in Abhängigkeit von der Dotierkonzentration unterschiedlich starke Tendenz zur Segregation zeigen. Zur genaueren Charakterisierung des Segregationsverhaltens wurden Experimente mit Photolelektronenspektroskopie (XPS) und Spektromikroskopie (ESCA-Mikroskopie) bei verschiedenen Dotierkonzentrationen durchgeführt. Dabei wurde festgestellt, dass Mg auch bei niedrigen Dotierkonzentrationen deutlich unterhalb der Schwellwertbedingung für die Bildung von Inversionsdomänengrenzen Segregation zeigt. Desweiteren konnte anhand von Spektromikroskopieexperimenten zum ersten Mal gezeigt werden, dass auch Si segregiert und sich dabei an facettierten Oberflächenrissen entlang der Kristallsymmetrieachsen anlagert.

HL 43.2 Mo 15:15 TU P164

Optical and magnetic properties of rare earth implanted AlN — •Gregor Öhl[1], U. Vetter[1,2], and H. Hofsäss[1] — [1]Georg-August-Universität, II. Physikalisches Institut, Friedrich-Hund-Platz 1, 37077 Göttingen — [2]Philipps-Universität, AG Oberflächenphysik, Renthof 5, 35032 Marburg

Rare earths (RE) in AlN already have been studied extensively. Nevertheless, as shown in recent studies e.g. on the system AlN:Gd [U. Vetter, Appl. Phys. Lett. 83,11 and Gruber, Vetter et al., Phys. Rev. B 69], where single systems with moderate Lanthanide doses implanted were investigated - RE in AlN show very promising features, e.g. for the use as electroluminescent emitters.

In this study we investigated single (at high doses) and double systems of RE in AlN thin films grown on SiC. The RE were implanted at different energies and fluences giving a square implantation profile. The implantation process was optimised, as was the post-implantation annealing procedure. RBS analysis was performed to monitor the annealing behaviour of the implantation profile, while possible clustering of the metal ions was monitored by XRD measurements. Optical properties were investigated by means of temperature dependent time-resolved cathodoluminescence studies, life-time and energy-transfer studies were performed on selected radiative intra-4f electron transitions of the implanted lanthanide ions. In addition, magnetic properties of the RE implanted AlN will be discussed.

HL 43.3 Mo 15:30 TU P164

MOCVD-grown GaMnN epilayers and nanostructures — •M. Strassburg[1,2], M.H. Kane[2,3], A. Asghar[2], Ch. Hums[1,4], J. Senawiratne[1], M. Alevli[1], N. Dietz[1], C.J. Summers[3], I.T. Ferguson[2], U. Haboeck[4], A. Hoffmann[4], D. Azamat[4], and W. Gehlhoff[4] — [1]Georgia State University, Department of Physics and Astronomy, Atlanta, GA 30302 — [2]Georgia Institute of Technology, Electrical and Computer Engineering, Atlanta, GA 30332 — [3]Georgia Institute of Technology, Materials Science and Engineering, Atlanta, GA 30332 — [4]Technische Universität Berlin, Institut für Festkörperphysik, D - 10623 Berlin

High-quality GaMnN epilayers and nanostructures providing room temperature (RT) ferromagnetism were achieved. The incorporation of up to 2-5 % of Mn was enabled without significant drop in the crystalline quality taking advantage of MOCVD growth. Structural quality and absence of second phases were confirmed by high-resolution XRD, AFM and Raman spectroscopy. Local coordination and environment, and the valence state of the magnetic dopants were identified by electron paramagnetic resonance (EPR). Direct correlation of the Mn induced midgap-band with the magnetization was observed. Using co-doping (Si, Mg), the RT magnetization were explored in MOCVD-grown n- and p-type GaMnN epilayers. Strong Fermi level dependence of the magnetization was observed until the complete loss of ferromagnetic behavior for Silicon concentrations of 10^{20} cm^{-3}. Hence, phase segregation or ferromagnetic clusters were ruled out to cause the observed ferromagnetism.

HL 43.4 Mo 15:45 TU P164

Selection rules for optical transitions of wurtzite InN — •P. Schley[1], R. Goldhahn[1], G. Gobsch[1], V. Cimalla[1], O. Ambacher[1], C. Cobet[2], N. Esser[2], J. Furthmüller[3], F. Bechstedt[3], H. Lu[4], and W.J. Schaff[4] — [1]Institut f. Physik, TU Ilmenau — [2]ISAS Berlin — [3]FSU Jena — [4]Cornell University Ithaca

Although it is now commonly accepted that the band gap of InN is lower than the long time used value of 1.9 eV, the large deviation between recently reported data (from 0.64 to 1.4 eV) requires clarification. One of the intrinsic properties of all nitrides is that the optical response at the band gap is strongly polarisation dependent due to the splitting of the valence bands at the Γ-point of the Brillouin zone, i.e. the absorption edge of the extraordinary dielectric function (DF) is shifted with respect to the ordinary one. We observed such a behaviour in the energy range below 1 eV. The DFs were determined by spectroscopic ellipsometry investigating a-plane InN films grown by MBE on r-plane sapphire substrates. From the energetic splitting the crystal field energy is determined with ∼30 meV taking into account the calculated spin-orbit energy of 12 meV (M. Cardona, Sol. Stat. Commun **116** (2000) 421). Knowing these energies we discuss the orientation dependence of oscillator strengths for the corresponding transitions. All results provide further evidence that InN has a band gap of about 0.65 eV at room temperature.

HL 43.5 Mo 16:00 TU P164

MD-simulations of high pressure synthesis of single crystalline GaN — •Karsten Albe und Paul Erhart — TU Darmstadt, Insitut für Materialwissenschaft, Petersenstr. 23, D-64287 Darmstadt

Bulk synthesis of gallium nitride from nitrogen and liquid gallium at high-pressures is a promising way to produce defect free crystallites that can be used as seeds for MBE growth. We have performed atomic scale molecular-dynamics simulations in order to study the basic mechanisms of solid phase formation using a newly develeped bond-order potential that realistically describes the nitrogen gas phase, pure gallium as well as various solid structures of GaN. By varying the gas pressure we investigate the process of nitrogen saturation of the gallium melt and the corresponding conditions for GaN crystallization. Moreover, we elucidate the basic mechanisms for dissociation of N_2 dimers at the liquid-gas interface.

HL 43.6 Mo 16:15 TU P164

Determination of the 2DEG density of an AlGaN/GaN HEMT by electroreflectance spectroscopy — •A.T. Winzer[1], R. Goldhahn[1], G. Gobsch[1], A. Link[2], M. Eickhoff[2], U. Rossow[3], D. Fuhrmann[3], and A. Hangleiter[3] — [1]Inst. f. Physik, TU Ilmenau, PF 100565, D-98684 Ilmenau — [2]Walter Schottky Institut, TU München, Am Coulombwall 3, D-85748 Garching — [3]Inst. f. Techn. Physik, TU Braunschweig, Mendelssohnstraße 2, D-38106 Braunschweig

A method for determination of the 2DEG density of an $Al_xGa_{1-x}N$/GaN high electron mobility transistor (HEMT) will be presented. The technique is based on electroreflectance spectroscopy, i.e. on the analysis of the Franz-Keldysh oscillations and the determination of the electric field strength in the AlGaN layer. Another result of the method is the polarization discontinuity between AlGaN and GaN which represents the polarization charge bound at the AlGaN/GaN interface. This property is of fundamental interest for the design of HEMTs.

We have investigated a transistor structure with 23% Al-content in the barrier. Using a Schottky gate contact the 2DEG density was adjusted between 0 and 10^{13} cm^{-2}. Magnetotransport measurements confirm the precision of our method. Furthermore, our findings indicate a 22% lower polarization discontinuity than theory predicts, taking into account the spontaneous and the piezoelectric contribution [Ambacher *et al.*, J. Phys.: Condens. Matter **14**, 3399 (2002)]. The results are discussed in terms of a simple plate capacitor model and by self consistent conduction band calculations.

HL 43.7 Mo 16:30 TU P164

Characterization of epitaxially laterally overgrown GaN structures by micrometer-resolved X-ray Rocking Curve Imaging — •Daniel Lübbert[1,2], Tilo Baumbach[1], Petr Mikulik[3], Petra Pernot[1,4], Lukas Helfen[1,4], Stacia Keller[5], and Steven DenBaars[5] — [1]Institut für Synchrotronstrahlung, FZK, D-Karlsruhe — [2]Humboldt-Universität, D-Berlin — [3]Masaryk University, CZ-Brno — [4]ESRF, F-Grenoble — [5]University of California, Santa Barbara, USA

Epitaxial lateral overgrowth (ELO) of GaN works by growing a nucleation layer on a substrate and covering by a mask with laterally periodic openings. Upon subsequent regrowth of GaN, dislocations from the wetting layer can propagate vertically through these mask windows, but not usually into the lateral GaN wings growing on both sides of the windows. The GaN lattice quality in ELO wings is therefore expected to be superior.

We have performed experimental investigations of the *local* lattice quality in ELO structures using a technique of spatially resolved X-ray diffraction named *Rocking Curve Imaging*. It allows to monitor the crystal lattice quality and ELO wing tilt in individual periods of the laterally periodic structure, with spatial resolution down to one micrometer. Results show a highly inhomogeneous lattice tilt distribution across the sample surface. The progressive bending of laterally overgrown areas can be analyzed, showing both concave and convex curvature of ELO wings, depending on growth conditions. Samples grown on different substrates (SiC vs. sapphire) and by different growth sequences (1S- and 2S-ELO) will be compared in view of their crystalline perfection.

HL 44 II-VI Halbleiter IV

Zeit: Montag 15:00–17:45 Raum: TU P-N201

HL 44.1 Mo 15:00 TU P-N201

Photoreflectance spectroscopy of high-quality ZnO — •H. Lösch[1], R. Goldhahn[1], G. Gobsch[1], A. Dadgar[2], N. Oleynik[2], J. Bläsing[2], and A. Krost[2] — [1]Institut f. Physik, TU Ilmenau — [2]Institut f. exp. Physik, Otto-von-Guericke Universität Magdeburg

We study the influence of preparation conditions on the optical properties of ZnO as determined by temperature-dependent photoreflectance (PR) spectroscopy. The epitaxial layers were grown by MOVPE on GaN/sapphire templates by a two-step growth process. First, a low-temperature ZnO buffer was deposited at 450 °C. Then, a high-temperature ZnO layer was grown at 900 °C. For doping with nitrogen, unsymmetrical-dimethyl-hydrazine with different molar flows were applied. Generally, doping results in a strongly enhanced magnitude of the PR spectra compared to unintentionally doped films. A further decrease of the line width for the free excitonic transitions is found if moderately doped layers are post-growth annealed in an oxygen atmosphere. Values of about 6 meV at low temperatures confirm the excellent film quality. The fit of the PR spectra for the c-axis layers yields a energetic splitting of 14 meV between the A- and B-excitons. The found lower transition probability of the A-exciton is in agreement with the calculations presented by Gil (PRB **64** (2001) 201301).

HL 44.2 Mo 15:15 TU P-N201

Ortsaufgelöste Lumineszenzuntersuchungen an epitaktisch gewachsenem ZnO — •F. Bertram, S. Giemsch, J. Christen, A. Dadgar und A. Krost — Inst. für Exp. Physik, Otto-von-Guericke-Universität, PF 4120, D-39016 Magdeburg

Wir präsentieren mikroskopisch-ortsaufgelöste Kathodolumineszenzmessungen (KL) an einer 7 μm dicken, epitaktisch gewachsenen ZnO-Schicht. ZnO wurde mittels MOVPE über Anpassungsschichten auf einem GaN/Saphir Template abgeschieden. Die Probenoberfläche ist planar, unterbrochen durch zwei Defektarten (Dichte $7\times10^6 cm^{-2}$). Man findet hexagonale Krater (Ø ca. 3 μm) und ausgedehnte Vertiefungen mit Querstegen. Am Rand kommt es zu einer Überhöhung. Das KL-Spektrum (T=5K) besteht aus scharfen exzitonischen Linien FX, I2/I3, I8 und I9. Die Verteilung der verschiedenen Rekombinationskanäle korreliert direkt mit der Morphologie. FX und I8 sind gleichmäßig über der planaren Oberfläche verteilt. An den Kratern kommt es zu einer Bandverschiebung zu kleineren Energien. Die Intensität von I8 sinkt hier rapide ab (interne Felder). Gleichzeitig wird I2/I3 an den Randüberhöhungen intensiver (präferentieller Einbau von Störstellen).

HL 44.3 Mo 15:30 TU P-N201

Diffusion von Ag in CdTe bei Ko-Diffusion von Cu oder Au — •F. Wagner, H. Wolf und Th. Wichert — Technische Physik, Universität des Saarlandes, D-66123 Saarbrücken

Es werden experimentelle Untersuchungen vorgestellt, die zeigen, dass die Diffusion von Ag in einkristallinem CdTe stark von der Anwesenheit anderer Gruppe I Elemente beeinflusst wird. Diese Diffusionsexperimente wurden mit den Radiotracern ^{111}Ag und ^{67}Cu durchgeführt.
Wird nach einseitiger Implantation von ^{111}Ag (60 - 80 keV) in einen 500 μm dicken CdTe Kristall auf die Implantationsseite Cu aufgedampft und anschließend der Kristall für 30 min bei 550 K getempert, befindet sich das implantierte Ag nahezu vollständig in einer Schicht von ca. 1 μm an der Rückseite des Kristalls. Die Ko-Diffusion von Cu beschleunigt somit deutlich die Diffusion von Ag. Wird dagegen als Radiotracer ^{67}Cu implantiert und anschließend Ag auf der Implantationsseite aufgedampft, so zeigt sich kein signifikanter Einfluss von Ag auf die Cu Diffusion. Ebenso wie Cu übt auch die Ko-Diffusion von Au einen deutlichen Einfluss auf die ^{111}Ag Diffusion aus, jedoch ist der Beschleunigungseffekt deutlich schwächer als im Fall der Ko-Diffusion von Cu. Alle Beobachtungen lassen sich dadurch erklären, dass (i) die Diffusion von Gruppe I Elementen in CdTe stark durch die Wechselwirkung mit interstitiellen Cd-Atomen (Kick-out Mechanismus) beeinflusst wird, (ii) interstitielle Gruppe I Elemente eine sehr hohe Beweglichkeit haben und (iii) Ag schwächer auf dem substitutionellen Platz des Cd Untergitters gebunden ist als Cu oder Au.
Gefördert durch das BMBF, Projekt 05KK1TSB/5 und die DFG, Projekt Wi715/-1

HL 44.4 Mo 15:45 TU P-N201

Spin flip Raman experiments on heavy doped ZnMnSe diluted magnetic semiconductors — •M. Lentze[1], D. Wolverson[2], P. Grabs[1], and J. Geurts[1] — [1]Physikalisches Institut der Universität Würzburg, EP III, Am Hubland, D-97074 Würzburg, Germany — [2]University of Bath, Dep. of Physics, Bath BA2 7YA, UK

Diluted magnetic semiconductors (DMS) are a promising component for the new spinbased information technology (Spintronics). For spin transport applications, a sufficient doping level is required. For the analysis of the magnetic properties of doped II-VI DMS, we apply spin flip Raman spectroscopy from free electrons under resonant excitation at the fundamental band gap. Our investigations are focused on BeZnMnSe: bulk-like BeZnMnSe epitaxial films with electron concentrations between 10^{17} cm^{-3} and 10^{19} cm^{-3}. Analysis of the Raman signal yields the effective g-factors, the effective Mn-concentration as well as the spin relaxation time. By measurements under different scattering geometry (forward scattering vs. backward scattering) the momentum transfer in the Raman scattering process was varied systematically. In this way we studied the behavior of conduction band electrons in the metal to insolator transition. From our investigations at extremely heavily doped samples we could affirm a model, based on free electrons. The obtained results for the spin relaxation time T_2 and spin diffusion coefficient D_s agree with electrical characterisations and theoretical predictions for these DMS.

HL 44.5 Mo 16:00 TU P-N201

Long-wavelength bound and unbound charge excitations in doped ZnO and ZnO based alloy thin films — •C. Bundesmann, M. Schubert, D. Spemann, H. v. Wenckstern, H. Hochmuth, E. M. Kaidashev, M. Lorenz, and M. Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstraße 5, D-04103 Leipzig, Germany

Doping and alloying of ZnO with different materials opens the path to interesting properties, like n- and p-type conductivity, ferroelectricity, ferromagnetism or band-gap-engineering, with possible applications in optoelectronics or spintronics.

Raman scattering is a perfect tool to study optical phonons in doped or alloy thin films, with the potential use to identify dopant or alloy material incorporation in ZnO thin films. Infrared spectroscopic ellipsometry (IRSE) allows for the determination of free charge carrier parameters, such as density, anisotropic mobility, and eventually effective mass. IRSE is a potential candidate for characterization of complex ZnO based device heterostructures, as recently shown for group-III-nitride heterostructures. (N,Li,P,Sb,Ga,Al)-doped ZnO and (Mg,Cd,Mn,Ni,Co,Fe,Cu)ZnO

alloy thin films are grown by pulsed laser deposition on sapphire substrates, and studied by Raman scattering and IRSE.[1] Experimental phonon modes are compared with MREI model and local mode calculation schemes.
[1] C. Bundesmann et. al, Appl. Phys. Lett. **81**, 2376 (2002); **83**, 1974 (2003); **85**, 905 (2004);.

HL 44.6 Mo 16:15 TU P-N201

Untersuchung der elektrischen Eigenschaften von dotierten II-VI-Bragg-Reflektoren — •K. Otte, C. Kruse, J. Dennemarck und D. Hommel — Institut für Festkörperphysik, Universität Bremen

Der kürzlich erbrachte Nachweis grüner Laseremission eines II-VI-basierten oberflächenemittierenden Lasers mit Vertikalresonator (VCSEL) bei Raumtemperatur (optisch gepumpt) lässt auch einen elektrischen Injektionsbetrieb realistisch erscheinen [1]. Die Schlüsselkomponenten in diesem Zusammenhang sind hochreflektive Bragg-Reflektoren (DBRs) mit ausreichender Leitfähigkeit in vertikaler Richtung. Es wurden n- und p-dotierte DBRs hergestellt, welche ZnSSe als Hochindex- und MgS/Zn(Cd)Se Übergitter (SLs) als Niedrigindexschichten verwenden (Substrat GaAs). Aus diesen Strukturen wurden durch Ionenätzen freistehende Mesen präpariert und zur Vermessung der elektrischen Eigenschaften mit In- bzw. Pd/Au-Metallkontakten versehen. Anhand von Strom-Spannungskurven lässt sich folgern, dass sich mit n-dotierten DBRs ausreichende Stromdichten erreichen lassen, wobei die Leitfähigkeit empfindlich von der Periode und Zusammensetzung des MgS/Zn(Cd)Se-SLs abhängt. P-dotierte DBRs dagegen zeigen einen um Größenordnungen höheren Widerstand und können wahrscheinlich in VCSELn nicht eingesetzt werden. Daher bietet sich ein VCSEL-Aufbau mit Tunnelübergang an, bei dem zwei n-dotierte DBRs Verwendung finden. [1] C. Kruse et al., phys. stat. sol.(b) 241, 731 (2004)

HL 44.7 Mo 16:30 TU P-N201

Hybrid epitaxial-colloidal semiconductor nanostructures — •C. Arens[1], N. Rousseau[1], D. Schikora[1], K. Lischka[1], O. Schöps[2], U. Woggon[2], M. V. Artemyev[3], E. Hertz[4], and D. Gerthsen[5] — [1]Universität Paderborn, Department Physik, Warburger Strasse 100, 33095 Paderborn — [2]Universität Dortmund — [3]Belarussian State University, Minsk — [4]Cornell University, Ithaca, NY — [5]Universität Karlsruhe

Using the well establish MBE process, we introduced for the first time colloidal nanocrystalls into monocrystaline semiconductor layer. CdSe/ZnS nanodots and nanorods (R≈3nm) on a ZnSe surface are capped by thin (d≈R) and thick (d>R) MBE-grown ZnSe layers. With HRTEM pictures we show the epitaxial link of the wet chemically prepared semiconductor nanocrystals to the crystal lattice of the ZnSe buffer and the MBE grown cap layer. In- and ex- situ characterisation of the samples (RHEED, HRXRD) are showing the ZnSe cap layer of high crystalinity. After the growth of the cap layer the dots have still their shape and emission spectrum. The results demonstrate that our method allows varying the dot density in a wider range than Stranski-Krastanov growth and allows the incorporation of dots with different emission wavelength in the host material.

HL 44.8 Mo 16:45 TU P-N201

Growth Optimization and Properties of Self-assembled CdSe/ZnSe Islands Formed by Low Temperature Epitaxy and In-situ Annealing — •S Mahapatra, G Astakhov, C Schumacher, U Bass, W Ossau, J Geurts, and K Brunner — EPIII, Physikalisches Institut, Universität Würzburg, Am Hubland, D-97074, Würzburg

Properties of CdSe quantum dots (QDs) on ZnSe, self assembled during MEE growth of 2-3 ML CdSe at 230°C and subsequent annealing in Se ambient between 310-340°C are compared with those of QDs grown by conventional MBE at 300°C. X-ray interference, photoluminescence (PL), AFM, and Raman spectroscopy have been used to determine the amount of CdSe, the exciton energies, size, and area-density of these QDs. In the former process, a transition from a streaky (2x1) RHEED pattern, after the growth of the CdSe layer, to a spotty one during annealing is indicative of SK-like 2D-3D transition. The low temperature growth suppresses intermixing of the group II species at the ZnSe-CdSe interface, thereby enabling strain relaxation by island formation during annealing. Despite a lower amount of incorporated CdSe (possibly due to desorption), PL peaks of these dots are remarkably red-shifted and broadened compared to the MBE grown samples. We discuss these effects in the context of intermixing, desorption, and strain relaxation by 3D island formation. Variation of growth and annealing parameters and their effects will also be presented.

HL 44.9 Mo 17:00 TU P-N201

Kohärente Spindynamik in semimagnetischen CdMnSe/ZnSe Quantenpunkten — •Thomas Schmidt[1], Michael Scheibner[1,2], Thomas A. Kennedy[2], Gerd Bacher[3], Lukas Worschech[1], Alfred Forchel[1], Taras Slobodskyy[4], Georg Schmidt[4] und Laurens W. Molenkamp[4] — [1]Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [2]Naval Research Laboratories, Washington, DC 20375, USA — [3]Werkstoffe der Elektrotechnik, Universität Duisburg-Essen, Bismarckstrasse 81, BA, 47057 Duisburg, Germany — [4]Experimentelle Physik III, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

Mittels zeitaufgelöster Kerr-Rotation an semimagnetischen CdMnSe/ZnSe Quantenpunkte ist es gelungen, die kohärente Dynamik von lokal miteinander wechselwirkenden Mn-Spins und photo-injizierten Ladungsträgerspins zu untersuchen. Aufgrund der unterschiedlichen g-Faktoren der Ladungsträger- und Mn-Spins ist es möglich, den kohärenten Spintransfer auf das Mn-System hinsichtlich der unterschiedlichen Beiträge zu analysieren. Eine Erhöhung der Mn-Konzentration führt zu einer Phasenverschiebung des Spintransfers, die auf einem Vorzeichenwechsel des effektiven exzitonischen g-Faktors beruht. Die reduzierte Dimensionalität der untersuchten Systeme bedingt lange, kohärenten Spinlebensdauern, die durch vergleichende Studien zum Hanle-Effekt bestätigt werden.

HL 44.10 Mo 17:15 TU P-N201

Photolumineszenz-Spektroskopie an einkristallinen, sphärischen ZnO-Nanopartikeln aus der Gasphase — •L. Schneider[1], S. Halm[1], G. Bacher[1], A. Roy[2], E. Kruis[2], S. Polarz[3], M. Merz[3] und M. Dries[3] — [1]Werkstoffe der Elektrotechnik, Universität Duisburg-Essen, Bismarckstr. 81, 47057 Duisburg — [2]Prozess- und Aerosolmesstechnik, Universität Duisburg-Essen, Bismarckstr. 81, 47057 Duisburg — [3]Anorganische Chemie I, Ruhr-Universität Bochum, Universitätsstr. 150, 44780 Bochum

Wegen seiner potenziellen Einsatzmöglichkeiten als effektive UV-Emitter sind ZnO-Nanopartikel von großem Interesse für die Optoelektronik. Fehlstellen im Nanokristall führen jedoch im allgemeinen dazu, dass neben der Bandkanten-Emission ein spektral breites Band sogenannter „grüner Defektlumineszenz“ beobachtet wird.
Wir präsentieren Photolumineszenz-Spektroskopiemessungen an ZnO-Nanopartikeln, welche per chemischer Gasphasensynthese (CVS) hergestellt wurden. Es wird gezeigt, dass bei richtiger Wahl der Prozessparameter die Defektlumineszenz selbst für Partikel mit einem Durchmesser von nur 10nm fast vollständig unterdrückt werden kann. Temperatur- und leistungsabhängige Experimente erlauben ein detaillierteres Verständnis der Rekombinationsprozesse.

HL 44.11 Mo 17:30 TU P-N201

Interdiffusion in single self-assembled ZnCdSe quantum dots — •Emanuela Margapoti[1], Lukas Worschech[1], Alfred Forchel[1], Georg Schmidt[2], and Laurens W. Molenkamp[2] — [1]Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg — [2]Experimentelle Physik III, Universität Würzburg, Am Hubland, 97074 Würzburg

Spectral properties of single self-assembled ZnCdSe quantum dots embedded in a ZnSe matrix were studied after several successively performed thermal annealing steps. Small mesas with only a small number of quantum dots were fabricated by electron beam lithography and wet etching. Comparable small annealing temperatures ranging between 100 to 240 °C each applied for 30s result in blue shifts of single exciton lines up to 100 meV. The observed blue shifts fit well to a model assuming an energy activated interdiffusion process with activation energies as small as 0.5 eV indicating that the diffusion properties are significantly altered compared to higher dimensional structures composed of the same material.

HL 45 Quantenpunkte und -drähte: Transporteigenschaften II

Zeit: Montag 15:00–17:30 Raum: TU P-N202

HL 45.1 Mo 15:00 TU P-N202

Magnetfeldabhängige Kapazitätsspektroskopie des Löchersystems von InAs-Quantenpunkten — •Peter Kailuweit[1], Dirk Reuter[1], Andreas D. Wieck[1], Ulrich Zeitler[2], Oliver Wibbelhoff[3] und Axel Lorke[3] — [1]Lehrstuhl für angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstraße 150, 44780 Bochum — [2]High Field Magnet Laboratory, University of Nijmegen, Toernooiveld 7, 6525 ED Nijmegen, Netherlands — [3]Fakultät für Experimentalphysik, Universität Duisburg-Essen, Lotharstraße 1, 47048 Duisburg

Nachdem das sukzessive Laden der elektronischen s- und p-Zustände in InAs-Quantenpunkten weitgehend beobachtet und geklärt ist, bleibt das kompliziertere Löchersystem noch relativ unverstanden. Mittels Kapazitätsspektroskopie wurden daher Schottkydioden mit eingebetteten InAs-Quantenpunkten untersucht.

Durch ein parallel zur Probenfläche angelegtes Magnetfeld wurde den tunnelnden Löchern ein zusätzlicher Impuls verliehen. Durch Wahl geeigneter Messfrequenzen lässt sich der Einfluß des magnetfeldinduzierten Impulses auf die Tunnelwahrscheinlichkeit bestimmen.

Dies erlaubt es, durch Messung bei verschiedenen Magnetfeldern die Aufenthaltswahrscheinlichkeit der Löcher im k-Raum für die einzelnen Ladungspeaks auszutesten und somit praktisch die Wellenfunktion abzubilden. Es wurden die ersten sechs Ladungspeaks untersucht.

HL 45.2 Mo 15:15 TU P-N202

Shot noise measurements at the Fermi Edge Singularity of InAs quantum dots — •N. Maire[1], T. Lüdtke[1], R. J. Haug[1], and K. Pierz[2] — [1]Institut für Festkörperphysik, Universität Hannover, D-30167 Hannover — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig

We investigate the noise properties of self-assembled InAs quantum dots embedded into a GaAs-AlAs-GaAs heterostructure. The I-V-characteristic shows a step-like dependence which can be directly linked to resonant tunneling through the ground states of single quantum dots. This allows us to measure the noise properties of single 0-dimensional states. We furthermore observe a strong overshoot of the current amplitude of a particular step with increasing magnetic fields and decreasing temperatures which we interpret as an electron-electron interaction effect, a so called Fermi Edge Singularity (FES).

The resulting noise power shows a frequency independent spectrum, the so called shot noise. This noise power is suppressed compared to the theoretical value $2eI$ of a single tunneling barrier as it is indeed expected for a double barrier resonant tunneling structure. This suppression is characterized by the dimensionless Fano factor $\alpha = S/2eI$; S being the average noise power density. We now analyze the FES in detail by measuring the Fano Factor for increasing magnetic fields up to 15 T and varying temperatures down to approx. 300 mK and compare the results with theoretical predictions.

HL 45.3 Mo 15:30 TU P-N202

Theorie des kohärenten Stroms durch Quantenpunktmoleküle — •Tobias Zibold, Matthias Sabathil und Peter Vogl — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching

Wir präsentieren eine quantitative, theoretische Untersuchung des ballistischen Ladungsträgertransports durch Quantenpunktmoleküle aus vertikal gestapelten InAs Quantenpunkten in einer InP Barriere. Hierzu verwenden wir eine kürzlich entwickelte (CBR) Methode [1], mit der eine effiziente Berechnung der ballistischen I-V-Kennlinie des vollständig dreidimensionalen Bauelements mit realistischen Quantenpunkten einschließlich Wetting Layern möglich ist. Die I-V-Kennlinie zeigt mehrere ausgeprägte Resonanzen und bietet eine Fülle an Informationen, die zu optischer Spektroskopie komplementär ist: die Energiedifferenz zwischen dem Grund- und dem ersten angeregten Zustand, die Kopplung zwischen den Quantenpunkten, die laterale Verschiebung sowie Größe und Form der Quantenpunkte. Wir können das berechnete Spektrum mit einfachen physikalischen Konzepten erklären und qualitative Tendenzen vorhersagen. Der Vergleich mit experimentellen Daten [2] ergibt eine gute Übereinstimmung mit unseren Berechnungen. Die CBR Methode basiert auf der Lösung der Schrödingergleichung und berücksichtigt die realistische Bandstruktur einschließlich Verspannungen und piezoelektrischer Ladungen. [1] D. Mamaluy et al., J. Appl. Phys. 93, 4628 (2003), [2] T. Bryllert et al., Appl. Phys. Lett. 82, 2655 (2003).

HL 45.4 Mo 15:45 TU P-N202

Mode coupling of spatially coincident electron wave guides — •S.F. Fischer[1], G. Apetrii[1], U. Kunze[1], D. Schuh[2], and G. Abstreiter[2] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum, D-44780 Bochum — [2]Walter Schottky Institut,Technische Universität München, D-85748 Garching

Mode coupling phenomena in electron wave guides lead to wave function mixing and splitting of degenerate one-dimensional (1D) energy levels. The direct experimental determination of splitting energies demands coherent ballistic electron transport and high 1D-subband spacings (>10 meV). Nanolithography with an atomic force microscope enables us to prepare spatially coincident 1D electron systems which meet these requirements and for which massive wave function mixing is expected. Quantum point contacts were fabricated from a modulation doped GaAs/AlGaAs system with a 30 nm wide square quantum well with two occupied 2D subbands. We find a rich mode spectrum by recording transconductance maxima at 2 K as a function of gate voltage and magnetic field. Magnetotransport spectroscopy of unprecedented resolution allows the proper identification of heretofore unresolved subtle interference induced by mode coupling. Imaging the of transconductance vs. drain- and gate voltage enables the direct determination of splitting energies (> 2 meV).

HL 45.5 Mo 16:00 TU P-N202

Quantum transport in single-walled carbon nanotubes — •Carola Meyer, Pablo Jarillo-Herrero, Sami Sapmaz, and Leo Kouwenhoven — Kavli Institute of Nanoscience, Delft University of Technology, PO Box 5046, 2600 GA, Delft, The Netherlands

Single-walled carbon nanotubes (SWCNTs) are one-dimensional conductors, either metallic or semiconducting depending on their chirality. In the past years, the study of quantum transport through SWCNTs has revealed many quantum phenomena, e.g. quantum dot shell filling, Fabry-Perot-like interference, Kondo effect, etc. Recently, few electron-hole dots on semiconducting SWCNTs have been demonstrated in our group, and the behavior in a magnetic field has been studied. It is possible to fabricate gate structures to deplete certain parts of these semiconducting tubes, i.e. to create tunable barriers. This opens up the opportunity for a scalable electron spin quantum computing concept, if microwaves can be coupled to the system. The unique properties of SWCNTs, i.e. small spin orbit coupling, small phonon density of states, and small abundance of nuclear spins, are expected lead to long coherence times of electron spins in the dots. Here, we will present our concept, discuss the main problems that have to be solved and show first attempts towards a device that could be used for quantum computing.

HL 45.6 Mo 16:15 TU P-N202

Impact of source/drain contacts on the performance of carbon nanotube field-effect transistors — •Joachim Knoch[1], Siegfried Mantl[1], Yu-Min Lin[2], Z Chen[2], Phaedon Avouris[2], and Joerg Appenzeller[2] — [1]Institut fuer Schichten und Grenzflaechen, ISG-1, Forschungszentrum Juelich — [2]IBM T.J. Watson Research Center, Yorktown Heights, NY10598 USA

Carbon nanotube field-effect-transistors (CNFETs)are attracting an increasing attention as building blocks of a future nano-electronics. In most of today's CNFETs, metallic contacts are used made of e.g. titanium in contact with the nanotube. This contact plays the crucial role for carrier injection into the channel and it was found that CNFETs rather behave as Schottky barrier (SB) devices than conventional MOSFETs. Models capturing scaling aspects of CNFETs consequently consider a metallic electrode in direct contact with the nanotube. However, a closer look at CNFET data also reveals discrepancies between predictions of the existing SB-models and measured CNFET characteristics. A particularly obvious aspect is the often encountered asymmetric ambipolar or even unipolar appearance of $I_d - V_{gs}$ curves for thin gate oxides, an observation that cannot be explained by existing models. Here, we present an extended SB-model where current injection from the metal contacts into the channel does not happen directly but is mediated by a "metal-poisoned" nanotube underneath the contacts. With this model the ex-

perimentally observed IV characteristics can be reproduced and over a large gate voltage range.

HL 45.7 Mo 16:30 TU P-N202

Conductance anomalies in nonlinear transport through a quantum point contact — •M. Fleischer[1], D.J. Schefzyk[1], D.A. Wharam[1], D.A. Ritchie[2], and M. Pepper[2] — [1]Institut für Angewandte Physik, Universität Tübingen, Auf der Morgenstelle 10, D-72076 Tübingen — [2]Cavendish Laboratory, University of Cambridge, Madingley Road, Cambridge CB3 0HE, UK

Transport measurements of quantum point-contacts lead to the well-known conductance quantisation in units of $G_0 = \frac{2e^2}{h}$. We have investigated point-contacts defined in the two-dimensional electron gas of a GaAs/AlGaAs heterostructure. The differential conductance exhibits plateaux at the expected integer multiples of G_0 and their half-integer counterparts at finite bias. In addition, there is a distinct step below the first plateau, widely known as the "0.7-structure", as well as a corresponding step below the second plateau, at about $1.6\,G_0$. At finite bias, both additional steps first develop into plateaux at about $0.8\,G_0$ and $1.5\,G_0$ respectively, then into side plateaux at intermediate values in analogy to the integer/half-integer structure, leading to a pattern of intersecting diamonds in the transconductance. The possible origin of extra steps has been considered in a numerical calculation of one-dimensional subbands.

HL 45.8 Mo 16:45 TU P-N202

Determination of electron and hole localization in InAs/GaAs quantum dots via direct observation of tunneling escape — •Martin Geller, Erik Stock, Christian Kapteyn, Roman Sellin, and Dieter Bimberg — Institut für Festkörperphysik, TU Berlin, Hardenbergstr. 36, D-10623 Berlin

We have determined the tunneling barrier height, which is equal to the entire ground state localization energy, for electrons and holes in InAs/GaAs quantum dots (QDs). For the first time this important value was obtained by measuring the tunneling time constant as function of an applied external electric field in time resolved capacitance measurements. Previously, we had shown that time resolved capacitance spectroscopy (DLTS) is a powerful tool to study thermal emission processes and thermal activation energies in QDs. However, for electrons - but also for holes - the competing tunneling process in an applied electric field makes it impossible to measure directly the localization energy. In fact, for electrons only the quantization energy can be derived, due to tunneling through the tip of the triangular barrier, and the hole localization energy is always underestimated. With this new developed method via direct observation of tunneling escape in capacitance transients, the obtained localization energy is 240 meV for the electrons and 190 meV for the holes. These values are in very good agreement with our predictions from 8-band k·p calculations. The work was funded by the SANDiE Network of Excellence of the European Commission, contract number NMP4-CT-2004-500101 and SFB 296 of DFG.

HL 45.9 Mo 17:00 TU P-N202

Determination of the electron confinement in self-organized 1.3 μm InGaAs/GaAs quantum dots by capacitance-voltage measurements — •Marcus Gonschorek, Heidemarie Schmidt, and Marius Grundmann — Universität Leipzig, Fakultät für Physik and Geowissenschaften, 04103 Leipzig, Germany

Using capacitance-voltage (CV) measurements we observe that due to electrons confined in InGaAs quantum dots the space charge behaviour of the n-GaAs-Schottky host diode is modified by additional plateau-like structures. We solved self-consistently the one-dimensional Poisson and drift-diffusion equation as a function of the voltage applied to the Schottky contact where the zero-dimensional density of the electron quantum dot states is modelled by Gaussian broadened lines. By comparing experimental and theoretical CV data obtained for differently doped n-GaAs Schottky diodes ($1 \times 10^{16} - 5 \times 10^{16}$ cm^{-3}) where identical layers of self-organized InGaAs quantum dots are incorporated, we show that the growth-related doping profile has a significant effect on the CV data. In order to determine the electron confinement in self-organized 1.3 μm InGaAs quantum dots, we carefully consider the temperature dependence of the Schottky barrier energy and use the CV data measured in the temperature range from 4 up to 310 K to separate the growth-related doping effects[1] from the quantum dot related charging effects. [1] R. Wetzler, A. Wacker, E. Schöll, C.M.A. Kapteyn, R. Heitz, and D. Bimberg, Appl. Phys. Lett. 77, 1671 (2000).

HL 45.10 Mo 17:15 TU P-N202

Elektrische Eigenschaften von nanoskaligen Ionenspuren — •A.K. Nix[1], D. Schwen[1], J.H. Zollondz[1], C. Ronning[1], C. Trautmann[2], H. Krauser[3] und H. Hofsäss[1] — [1]II. Physikalisches Institut, Universität Göttingen, Friedrich-Hund-Platz 1, D-37077 Göttingen — [2]Gesellschaft für Schwerionenforschung, Planckstr. 1, D-64291 Darmstadt — [3]Hochschule Harz Wernigerode, Friedrichstr. 57-59, D-38855 Wernigerode

In isolierenden tetraedisch gebundenen amorphen Kohlenstoffschichten (ta-C) können durch Bestrahlung mit schnellen schweren Ionen, z.B. Uran oder Gold, graphitische Ionenspuren erzeugt werden. Diese Ionenspuren mit hohem Aspektverhältnis und Durchmesser von ca. zehn Nanometer besitzen eine deutlich höhere Leitfähigkeit als ihre umgebende Matrix. Sie haben somit die Möglichkeit, als vertikale leitende Verbindungen in Multilagen zu dienen. An diesen Ionenspuren wurden Strom-Spannungs-Kennlinien mithilfe eines Rasterkraftmikroskops (AFM) unter Anlegen einer Biasspannung aufgenommen. Für die Untersuchung des elektrischen Ladungstransports wurden temperaturabhängige IV-Kennlinien aufgenommen, wobei ein Ensemble von Ionenspuren mit aufgedampftem Gold kontaktiert wurde. Weiterhin wurden auch Experimente durchgeführt, um eine einzelne Spur zu kontaktieren.

HL 46 Quantenpunkte und -drähte: Herstellung und Charakterisierung I

Zeit: Montag 16:45–18:00 Raum: TU P164

HL 46.1 Mo 16:45 TU P164

Atomistic investigation of InAs quantum dots at different growth stages — •Thomas Hammerschmidt, Peter Kratzer, and Matthias Scheffler — Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany

Recent experiments suggest that InAs quantum dots (QD's) grown on GaAs (001) undergo a shape transition during growth from 'hut' to 'dome'-like shapes, similar to Ge QD's on Si. From a thermodynamic point of view, QD formation is governed by the balance between the energy gain due to strain relief and the energy cost due to formation of QD side facets and edges. In order to account for both contributions, we have developed a carefully parameterized Abell-Tersoff bond-order potential. It reproduces the elastic constants as well as properties of both GaAs and InAs (001) surface reconstructions obtained from density-functional theory calculations with good accuracy and is transferable to the higher-index facets of QD's. Based on recent STM studies, we set up several detailed atomic structures of InAs QD's along the shape-transition path from a flat QD dominated by {137} facets to a fully developed QD dominated by {110} facets, some with partially grown facets. After relaxation with our potential we analyzed changes in the total energy and the strain-field. We find that small QD's favor the 'hut' shape and that the facets preferably grow from bottom to top, in agreement with experiment.

HL 46.2 Mo 17:00 TU P164

Struktur und Stöchiometrie von InAs/GaAs Quantenpunkten mit Sb-Beimischungen — •R. Timm, T.-Y. Kim, A. Lenz, H. Eisele, K. Pötschke, U. W. Pohl, D. Bimberg und M. Dähne — TU Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin

InAs Quantenpunkte in GaAs sind von entscheidender Bedeutung für die Optoelektronik. Ein vielversprechender Ansatz, um die industriell wichtige Wellenlänge von 1,3 μm zu erreichen, besteht in der Beimischung geringer Mengen von Antimon, wobei bereits die Anwesenheit von Sb während der Wachstumsphase zu einer Strukturänderung von InAs Quantenpunkten führt [1].

Mit Rastertunnelmikroskopie an Querschnittsflächen (XSTM) wurden InAs/GaAs Quantenpunkte mit Sb-Beimischungen untersucht, die mittels Metallorganischer Gasphasenepitaxie gewachsen wurden. XSTM ermöglicht die Charakterisierung von überwachsenen Quantenpunkten [2] und ist das einzige Verfahren, das die chemische Zusammensetzung solcher quarternärer Nanostrukturen mit atomarer Auflösung zeigen kann.

Für bestimmte Wachstumsbedingungen konnten einzelne Sb-Atome in den Benetzungsschichten nachgewiesen werden, nicht aber in den Quantenpunkten. Anhand der atomaren Struktur der untersuchten Quantenpunkte und Benetzungsschichten mit der jeweiligen lokalen Stöchiometrie wird der Einfluss des Antimons auf die InAs-Nanostrukturen diskutiert.

Diese Arbeit wurde unterstützt durch die Europäische Kommission im Rahmen des EU-Exzellenznetzwerks SANDiE.

[1] K. Pötschke, et al., Physica E **21**, 606 (2004)
[2] R. Timm, et al., Appl. Phys. Lett., *im Druck*

HL 46.3 Mo 17:15 TU P164

Selbstorganisierende In(Ga,Al)As-Quantenstrukturen — •Andreas Schramm, Stephan Schulz, Christian Heyn und Wolfgang Hansen — Institut für Angewandte Physik, Universität Hamburg, Jungiusstraße 11C, 20355 Hamburg, Germany

Beim epitaktischen Wachstum von verspannten, InAs-haltigen Schichten auf (001)-GaAs bilden sich spontan Nanostrukturen. Hier werden derartige, sogenannte selbstorganisierte In(Ga,Al)As-Nanostrukturen mit Feststoffquellen-Molekularstrahlepitaxie unter Verwendung von As_4 als Arsenquelle hergestellt und mit Rasterkraftmikroskopie (AFM) strukturell untersucht. Es werden Ergebnisse präsentiert, die die Abhängigkeit der Geometrie von Wachstumsparametern wie Substrattemperatur, Überwachstemperatur, Deckschichtmaterial, Bedeckung und Wartezeiten demonstrieren. Im Gegensatz zu GaAs als Bedeckungsmaterial, bei dem sich nur mit As_2 ringartige Strukturen bilden [1], erhält man mit AlAs als Deckmaterial auch mit As_4 bei geeigneten Parametern ring- und scheibenartige Strukturen. Der Grund hierfür liegt unter anderem in der kürzeren Diffusionslänge der Al auf der Oberfläche [2].

Weiterhin werden die strukturellen Eigenschaften der selbstorganisierenden Nanostrukturen mit Ergebnissen elektronischer Untersuchungen wie die Kapazitätsspektroskopie (CV) und die *Deep Level* Transienten Spektroskopie (DLTS) korreliert.

[1] Garcia et al, APL 71 2014 (1997)
[2] Lee et al, Nanotechnology 15 (2004) 848-850

HL 46.4 Mo 17:30 TU P164

Größenkontrolle von InAs Quantum Dashes — •Andres Sauerwald[1], Tilmar Kümmell[1], Gerd Bacher[1], André Somers[2], Ruth Schwertberger[2], Johann Peter Reithmaier[2] und Alfred Forchel[2] — [1]Werkstoffe der Elektrotechnik, Universität Duisburg-Essen, 47057 Duisburg, Germany — [2]Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

Gerade für selbstorganisierte Strukturen besteht reges Interesse, die Größe über Wachstumsparameter kontrolliert einzustellen. Wir untersuchen selbstorganisierte InAs/InGaAlAs Quantum Dashes (QDashes) mit unterschiedlichen nominellen InAs-Schichtdicken. Mit Raster-Transmissions-Elektronen-Mikroskopie (RTEM) können Größe, Form und chemische Zusammensetzung präzise bestimmt werden. Es zeigt sich, dass die absolute Höhe der QDashes für alle Proben proportional zur nominellen InAs-Schichtdicke ist, während das Höhe-Basis Verhältnis des pyramidenförmigen Querschnitts sich als unabhängig von der nominellen InAs Schichtdicke erweist. Durch Änderung eines einzigen Wachstumsparameters kann somit die Größe der QDashes über einen weiten Bereich (Faktor 3) kontrolliert und damit die Emissions-Wellenlänge zwischen 1.3μm und 1.9μm eingestellt werden.

HL 46.5 Mo 17:45 TU P164

Untersuchung von InAs/GaAs - Quantenpunkten mit Rastertunnelspektroskopie an Querschnittsflächen — •L. Ivanova[1], R. Timm[1], A. Lenz[1], M. Müller[1], H. Eisele[1], M. Dähne[1], O. Schumann[2], L. Geelhaar[2] und H. Riechert[2] — [1]Technische Universität Berlin, Institut für Festkörperphysik, PN4-1, Hardenbergstr. 36, 10623 Berlin — [2]Infineon Technologies, Corporate Research Photonics, 81730 München

Die Rastertunnelspektroskopie (STS) ermöglicht den Zugang zu den lokalen elektronischen Eigenschaften einer Oberfläche. Für die Untersuchung der lokalen Zustandsdichte als Funktion von Ort und Spannung können der Tunnelstrom und seine Ableitung verwendet werden.

Mittels Querschnitts-Rastertunnelspektroskopie (XSTS) wurden vergrabene InAs Quantenpunkt-Doppelstapel in GaAs untersucht, die mit Molekularstrahlepitaxie (MBE) mit geringer Stickstoffbeimischung gewachsen wurden. Der Stickstoff wurde dabei außerhalb der Bandlücke detektiert, was dafür spricht, dass er einen Störstellencharakter besitzt. STS-Bilder eines Quantenpunktes zeigen bei verschiedenen Spannungen eine Kontrastumkehr und unterschiedliche Zustandsdichteverteilungen.

HL 47 Hauptvortrag Samuelson

Zeit: Dienstag 10:00–10:45 Raum: TU P270

Hauptvortrag HL 47.1 Di 10:00 TU P270

Physics and quantum device applications of semiconductor nanowires — •Lars Samuelson — Lund University, Solid State Physics/the Nanometer Structure Consortium,Box 118, S-221 00 Lund, Sweden

Self-assembly of low-dimensional semiconductor materials and devices via seeded growth of semiconductor nanowires, is presently in the focus of much attention. The possibility to control formation of heterostructure interfaces within nanowires, with control on the atomic scale, has allowed ideal 1D and 0D semiconductor systems to be formed. I will describe recent progress in materials science, in the physics of nanowires as well as in demonstrated quantum devices.

HL 48 Symposium: Bio- and Neurotransistors

Zeit: Dienstag 10:45–13:15 Raum: TU P270

HL 48.1 Di 10:45 TU P270

Transistors with Ion Channels, Nerve Cells and Brain Tissue — •Peter Fromherz — Department of Membrane and Neurophysics, Max Planck Institute for Biochemistry, Martinsried, München

An overview is given on various aspects of transistor recording in neuronal systems using simple silicon chips and CMOS technology. On the biological side, the three levels of ion channels, nerve cells and brain tissue are considered. The geometry and electrical features of cell-chip contacts are analyzed with luminescent dyes taking advantage of fluorescence interference and of the Stark effect. The nature of signal transmission from ionic systems to the transistor is studied with recombinant sodium and potassium channels. On that basis, transistors are applied for various cellular systems: (i) Recombinant ligand-gated channels provide a basis for selective cell-based biosensors. (ii) Electrical excitation is recorded for individual nerve cells from snails and rats. (iii) The release of individual synaptic vesicles is detected. For brain tissue, dynamic electrical maps of neuronal activity are obtained at a resolution below 10 micrometer and 0.5 ms using large transistor arrays of a CMOS chip.

HL 48.2 Di 11:15 TU P270

Interfacing cells with microelectronics — •Günter Wrobel, Frank Sommerhage, Sven Ingebrandt, and Andreas Offenhäusser — Institute Thin Films and Interfaces (ISG-2), Forschungszentrum Jülich, 52425 Jülich, Germany

The interface between functional biological systems and inorganic materials is of central importance for the development of functional bioassays, biosensors and future information systems. Our efforts aim at developing neuroelectronic systems as well as complex sensors for biological and chemical diagnostics. In order to investigate the principles of the cell-transistor coupling genetically modified cells overexpressing voltage-gated ion-channels are used. In our experiments we have focussed on the time-dependence of the cell-transistor recordings. We examined the electrical coupling of HEK293 cells, which were stably transfected with

voltage-gated potassium or chloride channels. Cells were cultured on n- and p-channel field-effect transistors to compare the influence of the device type on the signal shape. The signals of the active ion channels of the whole cell and those in the contact region on the transistor gate are examined using electrophysiological techniques.

HL 48.3 Di 11:45 TU P270

Detecting DNA Hybridization by a Microfabricated Field-effect Sensor — •Jürgen Fritz — MIT Media Laboratory, 20 Ames Street, Cambridge, MA 02139, USA. — present adress: International University Bremen, Campus Ring 1, 28759 Bremen, Germany

Detecting the presence and activity of biomolecules by electronic means is of growing interest due to its potential to simplify and miniaturize biosensors or medical devices. Label-free electronic detection of biomolecules with a microfabricated device offers the advantage of online-monitoring of biological samples and processes, and miniaturization and parallelization of sensors into arrays by using standard microfabrication techniques. One route to achieve electronic detection of biomolecules is to detect the intrinsic molecular charge of biomolecules by a field-effect device. Here we report on a microfabricated field-effect sensor which detects the binding of short DNA molecules to its sensor surface 1. We show functionalization strategies for such a sensor, and concentration dependence and specificity of the sensor signal. We summarize field-effect detection of biomolecules, show its promises, limits, and future applications.

HL 48.4 Di 12:15 TU P270

A BioFET on the basis of intact insect antennae — •M. J. Schöning[1,2], S. Schütz[3], H. E. Hummel[4], H. Lüth[2], and C.-D. Kohl[5] — [1]Fachhochschule Aachen (Abteilung Jülich), Labor für Chemo- und Biosensorik — [2]Forschungszentrum Jülich, ISG — [3]Universität Göttingen, Fakultät für Forstwissenschaften und Waldökologie — [4]Universität Giessen, Institut für Phytopathologie und Angewandte Zoologie — [5]Universität Giessen, Institut für Angewandte Physik

More than one million species of insects with sometimes extraordinary sensory abilities present a tremendous potential of highly optimised chemoreceptors. To make these abilities usable for analytical tools, some interface between chemoreceptive organs of insects and microelectronic components of analytical instruments has to be established. One promising possibility is the design of biosensors on the basis of intact chemoreceptors utilising electrophysiological techniques, like electroantennography (EAG). For natural analyte concentrations the EAG responses have a rise time of 50 ms and a time constant for decay of about 200 ms. In order to circumvent, major drawbacks of conventional EAG methods such as electrical and mechanical instability, the need for pre-amplification and the limited ability for miniaturisation, we designed a direct field effect transistor (FET)-insect antenna junction, representing the first BioFET on the basis of intact insect antennae. Two different set-ups will be presented the whole-beetle BioFET and the isolated-antenna BioFET. Considering that detection limits of analytes are typically in the ppb range or even lower, a biosensor on the basis of intact chemoreceptors could serve as an analytical device with unrivalled data acquisition time.

HL 48.5 Di 12:45 TU P270

Biosensor Applications of AlGaN/GaN Solution Gate Field Effect Transistors — •Georg Steinhoff, Barbara Baur, Martin Stutzmann, and Martin Eickhoff — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, D-85748 Garching

AlGaN surfaces are chemically inert in aqueous solutions and non-toxic to living cells. Covalent functionalization with self assembled monolayers (SAMs) of APTES for the immobilization of single stranded oligonucleotides and of ODTMS for the subsequent deposition of lipid monolayers is possible, allowing label-free detection of DNA hybridization or the detection of ligand binding to specific receptors in lipid monolayers on functionalized gates of solution gate AlGaN/GaN heterostructure field effect transistors. A different approach for the realization of biosensors is the cultivation of living cells directly on the gate area and the measurement of their ionic response to chemical or physical stimuli. We systematically studied the electronic characteristics of AlGaN/GaN FET arrays for the detection of electrical cell signals, such as low-frequency noise, transconductance and the sensitivity towards specific ions. Extracellular action potential recordings from a confluent layer of rat heart muscle cells cultivated directly on the non-metallized gate surface are discussed.

HL 49 Photonische Kristalle II

Zeit: Dienstag 10:45–13:15 Raum: TU P164

HL 49.1 Di 10:45 TU P164

Nonlinear optical experiments on waveguide plasmon polaritons using 5fs pulses — •Matthias W. Klein[1], Thorsten Tritschler[1], Stefan Linden[2], and Martin Wegener[1] — [1]Institut für Angewandte Physik, Universität Karlsruhe (TH), Wolfgang-Gaede-Straße 1, 76131 Karlsruhe, Germany — [2]Institut für Nanotechnologie, Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft, 76021 Karlsruhe, Germany

We present improved experiments and theoretical modeling of the linear and third-harmonic (TH) optical response of particle plasmons coupled resonantly to a slab waveguide. Our samples consist of lithographically patterned gold stripes on top of a HfO_2 waveguide. This system shows an avoided crossing in linear optics [1] and first nonlinear experiments have been presented [2]. In our experiment we use 5fs pulses from a Ti:Sa oscillator and resolve the TH signal both temporally *and* spectrally. The TH signal exhibits a pronounced beating versus time delay for specific spectral components, an exponential decay for other components, and shows evidence of partial destructive interference. The data fit very well to our theoretical model based on two coupled Lorentz oscillators, which also explains Fano-like lineshapes in the linear spectra. Moreover, we analytically show that the determination of the homogeneous linewidth of particle plasmon ensembles via second or third-harmonic generation experiments is *not* possible, thus contradicting Ref. [3].

[1] A. Christ et al., Phys. Rev. Lett. **91**, 183901 (2003)
[2] T. Zentgraf, A. Christ, J. Kuhl, and H. Giessen, submitted (2004)
[3] B. Lamprecht et al., Appl. Phys. B **69**, 223 (1999)

HL 49.2 Di 11:00 TU P164

Dispersion properties of coupled modes in photonic crystal waveguides — •Alexander Petrov and Manfred Eich — TU Hamburg-Harburg, AB 4-09, Eissendorfer Strasse 38, D-21073 Hamburg, Germany

The power flow redistribution in photonic crystal line-defect waveguides can lead to the appearance of modes with very small group velocities away from the Brillouin zone edge. There are also modes with the power flow distribution similar to the one of conventional dielectric waveguides, these modes propagate with normal group velocities. High values of dispersion can be obtained when different frequencies propagate with different group velocities. This can be achieved by coupling of two different modes in a single waveguide or between two parallel waveguides. Several designs are investigated with band diagrams and time domain simulations. Several hundred ps/nm/mm dispersion without third order dispersion is predicted on the bandwidth of a single wavelength division multiplexing channel.

HL 49.3 Di 11:15 TU P164

Coupled Resonator Optical Waveguides (CROWs) Doped With Nanocrystals — •Björn M. Möller[1], Mikhail V. Artemyev[2], Reinhold Wannemacher[3], and Ulrike Woggon[1] — [1]University of Dortmund — [2]Belarussian State University, Minsk — [3]Universität Leipzig

In this contribution, we study CdSe-doped microspheres of radii between two and four optical wavelengths as building blocks for coupled resonator optical waveguides (CROWs) [1]. Unlike other types of optical waveguides, waveguiding through CROWs is achieved through weak coupling between otherwise localized high-Q optical cavities. The coherently coupled microsphere cavities were prepared by impregnating polystyrene microspheres with a subsurface layer of CdSe nanocrystals [2]. Exactly size-matched microspheres (< 0.1 % size deviation) have been pre-selected via their Mie resonances. The coupled cavities, arranged in linear chains and various two-dimensional geometries are studied by microphotoluminescence spectroscopy and polarization sensitive mode mapping [3]. Waveguides consisting of more than five coherently coupled cavities with radii around 2.25 μm have been achieved.

The financial commitment of the DFG (SPP 1113 - Photonic Crystals) is gratefully acknowledged.
[1] A. Yariv, *et al.*, Opt. Lett. **24**, 711 (1999)
[2] U. Woggon *et al.*, J. Appl. Phys. B **77** (5), 469 (2003)
[3] B. M. Möller *et al.*, Phys. Rev. B **70** (11), 115323 (2004)

HL 49.4 Di 11:30 TU P164

Zur Form holographisch hergestellter Photolackstrukturen — •Daniel C. Meisel[1,2,3] und Martin Wegener[1,2,3] — [1]Inst. f. Nanotechnologie, Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft, D-76021 Karlsruhe — [2]Inst. f. Angewandte Physik, Univ. Karlsruhe (TH), — [3]DFG-Centrum für Funktionelle Nanostrukturen

Holographisch hergestellte poröse Photolackstrukturen können als Template für Photonische Kristalle dienen [1,2]. Die Form der Struktur wird üblicherweise als Isointensitätsfläche des Interferenzfeldes beschrieben [1,2,3]. Eine genauere Untersuchung ergab jedoch, dass insbesondere die Form des Motifs der Kristallstruktur trotz gleicher Belichtung stark davon abhängt, wie die Prozessierung des Photolackes durchgeführt wird. Die Translationssymmetrie hingegen ergibt sich zwingend aus dem Interferenzmuster. Es werden zu dieser Frage experimentelle und theoretische Resultate vorgestellt und Konsequenzen daraus diskutiert.
[1] M. Campbell, D. N. Sharp, M. T. Harrison, R. G. Denning und A. J. Turberfield, Nature **404**, 54 (2000)
[2] Yu. V. Miklyaev, D. C. Meisel, A. Blanco, G. von Freymann, K. Busch, W. Koch, C. Enkrich, M. Deubel und M. Wegener, Appl. Phys. Lett. **82**, 1284 (2003)
[3] D. C. Meisel, M. Wegener und K. Busch, Phys. Rev. B **70**, 165104 (2004)

HL 49.5 Di 11:45 TU P164

Electro - Optical Tuning of Photonic Crystal Structures — •Markus Schmidt[1], Manfred Eich[1], Uwe Hübner[2], and Hans-Georg Meyer[2] — [1]Technische Universität Hamburg-Harburg, Materials in Electrical Engineering and Optics, Eissendorfer Str. 38, D-21073 Hamburg — [2]Institut fuer Physikalische Hochtechnologie Jena e.V., Abt. Kryoelektronik, A. Einstein Str.9, D-07745 Jena

Photonic crystals, characterized by a periodic dielectric function, are key elements in future integrated optics. In this respect, electro - optical switches and filters which allow to address different wavelength division multiplexing (WDM) channels are very attractive perspectives in nanophotonics. Therefore, we introduce a new concept which is based on two dimensional photonic crystal resonators with an optically nonlinear waveguide core. The core consists of a high electric field poled polymer, covalently functionalized with nonlinear dye molecules. A quasistatic electric field perpendicular to the slab waveguide axis induces a refractive index change resulting from the Pockels effect. Due to the fact that the spectral properties of the resonant structure of the resonators strongly depend on the refractive index, the transmission characteristic is changed. We realized a finite two dimensional photonic crystal line defect resonator consisting of P(MMA/DR-1) as core material. Shifting of the resonator peak and ac modulations have been observed experimentally. Thus, we demonstrate an electro - optical device made from a nonlinear optical photonic crystal.

HL 49.6 Di 12:00 TU P164

Characterizing and Controlling Photonic Crystal Cavities with Scanning Probe Techniques — •Femius Koenderink, Ben Buchler, and Vahid Sandoghdar — Nano-Optics Group, Laboratory of Physical Chemistry, ETH Zurich, Switzerland

Solid state optical resonators that confine light in ultrasmall volumes currently enjoy wide interest, partly rooted in cavity quantum electrodynamics and partly motivated by a range of applications, including control of spontaneous emission, realization of low threshold lasers, optical switching and sensors. A particular advantage of photonic crystal microcavities is that one can achieve subwavelength cavity dimensions while keeping moderately high quality factors of up to 10^5. In our work we use Scanning Near-field Optical Microscopy to image directly the spatial extent of light. In addition to imaging, we discuss how a near-field probe can be used to manipulate the resonances of a photonic crystal microcavity. By performing Finite Difference Time Domain (FDTD) as well as perturbative analytic calculations, we demonstrate that it is possible to shift the resonance of a microcavity over a large range while maintaining a high quality factor. We discuss prospects of this technique for opto-mechanical switching and tuning of photonic crystals.

HL 49.7 Di 12:15 TU P164

Hin zu Metamaterialien mit negativem Brechungsindex bei optischen Frequenzen — •S. Linden[1], C. Enkrich[2,3], M. Wegener[2,3], J. Zhou[4], T. Koschny[4] und C. M. Soukoulis[4] — [1]Institut für Nanotechnologie, Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft, D-76021 Karlsruhe, Germany — [2]Institut für Angewandte Physik, Universität Karlsruhe (TH), D-76128 Karlsruhe, Germany — [3]DFG-Center for Functional Nanostructures (CFN) — [4]Ames Laboratory and Department of Physics and Astronomy, Iowa State University, Ames, Iowa 50011, U.S.A.

Mittels Elektronenstrahllithographie lassen sich Metamaterialien mit einer magnetischen Resonanzfrequenz von 100 THz realisieren. Die magnetische Antwort der metallischen, unmagnetischen Split-Ring-Resonatoren (SRR) beruht auf der Anregung der LC-Resonanz durch das eingestrahlte Lichtfeld. Für senkrechten Einfall koppelt das elektrische Feld an die Kapazität der SRR. Die experimentell bestimmten Spektren sind in guter Übereinstimmung mit den theoretischen Erwartungen. Zusätzliche numerische Simulationen zeigen, dass die hier vorgestellten Metamaterialien einen Frequenzbereich mit negativer Permeabilität aufweisen, falls eine Ankopplung an die LC-Resonanz über das Magnetfeld erfolgt. Zusammen mit einer negativen Permitivität kann dies zu Metamaterialien mit negativem Brechungsindex führen.

HL 49.8 Di 12:30 TU P164

Herstellung von Metamaterialien mit magnetischer Resonanz für den Telekommunikationsbereich — •C. Enkrich[1,2], F. Perez-Willard[2,3], S. Linden[4], M. Wegener[1,2,3], J. Zhou[5], T. Koschny[5] und C. M. Soukoulis[5] — [1]Institut für Angewandte Physik, Universität Karlsruhe (TH), 76128 Karlsruhe, Germany — [2]DFG-Center for Functional Nanostructures (CFN), Universität Karlsruhe (TH), 76128 Karlsruhe, Germany — [3]Laboratorium für Elektronenmikroskopie, Universität Karlsruhe (TH), 76128 Karlsruhe, Germany — [4]Institut für Nanotechnologie, Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft, 76021 Karlsruhe, Germany — [5]Ames Laboratory and Department of Physics and Astronomy, Iowa State Univerisity, Ames, Iowa 50011, U.S.A.

Durch Nanostrukturierung lassen sich Metamaterialien auf der Basis von periodisch angeordneten LC-Schwingkreisen mit magnetischer Resonanz bei Telekommunikationswellenlängen herstellen. Voraussetzung hierfür sind moderne Herstellungsverfahren, die eine minimale Strukturgröße kleiner als 60 nm ermöglichen. Wir haben eine neue Methode getestet, bei der die Proben mit Hilfe eines "Focused Ion Beam Systems" nanostrukturiert werden. Diese bietet gegenüber der Elektronenstrahl-Lithographie [1] den Vorteil, dass das Ergebnis der Strukturierung direkt untersucht und optimiert werden kann ("Rapid Prototyping"). Mit diesem Verfahren wurden Strukturen mit Resonanzwellenlängen unterhalb 1,5 μm hergestellt und die Abhängigkeit von verschiedenen Geometrieparametern untersucht.
[1] S. Linden et al., Science, **306** (2004)

HL 49.9 Di 12:45 TU P164

High quality polymer opals as photonic crystals — •Rudolf Zentel[1], Jianhui Ye[1], Birger Lange[1], Friederike Fleischhaker[1], Marc Egen[1], Frederik Jonsson[2], Sergei Romanov[2], and Clivia Sotomayor Torres[2] — [1]Fachbereich Chemie, Duesbergweg 10-14, Universität Mainz, D-55099 Mainz, Germany — [2]NMRC, Lee Maltings,, Prospect Row, Cork, Ireland

Polymer opals, which are self-assembled from solution, can be made easily, over large areas and with relatively low cost. A possible use of these materials as 3D photonic crystals is -so far- limited by the quality of the crystalline packing and by their refractive index contrast. The refractive index contrast necessary for a "full band gap"might be achievable by the preparation of high refractive index inorganic replica. We want to address here (I) the aspect of the quality of the crystal lattice and (II) the patterning of opaline materials. Concerning the crystal quality (I) we can show that by optimizing the synthesis of colloidal particles (this leads to highly monodisperse colloids) and the crystallization procedure at the same time, large (cm size) high quality colloidal crystals can be obtained. Also heterostructures with different crystal parameters are accessible. Concerning the patterning of opals (II) E-beam lithography can be used for all PMMA based systems. This allows it even to inscribe artificial defects into polymer opals. Also photoprocessable polymer opals are now at hand. Alternatively it is possible to direct the crystallization of the colloids on a substrate to the desired places. This makes it possible to integrate 3D photonic structures into a complex 2D pattern.

HL 49.10 Di 13:00 TU P164

Silicon double inversion of polymeric templates: a route towards functional 3D photonic band gap materials — •Georg von Freymann[1], Nicolas Tétreault[1], Geoffrey A. Ozin[1], Markus Deubel[2,3,4] und Martin Wegener[2,3,4] — [1]Materials Chemistry Research Group, Department of Chemistry, University of Toronto, M5S 3H6, Toronto, Canada — [2]Institut für Angewandte Physik, Universität Karlsruhe (TH), 76128 Karlsruhe — [3]Institut für Nanotechnologie, Forschungszentrum Karlsruhe, 76021 Karlsruhe — [4]CFN, Universität Karlsruhe (TH), 76128 Karlsruhe

We present the successful silicon double inversion of three-dimensional polymeric templates for Photonic Crystals.

In a first step, the high-quality polymer template [1] is infiltrated via a room temperature silica chemical vapor deposition (CVD) process. Plasma etching and thermal combustion subsequently remove the original polymer template. In a second step, the silica template is infiltrated with silicon via Si-CVD with disilane as a precursor. The silica backbone is finally removed by wet chemical etching, leaving behind a replica of the original polymer template cast in silicon. In combination with plasma treatment [2] of the original template, our method opens a facile way for the production of large scale functional 3D Photonic Crystals at telecommunication wavelengths.

[1] M. Deubel et al., Nature Materials 3, 444 (2004)

[2] G. von Freymann et al., Photonics and Nanostructures, in press (2004)

HL 50 Nanodrähte

Zeit: Dienstag 10:45–13:30 Raum: TU P-N201

HL 50.1 Di 10:45 TU P-N201

Template-directed fabrication of periodic ZnO nanowire arrays and the electrical characterizations by SEM nanomanipulator — •Hongjin Fan[1], Frank Fleischer[1], Woo Lee[1], Kornelius Nielsch[1], Margit Zacharias[1], Armin Dadgar[2], and Alois Krost[2] — [1]Max Planck Institute of Microstructure Physics, Halle (Saale) — [2]Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg

We report the successful fabrication of periodical arrays of single-crystalline ZnO nanowire arrays by combining substrate nanopatterning and catalyst-directed epitaxial growth. First, ordered arrays of Au nanodots were obtained by using metal nanohole membranes as shadow mask for Au deposition. This novel type of shadow mask was obtained from an electrochemical duplication process of anodic porous alumina. Subsequent vapor-phase growth resulted in vertically-aligned and hexagonal-arranged ZnO nanowires on GaN/Si substrates. The Au nanodots served as both catalyst and site-specific template for the growth of ZnO nanowires. As the size (30 to 250 nm) of the Au nanodots is tunable by choosing different masks for the Au deposition, the resulting ZnO wires are adjustable in their diameters. For the electrical characterizations, the ZnO nanowires were transferred to an oxide-coated Si substrate. A SEM-based nanomanipulator system, in which two independent sharp needles serve as electrodes, was employed to measure the I-V characteristics of individual ZnO nanowire. Results on this will be shown in detail.

HL 50.2 Di 11:00 TU P-N201

ZnO Nanorods Fabricated by Solution Synthesis and Chemical Vapor Deposition on Patterned Substrates — •Thomas Büsgen, Michael Hilgendorff, Witold Kandulski, Adam Kosiorek, Peter Karageorgiev und Michael Giersig — caesar research center, Ludwig-Erhard-Allee 2, 53175 Bonn, Germany

We will present the current results of preparations and characterizations of ZnO nanorods and -wires. Small ZnO nanorods of 10 nm in diameter and aspect ratios up to 10 have been synthesized in alcoholic solutions by a sol-gel approach using appropiate surfactants.

Larger ZnO wires of several microns in length and 100 nm in diameter were fabricated by chemical vapor deposition. The wire growth has been catalyzed by highly ordered Au islands, pre-patterned on sapphire substrates by nanoshadow lithography.

The as prepared ZnO materials have been characterized by SEM, TEM, NSOM, and optical spectroscopy. Their properties will be discussed in view of future applications.

HL 50.3 Di 11:15 TU P-N201

Catalyst–Nanostructure Interaction in Growth of ZnO and ZnS 1–D Nanostructures — •Christine Borchers, Sven Müller, Daniel Stichtenoth, and Carsten Ronning — II. Physikalisches Institut, Universität Göttingen, 37077 Göttingen

Vapor-liquid-solid is a well established process in catalyst guided growth of 1–D nanostructures, i.e. nanobelts and nanowires. The catalyst particle is generally believed to be in the liquid state during growth, and it is the site for adsorbing incoming molecules. The crystalline structure of the catalyst may not have any influence on the structure of the grown nanostructures. In this presentation, using Au guided growth of ZnO and ZnS nanostructures, we show that the interfaces between the catalyst droplet and the nanostructure grow in well defined mutual crystallographic relationships. The catalyst droplet directs the nanostructure's growth direction and defines its diameter. Possible alloy, intermetallic, or eutectic phase formation during catalysis are elucidated.

HL 50.4 Di 11:30 TU P-N201

Modifikation von ZnS Nanobändern durch Ionenbestrahlung — •Daniel Stichtenoth, Daniel Schwen, Sven Müller, Christine Borchers und Carsten Ronning — II. Physikalisches Institut, Universität Göttingen, Friedrich-Hund-Platz 1, D-37077 Göttingen, Germany

ZnS als ein II-VI Halbleiter mit direkter Bandlücke von 3,66 eV in der kubischen und 3,74 eV in der wurzitischen Phase eignet sich aufgrund seiner besonderen optischen Eigenschaften wie einem hohem Brechungsindex zur Fertigung optoelektronischer Bauteile. Halbleiter Nanobänder mit einer Dicke von 20nm - 200nm und einem hohen Aspektverhältnis wurden durch einen einfachen thermischen CVD Prozess sythetisiert. TEM Untersuchungen ergaben, dass die entstandenen Nanobänder sowohl wurzitische als auch kubische Kristallstruktur haben. Geeignete Fremdatome zur Dotierung der Bänder wurden durch Ionenimplantation eingebracht. Defekte wurden durch Anlassen weitesgehend ausgeheilt. An den Proben wurden Photo- und Kathodolumineszenz Untersuchungen in einem Temperaturbereich von 12K - 300K als Funktion der Anlasstemperatur durchgeführt. Zusätzlich werden in diesem Vortrag zeitaufgelöste Messungen an ausgewählten Zuständen diskutiert.

HL 50.5 Di 11:45 TU P-N201

Wachstum und Dotierung von ZnO Nanodrähten — •Sven Müller, Daniel Stichtenoth, Daniel Schwen, Tania Hernan Hakansson, Christine Borchers und Carsten Ronning — II. Physikalisches Institut, Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany

ZnO Nanodrähte wurden mit einem einfachen CVD Verfahren hergestellt. Dazu wurden hexagonal angeordnete Goldkatalysatorpunkte durch Nanospherelithographie auf geeignete Substrate aufgebracht. Diese Goldpunkte wirken im anschließenden Vapor-Liquid-Solid (VLS) Wachstum der Nanodrähte als Katalysator. Die hergestellten Nanodrähte wurden mit Al+ (als Donator) und N+ (als Akzeptor) Ionen und einer Energie von 25 keV bestrahlt, um einen p- und n-typ-Dotierung zu erhalten. Die anschließenden TEM und Photolumineszenzuntersuchungen für die unterschiedlichen Implantationsdosen wurden direkt nach dem Implantieren und nach dem Ausheizen untersucht. Die Ergebnisse zum Wachstum und zur Implantation werden in diesem Vortrag diskutiert.

HL 50.6 Di 12:00 TU P-N201

Wachstum von Silizium Nanodrähten auf Si-(111)-Substraten mittels Molekularstrahlepitaxie — •Luise Schubert[1], Nikolai D. Zakharov[1], Gerald Gerth[1], Hartmut S. Leipner[2], Peter Werner[1] und Ulrich Gösele[1] — [1]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle (Saale) — [2]Martin-Luther-Universität, Abteilung Physik, Halle (Saale)

Nanodrähte aus Halbleitermaterialien werden zumeist mittels CVD (chemical vapour deposition) hergestellt. Dabei dienen kleine Metalltröpfchen auf der Substratoberfläche als Katalysatoren für den Wachstumsprozeß, welcher als VLS (vapour liquid solid)-Mechanismus in der Literatur beschrieben wird. Erste Arbeiten unserer Arbeitsgruppe zeigen,

daß es ebenfalls möglich ist, Silizium-Nanodrähte auf der Basis der Molekularstrahlepitaxie (MBE) wachsen zu lassen. Diese Methode hat den Vorteil, daß diese Nanostrukturen unter sehr sauberen und kontrollierbaren Bedingungen gezüchtet werden können [1]. Das Wachstum der mittels MBE hergestellten Silizium Nanodrähte läßt sich jedoch nicht ausschließlich mit dem klassischen Modell des VLS-Mechanismus beschreiben. Die Experimente zeigen, daß neben thermodynamischen Wachstumsbedingungen zusätzlich Oberflächendiffusionsprozesse einen entscheidenden Einfluß auf die Ausbildung von Nanodrähten haben. Die Herstellung von entsprechenden Si/Ge-Heterostrukturen wird ebenfalls diskutiert.

[1] L. Schubert et al, Appl. Phys. Lett. 84, 4968-70 (2004)

HL 50.7 Di 12:15 TU P-N201

Paramagnetic Defects of Chemically Modified Silicon Nanowires — •A. Baumer[1], M. Loeb[1], M. Stutzmann[1], M.S. Brandt[1], F.C.K. Au[2], and S.T. Lee[2] — [1]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany — [2]Center of Super-Diamond and Advanced Films & Department of Physics & Material Science, City University of Hong Kong, Hong Kong SAR, China

The paramagnetic defects of Si nanowires (SiNWs) obtained by oxide-assisted growth were studied by electron spin resonance spectroscopy. For the as-grown nanowires with a typical diameter of $10-15$ nm, three different defects were found: Dangling bonds or P_b-centers with $g = 2.0065$, located at the interface of the crystalline core to the surrounding oxide, E'-centers with $g = 2.0005$ and EX-centers with $g = 2.00252$, located in the oxide. For the EX-centers, the characteristic hyperfine lines separated by 16.4 G were detected. The as-grown Si nanowires showed a spin density of about 10^{11}cm^{-2}. H termination of the nanowires via hydrofluoric acid decreases the spin density drastically to $2 \cdot 10^{9}\text{cm}^{-2}$. Further chemical modification of the H-terminated nanowires via hydrosilylation with alkenes provides alkyl-terminated nanowires as verified by Fourier-transform infrared-spectroscopy. The alkyl-terminated nanowires showed a spin density of about 10^{10}cm^{-2}, which is stable for at least several weeks.

HL 50.8 Di 12:30 TU P-N201

Theoretical study of reaction pathways of the formation and decay of 1D nanostructures — •Karl-Heinz Heinig und Lars Röntzsch — Forschungszentrum Rossendorf, Dresden

Nanowires have fascinating properties. Also the kind and strength of driving forces for their structural evolution differ from macroscopic systems, thus opening new routes for their synthesis. And, with respect to interface energy, nanowires are unstable, during their decay new self-organized 1D structures evolve.

This presentation summarizes reaction pathways of the formation and decay of 1D nanostructures predicted by atomistic computer simulations. It will be shown that nanowire synthesis by phase separation from supersaturated 1D traces relies on different time scales of different processes involved: (i) phase separation is faster than long-range diffusion, thus, initially small nanodroplets form. (ii) Short-range diffusion is fast, thus, lateron the minority phase is concentrated/unified to a wire (ripening, coalescence). (iii) On a long time scale, the wire lowers its surface energy by peristaltic undulations and decays finally into large droplets (Rayleigh instability). Each process can be governed in order to fabricated functional structures. For instance, crosspoints of nanowires accelerates the wire instability locally, which leads to a nanodot separated by nm gaps from the four nanowires. Such a Si structure embedded in SiO_2 might operate as a room temperature single electron transistor.

HL 50.9 Di 12:45 TU P-N201

Switching between one and two dimensions: conductivity of Pb–induced chain structures on Si(557) — •C. Tegenkamp, Z. Kallasy, H.-L. Günter, V. Zielasek, and H. Pfnür — Institut für Festkörperphysik, Abteilung Oberflächen, Appelstr. 2, 30167 Hannover, Germany

The conductivity of epitaxially grown Pb–structures on Si(557) has been measured. Different characteristic transport mechanisms have been found: For coverages above the percolation limit(0.6ML) up to 3ML the electronic transport in the annealed Pb–films is activated. Furthermore, the uniaxial symmetry of the Si(557) surface is reflected directly in a higher conductance in the parallel direction compared to the direction perpendicular to the steps. For coverages higher than 3ML a metallic behavior is found for both directions, i.e. the conductance decreases with increasing temperature. In contrast, already one ML, but annealed to 640K, leads to the formation of atomic wires, as seen by STM, with an extremely high and quasi one–dimensional surface state conductance along the wire direction. At a critical temperature of T_c=78K, the system switches from low to high conductance anisotropy, with a metal–insulator transition in the direction perpendicular to the chain structure, while in the direction along the chains conductance with a $(1/T + const.)$ temperature dependence was found. STM has shown further, that the 1D/2D transition is associated with an order–disorder phase transition of a 10-fold superperiodicity along the Pb chains.

HL 50.10 Di 13:00 TU P-N201

Leitende Ionenspuren in diamantartigem Kohlenstoff — •J.-H. Zollondz[1,2], D. Schwen[1], C. Trautmann[3] und H. Hofsäss[1] — [1]II. Physikalisches Institut, Universität Göttingen, Friedrich-Hund-Platz 1, 37077 — [2]Hahn-Meitner-Institut, Glienickerstr. 100, 14109 Berlin — [3]Gesellschaft für Schwerionenforschung, Planckstr. 1, 64291 Darmstadt

Schwere Ionen (z.B. 1 GeV Uran oder auch 600 MeV Gold) erzeugen in diamantartigen Kohlenstoff-Filmen nanoskopische leitende Ionenspuren. Das Durchdringen des amorphen Materials mit schweren Ionenen führt zu einer strukturellen Änderung. Diese Änderung resultiert in leitenden Drähten mit 8 nm Durchmesser deren Leitfähigkeit um vier Grössenordnungen höher als die des umgebende Materials ist. Ergebnisse mittels Rasterkraft-Mikroskopie in Verbindung mit Stromkartierung und lokalen Strom-Spannungs-Charkeristiken werden vorgestellt, wobei die Variation der Ionenart als auch der Einfluss deren Ladungszustands untersucht wurde.

HL 50.11 Di 13:15 TU P-N201

Electrical Transport in GaN-whiskers — •Raffaella Calarco[1], Ralph Meijers[1], Thomas Richter[1], Ali Irfan Aykanat[1], Toma Stoica[1,2], Michel Marso[1], and Hans Lüth[1] — [1]Institute of Thin Films and Interfaces (ISG1) and CNI - Centre of Nanoelectronic Systems for Information Technology, Research Center Jülich, 52425 Jülich, Germany — [2]INCDFM, Magurele, POB Mg7, Bucharest, Romania

Among different types of nanostructures, semiconductor nanowires and nanotubes are extremely interesting as building blocks for nanoelectronics, due to their suitability for fabricating both nanoscale devices and interconnects. GaN whiskers are reproducibly grown by plasma assisted molecular beam epitaxy on Si(111). The nanocolumns density and diameter are controlled by means of the III/V ratio. The nanocolumns grow parallel to the [111] direction of the Si substrate. The whiskers have been released from the Si(111) substrate and deposited on a Si(100) host substrate covered with a layer of 400nm silicondioxide, finger shaped electrical leads (Ti/Au) are subsequently patterned on it. The electrical behavior of metal semiconductor metal, MSM Schottky barrier photodiode nanostructures is analyzed by means of current voltage measurements with and without UV illumination. The influence of the whisker diameter on the electrical properties has been analysed.

HL 51 GaN: Präparation und Charakterisierung III

Zeit: Dienstag 10:45–13:15 Raum: TU P-N202

HL 51.1 Di 10:45 TU P-N202

Functionalization of Group III-Nitride Surfaces for Biosensor Applications — •Barbara Baur, Georg Steinhoff, Thomas Wassner, Martin Stutzmann, and Martin Eickhoff — Walter Schottky Institut, Technische Universität München, D-85748 Garching

Group III-nitrides are promising substrate materials for biophysical applications as they combine excellent electronic characteristics with biocompatibility and long term stability in liquid electrolytes. In particular, AlGaN/GaN electrolyte gate field effect transistors (EGFETs) have a great potential as sensor devices for electronic detection of biochemical processes, such as the recently demonstrated recording of cell signals. As a critical issue in the development of AlGaN-based biochemical transducers, the design and the analysis of inorganic/organic interface are adressed in this contribution.

We have studied the covalent functionalization of AlGaN-surfaces by deposition of self assembled layers (SAMs) of two different kinds of silane molecules. The deposition of octadecyltrimethoxysilane (ODTMS) resulted in hydrophobic AlN- and GaN-surfaces. For immobilization of DNA on AlGaN-surfaces the formation of SAMs of aminopropyltriethoxysilane (APTES) was studied. The functionalized surfaces were investigated by atomic force microscopy, X-ray photoelectron spectroscopy, X-ray reflectivity, thermal desorption and fluorescence microscopy. The detection of DNA hybridization with complementary sequences immobilized on GaN surfaces by fluorescence microscopy will be presented and the label free electronic detection of DNA with AlGaN-based devices is discussed.

HL 51.2 Di 11:00 TU P-N202

Elektrische Eigenschaften von ausgedehnten lokalen Defekten in GaN — •A. Krtschil, A. Dadgar, T. Riemann, J. Christen und A. Krost — Inst. f. Exp. Physik, Uni Magdeburg, PF4120, 39016 Magdeburg

In dieser Arbeit werden mit Hilfe von Rasterkapazitäts- (SCM) und Rasteroberflächenpotentialmikroskopie (SSPM) sowie mittels ortsaufgelöster Kathodolumineszenzmikroskopie ausgedehnte strukturelle Defekte in MOCVD-gewachsenen GaN-Schichten auf Saphirsubstrat sowie freistehendem HVPE-GaN untersucht. Im Gegensatz zu den integralen elektrischen Standardverfahren I-V/C-V-Analyse, Hall-Effekt oder Transientspektroskopie liefern SSPM und SCM Informationen über Ladungsträgerkonzentrationsgradienten, lokalisierte Ladungen und interne Feldkomponenten mit einer örtlichen Auflösung in der Größenordnung von 20 nm. Die gezeigten ausgedehnten Defekte reichen von Versetzungen über hexagonale Hillocks bzw. invertierte Pyramiden bis hin zu Mikrorissen und sind charakteristisch für MOCVD- und HVPE-gewachsenes GaN. Außerdem werden temperaturabhängige und optisch angeregte SSPM-Scans an diesen Defekten vorgestellt, aus denen die dazu korrespondierenden Energieniveaus der elektrisch aktiven Defekte bestimmt werden. Die Abhängigkeit dieser Defekteigenschaften von der Dotierung der Schicht (undotiert, Mg-, Fe-, Si-Dotierung) wird diskutiert.

HL 51.3 Di 11:15 TU P-N202

Laterales Überwachsen strukturierter Si(111)-Substrate mit GaN und AlN-Zwischenschichten — •L. Reissmann[1], A. Strittmatter[1], U. Haboeck[1], A. Hoffmann[1], D. Bimberg[1], P. Veit[2] und J. Christen[2] — [1]Technische Universität Berlin, Inst. f. Festkörperphysik, Sekr. PN 5-2, Hardenbergstrasse 36, 10623 Berlin — [2]Otto-von Guericke-Universität Magdeburg, Inst. f. Experimentelle Physik, PF 4120, D-39016 Magdeburg

Strukturierte Si(111)-Substrate bieten die Möglichkeit einer effizienten Defektreduktion in GaN-Epitaxieschichten durch laterales Überwachsen. Allerdings ist es auch beim lateralen Überwachsen notwendig, eine kompressive Verspannung der wachsenden GaN-Schicht beim Wachstum aufzubauen, um die thermisch induzierte tensile Verspannung zu kompensieren. Mittels dünner AlN-Zwischenschichten gelingt es auch auf strukturierten Si(111)-Substraten eine solche kompressive Verspannung in den GaN-Schichten aufzubauen. TEM-Aufnahmen belegen, dass die Defektverteilung durch die AlN-Schichten nicht modifiziert wird. Insbesondere entstehen in den lateral überwachsenen Bereichen keine neuen Versetzungen. Im Gegensatz hierzu wird die seitliche Facette der lateral wachsenden GaN-Schicht von AlN-Schichten bei bestimmten Wachstumsparametern beeinflusst. Dies äußert sich in willkürlich auftretenden Einschnürungen der lateralen Wachstumsfront, die bis zur Kante des Si-Steges reichen können. Eine durchgängige Passivierung der Si-Oberfläche ist notwendig, um das sog. melt-back etching zu verhindern. Wir präsentieren entsprechende Wachstumsprozesse zur Herstellung von extrem defektarmen GaN Pufferschichten.

HL 51.4 Di 11:30 TU P-N202

Lumineszenz von InGaN/GaN-Quantenpunktschichten in Abhängigkeit von der Versetzungsdichte und der Schichtanzahl — •A. Strittmatter[1], L. Reissmann[1], A. Hoffmann[1], D. Bimberg[1], P. Veit[2], T. Riemann[2] und J. Christen[2] — [1]Technische Universität Berlin, Inst. f. Festkörperphysik, Sekr. PN 5-2, Hardenbergstrasse 36, 10623 Berlin — [2]Otto-von Guericke-Universität Magdeburg, Inst. f. Experimentelle Physik, PF 4120, D-39016 Magdeburg

Einzel- und Mehrfach-Quantenpunktschichten bestehend aus InGaN/GaN-Stapeln wurden mittels MOCVD auf mit Stegen strukturierten Si(111)-Substraten gewachsen. Der GaN-Puffer zeigt in den Bereichen oberhalb der Si Stege eine hohe Versetzungsdichte von ca. $10^{10} cm^{-2}$ und eine sehr niedrige ($10^{7} cm^{-2}$) Versetzungsdichte in den lateral überwachsenen Gebieten. Interessanterweise bildet die Lumineszenz einzelner InGaN-Schichten die Versetzungsdichte scharf ab, in dem die Lumineszenz in den versetzungsarmen Gebieten zu grösseren Wellenlängen verschiebt. Im Gegensatz hierzu zeigt die Lumineszenz gestapelter InGaN/GaN-Schichten auf solchen strukturierten Si-Substraten kein derartiges Abbild der Versetzungsdichte. Eine mögliche Erklärung wäre ein sättigbarer Trapping-Mechanismus für In-Atome an Versetzungen. Die Arbeiten werden gefördert durch die Europäische Union im Rahmen des SANDiE Network of Excellence (Fördernummer: NMP4-CT-2004-500101) und durch den Sfb 296 der DFG.

HL 51.5 Di 11:45 TU P-N202

MOVPE Wachstum von AlInN — •Armin Dadgar, Fabian Schulze, Jürgen Bläsing, André Krtschil, Hartmut Witte, Annette Diez und Alois Krost — Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg, Postfach 4120, 39016 Magdeburg

AlInN deckt einen weiten Bandlückenbereich von 6.2 (AlN) bis ca. 0.8 eV (InN) ab und kann mit einer In-Konzentration von ca. 18% gitterangepaßt auf GaN gewachsen werden. Letzteres ermöglicht eine Reihe von interessanten Anwendungen für elektronische (FETs) und optoelektronische (RCLED, VCSEL) Bauelemente. Aufgrund der unterschiedlichen Anforderungen an das Wachstum von AlN und InN gibt es jedoch Probleme, ein geeignetes Wachstumsfenster für das MOVPE Wachstum zu finden. Wir zeigen, wie hochwertige AlInN Schichten mit Indiumkonzentrationen von ca. 9-25% auf GaN auf Silizium gewachsen werden können. Detaillierte Röntgendiffraktometrieuntersuchungen zeigen, daß sich die AlInN Komposition über der Schichtdicke stark ändert. Möglichkeiten, diese Konzentrationsänderung zu reduzieren, werden aufgezeigt.

HL 51.6 Di 12:00 TU P-N202

MOVPE-Wachstum von GaN(As,P) auf Si(001) — •Fabian Schulze, Jürgen Bläsing, Armin Dadgar, Anette Diez und Alois Krost — Institut für Experimentelle Physik, Otto-v.-Guericke-Universität Magdeburg, PF 4120, 39104 Magdeburg

Die moderne Halbleiterelektronik basiert auf Substraten mit kubischer Kristallstruktur in (001)-Orientierung. Zur Integration von GaN-basierten Bauelementen mit der etablierten Si-Elektronik ist es daher vorteilhaft, (001)-orientiertes Silizium anstelle des für das GaN Wachstum derzeit verwendeten Si(111) als Substratmaterial zu verwenden. Aus Symmetriegründen ist es notwendig, eine zusätzliche Vorzugsrichtung auf einem Si(001)-Substrat zu erzeugen, die eine von zwei möglichen azimuthalen Orientierungen des hexagonalen (0001) GaN selektiert. Zum Studium der Grenzfläche zwischen kubischen und hexagonalen Systemen wurden durch Umwandlung von Ga(As,P) in GaN und von GaN in Ga(N,As,P) Modellsysteme gewachsen und mittels Röntgenbeugungsmethoden und REM analysiert. Des Weiteren wird der Einfluss der Wachstumstemperatur einer AlN-Keimschicht auf die kristalline Qualität des GaN sowie Auswirkungen eines Substrat-Fehlschnittes in [110]-Richtung untersucht. Bei einer AlN-Wachstumstemperatur von 1145° konnte eine reine c-Achsen Orientierung der GaN-Kristallite mit einer Halbwertsbreite von 0.13° in Röntgen $\theta/2\theta$-scans erzielt werden.

HL 51.7 Di 12:15 TU P-N202

Verspannungsfelder einzelner Versetzungen in Galliumnitrid — •Nikolaus Gmeinwieser[1], Peter Gottfriedsen[1], Ulrich T. Schwarz[1], Werner Wegscheider[1], André Krtschil[2], Rainer Clos[2], Georg Brüderl[3] und Volker Härle[3] — [1]Naturwiss. Fakultät II- Physik, Univ. Regensburg, Universitätsstr. 31, 93053 Regensburg, Germany — [2]Otto-von-Guericke-Univ. Magdeburg, Universitätsplatz 2, 39106 Magdeburg, Germany — [3]OSRAM Opto Semiconductors GmbH, Wernerwerkstr. 2, 93049 Regensburg, Germany

Durch die geringe Defektdichte aktuell erhältlicher Bulk-GaN Templates von deutlich unter 10^8 cm^{-2}, sind einzelne Defekte in diesen Materialien hoch aufgelösten spektroskopischen Untersuchungen zugänglich. Micro-Photolumineszenz (μPL) bei tiefen Temperaturen bietet ausreichend räumliche und spektrale Auflösung, um von Verspannungsfeldern einzelner Defekte verursachte Linienverschiebungen der bandkantennahen PL in ihrer unmittelbaren Nähe zu bestimmen. Begrenzt durch die räumliche Auflösung zeichnen sich bei Oberflächenscans Durchstoßpunkte von Defekten als ca. 1 μm große Gebiete mit geringer PL-Intensität und erhöhten Linienbreiten ab. Die bandkantennahen Spektrallinien sind auf gegenüberliegenden Seiten des Defektes rot- bzw. blauverschoben, was einer tensilen resp. kompressiven Verspannung entspricht. Diese dipolartige Struktur ist noch in mehreren Mikrometern Entfernung vom Versetzungskern nachweisbar. Für diesen Bereich werden Vergleiche der Messergebnisse mit elastizitätstheoretischen Berechnungen durchgeführt. Die elektrische Potentialverteilung in Umgebung der geladenen Versetzungen wird mittels Rasteroberflächenpotentialmikroskopie untersucht.

HL 51.8 Di 12:30 TU P-N202

Electrical and Optical Properties of Highly Si-Doped AlN — •Martin Hermann[1], Florian Furtmayr[1], Markus Maier[1], Martin Stutzmann[1], Eva Monroy[2] und Martin Eickhoff[1] — [1]Walter Schottky Institut, Technical University Munich, Am Coulombwall 3, D-85748 Garching, Germany — [2]CEA-Grenoble, 17 rue des Martyrs, 38054 Grenoble Cedex 9, France

Within the group III-nitride alloy system, AlN has the widest direct band gap of 6.2 eV, which makes it a useful material for optoelectronic applications in the UV spectral regime. For such applications the achievement of controllable n-type conductivity is crucial. Silicon, known as shallow donor in Ga-rich AlGaN alloys, is considered as the preferable donor in AlN. Due to its high ionization energy, it is difficult to achieve a significant conductivity. One possible approach is the increase of the Si-concentration above the threshold for impurity band formation, estimated to approximately 1 at. %.

We present a systematic study of highly Si-doped AlN layers grown by MBE on c-plane sapphire. Electrical characterization revealed an increasing donor ionization energy up to 240 meV for a Si content of 1.1×10^{21} cm^{-3}. For higher silicon concentrations we observed a sharp increase in conductivity by four orders of magnitude, attributed to the onset of impurity band conduction.

In addition, optical characterisation by absorption and cathodoluminescence measurements were performed and the influence of strong Si-doping on the optical properties of AlN is discussed.

HL 51.9 Di 12:45 TU P-N202

Strukturelle Untersuchungen an Mn-dotierten GaN-Schichten — •T. Niermann, M. Kocan, M. Röver, M. Seibt und A. Rizzi — IV. Physikalisches Institut der Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

Für den magnetisch verdünnten Halbleiter GaN:Mn sagen theoretische Arbeiten ferromagnetische Eigenschaften bei Raumtemperatur vorher. Wir haben strukturelle Untersuchungen mittels hochaufgelöster Transmissionselektronenmikroskopie (HRTEM) und energiedispersiver Röntgenanalyse (EDX) an per Molekularstrahlepitaxie (MBE) gewachsenen hexagonalen GaN:Mn-Schichten durchgeführt. Bei der Herstellung wurde zwischen die GaN:Mn-Schicht und das (111)-Si-Substrat eine AlN-Pufferschicht gewachsen, die die Defektdichte im GaN reduziert. Bei einem Mn-Anteil von 5% ist ein Teil des Mn homogen im GaN gelöst. Zusätzlich finden sich etwa 10 nm große Mn-reiche Ausscheidungen, die vorwiegend an Versetzungen beobachtet werden. Wir diskutieren die möglichen Phasen dieser Ausscheidungen.

HL 51.10 Di 13:00 TU P-N202

Heteroepitaxial Growth of Group III-Nitrides on Diamond — •Olaf Weidemann, Martin Hermann, Markus Maier, Martin Stutzmann und Martin Eickhoff — Walter Schottky Institut, Technical University Munich, Am Coulombwall 3, D-85748 Garching, Germany

The combination of group III-nitrides with diamond allows to overcome several basic problems of the individual material systems such as the lack of band-gap engineering in diamond, the substrate thermal conductivity of group III-nitrides or the doping problem. It is challenging to produce n-type diamond and, up to date, p-type doping of AlN has not been realized. However, the combination of p-type diamond with n-type AlGaN allows the fabrication of UV light emitting diodes. in addition diamond as a substrate is an excellent heat sink for high power devices.

We have studied the influence of diamond surface termination (O or H) and orientation {(001) or (111)} on the growth of group III-nitrides. We have deposited epitaxial layers (GaN, AlN), which were subsequently overgrown with a GaN/AlGaN/GaN heterostructure. High resolution X-ray diffraction measurements were performed to determine the crystal quality and orientation with respect to the diamond substrate. Due to the pyro- and piezoelectric character of group III-nitrides, close to one of the interfaces a two-dimensional electron gas (2DEG) is formed. Using capacitance-voltage profiling, the position of the 2DEG and thus the polarity of the material can be determined.

HL 52 Hauptvortrag Mirlin

Zeit: Dienstag 14:15–15:00 Raum: TU P270

Hauptvortrag HL 52.1 Di 14:15 TU P270

2D electron gas under microwaves: Theory of oscillatory photoresistivity and zero-resistance states — •A.D. Mirlin[1,2], I.A. Dmitriev[1], M.G. Vavilov[3], I.L. Aleiner[4], and D.G. Polyakov[1] — [1]Inst. fuer Nanotechnologie, Forschungszentrum Karlsruhe, 76021 Karlsruhe — [2]Inst. fuer Theorie der kondensierten Materie, Universitaet Karlsruhe, 76128 Karlsruhe — [3]Dept. of Applied Physics, Yale University, New Haven, CT 06520, USA — [4]Physics Dept., Columbia University, New York, NY 10027, USA

Recent experiments have discovered that the resistivity of a 2D electron gas subjected to microwave radiation exhibits striking magnetooscillations and that at sufficiently high microwave power regions of zero resistance develop. We review the theory of this spectacular phenomena. Considering different mechanisms, we show that leading contribution is due to the effect of the microwaves on the electron distribution function. We analyze the spontaneous formation of the zero-resistance domains, as well as inelastic relaxation due to electron-electron collisions governing the temperature dependence of the effect. We further predict that the above mechanism induces also strong magnetooscillations of the local compressibility. The compressibility measurements should provide information about the domain structure of zero-resistance states. Finally, open questions are discussed.

HL 53 Transport im hohen Magnetfeld/Quanten-Hall-Effekt

Zeit: Dienstag 15:00–16:45 Raum: TU P270

HL 53.1 Di 15:00 TU P270

Edge states at corner junctions of two orthogonal quantum Hall systems — •Lucia Steinke and Matthew Grayson — Walter Schottky Institut, TU München, D-85748 Garching, Germany

Recently Grayson et al. [1] succeeded in fabricating a new kind of GaAs/AlGaAs heterostructure with a high-mobility two-dimensional electron system bent at an atomically sharp 90° angle. When a quantizing magnetic field is applied to the structure with a tilt angle θ, the system represents a corner junction of two orthogonal quantum Hall systems with filling factor ratio $\frac{\nu_1}{\nu_2} = \frac{n_1}{n_2} \tan\theta$, where n_1 and n_2 are the 2D electron densities on the respective facets. The bandstructure of this novel quantum Hall line junction in a tilted magnetic field was calculated in the Hartree approximation, revealing a non-trivial corner dispersion. Based on the calculated results for the edge channel spectrum, the corner state could be interpreted as a hybrid system of quantum Hall edges with a bound wire state at the corner. Repeated calculations at various tilted magnetic fields allowed predictions about the conductance properties of the corner states, yielding qualitative explanations for the experimental results presented in Ref. [1].

[1] M. Grayson, D. Schuh, M. Huber, M. Bichler, and G. Abstreiter, APL, to be published; M. Grayson, D. Schuh, M. Bichler, M. Huber, G. Abstreiter, L. Hoeppel, J. Smet, and K. von Klitzing, Physica E 22, 181 (2004)

HL 53.2 Di 15:15 TU P270

Activation gaps of different fractional quantum Hall states — •A.F. Dethlefsen[1], F. Schulze-Wischeler[1], R.J. Haug[1], and W. Wegscheider[2] — [1]Institut für Festkörperphysik, Universität Hannover, D-30167 Hannover — [2]Institut für Angewandte und Experimentelle Physik, Universität Regensburg, D-93040 Regensburg

The activation gap Δ of the fractional quantum Hall states at constant fillings $\nu = 2/3$, $2/5$ and $1/3$ has been measured as a function of the perpendicular magnetic field B for various electron densities. For each density we measured the temperature dependence of the resistivity $\rho_{xx}(T)$. We observe activated transport $\rho_{xx} \propto \exp(-\Delta/2T)$. A linear dependence of Δ on B is observed for $\nu = 2/3$ and $2/5$ while approaching the spin polarization transition for both fillings with different slopes. This allows a direct measurement of the g-factor of composite fermions (CFs).

To obtain a deeper insight in the dependence of the activation gap on the electronic filling factor we perform further measurements at filling factor $\nu = 1/3$ in a wider magnetic field range, where spin-effects should only play a role at small magnetic fields.

[1] F. Schulze-Wischeler, E. Mariani, F. Hohls and R. J. Haug, Phys. Rev. Lett. **92**, 156401 (2004

HL 53.3 Di 15:30 TU P270

Spin Splitting Studied by Tunneling between Edge States — •G. Sukhodub[1], R. Winkler[1], F. Hohls[1], R. J. Haug[1], D. K. Maude[2], D. Reuter[3], and A. D. Wieck[3] — [1]Institut für Festkörper Physik, Universität Hannover, Germany — [2]High Magnetic Field Laboratory, CNRS, Grenoble, France — [3]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Germany

A concept of selective population and detection of edge states (ES's) in the quantum Hall regime attracted considerable attention in recent years. Dependent on the width of an incompressible strip separating two ES's and on the length of the interaction region between them two different transport regimes, viz. equilibrated and adiabatic, can be realized. At filling factor three, for instance, decoupled transport in the innermost ES was recently demonstrated which allowed to identify an interedge magnetoplasmon mode [1].

At filling factor two, which is the subject of the present study, a transition from the adiabatic to the equilibrated regime was investigated as a function of the in-plane magnetic field. We found that the Zeeman energy with $|g^*| = 0.44$ mainly accounts for the observed threshold voltage. The deviation from the linear dependence on the magnetic field at higher fields is in good agreement with a self-consistent calculation of the subband structure. There are no indications of exchange interaction considerably affecting the measured energy gaps at the edge of a two-dimensional system.

[1] G. Sukhodub, F. Hohls, and R. J. Haug, Phys. Rev. Lett. **93**, 196801 (2004)

HL 53.4 Di 15:45 TU P270

Parametric resonance of a two-dimensional electron gas under bichromatic irradiation — •Christian Joas[1], Mikhail E. Raikh[2], and Felix von Oppen[1] — [1]Fachbereich Physik, FU Berlin, Arnimallee 14, D-14195 Berlin — [2]Department of Physics, University of Utah, Salt Lake City, UT 84112

In ultrahigh mobility 2D electron systems, even a weak nonparabolicity of the electron dispersion, by violating Kohn's theorem, can have a drastic effect on dc magnetotransport under ac (microwave) drive. We study theoretically the manifestation of this effect in the dc response to the combined action of two driving ac-fields (bichromatic irradiation) within a simple classical model. Compared to the case of monochromatic irradiation, which is currently intensively studied both experimentally and theoretically, the presence of a second microwave source provides additional insight into the properties of an ac-driven 2D electron gas. We show[1] that nonparabolicity gives rise to new qualitative effects specific to bichromatic irradiation, namely parametric resonance and multistability within certain frequency ranges. For suitable microwave frequencies, this parametric instability can manifest itself in the dc properties of the system.

[1] C. Joas, M. E. Raikh, F. von Oppen, preprint cond-mat/0405443, to appear in Phys. Rev. B

HL 53.5 Di 16:00 TU P270

Spin-polarized Edge-States of Quantum Hall Systems on Silicon Basis — •Carsten Kentsch, Wolfgang Henschel, and Dieter P. Kern — Institut für Angewandte Physik, Auf der Morgenstelle 10, 72076 Tübingen

Spin-polarized electrons exist in the edge-states of two-dimensional electron gases (2DEG) at high magnetic fields. They can be used to study the scattering between the spin-states by measuring the electric current. Recently 2DEG-systems in silicon have attracted attention as the main isotope of silicon has no nuclear spin. This means that the probability of spin scattering of the electrons with the base material is much lower than e.g. in GaAs based systems. As a consequence the life times of the spin-polarized electrons are expected to be longer. They can be used for the detection of nuclear spin states of specifically implanted phosphorus atoms which are suitable as quantum bits in quantum computers.

Here Hallbar structures on the basis of MOS-transistors with chromium split-gates below a Ti/Al topgate were fabricated to determine possible electron transfer between edge states. They were characterized at magnetic field strengths of up to 8 Tesla and a temperature of 1.5 Kelvin.

HL 53.6 Di 16:15 TU P270

Einfluss der Spin-Bahn-Wechselwirkung auf den Magnetotransport in Elektronenkanälen — •Ralf Dinter[1], Stephan Löhr[1], Stephan Schulz[1], Christian Heyn[1], Stefan Kettemann[2] und Wolfgang Hansen[1] — [1]Universität Hamburg, Institut für Angewandte Physik, Jungiusstr. 11, 20355 Hamburg — [2]Universität Hamburg, I. Institut für Theoretische Physik, Jungiusstr. 9, 20355 Hamburg

An Hallstreifen aus GaAs/AlGaAs-Heterostrukturen verschiedener Breite zwischen 100 und 2,7 Mikrometer wurde der Einfluss der Spin-Bahn-Wechselwirkung auf den Magnetotransport untersucht.

Bei der schwachen Lokalisierung handelt es sich um ein kohärentes Rückstreuphänomen, das zu einem negativen Magnetowiderstand führt. Entscheidend für die Beobachtung ist, dass die Phasenkohärenz entlang eines geschlossenen diffusiven Weges erhalten bleibt. Ändert sich zusätzlich der Spin-Zustand entlang des Pfades, so kommt es zu einem positiven Magnetowiderstand, der schwachen Antilokalisierung. Sie bietet eine Möglichkeit, die Stärke der Spin-Bahn-WW zu bestimmen. Es werden Messungen vorgestellt, die einen deutlichen Einfluss der Kanalbreite auf die Antilokalisierung in den GaAs/AlGaAs-Strukturen demonstrieren.

Alternativ wird die Spin-Bahn-WW anhand des charakteristischen Schwebungsmusters in der Shubnikov-de Haas-Oszillation bestimmt. Bei Verkleinerung der Kanalbreite unter 50 Mikrometer zeigt sich hier ein unerwartetes Verschwinden des Schwebungsmusters in der SdH-Messung, das nicht im Rahmen der üblichen Modelle zur Beschreibung der Spin-Bahn-WW verstanden werden kann.

HL 53.7 Di 16:30 TU P270

First experiments in epitaxial growing of carbon doped two-dimensional hole gases (2DHGs) in GaAs/AlGaAs heterostructures resulting in mobilities beyond 10^6cm^2/Vs — •Christian Gerl, Stefan Schmult, Hans Peter Tranitz, and Werner Wegscheider — Universität Regensburg, Institut für Experimentelle und Angewandte Physik, 93040 Regensburg

The almost perfect lattice match between Galliumarsenide (GaAs) and Aluminumarsenide (AlAs) yield some important developments in the heteroepitaxy within the last 30 years. Results are for example high electron mobility two-dimensional electron gases exceeding mobility values in the order of 10^7cm^2/Vs. High electron mobilities are essential for the fractional quantum hall effect. Even if the epitaxial growth of low-dimensional high mobility electron systems in GaAs/AlGaAs heterostructures is a state of the art technique today, the growth of similar holes systems is still a fundamental challenge. Beryllium, for instance, acts like an acceptor in (001) GaAs and AlGaAs, with the disadvantage of the segregation for the underlying growth conditions. Silicon, acting as the standard donor in the considered material system for many growth directions, can also yield hole doping, e.g. on (311) GaAs. Recently, the signature of the quantum hall effect in carbon-doped 2DHGs has been reported. We will present our results on C-doped high mobility 2DHGs in the heterosystem GaAs/$Al_{0.33}Ga_{0.67}As$. Optimization has led to hole mobilities up to 1.1×10^6cm^2/Vs at densities of 2.5×10^{11}cm^2 determined in low temperature magnetotransport measurements.

HL 54 Photonische Kristalle III

Zeit: Dienstag 15:00–16:30 Raum: TU P164

HL 54.1 Di 15:00 TU P164

Laser Direct Writing of three-dimensional Photonic Crystals in high-index of refraction chalcogenide glasses — •Sean Wong[1], Georg von Freymann[1], Geoffrey A. Ozin[1], Markus Deubel[2,3,4] und Martin Wegener[2,3,4] — [1]Materials Chemistry Research Group, Department of Chemistry, University of Toronto, M5S 3H6, Toronto, Canada — [2]Institut für Angewandte Physik, Universität Karlsruhe (TH), 76128 Karlsruhe — [3]Institut für Nanotechnologie, Forschungszentrum Karlsruhe, 76021 Karlsruhe — [4]CFN, Universität Karlsruhe (TH), 76128 Karlsruhe

We present a two-step method for the direct fabrication of high-index of refraction three-dimensional Photonic Crystals.

Direct laser writing [1] in arsenic-sulphur based thin films of chalcogenide glasses with high-intensity 120fs pulses induces a local chemical phase change via two-photon absorption to As_2S_3. The inscribed three-dimensional Photonic Crystals are subsequently etched out with a specially designed wet chemical etchant. In principle, the index of refraction of As_2S_3 ($n = 2.45$) is high enough to open a complete band gap in diamond-like crystal structures, e.g. the woodpile structure, although further optimization of the writing process is required to achieve this goal. As our approach does not require any subsequent inversion with high index material, it might prove as a new route for the direct fabrication of functional Photonic Crystals.

[1] M. Deubel et al., Nature Materials 3, 444 (2004)

HL 54.2 Di 15:15 TU P164

Focusing and negative group velocity in a planar array of dielectric rods — •Dan Davidov[1], Yair Neve-Oz[1], Yuval Saado[1], Michael Golosovsky[1], and Avri Frenkel[2] — [1]Racah Institute of Physics, Hebrew University of Jerusalem, 91904 Jerusalem, Israel — [2]ANAFA Electromagnetic Solutions Ltd, P.O.B. 5301, Kiriat Bialik 27000, Israel

We suggest 2D photonic crystals (PC) consisting of a periodical array of dielectric rods in which array of point defects form a superlattice. The defects are made from different dielectric rods with different sizes and different dielectric constants. The distance between the defects is such that they are electromagnetically coupled to form coupled cavity propagating mode, CCM . This results in a defect band inside the photonic bandgap. Simulations using ANSOFT software demonstrate, at frequencies corresponding to the defect band, an extremely low group velocity in finite size PC and a negative group velocity in the band structure of infinite size PC. The above results are based on simulations. As a first step towards implementation, we have constructed a 2D photonic band gap material consisting of dielectric rods designed to operate in the mm wave range. In particular, we made from it a concave mirror and showed that in the frequency range corresponding to photonic stopband this mirror allows wave focusing with the spot size of 0.35 lambda. In this case simulations and experiments completely agree, so we are confident that a negative group velocity both in the microwave and in the infrared range can be realized using the CCM idea presented here.

HL 54.3 Di 15:30 TU P164

GaN Photonische Kristall Membran Kavitäten — •Cedrik Meier[1,2], Kevin Hennessy[1], Elaine D. Haberer[1], Rajat Sharma[1], Kelly McGroddy[1], Steven P. DenBaars[1], Shuji Nakamura[1] und Evelyn L. Hu[1] — [1]Materials Department, University of California, Santa Barbara, CA 93106 — [2]Experimentalphysik, Universität Duisburg-Essen, D-47048 Duisburg

Photonische Kavitäten wie Mikrodisks, Mikropillars und Photonische Kristall-Kavitäten bieten die Möglickeit, Licht in definierte, wohldefinierte Moden einzuschließen. Durch Kopplung von aktiven Schichten (Q-Dots / Wells) an diese Moden kann die Emission verändert werden (Purcell-Effekt). Anwendungen sind etwa Lasing mit niedriger Schwelle oder in der Quanten-Kryptographie. Von allen o. a. photonischen Resonatoren bieten Defekte in photonischen Kristallen das kleinste Modenvolumen bei hohen Q-Faktoren. Um dies zu erreichen, stellen wir dünne Membranstrukturen mit einem 2D photonischen Kristall-Defekt her. In vertikaler Richtung sorgt der Unterschied im Brechungsindex zwischen GaN und der Umgebung für den photonischen Einschluss. Die Herstellung solcher Membranen in verschiedenen Materialien kann durch konventionelles selektives Ätzen erreicht werden. In GaN ist dies nicht möglich, da in diesem System keine konventionelle Nass-Ätze zur Verfügung steht. Wir verwenden daher Bandgap-selektives photoelektrochemisches Ätzen, um eine Opferschicht selektiv zu unterätzen, während die aktive Schicht nicht angegriffen wird. Wir stellen unsere Ergebnisse zur erfolgreichen Herstellung solcher Membranen vor. Wir stellen auch FDTD Simulationen vor, um die Eigenschaften dieser Defekte in GaN zu diskutieren.

HL 54.4 Di 15:45 TU P164

Investigation on fabrication-related disorder in three-dimensional macroporous silicon photonic crystals — •Sven Matthias, Frank Müller, Reinald Hillebrand, and Ulrich Gösele — Max Planck Institute of Microstructure Physics; Weinberg 2; D-06120 Halle; Germany

Recently it was demonstrated that different kinds of simple cubic three-dimensional photonic crystals could be fabricated in macroporous silicon possessing a complete photonic bandgap. We will focus in detail on the photoelectrochemical etching process and its important parameters. The fabrication-related disorder is investigated by FTIR-spectroscopy and SEM pictures. We will figure out, how several parameters of the fabrication process influence the degree of disorder. A route towards an optimized three-dimensional photonic crystals based on macroporous silicon will be given.

HL 54.5 Di 16:00 TU P164

Fabrication of photonic crystals and templates by two-photon polymerization technique — •Aleksandr Ovsianikov[1], Ruth Houbertz[2], and Boris Chichkov[1] — [1]Laser Zentrum Hannover e.V. — [2]Fraunhofer-ISC Würzburg

Two-photon polymerization (2PP) is a powerful technology for the fabrication of 3D structures with submicrometer resolution. In this contribution we present our recent results on the fabrication of woodpile photonic crystal structures and investigation of their optical properties. The specific applied photosensitive materials are ORMOCER and SU8. Photonic crystals fabricated in these materials exhibit a bandgap in the near infrared spectral region. First results of template fabrication for the realization of high refractive index Ti:O2 replicas will be demonstrated.

HL 54.6 Di 16:15 TU P164

Spektroskopie von Quantenpunkten in Resonatoren auf der Basis photonischer Kristalle — •Martin Kamp, Rafael Herrmann, Helmut Scherer, Sergei Zaitsev, Stephan Reitzenstein und Alfred Forchel — Technische Physik, Am Hubland, D-97074 Würzburg

Photonische Kristalle ermöglichen durch ihre Bandlücke die Herstellung von Resonatoren mit kleinen Modenvolumina und hohen Güten. Durch die Kombination mit Schichten aus selbstorganisierten Quantenpunkten können Effekte wie z.B. die Erhöhung der spontanen Emissionrate (Purcell-Effekt) beobachtet werden. Als vielversprechenste Geometrie haben sich dabei zweidimensionale photonische Kristalle auf der Basis von Halbleitermembranen herausgestellt. Wir berichten über die Herstellung und Spektroskopie von derartigen Strukturen. Die Resonatoren sind durch ein oder mehrere ausgelassene Löcher in einem hexagonalen photonischen Kristallgitter definiert. Als Membran wird eine dünne GaAs Schicht verwendet, die durch eine Kombination von Trockenätzen und anschliessender selektiver nasschemischer Entfernung einer Opferschicht strukturiert wird. In der Mitte der Membran befindet sich eine Lage von InGaAs Quantenpunkten. Im Lumineszenzspektrum zeigen sich die Resonatormoden als scharfe Linien über einem breiten Untergrund von Leckmoden. Die Güte der Resonanzen wird dabei durch die Position der Löcher in der Berandung starkt beeinflusst. Zur Optimierung der Güten wird die Feldverteilung im Resonator so eingestellt, dass sie möglichst wenig Anteile von Blochmoden über der Lichtline enthält.

HL 55 Quantenpunkte und -drähte: Herstellung und Charakterisierung II

Zeit: Dienstag 15:00–16:30 Raum: TU P-N201

HL 55.1 Di 15:00 TU P-N201

Querschnitts-Rastertunnelmikroskopie an stickstoffhaltigen InAs/GaAs-Heterostrukturen — •M. Müller[1], A. Lenz[1], L. Ivanova[1], R. Timm[1], H. Eisele[1], M. Dähne[1], O. Schumann[2], L. Geelhaar[2] und H. Riechert[2] — [1]Technische Universität Berlin, Institut für Festkörperphysik, PN4-1, Hardenbergstr. 36, 10623 Berlin — [2]Infineon Technologies, Corporate Research Photonics, 81730 München

Die Rastertunnelmikroskopie an Querschnittsflächen ist eine geeignete Methode zur Untersuchung vergrabener Heterostrukturen, ihrer Struktur und chemischen Komposition[1]. Untersucht wurden mittels Molekularstrahlepitaxie gewachsene, vergrabene InAs/GaAs Quantenpunkt-Doppelstapel, die unter verschiedenen Wachstumsparametern, insbesondere Stickstoffbeimengungen in der Quantenpunktschicht und der Zwischenschicht hergestellt wurden.

Beobachtet wurde eine zunehmende Veränderung der Quantenpunktform und eine teilweise Auflösung der Benetzungsschicht. Ferner wurden Oberflächendefekte beobachtet, die beim Spalten des Kristalls aufgrund von Verspannungen durch den Stickstoffeinbau entstehen[2]; ebenso konnte der Einbau von Stickstoff in das GaAs-Substrat auf atomarer Ebene untersucht werden.

[1] A. Lenz, R. Timm, H. Eisele, M. Dähne et al.,
Appl. Phys. Lett. **81**, 5150 (2002)
[2] H. A. McKay, R. M. Feenstra, J.Vac.Sci.Technol. B **19**, 1644 (2001)

HL 55.2 Di 15:15 TU P-N201

Aligned InAs quantum dots grown on an epitaxially patterned (110) GaAs surface — •Jochen Bauer, Dieter Schuh, Emanuelle Uccelli, Robert Schulz, Max Bichler, Jonathan Finley, and Gerhard Abstreiter — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, D-85748 Garching

The control of the position of quantum dots is an important demand for the use of quantum dots in future devices and can e.g. be achieved by lithographic methods. A new approach is to self-align InAs quantum dots on defined positions on a (110) GaAs surface as recently demonstrated [1]. Here the template to determine the position of the quantum dots is fabricated using the cleaved edge overgrowth technique (CEO): In a 1st growth step, a series of AlAs layers is grown with molecular beam epitaxy (MBE) on (001) GaAs. By *in situ* cleaving this substrate, a smooth (110) GaAs surface with alternating GaAs and AlAs stripes is obtained. The subsequent deposition of InAs on this surface leads to the formation of InAs quantum dots on top of the AlAs stripes. Due to the high precision of MBE, an atomically precise positioning of these quantum dot chains is possible. Futhermore the size of the quantum dots is correlated with the thickness of the AlAs-stripes, and, hence, can be adjusted in the first MBE growth step. Therefore also the emission energy of these dots is adjustable and μ-PL investigations demonstrate the good optical qualities of these quantum dots.

[1] J. Bauer et al., Appl. Phys. Lett. 85, 4750(2004)

HL 55.3 Di 15:30 TU P-N201

Optical investigation of nanoelectromechanical actuations — •Christine Meyer, Heribert Lorenz, and Khaled Karrai — Center for NanoScience and Physics Department, LMU München

Due to their small sizes and their even smaller actuation ranges nanoelectromechanical systems (NEMS) are not easy to characterize. Electron microscopy seems to be well suited for their investigation but the electrical interaction with the nanostructures can be highly destructive. Here, we present an all-optical method to non-destructively detect NEMS deflections and thus test the functionality of nanomechanical actuators.

The optical investigation was performed on silicon-based cantilevered nanobeams defined by electron-beam lithography. The free-standing cantilevers were either located 400 nm above a silicon substrate or the substrate right beneath the cantilevers was removed. Electrostatic actuation of the nanostructures was achieved by applying a voltage drop between two cantilevers.

Images of the NEMS were taken by confocal scanning optical microscopy while the cantilevers were electrostatically actuated under a low frequency voltage. By demodulation at the actuation frequency displacements of less than 0.5 nm were resolved.

HL 55.4 Di 15:45 TU P-N201

Structure and morphology of InGaN nano-islands on GaN studied by STM — •Subhashis Gangopadhyay, Thomas Schmidt, Sven Einfeldt, Tomohiro Yamaguchi, Detlef Hommel, and Jens Falta — Institute of Solid State Physics, University of Bremen, P. O. Box 330440, Bremen 28334, Germany

Scanning tunneling microscopy (STM) has been used to study the structure and morphology of InGaN nano-islands on GaN/Sapphire. InGaN islands were grown by metal organic vapor pressure epitaxy (MOVPE) for different choices of growth temperature, InGaN deposit, growth rate and III:V flux ratio. After growth, the samples were transferred to the UHV-STM analysis chamber under nitrogen ambient to suppress surface oxidation. Depending on the various growth parameters, three different types of InGaN islands are observed. The lateral size (diameter) of the islands was ranging from 15 nm to 100 nm whereas the height of the islands varied from 1 nm to 8 nm. The top of the larger islands (650°C growth temperature), appears very flat and a spiral disc-like growth with monolayer step-height was observed. Excess In was found in droplets preferentially on the top of the InGaN islands. For smaller islands (600°C growth temperature), homogeneously distributed island with high density were observed.

HL 55.5 Di 16:00 TU P-N201

One-Dimensional Electronic States on Si(111)-2×1: Observation of a Coulomb Gap at low T — •J. K. Garleff[1], M. Wenderoth[1], R. G. Ulbrich[1], C. Sürgers[2], and H. v. Löhneysen[2] — [1]IV. Physikalisches Institut, Universität Göttingen, D-37077 Göttingen — [2]Physikalisches Institut and DFG Center for Functional Nanostructures (CFN), Universität Karlsruhe, D-76128 Karlsruhe

Scanning tunneling microscopy and -spectroscopy was performed on Si-(111)-2×1 at 8 K with a spectral resolution of ∼10 mV. A disorder induced tail of the surface conduction band is observed in the surface band gap *below* the Fermi energy E_F. At $E = E_F$ a Coulomb gap of width W of up to 150 mV opens. W scales inversely with the undisturbed length L^{-1} of the π-bonded chain between two monatomic steps on the cleaved surface ($10nm \leq L \leq 100nm$). In the case of π-bonded chains that contain a substitutional Phosphorus (P) atom, W increases according to the shortened length of the chain. The enlarged gap is found only on the individual chain interrupted by the P atom. This experimental observation excludes any coupling between neighboring π-bonded chains. Within a factor 2, the measured $W(L^{-1})$ fits quantitatively to the Coulomb gap

calculated from the capacitance [1] of the one dimensional (1D) segments of the π-bonded chains with finite length. The scaling $W \propto L^{-1}$ and the absence of coupling between the chains is interpreted as experimental evidence for a 1D electronic system in the π-bonded chains at low temperature $T = 8K$.

[1] D. V. Averin and K. K. Likharev, J. Low Temp. Phys. 62, 345 (1986)

HL 55.6 Di 16:15 TU P-N201

Einfluss der Verspannung auf die Bildung von GaInAs/GaAs Quantenpunkten — •A. Löffler[1], J.-P. Reithmaier[1], A. Forchel[1], A. Sauerwald[2], T. Kümmell[2] und G. Bacher[2] — [1]Technische Physik, Universität Würzburg — [2]Werkstoffe der Elektrotechnik, Universität Duisburg-Essen

Selbstorganisierte Quantenpunktstrukturen im GaInAs/GaAs-Materialsystem werden üblicherweise im sogenannten "Stranski-Krastanov"-Wachstumsmodus hergestellt. Hierbei ist die Verspannung die treibende Kraft für die Bildung der Quantenpunkte, die sich ab einer gewissen kritischen Schichtdicke bilden. Dabei wird die Dichte und Größe der Quantenpunkte im Wesentlichen durch die abgeschiedene Materialmenge bzw. deren Zusammensetzung beeinflusst.

Um insbesondere große Quantenpunktstrukturen mit geringer Dichte für Grundlagenuntersuchungen herzustellen, wurde der Einfluss der Verspannung auf die Quantenpunktbildung untersucht, wobei der Indiumgehalt sukzessive von 60 % über 45 % auf 30 % reduziert wurde. Die Quantenpunktstrukturen wurden in einer Feststoffquellen-MBE gewachsen, mit Tieftemperatur-Photolumineszenz-Messungen optisch charakterisiert bzw. ihre Morphologie mittels REM- bzw. TEM-Messungen untersucht.

HL 56 Photovoltaik I

Zeit: Dienstag 15:00–16:30 Raum: TU P-N202

HL 56.1 Di 15:00 TU P-N202

Voltage dependent series resistance of thin film Cu(In, Ga)Se_2 solar cells — •Osama Tobail and Juergen Werner — Pfaffenwaldring 47, D-70569 Stuttgart, Germany

Series resistance R_s and ideality factor n_{id} deteriorate the performance of solar cells. Usually, we measure the dark current(I)/voltage(V)-curves and determine R_s and the n_{id} from a plot of conductance(G)/current(I) versus conductance(G) [1]. However, in the case of Cu(In, Ga)Se_2 (CIGS) this plot is curved, indicating that R_s decreases with increasing V. In order to investigate this V-dependence in details, we use a series of samples with different thicknesses of the CdS-buffer and the CIGS-absorber. The ideality factor n_{id} from the dark I/V-curve depends on the buffer thickness and correlates with the V-dependence of R_s. An analysis of the *illuminated* I/V-curves at different illumination levels is particularly suitable to investigate the voltage dependent R_s in more details. The series resistance R_s consists of two parts: One part is independent of V, the other part decays exponentially with V. This voltage dependence of R_s is the result of a voltage dependent charge at the grain boundaries of the polycrystalline CIGS solar cells.

[1] J. H. Werner, Appl. Phys. A47, 291 (1988).

HL 56.2 Di 15:15 TU P-N202

Effect of Zn and Mg doping on the electronic properties of CuInS2 thin films and solar cells — •Tobias Enzenhofer, Thomas Unold, Roland Scheer, and Hans-Werner Schock — Hahn-Meitner-Institut Berlin, Glienicker Str. 100, D-14109 Berlin

Solar cells based on CuInS2 still suffer from Voc limitation compared to the theoretically achievable value as expected from the optical band gap of 1.5 eV. Open circuit voltage can be significantly enhanced from about 700 mV to more than 800 mV via controlled doping by Zinc or Magnesium, whereas the efficiency remains mostly constant. The increase of the open circuit voltage occurs in spite of an extended red response. In order to investigate this phenomenon we used on the one hand well-known standard tools to perform the basic characterisation of photovoltaic cells (I/U and quantum efficiency (QE) measurements). On the other hand we applied photoluminescence spectroscopy (PL) to analyse the defect structure of doped CuInS2. By combining electrical and photoluminescence analyses we evaluate the influence of doping on the device properties, i.e. the quality of the CuInS2-absorber layers and the ZnO-CdS-CuInS2 heterostructure.

HL 56.3 Di 15:30 TU P-N202

Static solar concentrators under Stuttgart insolation conditions — •C. Carlsson, M. B. Schubert, and J. H. Werner — Institut für Physikalische Elektronik, Uni-Stuttgart, Pfaffenwaldring 47, 705 69 Stuttgart

Static concentrators offer a possibility to concentrate sun light onto solar cells without a costly tracking device. The annual efficiency of such concentrators depends on their specific design, on the inclination angle towards the sun, as well as on the insolation conditions. This study evaluates the gain of two- and three-dimensional V-trough concentrators with a side-wall angle of 60°, located in Stuttgart with a tilt towards South with 48°. In order to simulate the optical acceptance of the V-troughs for all relevant incident angles of light, we developed an appropriate raytracing program. Calculations using the optical acceptance and radiation data representative for Stuttgart yield an annual irradiance gain of the order of 1.5 for both types of concentrating systems. In contrast to our first expectations, the three-dimensional trough exhibits a slightly lower annual irradiance gain than the two-dimensional system. This effect is explained by enhanced shadowing effects due to the restricted acceptance angle in the East-West direction.

HL 56.4 Di 15:45 TU P-N202

Local inhomogeneities of the quality of the photo excited state and of material composition in $Cu(In,Ga)Se_2$-absorbers in the few micrometer scale by sub-micron resolved photoluminescence — •Levent Gütay, Rudolf Brüggemann, and Gottfried Heinrich Bauer — Institute of Physics, Carl von Ossietzky University Oldenburg, Germany

We have recorded spectrally resolved photoluminescence from $Cu(In,Ga)Se_2$ absorbers (Ga content of 29% and 46%) deposited on Mo coated substrates and overcoated by a 50 nm thick CdS layer. The absorber quality corresponds to pilot line thin film solar cell production with module efficiencies of 12-14 %. We translate the lateral variation of the luminescence yield into the splitting of the quasi Fermi levels, say laterally varying open circuit voltages. Further we discuss the laterally varying low energy wing of PL-spectra, reflecting variations of optical threshold energies for absorption/emission (band gap) of about 15 meV, in terms of variations in material composition, such as Ga-content. The comparison of XPS-analyses with high lateral resolution fits qualitatively to this explanation.

HL 56.5 Di 16:00 TU P-N202

Amorphous silicon solar cells under different illumination levels — •A. Al Tarabsheh, M. B. Schubert, and J. H. Werner — Institut für Physikalische Elektronik, Uni-Stuttgart, Pfaffenwaldring 47, 705 69 Stuttgart

The use of hydrogenated amorphous silicon-based (a-Si:H) solar cells in consumer products, and their potential for clothing-integrated photovoltaics (*ipv*) motivate us to study their performance under different illumination levels. In this work, we analyse the current/voltage (I/V) characteristics of a-Si:H solar cells as a function of the illumination intensity Φ. We start with the most simple equivalent circuit model of a real solar cell, with incorporating series and parallel resistances. Our measurements yield in an illumination-intensity dependent parallel resistance $R_p(\Phi)$ rather than a constant one. The decrease in R_p with Φ follows a power law, which we explain by the photoconductivity of parallel resistances that are distributed over the whole solar cell area. The dependence of R_p on Φ deteriorates the solar cell fill factor FF and conversion efficiency at high illumination levels. Therefore the implicit relation between FF and open-circuit voltage, which is generally valid for ideal solar cells, does not hold for our cells.

HL 56.6 Di 16:15 TU P-N202

Photoluminescence, Open Circuit Voltage, and Photocurrents in $Cu(In,Ga)Se_2$ Solar Cells with Lateral Submicron Resolution — •Tim Jürgens, Levent Gütay, Rudolf Brüggemann, and Gottfried Heinrich Bauer — Institute of Physics, Carl von Ossietzky University Oldenburg, Germany

Thin film $Cu(In,Ga)Se_2$ solar cells prepared under conditions similar

to pilot line module production have been analyzed with respect to local photoluminescence and according splitting of quasi-Fermi levels with submicron lateral resolution under open circuit and short circuit conditions. The lateral patterns of luminescence yields, announcing variations of quasi-Fermi energies in the range of some tens of meV and extending to some microns, by far exceed the size of individual grains of 1 micron or less. The response of PL, say, of local V_{oc}, with that of short circuit currents turns out to be anti-correlated significantly. This behaviour will be discussed in terms of a two dimensional network coupling illuminated and dark regimes and containing non-linear elements.

HL 57 Poster IIa

Zeit: Dienstag 16:30–19:00 Raum: Poster TU E

HL 57.1 Di 16:30 Poster TU E

Modellierung des elektrischen Verhaltens organischer Feldeffekt-Transistoren — •Christoph Pannemann, Thomas Diekmann und Ulrich Hilleringmann — Universität Paderborn, Fakultät EIM-E, Sensorik, Warburger Str. 100, D-33098 Paderborn

Organische Feldeffekt-Transistoren (OFET) wurden durch thermisches Verdampfen des Halbleitermaterials Pentacen auf 100mm Silizium Substraten hergestellt. Durch kontinuierliche Kontrolle und Justage der Präparations-Bedingungen konnte eine deutliche Steigerung der Homogenität der elektrischen Parameter, wie z.B. der Schwellenspannung und des on-Stroms, erzielt werden. Die statistische Auswertung ergab eine gute Reproduzierbarkeit der Ergebnisse über die gesamte Waferoberfläche. Anschließend wurde die Übertragbarkeit der üblicherweise zur Beschreibung von OFETs herangezogenen MOS-Gleichungen modelliert und ergab eine gute Übereinstimmung mit den gemessenen Daten. Lediglich bei erhöhten Kontaktwiderständen zeigten sich im Anlaufbereich der Ausgangskennlinie größere Abweichungen.

HL 57.2 Di 16:30 Poster TU E

Fabrication and characterisation of nanoscale p-type organic field-effect transistors — •D. V. Pham[1], C. Bock[1], U. Kunze[1], D. Käfer[2], G. Witte[2], and CH. Wöll[2] — [1]Lehrstuhl für Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum, D-44780 — [2]Lehrstuhl für Physikalische Chemie I, Ruhr-Universität Bochum, D-44780

Shifting the channel length L of an organic field-effect transistor (OFET) from micrometer scale structures to nanometer scale a lower driving voltage and an improved cutoff frequency is expected. However, in a bottom-contact structure the ordering of the organic film depends on the channel length and on the growth temperature. We use electron-beam-lithography and lift-off technique to deposit nanoscale Ti/Au electrodes on thermally n-type oxidized silicon (d = 40 nm). The channel length was varied from 5 μm to 100 nm. On top of the electrodes a 60 - 120 nm pentacene film is grown by organic molecular beam epitaxy. We study the correlation of the morphology of the organic film in the active region for different growth temperatures and the output and transfer characteristics of the OFET. Two-terminal and four-terminal measurements enable to eliminate the contact resistance, which becomes more and more important for short channel length. Rubrene is also a promising candidate for high mobility OFETs. Therefore analogue investigations are done on rubrene field-effect structures.

HL 57.3 Di 16:30 Poster TU E

Density of Occupied States in Layers of DNA Bases on H-passivated Si(111) — •S. Seifert, G. Gavrila, S.D. Silaghi und D.R.T. Zahn — Institut für Physik, Technische Universität Chemnitz,D-09107 Chemnitz

The (opto-)electronic properties of the four DNA bases adenine, cytosine, guanine and thymine may suggest the possibility to use them in bio-electronic applications. There is, however, little knowledge or experimental data regarding the electronic structures of these materials. Therefore a systematic photoelectron spectroscopy study was performed for DNA base layers. Such layers were prepared with various thicknesses by organic molecular beam deposition on H-passivated Si(111) under ultra high vacuum conditions. Ultraviolet photoelectron spectroscopy (UPS) with an excitation energy of 21.2 eV (He I radiation) in normal emission was employed to determine the density of occupied states (DOOS) of these layers. The results are compared to previously obtained information on the combined density of states obtained by variable angle spectroscopic ellipsometry and the calculated electronic states of single molecules.

HL 57.4 Di 16:30 Poster TU E

Combined Raman Spectroscopy and Electrical Characterization of Pentacene Based Organic Field Effect Transistors — •B.A. Paez[1], G. Salvan[1], L. Mancera[1], R. Scholz[1], C. Pannemann[2], U. Hilleringmann[2], and D.R.T. Zahn[1] — [1]Institut für Physik, Technische Universität Chemnitz, Chemnitz, Germany — [2]Universität Paderborn, Paderborn, Germany

Pentacene organic field effect transistors with a channel geometry of 16 μm width, 100 μm length, 30 nm active layer, and a dielectric thickness of 150 nm (SiO_2), were characterized by Raman spectroscopy and current-voltage (IV) measurements.

In the Raman measurements a change in band intensities is observed upon applying a gate voltage, but no shifts in the phonon positions were observed within the resolution of the set-up (0.7 cm^{-1}). The results indicate a morphological change of the active layer induced by the gate field.

The current-voltage (IV) characteristics were measured in darkness and under illumination with monochromatic laser light. The results reveal an increase in the drain current upon illumination with a maximum at 2.54 eV photon energy. The dependence of the current-voltage (IV) characteristics on the photon energy was fitted to a modified OFET model allowing for ambipolar charge transport.

HL 57.5 Di 16:30 Poster TU E

Luminescence Quenching experiments in Thin Films of PTCDA and MePTCDI, — •André Holzhey, Karl Leo und Michael Hoffmann — TU Dresden, Institut für Angewandte Photophysik (IAPP), 01062 Dresden, Germany, www.iapp.de

CW and time resolved photoluminescence and luminescence quenching of 3,4:9,10-perylene-tetracarboxylic-dianhydride (PTCDA) and N,N'-dimethylperylene-3,4:9,10-dicarboximide (MePTCDI) thin layers show a dependence on the evaporation process, especially due to different degeneration of layers for different multilayer structures. Investigation of these dependencies allows to compare current measurements to previous results of exciton diffusion experiments by R. Schüppel [1]. It permits a more detailed view on exciton diffusion parameters of PTCDA and MePTCDI and on the diffusion mechanism. Using a spectrofluorometer and a revised streak camera setup, the surface luminescence quenching in double layers is investigated for various layer thicknesses, excitation energies and temperatures. The dependence on excitation energy allows conclusions about the interplay between exciton relaxation and diffusion.

[1] R. Schüppel, T. Dienel, K. Leo and M. Hoffmann, J. Lum., in press (2004)

HL 57.6 Di 16:30 Poster TU E

Dynamic behaviour and scaling properties of OFETs with channel lengths between 50 μm and 100 nm — •Jörg Seekamp, Tobias Muck, Arne Hoppe, Torsten Balster, and Veit Wagner — School of Engineering and Science, International University Bremen, 28759 Bremen, Germany

A major demand to organic field effect transistors (OFETs) is the improvement of their dynamic properties. The maximum operating frequency of the transistor follows from the gradual channel approximation: $f_t = \frac{\mu V'_{ds}}{2\pi L^2}$; $V'_{ds} := \min(V_{gs} - V_t, V_{ds})$. For this frequency the input current, i.e. I_{gate}, is equal to the output current, i.e. I_{drain}. At higher frequencies a given stage of an electronic circuit is no longer able to drive a following stage of the same type. For an OFET with $L = 100\ nm, \mu = 0.01\ \frac{cm^2}{Vs}$, $V'_{ds} = 1.7\ V$ this results in $f_t = 27\ MHz$. In this contribution transit frequencies for the small signal case and the switching behaviour of OFETs with channel lengths between 50 μm and 100 nm are presented. For a common gate bottom electrode device geometry f_t from 100 Hz to 10 kHz were measured for channel length between 50 μm and 1 μm. Geometry effects are accounted for by introducing a geometry factor: $f_t = a\frac{\mu V'_{ds}}{2\pi L^2}$. Further deviations of measured f_t with respect to the ex-

pected values are discussed in terms of the organic material properties and interfaces to the gate isolator and electrodes.

HL 57.7 Di 16:30 Poster TU E

Determination of hole mobility and lifetime in bulk heterojunction solar cells by photoinduced absorption spectroscopy — •Stefan Voigt[1], Uladzimir Zhokhavets[1], Gerhard Gobsch[1], Maher Al-Ibrahim[2,3], Oliver Ambacher[2] und Steffi Sensfuss[3] — [1]Institute of Physics, Ilmenau Technical University, 98684 Ilmenau, Germany — [2]Centre of Micro- and Nanotechnologies, Ilmenau Technical University, 98684 Ilmenau, Germany — [3]TITK Inst. Rudolstadt, Dept. Functional Polymer Systems, 07407 Rudolstadt, Germany

Increasing the power conversion efficiency of bulk heterojunction polymer/fullerene solar cells is the aim of numerous research groups for several years. In particular, the efficiency is limited due to low charge carrier mobilities μ and lifetimes τ. In order to improve the efficiency, the product $\mu\tau$ needs to be increased. In our work, the hole mobility and lifetime in poly(3-hexylthiophene) (P3HT) / [6,6]phenyl-C61-butric acid methyl ester (PCBM) solar cells were determined by photoinduced absorption (PIA) spectroscopy. The hole lifetime was determined from the frequency dependence of the PIA - signal. The out-of-plane hole mobility was deduced from the dependence of the hole lifetime on the applied voltage. The influence of annealing temperature on these parameters was investigated.

HL 57.8 Di 16:30 Poster TU E

Correlation effects in dense mass-asymmetric electron-hole plasmas — •Michael Bonitz[1], Vladimir Filinov[2], Vladimir Fortov[2], Pavel Levashov[2], and Holger Fehske[3] — [1]Institute for Theoretical Physics and Astrophysics, Christian-Albrechts-University Kiel, Leibnizstrasse 15, 24098 Kiel — [2]Institute for High Energy Density, Russian Academy of Sciences, Moscow, Russia — [3]Institute of Physics, Ernst-Moritz-Arndt-University Greifswald

Insulating excitonic phases in strongly correlated semiconductors, insulator-metal transition and the possibility of exciton Bose condensation are attracting increasing interest, e.g. [1].

A theoretical approach which is particularly well suited to describe these phenomena is the path integral quantum Monte Carlo (PIMC) method. We present simulation results for the excitonic phase diagram of $TmSe_{0.45}Te_{0.55}$ which was measured in Ref. [1]. In particular, we calculate the fraction of the electron-hole and hole-hole bound states, pair correlation functions, snapshots of the particle positions, internal energy and equation of state of a mass-asymmetric electron-hole plasma. Data for the isotherms T=30-300 K are presented. Density-temperature regions have been found for existence of excitons, bi-excitons and many-particle clusters. The transition to a metallic state is detected [2].

[1] P. Wachter, B. Bucher, and J. Malar, Phys. Rev. B 69, 094502 (2004); [2] V. Filinov, H. Fehske, and M. Bonitz, New J. Phys. (2005)

HL 57.9 Di 16:30 Poster TU E

Thermoelectric Properties of Disordered Systems — •A. Croy[1,2], R. A. Römer[1], A. MacKinnon[3], and M. Schreiber[2] — [1]Department of Physics & Centre for Scientific Computing, University of Warwick, Coventry CV4 7AL, UK — [2]Institut für Physik, Technische Universität, 09107 Chemnitz, Germany — [3]Blackett Laboratory, Imperial College London, London SW7 2BW, UK

The electronic properties of disordered systems at the metal-insulator transition (MIT) have been the subject of intense study for several decades. Thermoelectric properties at the MIT, such as thermopower and thermal conductivity, however, have been relatively neglected. Using an extension of the recursive Green's function method [1,2], we are able to calculate the low temperature behavior of all kinetic coefficients L_{ij} for long strips or bars. From these we can deduce the electrical conductivity σ, the thermopower S and the Peltier coefficient Π and the thermal conductivity κ, as well as the Lorenz number L_0. Our method does not rely on any assumptions on the form of the electrical conductivity. We present results for 3D systems and show the influence of the inelastic scattering time parameter, which can be interpreted as a non-trivial energy-scale associated with inelastic (phonon) scattering. This is relevant for the temperature dependence of the kinetic coefficients.

[1] A. MacKinnon, Z. Phys. **B59**, 385 (1985)
[2] R. A. Römer, A. MacKinnon, C. Villagonzalo, J. Phys. Soc. Jpn. **72** Suppl. A, 167–168 (2003)

HL 57.10 Di 16:30 Poster TU E

Anomalously localized states in the 3D Anderson model of localization — •Philipp Cain and Michael Schreiber — Institut für Physik, Technische Universität, D-09107 Chemnitz

We investigate the localization behavior of critical wave functions in the band center of the three-dimensional (3D) Anderson model of localization for large system sizes $N \leq 111^3$. In a recent numerical study of a 2D $SU(2)$ model it has been demonstrated [1] that among the critical states one can find very strongly localized states. These anomalously localized states (ALS) arise from statistical fluctuations of the disorder potential and are observed also for infinite N. While there is no influence of ALS on transport properties in the metallic regime, ALS can lead to deviations of critical properties at the metal-insulator transition [1] and have to be eliminated before the ensemble average. In order to discriminate ALS from "normal" critical states we use a quantity derived from a multifractal-correlation function [1]. With this method we can verify the existence of ALS also for the 3D Anderson model of localization which belongs to a different universality class than $SU(2)$.

[1] H. Obuse and K. Yakubo, Phys. Rev. B **69**, 125301 (2004).

HL 57.11 Di 16:30 Poster TU E

Crystal structures and electronic properties of $(A_3N)E$ (A = Ca, Sr, Ba; E = Sb, Bi) — •Miriam Schmitt[1], Vivien Petzold[1], Diana Clausnitzer[1], Waltraut Wustmann[1], Clemens Räder[1], Ralf Kliemt[1], Ulf Lorenz[1], and Helge Rosner[2] — [1]Technische Universität Dresden — [2]MPI for Chemical Physics of Solids Dresden

Due to their outstanding properties binary and ternary nitrides have raised increasing interest recently [1]. Here, we present a comparative study of the crystal structure and the electronic structure of the compound family $(A_3N)E$ (A = Ca, Sr, Ba; E = Sb, Bi). These systems crystallize in an anti-perovskite structure type (A= Ca, Sr cubic; A = Ba hexagonal). For the electronic structure calculations a full potential non-orthogonal local-orbital scheme (FPLO) was used. To investigate the phase stability of the structures a lattice optimization for both the cubic and hexagonal structures was applied. The calculated ground states are in accord with the experimental results [1]. In agreement with experimental findings, all structures show insulating behaviour. In the case of $(Ba_3N)E$ (E= Sb, Bi) a phase transition from hexagonal to cubic structure under pressure as well as a metal insulator transition is predicted.

[1] F. Gäbler *et. al.* Z. Anorg. Allg. Chem. **630**, 2292 (2004)

HL 57.12 Di 16:30 Poster TU E

Magnetic Freeze-Out in a Double-Barrier Resonant-Tunneling device — •Jens Könemann and R. J. Haug — Inst. f. Festkörperphysik, Uni Hannover, Appelstrasse 2, D-30167 Hannover, Germany

In our work we have investigated the single-electron tunneling (SET)in a double-barrier resonant-tunneling device with a relatively lightly-doped emitter. Our sample is a double-barrier resonant-tunneling device consisting of a 10 nm thick GaAs quantum well with 5 nm and 8 nm thick $Al_{0.3}Ga_{0.7}As$ tunneling-barriers and of a highly-doped emitter with a nominal dopant concentration of $1 \cdot 10^{17}$ cm^{-3}. We observe in our transport data a temperature and magnetic-field dependent shift of the position of the SET current steps which we interprete as a magnetic freeze-out of electrons in the emitter of our device. As a result, we are able to extract typical activation energies of the low-temperature transport below between 350 mK and 1 K.

HL 57.13 Di 16:30 Poster TU E

Optical properties and ion-damage problems of nano-fabricated GaN structures using focused-ion-beam etching — •H. Lohmeyer, K. Sebald, J. Gutowski, R. Kröger, J. Dennemarck, and D. Hommel — Institute of Solid State Physics, University of Bremen, Germany

Focused-ion-beam (FIB) etching is a promising technique for the fabrication of structures on a submicron scale which are required for the realisation of novel optoelectronic devices. So far there are few reports on the application of the FIB process to GaN samples especially with respect to possible ion damage affecting the optical properties. We present results of spatially resolved photoluminescence (μ-PL) investigations on FIB-processed InGaN/GaN quantum well samples.

Structures with lateral dimensions of 20 μm down to 200 nm have been prepared using a FEI NOVA NanoLab 200 system. By scanning electron microscopy the conformity of the structures for various etching parameters was controlled.

The μ-PL analysis reveals a fatal surface damage on large scales already at intermediate ion currents when working on unprotected samples. We show that the use of appropriate beam currents and protection layers enables us to fabricate structures on a submicron scale without significant ion damage. The optical properties of these small mesa structures which allow PL experiments with sub-wavelength resolution are discussed in detail.

HL 57.14 Di 16:30 Poster TU E

Strukturierung von SiC und GaN und laterales überwachsen mit GaN/$Al_xGa_{1-x}N$ — •B. Postels, N. Riedel, D. Fuhrmann, U. Rossow und A. Hangleiter — TU Braunschweig, Inst. f. Techn. Physik, 38106 Braunschweig; b.postels@web.de

Laterales Wachstum erzielt eine Defektreduktion, die für Bauelemente wie Leuchtdioden und Laser nötig bzw. vorteilhaft ist. Hier wird maskenloses laterales Wachstum auf strukturiertem SiC und GaN betrachtet. Die chemisch sehr beständigen Halbleiter werden photoelektrochemisch strukturiert, wobei mit verschiedenen Elektrolyten (H_2SO_4, wässrige KOH) SiC in den Fenstern von Metallmasken oxidiert wird. Das Oxid wird mit HF entfernt, wobei 1-2μm tiefe Gräben entstehen. Bei GaN wird das entstehende Oxid schon beim Prozess gelöst. Beim Überwachsen von strukturiertem SiC mit GaN stellen wir eine reduzierte Defektdichte fest, die begrenzt ist durch Versetzungen die am Grabenboden entstehen. Durch Variation der Ätzbedingungen wird versucht das Problem durch noch tiefere Gräben zu lösen. Bei H_2SO_4 erwies sich die Stabilität der Masken bzw. ihr Unterätzen als problematisch. Mit wässriger KOH dagegen konnte die Tiefe auf über 2μm gesteigert werden. Dabei wird bei niedrigen Konzentrationen ein Oxid aufgebaut und bei hohen Konzentrationen bildet sich tendenziell poröses SiC aus. Für eine weitere Steigerung der Tiefe scheint der Übergangsbereich optimal zu sein, wobei Ätzpausen nötig zu sein scheinen. Schwierig ist das Überwachsen mit $Al_xGa_{1-x}N$, bei dem eine geringe laterale Wachstumsrate und eine laterale Variation in x_{Al} festgestellt wird. Das Verhalten unterscheidet sich zwischen den Stegorientierungen.

HL 57.15 Di 16:30 Poster TU E

Einfluss der Nukleation auf GaN/AlGaN SQW-Strukturen und deren Alterung — •T. Retzlaff[1], D. Fuhrmann[1], N. Riedel[1], U. Rossow[1], G. Ade[2], P. Hinze[2] und A. Hangleiter[1] — [1]TU Braunschweig, Inst. f. Techn. Phys., 38106 Braunschweig; t.retzlaff@tu-bs.de — [2]Physikalisch Technische Bundesanstalt, 38116 Braunschweig

Die Effizienz UV-emittierender AlGaN/GaN QWs hängt entscheidend von der Qualität der AlGaN-Pufferschichten ab. Mittels MOVPE wurden AlGaN-Schichten und darauf aufbauend GaN/AlGaN SQW und MQW-Strukturen auf Saphir Substraten hergestellt. AFM, TEM und REM wurden zur strukturellen Charakterisierung der Proben genutzt. AlGaN-Schichten auf (In)GaN-Nukleationsschichten zeigen offene röhrenartige Strukturen, die defektkorreliert sind und in Substratnähe entstehen. In der Nähe dieser Defekte kommt es zum Wachstum von $Al_xGa_{1-x}N$ mit geringerem Al-Gehalt. Unter Nutzung einer AlN-Nukleation kann die Zahl der offenen Strukturen drastisch reduziert werden, was sich auch in der Unterdrückung der defektkorrelierten PL-Emission äußert. Temperaturabhängige PL-Messungen zeigen eine Verbesserung der internen Quanteneffizienz für QWs auf AlN-Nukleation im Vergleich zur (In)GaN-Nukleation. Es zeigt sich, dass QWs auf AlGaN mit röhrenartigen Strukturen einem Alterungsprozess unterliegen, der sich in einer Verschiebung der QW-Emission äußert. Anätzen der Proben in KOH führt zur Regeneration des Ausgangszustandes. Bei den verbesserten AlGaN-Schichten wurde dieses Verhalten nicht beobachtet, sodass ein Zusammenhang mit den offenen Strukturen naheliegt. Mögliche Ursache für die Alterung der Proben ist ein Oxidationsprozess der offenen Oberfläche.

HL 57.16 Di 16:30 Poster TU E

Elektrische Feldabhängigkeit der Photolumineszenzspektren in InGaN/GaN Heterostrukturen — •Harald Braun[1], Nikolaus Gmeinwieser[1], Ulrich T. Schwarz[1], Werner Wegscheider[1], Elmar Baur[2], Georg Brüderl[2], Alfred Lell[2] und Volker Härle[2] — [1]Naturwissenschaftliche Fakultät II- Physik, Universität Regensburg, Universitätsstr. 31, 93053 Regensburg, Germany — [2]OSRAM Opto Semiconductors GmbH, Wernerwerkstr. 2, 93049 Regensburg, Germany

Um eine weitere Leistungssteigerung bei Galliumnitrid basierten Leucht- und Laserdioden zu ermöglichen ist eine gute Kenntnis von den Vorgängen in der aktiven Zone nötig. InGaN/GaN Quantentröge weisen ein hohes intrinsisches, pyro- und piezoelektrisches Feld auf. Durch eine angelegte Spannung können diese Felder kompensiert werden, was sich in einer Änderung der Emissionswellenlänge und -Intensität wiederspiegelt. Unser konfokaler Mikro-Photolumineszenz (μPL) Messplatz ermöglicht die Kombination von Elektrolumineszenz und feldabhängiger Photolumineszenz bei verschiedenen Temperaturen bis hin zu 4 K. Die Ergebnisse lassen Rückschlüsse auf den Mechanismus der Ladungsträgerrekombination zu. Durch die hohe Ortsauflösung lassen sich diese Methoden auch für Facetten von Laserdioden anwenden.

HL 57.17 Di 16:30 Poster TU E

Investigation of electronic properties of AlGaN/GaN heterostructures using modulation spectroscopy — •A.T. Winzer[1], R. Goldhahn[1], G. Gobsch[1], A. Dadgar[2], A. Krtschil[2], H. Witte[2], A. Krost[2], O. Weidemann[3], and M. Eickhoff[3] — [1]Inst. f. Physik, TU Ilmenau, PF 100565, D-98684 Ilmenau — [2]Inst. f. Techn. Physik, Otto-von-Guericke-Universität Magdeburg, D-39016 Magdeburg — [3]Walter Schottky Institut, TU München, Am Coulombwall 3, D-85748 Garching

Photoreflectance (PR) and electroreflectance (ER) measurements have been proven the most sensitive tools for determining the electric field strength F in the barrier of AlGaN/GaN heterostructures with a two-dimensional electron gas (2DEG).

We present a comparative study of both methods applied to samples grown on Si(111) with different Al-contents and semitransparent Pt Schottky gate contacts. A strong deviation of F between the as grown surface (PR) and the gated area (ER) was found, which originates in the increase of band bending below the Schottky contact. Similarly, the determined 2DEG density has reduced from 4.7x10^{12} cm^{-2} (PR) to 2.8x10^{12} cm^{-2} (ER), as confirmed by C-V and Hall measurements. Temperature dependent measurements ($5\,K < T < 300\,K$) verify the influence of strain (piezoelectric polarization) on F.

2DEG depletion by negative gate bias provides the possibility to study the GaN free excitons, whereas band filling effects (Burstein-Moss shift) can be observed when the gate potential is increased.

HL 57.18 Di 16:30 Poster TU E

MOVPE Wachstum von AlN auf GaN — •Fabian Schulze, Jürgen Bläsing, Armin Dadgar, Thomas Hempel, Anette Diez, Alois Krost und Jürgen Christen — Institut für Experimentelle Physik, Otto-v.-Guericke-Universität Magdeburg, PF 4120, 39104 Magdeburg

Eine Standardmethode zur Verspannungskontrolle von dicken GaN-Schichten ist der Einsatz von AlN-Zwischenschichten. Zum genaueren Verständnis der mikrostrukturellen Prozesse und Wirkungen dieser Zwischenschichten wurde das initiale MOVPE Wachstum von AlN auf GaN untersucht. Dazu wurden verschiedene Serien von AlN-Schichten mit unterschiedlicher Wachtumstemperatur, TMAl-Fluss, und Schichtdicke hergestellt und bezüglich Morphologie, Gitterparameter und Qualität charakterisiert. Die Beurteilung der Oberflächenstruktur bis in den nm Bereich erfolgte mittels FE-REM. Die Gitterparameter der hexagonalen AlN-Zelle wurden mittels verschiedener Röntgenbeugungsmethoden bestimmt. Dabei zeigt das AlN bei niedrigen Depositionstemperaturen ein polykristallines, nanostrukturiertes Wachstum mit schwacher Vorzugsorientierung und vollständiger Relaxation. Bei höheren Temperaturen (>1000°C) zeigen die Oberflächen auch bei kleinsten Schichtdicken eine ausgeprägte Rissstruktur im nm-Bereich. Diese Schichten sind deutlich besser texturiert und ermöglichen ein vollverspanntes Aufwachsen der folgenden GaN-Schichten.

HL 57.19 Di 16:30 Poster TU E

Quantenpunktlaser auf InP für den 1.9 μm Wellenlängenbereich — •Andre Somers, Wolfgang Kaiser, Johann Peter Reithmaier und Alfred Forchel — Technische Physik, Universität Würzburg, Würzburg

Seit längerem ist es möglich quantenpunktähnliche Strukturen mittels selbstorganisiertem Wachstums auf InP-Substraten herzustellen die vergleichbare Eigenschaften zeigen wie InAs-Quantenpunkte auf GaAs. Damit erschloss sich für Quantenpunktlaser ein neuer Wellenlängenbereich von über 1.4 μm. Durch das Einschließen der Quantenpunkte in einen Quantenfilm ist es möglich die Emissionswellenlänge weiter in den langwelligen Bereich zu schieben.

Der in diesem Beitrag präsentierte Laser erreicht mit Hilfe dieser Methode eine Emissionswellenlänge von 1.88 μm. Dabei wurden Schwellenstromdichten unter 1 kA/cm^2 für 1 mm lange Breitstreifenlaser mit unverspiegelten Facetten erreicht. Ein weiterer Vorteil der Quantenpunkt-

laser gegenüber herkömmlichen Quantenfilmlasern ist die geringe Verschiebung der Wellenlänge mit der Temperatur. Diese ist vergleichbar mit der durch die Veränderung des Brechungsindex hervorgerufenen Verschiebung und ermöglicht die Realisierung von extrem temperaturstabilen DFB-Lasern. Da Wasser bei 1,877 μm eine Absorptionslinie besitzt ist dies vor allem für die Herstellung von Gassensoren von besonderem Interesse.

HL 57.20 Di 16:30 Poster TU E

Properties of quantum-cascade lasers with metallic mirror coatings and metallic distributed feedback gratings in the 10 μm spectral range — •S. Höfling[1], J. Seufert[2], M. Fischer[2], J. Koeth[2], P. Eugster[1], J.P. Reithmaier[1], and A. Forchel[1] — [1]Technische Physik, Universität Würzburg, Würzburg — [2]nanoplus, Nanosystems and Technology GmbH, Gerbrunn

Manufacturing highly reflective coatings in the 10 μm spectral region is challenging due to the lack of dielectric materials with low absorption. A way to overcome this problem is the application of metallic coatings deposited on the insulated facet. We fabricated these types of mirrors on GaAs based bound-to-continuum quantum-cascade (QC) lasers and observed a reduction by 15 % of the threshold current densities, increased quantum efficiencies, and an increase in maximum operation temperatures by 20 K to 359 K (86 °C).

In addition, based on different cascade structures we fabricated single mode QC lasers with distributed feedback metal gratings on top of the laser ridge. Operating these devices at 280 K (240 K), which is readily available with thermoelectric coolers, single mode output powers exceeding 15 mW at 11.1 μm (9.5 μm) were achieved. Furthermore, we report device properties such as the wavelength tuning behavior depending on both the grating period and the heat sink temperature, far field patterns and the high duty cycle performance depending on different packaging techniques.

HL 57.21 Di 16:30 Poster TU E

Population inversion in GaAs/$Al_{0.33}Ga_{0.67}As$ and GaAs/$Al_{0.45}Ga_{0.55}As$ quantum-cascade structures — •L. Schrottke, S. L. Lu, R. Hey, M. Giehler, H. Kostial, and H. T. Grahn — Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5–7, 10117 Berlin, Germany

The laser level population in undoped GaAs/(Al,Ga)As quantum-cascade structures (QCS) is investigated by interband photoluminescence spectroscopy. We compare QCSs with different Al content in the barriers (x = 0.33 and 0.45). The larger conduction band offset for the GaAs/$Al_{0.45}Ga_{0.55}As$ structure improves the electron confinement for the upper laser level and significantly decreases the leakage current into the quasi-continuum, which results in a reduction of the threshold current density. From the calculated lifetimes of the laser levels, the population ratio for the two structures is estimated to be similar. However, the experimental results show that the population ratio for $x = 0.45$ appears to be larger than for $x = 0.33$. At the same time, the line width of the upper laser level is narrower than the one for $x = 0.33$, which agrees with the smaller variation of the lasing energies of the corresponding QC lasers. We discuss possible mechanisms for this broadening and the apparent reduction of the population ratio in structures with $x = 0.33$ as well as the consequences for the population inversion with respect to the threshold current densities.

HL 57.22 Di 16:30 Poster TU E

Modification of Oscillator Strength in Self-Assembled QDs Using a Laterally Applied Electric Field — •Ruth Oulton[1], Matthias Schwab[1], Cedric Bardot[1], Manfred Bayer[1], Viktorina Stavarache[2], Dirk Reuter[2], and Andreas Wieck[2] — [1]Experimentelle Physik II, Universität Dortmund, D-44221 Dortmund, Germany — [2]Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstraße 150, Gebäude NB, D-44780 Bochum, Germany

We report the results of preliminary investigations into a p-i-n structure with an intrinsic region 2μm wide that allows a field of up to 150kVcm^{-}1 to be applied in the lateral direction. Time resolved photoluminescence measurements on ensembles embedded in such a structure reveals an increase in the radiative lifetime of the exciton of 30% with increasing electric field. This fact, along with a significant decrease in the intensity with increasing applied field indicate a decrease in oscillator strength, and hence electron-hole overlap as the field is applied. Measurements on a low density of QDs in such structures reveal a weak Stark shift to lower energy as the field is applied, giving further indications of wavefunction modification.

HL 57.23 Di 16:30 Poster TU E

Quantenpunkte in periodischen Magnetfeldern — •Daniel Buchholz und Peter Schmelcher — Institut für Theoretische Chemie Universität Heidelberg, Im Neuenheimer Feld 229, 69120 Heidelberg

In dieser theoretischen Arbeit wird ein Einelekronenquantenpunkt in einem periodischen Magnetfeld der Form $B_{z,m}\cos(kx + \varphi_z)$ behandelt. Das Spektrum und die Elektronendichten werden für viele Parameterwerte berechnet, und ihre k-Abhängigkeit bestimmt. Für k=0 ist das System integrabel; die Energieniveaus entsprechen denen eines anisotropen harmonischen Oszillators. Für kleine k-Werte treten viele vermiedene Niveaukreuzungen auf und die Elektronendichte des Grundzustandes erweist sich als stark abhängig von k und φ_z. Für große k-Werte, zeigt sich, daß die niedrigsten Energien wieder denen des harmonischen Oszillators entsprechen, d.h. die Energieniveaus sind äquidistant und nahezu entartet. Der typische Wert von k, ab dem diese Entartung auftritt, wächst mit der Anregungsenergie. Dieser Effekt lässt sich mit Störungstheorie erster Ordnung erklären. Für höhere Energien und bei größeren k wird diese Quasientartung aufgehoben. Darüber hinaus wird die klassische Dynamik für den Quantenpunkt untersucht. Schon bei relativ kleinem k ist der Phasenraum chaotisch. Für große k überwiegen die chaotischen Bereiche, es bleibt aber ein regulärer Bereich erhalten.

HL 57.24 Di 16:30 Poster TU E

Optische Eigenschaften und Modifikation von II - VI Halbleiter Nanobänder — •Daniel Stichtenoth, Daniel Schwen, Sven Müller, Christine Borchers und Carsten Ronning — II. Physikalisches Institut, Universität Göttingen, Friedrich-Hund-Platz 1, D-37077 Göttingen, Germany

ZnS und ZnO als Beispiel für II-VI Halbleiter mit großer direkter Bandlücke zeigen interessante optische Eigenschaften, die sie für die Anwendung als optoelektronische Bauteile interessant machen. ZnS und ZnO Nanobänder mit hohem Aspektverhältnis wurden durch einen einfachen thermischen CVD Prozess sythetisiert. Die optischen Eigenschaften wurden mittels temperaturabhängiger Photo- und Kathodolumineszenz untersucht. Zusätzlich wurden zeitaufgelöste Messungen an ausgewählten Zuständen vorgenommen. Ein weiterer Schwerpunkt lag darauf, geeignete Fremdatome zur Dotierung der Nanobänder durch Ionenimplantation einzubringen und den Einfluss auf die Lumineszenz zu untersuchen.

HL 57.25 Di 16:30 Poster TU E

Kontrolle der Exziton-Dekohärenz durch Anregung mit einer Pulsfolge — •Annette Krügel[1], Paweł Machnikowski[2], Vollrath Martin Axt[1] und Tilmann Kuhn[1] — [1]Institut für Festkörpertheorie, Westfälische Wilhelms-Universität, 48149 Münster, Deutschland — [2]Institute of Physics, Wrocław University of Technology, 50-370 Wrocław, Poland

Wir untersuchen das phonon-induzierte Dephasieren des Exziton-Zustandes in einem Halbleiter-Quantenpunkt. Es zeigt sich, dass die Anregung mit einer Folge von Pulsen im Vergleich mit einer Einzel-Puls-Anregung den Verlust der Kohärenz reduzieren kann. Steht für die Kontrolle nur ein festes Zeitfenster zur Verfügung, so beobachten wir bei Anregung mit einer Folge optimierter kurzer Pulse einen höheren Grad an Kohärenz, als wenn ein einzelner Gauß-Puls benutzt wird. Der Grad der Verbesserung ist bereits für eine geringe Anzahl von Pulsen (zwei bis vier) sehr deutlich, danach steigt er nur noch marginal. In unseren Rechnungen behandeln wir die Wechselwirkung mit dem Lichtfeld nichtperturbativ, die Elektron-Phonon-Wechselwirkung entwickeln wir zum einen in Bornscher Näherung bis zur zweiten Ordnung in den Phonon-Kopplungskonstanten und vergleichen mit der zweiten Ordnung in der Korrelationsentwicklung.

HL 57.26 Di 16:30 Poster TU E

High resolution photocurrent-spectroscopy of a single quantum dot — •Patrick Ester[1], Stefan Stufler[1], Artur Zrenner[1] und Max Bichler[2] — [1]Universität Paderborn, Warburger Straße 100, D-33098 Paderborn, Germany — [2]Walter Schottky Institut, Technische Universität München, Am Coulombwall, D-85748 Garching, Germany

We report on high resolution photocurrent spectroscopy of a single quantum dot. Our attention applies to the two-level character of a single InGaAs/GaAs quantum dot, defined by the ground state exciton. With high resolution photocurrent spectroscopy we analyze the behaviour of a single quantum dot under cw-excitation. Experiments include linewidth, power-broadening and saturation analysis. In the limit of low optical excitation we observe a ground state linewidth down to 4 μeV. With in-

creasing excitation intensities the linewidth shows a characteristic power broadening. This effect is a direct consequence of the saturation of the absorption in a two-level system under conditions of high excitation intensities. Due to the high resolution we further are able to measure the excitonic fine structure splitting. The results of the cw-excitation experiments indicate an almost perfekt quantum mechanical two-level system. This can be taken as a basis for coherent manipulations of the quantum dot, important for possible applications in quantum information processing.

HL 57.27 Di 16:30 Poster TU E

Lumineszenz- und Ladungsträgerdynamik in Halbleiter-Quantenpunkten — •Timo Aschenbrenner[1,2], Jan Wiersig[1], Frank Jahnke[1] und Detlef Hommel[2] — [1]Institut für Theoretische Physik, Universität Bremen, 28334 Bremen, Deutschland — [2]Institut für Festkörperphysik, Universität Bremen, 28334 Bremen, Deutschland

Für Halbleiter-Quantenpunkte auf einer quasi-zweidimensionalen Benetzungsschicht wird das Wechselspiel von Lumineszenz und Ladungsträgerdynamik theoretisch untersucht. Zur Beschreibung der spontanen Emission werden die Halbleiter-Lumineszenzgleichungen [1] für Quantenpunktsysteme formuliert. Die mit diesen Gleichungen berechneten Emissionsspektren werden mit Absorptionsspektren verglichen.

In der Ladungsträgerdynamik werden neben den optischen Prozessen, wie z.B. die spontane Emission, der Einfang der Elektronen und Löcher aus der Benetzungsschicht in die Quantenpunktzustände sowie die Relaxation zwischen den Quantenpunktzuständen berücksichtigt. Ausgehend von den mikroskopisch berechneten Streuprozessen [2] wird ein Ratengleichungsmodell begründet. Ergebnisse werden zur zeitlichen Dynamik der Lumineszenz vorgestellt.

[1] M. Kira, F. Jahnke, W. Hoyer, and S.W. Koch, Progress in Quantum Electronics **23**, 189 (1999)
[2] T. R. Nielsen, P. Gartner and F. Jahnke, Phys. Rev. B **69**, 235314 (2004)

HL 57.28 Di 16:30 Poster TU E

Quantum Optical Studies of Single InP/GaInP Quantum Dots — •Gareth Beirne[1], Peter Michler[1], and Heinz Schweizer[2] — [1]5th Institute of Physics, University of Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany — [2]4th Institute of Physics, University of Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany

Using the Stranski-Krastanow growth mode, the MOVPE deposition of InP on GaInP can be used to produce 2 distinct types of coherently strained quantum dots (QDs). We refer to the structures with an average height of 5 nm as type A dots and the structures with an average height of 20 nm as type B dots. The type B structures are expected to exhibit a Type II band alignment, with the electron confined in the dot and the hole located in the wetting layer or barrier material. Under continuous wave excitation at 4 K (1.7763 eV, 15.9 kW cm-2), broad (FWHM = 0.50 meV) and intense (131,000 counts/sec) exciton emission at 1.6558 eV was observed from a single type B InP/GaInP QD, contained in a 500 nm (diameter) mesa structure. Subsequent continuous and pulsed photon statistics measurements performed on the same dot display clear antibunching effects, and in the pulsed case, single photon emission on demand was achieved at a wavelength of 748.8 nm (a value closely matching the optimal detection wavelength of silicon-based single photon detectors). Finally, we have investigated whether the addition of aluminium to the barrier material extends the temperature range over which single photon emission may be realised using type B InP QDs.

HL 57.29 Di 16:30 Poster TU E

Spin flip Raman studies on CdSe/ZnSe quantum dots — •M. Wisniewski, M. Lentze, T. Slobodskyy, G. Astakhov, and J. Geurts — Physikalisches Institut der Universität Würzburg, EP III, Am Hubland, D-97074 Würzburg

The high potential of CdSe quantum dots is well known since several years. They are a possible candidate for optical and electrical applications like laser diodes in the green and blue spectral range. To get a better understanding of their properties we made an analysis by optical measurements e.g. photoluminescence, photoluminescence excitation and spin flip Raman spectroscopy under resonant excitation. Our samples contained 1 Monolayer CdSe embedded in a ZnSe matrix. Photoluminescence measurements were used to analyse excitonic transitions, and spin flip Raman spectroscopy for detection of the effective g-factors of dots and matrix. By tuning the incident photon energy, we exploited the specific ability of resonant Raman scattering to focus the specific sensitivity either on the CdSe dots ($E_{res} = 2.65eV$) or on the ZnSe matrix ($E_{res} = 2.80eV$). For analyzing the dots we utilize the resonance from a dark exciton whose energy is close to the photoluminescence peak of CdSe.

HL 57.30 Di 16:30 Poster TU E

Theory of Acoustic Phonons in Semiconductor Nanostructures: Continuum versus Microscopic Description — •Milana Michaljowa, Frank Grosse, and Roland Zimmermann — Institut für Physik der Humboldt-Universität zu Berlin, Newtonstr. 15, 12489 Berlin, Germany

Acoustic phonons (AP) play the dominant role in dephasing of optical excitations in nanostructures at low temperatures [1]. A detailed knowledge about the AP spectrum in these low dimensional nanostructures is therefore essential for a quantitative description. Based on ab initio calculations phonon spectra for realistic quantum dot structures are calculated within the continuum elasticity theory and compared to atomistic simulations employing a valence-force-field model [2]. For a few simple geometries we compare the results with analytic expressions. We consider isotropic, cubic (zincblende), and hexagonal (wurtzite) crystal structures. Our theory is therefore applicable to a large group of compound semiconductors. Special focus is given to the InAs/GaAs and InGaN/GaN quantum dot systems.

[1] E. Muljarov and R. Zimmermann accepted Phys. Rev. Lett. **93** (2004). [2] F. Grosse and J. Neugebauer Phys. Rev. B **63**, 085207 (2001).

HL 58 Poster IIb

Zeit: Dienstag 16:30–19:00 Raum: Poster TU F

HL 58.1 Di 16:30 Poster TU F

Two-particle correlations in crystalline systems — K. Morawetz[1,2], E. P. Nakhmedov[3], B. Schmidt[1], M. Schreiber[1], and C. Radehaus[3] — [1]Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany — [2]Max-Planck-Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, 01187 Dresden, Germany — [3]Opto- and solid state electronics, Chemnitz University of Technology, 09107 Chemnitz, Germany

Correlations of two vacancies or defects in crystalline dielectrics are studied by means of a DFT based ab initio method. The dependence of the interaction energy on the defect separation is computed to study the leakage current through a gate dielectric of MOSFET devices. Simulation of the critical radius of the two-particle correlation allows us to suggest a percolation path formation in the dielectrics. As a toy model, the correlated two-particle problem is solved analytically in the presence of a finite cavity. The method is demonstrated here in terms of exactly solvable models for both the cavity as well as the two-particle correlation where the two-particle potential is chosen in separable form. The two-particle phase shift is calculated and compared to the single-particle one. We find a Fano resonance behavior due to the interference of single- and two-particle channels. The two-particle bound state behavior is discussed and the influence of the cavity on the binding properties is calculated.

[1] K. Morawetz, M. Schreiber, B. Schmidt, A. Ficker, P. Lipavský, Phys. Rev. B submitted, cond-mat/0409325
[2] E. P. Nakhmedov, M. Trentzsch, C. Schubert, I. Kabadshow, E. Nadimi, K. Wieczorek, and C. Radehaus, in preparation, 2004

HL 58.2 Di 16:30 Poster TU F

Magnetotransport measurements on GaAs/AlGaAs quantum rings — •A. Mühle[1], R. J. Haug[1], W. Wegscheider[2], and M. Bichler[3] — [1]Institut für Festkörperphysik, Universität Hannover, D-30167 Hannover — [2]Angewandte und Experimentelle Physik, Universität Regensburg, D-92040 Regensburg — [3]Walter Schottky Institut, TU München, D-85748 Garching

We present transport measurements done in dependence of an external magnetic field on quantum rings of different sizes on the surface of GaAs/AlGaAs heterostructures. These rings were fabricated by atomic force microscope lithography utilising local anodic oxidation [1]. Using

in-plane gates, the energy of the electrons in the arms of the rings as well as the coupling of the structures to the leads can be controlled.

While sweeping the magnetic field in the regime with only one occupied subband and a conductivity of a few e^2/h, Aharonov-Bohm oscillations appear that show a modulation of their amplitude with a period of several hundred mT.

We attribute this phenomenon to spin-orbit effects.

[1] U. F. Keyser et al., Phys. Rev. Lett. **90**, 196601-1 (2003)

HL 58.3 Di 16:30 Poster TU F

Noise measurements of vertical coupled InAs quantum dots — •P. Barthold[1], N. Maire[1], F. Hohls[1], A. Nauen[2], R. J. Haug[1], K. Pierz[3], and T. Bryllert[2] — [1]Institut für Festkörperphysik, Universität Hannover, D-30167 Hannover — [2]Div. of Solid State Physics, P.O. BOX 118, SE-221 00 Lund — [3]Physikalisch- Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig

We present noise measurements of resonant single electron tunnelling through individual and vertical coupled self-organised InAs quantum dots (QDs) at temperatures down to 1.5 K.

In the first case our samples consist of a GaAs/AlAs/GaAs tunnelling structure with self-organised InAs QDs embedded in the AlAs. Depending on the bias voltage we find that the shot noise is suppressed in respect to the full Poissonian value $2eI$. This suppression is characterised by the Fano factor $\alpha = S/2eI$ whose modulation was perceived in the experiment. We investigate the noise generated by the sample with a current amplifier in a range from 0 to 10 kHz, and a spectrum analyser that uses Fast Fourier Transformation. Above 1 kHz the noise shows a frequency-independent behaviour indicating the presence of shot noise.

In the second case we investigate with the same setup two different types of samples, GaInAs/InP/GaInAs and GaAs/AlAs/GaAs heterostructures in which two layers of vertical coupled InAs QDs are embedded. With both samples we observe definite peaks in the I-V-characteristic as aspected. Due to the bias voltage modulations of α are found. While the peaks in the I-V-characteristic show a slight change at different temperatures the modulation of α shows a distinct behaviour.

HL 58.4 Di 16:30 Poster TU F

Wave-function mixing in tunnel-coupled quantum point contacts — •G. Apetrii[1], U. Kunze[1], D. Schuh[2], and G. Abstreiter[2] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum, D-44780 Bochum — [2]Walter Schottky Institut, Technische Universität München, D-85748 Garching

Closely spaced vertically stacked quantum point contacts (QPCs) were prepared on a GaAs/AlGaAs heterostructure comprising two 14.5 nm wide GaAs quantum wells (QWs) separated by a 1 nm wide $Al_{0.32}Ga_{0.68}As$ barrier. The tunnel interaction of the two-dimensional electron systems contained in the two QWs is characterized at equilibrium by a symmetric-antisymmetric energy gap of 4 meV. The QPCs were processed by lithography with an atomic force microscope and subsequent wet-chemical etching. In two-terminal conductance and transconductance measurements at 4.2 K two series of signals originating in the two QPCs were identified. A top-gate/back-gate system together with a cooling bias technique were used for tuning the energy spectra of the tunnel-coupled QPCs in order to obtain degeneracies of 1D subbands. Clear anticrossings with mixing of the 1D wave functions are observed in grey-scale transconductance plots versus top-gate and back-gate voltage. Large anticrossing energy gaps amounting to 5 meV were determined experimentally by means of measurements under dc drain voltage.

HL 58.5 Di 16:30 Poster TU F

Conductance anomalies in a quantum point contact — •D.J. Schefzyk[1], M. Fleischer[1], S. Jauerneck[1], D.A. Wharam[1], D.A. Ritchie[2], and M. Pepper[2] — [1]Institut für Angewandte Physik, Universität Tübingen, Auf der Morgenstelle 10, D-72076 Tübingen — [2]Cavendish Laboratory, University of Cambridge, Madingley Road, Cambridge CB3 0HE, UK

Transport measurements of quantum point-contacts exhibit conductance quantisation in units of $G_0 = \frac{2e^2}{h}$. Often additional steps are observed which cannot be accounted for in the simple picture of perfectly transmitting one-dimensional subbands. In the linear gate characteristics, the observed transconductance structure moves parabolically towards lower absolute values of gate voltage with increased perpendicular magnetic field. In addition, we see distinct side plateaux at finite magnetic field. The zero field differential conductance in the nonlinear regime exhibits plateaux at integer multiples of G_0 and half-integer plateaux at finite bias as well as distinct steps below the first and second plateau. At finite bias, they develop into side plateaux, leading to a pattern of intersecting diamonds in the transconductance. The possible origin of additional steps has been considered in a numerical calculation of one-dimensional subbands.

HL 58.6 Di 16:30 Poster TU F

Transport spectroscopy of quantum point contacts — •F. Hohls, A. C. Graham, M. Pepper, and D. A. Ritchie — Cavendish Laboratory, University of Cambridge, Madingley Road, Cambridge CB3 0HE, UK

The conductance of a quantum point contact (QPC) is quantized to $G = n(2e^2/h)$ as expected for a non-interacting one-dimensional system. Additional features were observed for clean QPCs, the so called 0.7 structure [1] which is an additional plateau or shoulder at a conductance of $0.7(2e^2/h)$. Recently additional structures were discovered at higher conductance, the so called 0.7 analogue [2]. These features are a manifestation of electron-electron interaction. Different explanations were offered, e.g. spontaneous spin polarization or a Kondo like effect, but the experimental results are not yet unambiguous in favour of one of them.

One of the key questions is the opening of additional energy gaps and their dependence on external parameters. We address this issue using non-linear transport spectroscopy on high quality QPCs. Beside the traditional technique measuring the nonlinear response of the QPC we also employ a new method using a quantum dot as an energy sensitive detector for ballistic electrons.

[1] K. J. Thomas *et al.*, PRL **77**, 135 (1996).
[2] A. C. Graham *et al.*, PRL **91**, 136404 (2003).

HL 58.7 Di 16:30 Poster TU F

Optical properties of phase change materials for optical and electronic data storage with ab initio methods — •Wojciech Wełnic[1,2], Silvana Botti[2], Lucia Reining[2], and Matthias Wuttig[1] — [1]I. Physikalisches Institut, RWTH Aachen, 52056 Aachen, Germany — [2]Laboratoire des Solides Irradiés, École Polytechnique, 91128 Palaiseau cedex - France

In this work excited state calculations are presented for GeTe, the basic phase-change-material. Due to a significant change of optical reflectivity and electric conductivity upon phase transition from the amorphous to the crystalline state these materials are promising candidates for future data storage applications.

The focus of the project is on the optical and electronic properties in different phases of GeTe, ranging from the two crystalline phases, to defect structures and the amorphous phase. The origin for the difference of these properties in the different states is examined. The amorphous structure is obtained in two different ways: on one side we employ *ab initio* MD within a 64-atom supercell and on the other side we use a simple model structure which reproduces the local configuration reported in earlier experimental work. The electronic structure is presented in the GW-correction and the spectra are calculated within TDDFT and GW-RPA. They are compared with experimental data of thin film GeTe-samples. Differences between theory and experiment are discussed as well as the changes in the optical and electronic properties upon phase transition from the crystalline to the amorphous state.

HL 58.8 Di 16:30 Poster TU F

Interferometric cantilever magnetometer for de Haas-van Alphen effect studies — •N. Ruhe, J.I. Springborn, Ch. Heyn, D. Heitmann, and D. Grundler — Institut für Angewandte Physik, Uni Hamburg, Jungiusstr. 11, 20355 Hamburg

The magnetization M provides access to the ground state energy and electron-electron interaction of a two-dimensional electron system (2DES) [1]. At low temperature T and in a high magnetic field B, the de Haas-van Alphen effect occurs. We detect these oszillations by means of the torque $\vec{M} \times \vec{B}$ acting on a quasistatic micromechanical cantilever magnetometer (MCM), which is made from a GaAs/AlGaAs heterostructure. The deflection of the flexible Cantilever is measured by a fiber-optics interferometer at $T = 300$ mK up to $B = 15.5$ T. The resolution of the interferometer is about 0.4 nm corresponding to a sensitivity of $2 \cdot 10^{-14}$ J/T at $B = 10$ T. In comparison to a capacitive read-out technique [1] the fiber-optics interferometer has the advantage that (i) a higher sensitivity might be reached and that (ii) electrical contacts and field-effect electrodes can be attached to the 2DES without degrading to the sensitivity. In current experiments we study the magnetization and

magneto-transport simultaneously. Our latest results will be presented. We thank A. Schwarz for continuous support of the work and the DFG for financial support via GR1640/1 and via SFB508.
[1] M. Schwarz *et al.*, Phys. Rev. B **65**, 245315 (2002).

HL 58.9 Di 16:30 Poster TU F

THz-Photoleitung an HgTe/HgCdTe-Quanten-Hall-Detektoren — •R. Bonk[1], C. Stellmach[1], C. Becker[2], V. Hock[2], G. Hein[3] und G. Nachtwei[1] — [1]Inst. f. Techn. Physik, TU-Braunschweig, Mendelssohnstr.2, D-38106 Braunschweig — [2]Fakultät für Physik und Astronomie, Julius-Maximilians-Universität Würzburg, Am Hubland, D-97074 Würzburg — [3]Phys.-Tech. Bundesanstalt, Bundesallee 100, D-38116 Braunschweig

Die Arbeit behandelt die Terahertz-Photoleitung an zweidimensionalen MCT-Quantenwall-Strukturen (HgTe/HgCdTe) im Quanten-Hall-(QH)-Regime.Im Materialsystem GaAs/GaAlAs werden für Ferninfrarot-(FIR)-QH-Detektoren tiefe Temperaturen (ca. 4K) und hohe Magnetfelder (ca. 5T) benötigt. Bei MCT-Proben hingegen sind auf Grund der kleineren effektiven Masse auch deutlich kleinere Magnetfelder möglich, was MCT-Systeme zu einem viel versprechenden Material für empfindliche FIR-Quanten-Hall-Detektoren, z.B. zur Festkörperspektroskopie, werden lässt. Für spektrale sowie zeitaufgelöste Untersuchungen werden impedanzangepasste Photoleitungsmessungen an verschiedenen MCT-Systemen mit Hallbar- und Corbinostrukturierung unter Verwendung eines p-Ge-Lasers (Wellenlängen von 120-180 μm) respektive Glowbars (thermischer Strahler) im FIR durchgeführt. Damit werden Relaxationszeiten der Ladungsträger beim optisch bewirkten Zusammenbruch des QH-Effektes in Hinblick auf die Anwendung eines schnellen Detektors untersucht.

HL 58.10 Di 16:30 Poster TU F

Magnetotransport zur Charakterisierung von AlGaN/GaN-Heterostrukturen — •K. Knese, F. Vogt, N. Riedel, U. Rossow, C. Stellmach und G. Nachtwei — Inst. f. Techn. Physik, TU-Braunschweig, Mendelssohnstr. 2, D-38106 Braunschweig

Die Gruppe III-Nitride bilden eine viel versprechende Möglichkeit für Anwendungen als elektronische Bauelemente, die bei hohen Temperaturen und hohen Frequenzen arbeiten. Allerdings weisen Bauelemente dieser Materialklasse oft noch unbefriedigende elektrische Kenndaten auf. Dies ist eine Folge von teilweise noch unverstandenen Streumechanismen, welche die Beweglichkeit der Elektronen limitieren. Diese Arbeit beschäftigt sich mit den Magnetotransport-Eigenschaften des zweidimensionalen Elektronensystems in AlGaN/GaN-Heterostrukturen, aus denen die Streumechanismen ermittelt werden können. Es werden Shubnikov-de Haas-Messungen an verschiedenen Proben zur Bestimmung der Elektronenkonzentrationen, Beweglichkeiten, effektiven Elektronenmassen, Transport- und Quantenstreuzeiten durchgeführt. Zusätzlich werden SdH-Oszillationen bei unterschiedlichen Neigungswinkeln des Magnetfeldes gemessen, die eine Bestimmung der Spinaufspaltung und des effektiven Landé-Faktors der Elektronen ermöglichen.

HL 58.11 Di 16:30 Poster TU F

Echtzeitmessung der Relaxation des Photosignals von Quanten-Hall-Terahertz-Detektoren in Corbino-Geometrie — •C. Stellmach[1], Yu. Vasilyev[2], A. Hirsch[1], G. Hein[3] und G. Nachtwei[1] — [1]Inst. f. Techn. Physik, TU-Braunschweig, Mendelssohnstr. 2, D-38106 Braunschweig — [2]A.F. Ioffe Physical Technical Institute, Polytekhnicheskaya 26, 194021 St. Petersburg, Russia — [3]Phys.-Techn. Bundesanstalt, Bundesallee 100, D-38116 Braunschweig

Wir präsentieren Photoleitfähigkeits-Messungen im Ferninfrarot an Quanten-Hall-(QH)-Systemen. Es wurden mehrere QH-Proben untersucht, die in Corbino Geometrie mit großer photoaktiver Fläche strukturiert waren ($A \approx 6$ mm^2). Als Strahlungsquelle stand ein ein p-Ge Laser im Pulsbetrieb zur Verfügung, der Messungen im Wellenlängenbereich zwischen ca. $120\mu\text{m} \leq \lambda \leq 180\mu$m (entspricht 2.5THz bis 1.5THz) erlaubt. Der Laser wird mit einer speziellen FET basierten Hochspannungs-Pulsquelle mit kurzer Schaltzeit betrieben. Das Photosignal wird impedanzangepasst erfasst. Dies erlaubt es intrinsische Zeitskalen des QH-Systems aufzulösen. Es zeigt sich, dass die Relaxationszeit des Photosinals spannungsabhängig ist und im Bereich von ca. 20ns bis 150ns liegt. Zusätzlich wurde das Photosignal in Abhängigkeit von Magnetfeld, Ladungsträgerkonzentration (steuerbar über eine Gate-Spannung) und Probenspannung gemessen um die spektrale Selektivtät zu bestimmen. Es zeigt sich, dass die spektrale Auflösung der QH-Detektoren eine Funktion Probenspannung ist.

HL 58.12 Di 16:30 Poster TU F

Spin-Flip Excitations and Composite Fermions — •G. Meissner and U. Schmitt — Theoretische Physik, Universität des Saarlandes, Postfach 15 11 50, D-66041 Saarbrücken

Dispersion relations for spin-flip modes of composite Fermions are examined by employing a Chern-Simons gauge theory in the limit of low Zeeman energy. The calculated finite-wave-vector excitations, in which a spin-reversed composite Fermion of the spin-polarized filled lowest Landau level is promoted to the next, are compared with the collective excitations of Laughlin's incompressible quantum liquid at the corresponding fractional filling factor one third. Modifications due to finite thickness effects in this interacting two-dimensional electron system at high magnetic fields are considered in view of a comparison of the calculated dispersion relations with inelastic light-scattering experiments.

HL 58.13 Di 16:30 Poster TU F

Measurements of the electrical excitation of QH-devices in the real time domain — •G. Vasile[1,2], C. Stellmach[1], and G. Nachtwei[1] — [1]Inst.f.Technische Physik, der TU Braunschweig, Mendelssohnstrasse 2, D-38106 Braunschweig — [2]National Institute of Research-Development for Cryogenics and Isotopic Technologies, Str. Uzinei Nr. 4, R-1000 Rm. Valcea, Romania

We have performed real time domain measurements of the electrical excitation on Corbino devices (measured with impedance-matching circuit) in order to determine the excitation and relaxation times. We have used Corbino devices of inner radius $R_1 = 100\mu$m, outer radius $R_2 = 150\mu$m and various mobilities ($\mu = 8 \times 10^5$ cm^2/Vs, $\mu = 1.6 \times 10^6$ cm^2/Vs). A pulse generator send through a high frequency cable rectangular pulses to the Corbino disc and via another high frequency cable the sample response, picked up from a 50 Ω serial resistor with the Corbino disc, is read on the oscilloscope. We have used rectangular shapes of 90-180 ns pulse width, 300 ns pulse period and from 0.2 V up to 1.0 V applied voltages. In this way we were able to determine relaxation times of a few nanoseconds according to previous measurements. The higher voltage the shorter response time due to the fact by increasing the applied voltage, the Landau levels are tilted more and more resulting in smaller tunnelling distance between the initial and final tunnelling states, therefore a higher tunnelling rate and consequently a smaller drift length of electrons. According to the drift model, at constant drift length, the response time of the sample should be inverse proportional to the applied voltage, but our measurements yield another dependence.

HL 58.14 Di 16:30 Poster TU F

Nonchiral Edge States and the Chiral Metal Insulator Transition — •Stefan Kettemann[1], Alexander Struck[1], Bernhard Kramer[1], and Tomi Ohtsuki[2] — [1]1. Institut fuer Theoretische Physik, Uni Hamburg, Jungiusstrase 9, 20355 Hamburg — [2]Sophia University , Tokyo

The quantum phase diagram of disordered quantum wires in a strong magnetic field is studied. Sharp localization transitions of chiral edge states are found. These are shown to result in zero temperature discontinuous transitions of the 2–terminal conductance between exactly integer plateau values and zero, reminiscent of first order phase transitions. This transition, the chiral metal insulator transition (CMIT)[1], is studied as function of wire width, steepness of the confinement potential and the strength and correlation length of the disorder potential. A unique state is identified at the transition, corresponding to a superposition of edge states with opposite chirality. The bulk contribution to this state is found to decrease with the increase of the wire width, characterising this state as a new state, distinguishable from the other states, existing in the quantum Hall wire [2], namely, extended edge states, 2D localised states, quasi-1-D localised states, and 2D critical states. [1] S. Kettemann, B. Kramer, T. Ohtsuki, JETP Letters 80, 316 (2004) [2] S. Kettemann, Phys. Rev. B 69, 035339 (2004).

HL 58.15 Di 16:30 Poster TU F

Transition between incompressible states of different spin polarization: a half-polarized ground state? — •Karel Výborný and Daniela Pfannkuche — 1st Institute of theoretical physics, Jungiusstr. 9, University of Hamburg, 20355 Hamburg

Incompressible fractional quantum Hall states are not always fully spin polarized and even transitions between ground states of different spin (but at fixed filling factor) can be achieved by tuning the Zeeman splitting. This is also the case at $\nu = 2/3$ where the transition between a spin-singlet ground state (GS) and a fully polarized GS was observed

experimentally as a huge longitudinal magnetoresistance effect. Experiments suggested that the system constitutes a quantum Hall ferromagnet [1] or that a stable half-polarized ground state in the middle of the transition occurs [2].

We study this transition using exact diagonalization with electrons on torus. For homogeneous systems we find a low excited half-polarized state around the transition which might become the GS in the thermodynamical limit. We study its structure and compare it to the singlet and polarized GS's.

Adding magnetic inhomogeneities into the system we investigate stability of all three involved GS's and tendency to build up domains like in conventional ferromagnets.

[1] S. Kronmüller et al., *Phys. Rev. Lett.*, **81**, 2526 (1998); J. Smet et al., *Nature*, **415**, 281 (2002)

[2] I. V. Kukushkin et al., *Phys. Rev. Lett.*, **82**, 3665 (1999)

HL 58.16 Di 16:30 Poster TU F

Composite fermions in disordered systems — •Christian Müller and Daniela Pfannkuche — Institut für Theoretische Physik Universität Hamburg

The electronic properties of a disordered system in the fractional quantum Hall regime are studied. To this end, the correlation of wavefunction vortices (Composite Fermions) and electrons are studied in a system subject to periodic boundary conditions using exact diagonalization methods for up to 5 spin-polarized electrons. The model impurity is of gaussian shape.

For a strong gaussian-shaped impurity potential a quantized charging of the resulting quantum dot is found. The vortex-vortex correlation becomes weaker for stronger disorder potentials, pointing to a possible breakdown of the FQH regime.

HL 58.17 Di 16:30 Poster TU F

Interactions at the Integer Quantum Hall Transition — •Christoph Sohrmann and Rudolf A. Römer — Department of Physics, University of Warwick, Coventry CV47AL, UK

Electron-electron interactions seem to play a surprisingly small role in the description of the integer quantum Hall effect, considering that for just slightly different filling factors the interactions are of utmost importance causing the interaction-mediated fractional quantum Hall effect. However, recent experiments by Cobden et al. [1] constitute strong evidence for the importance of electron-electron interactions even in the integer effect. Measurements of the conductance on mesoscopic MOSFET devices show regular patterns along the plateau transitions when viewed as a function of the two parameters magnetic field and gate voltage. In contrast to the expected random behaviour of the sample specific conductance fluctuations those patterns are most likely interaction driven and demand explanation. Starting from the random Landau matrix approach as an effective numerical model for non-interacting quantum Hall physics, we treat interactions in an approximative Hartree-Fock scheme and investigate the role of the interactions in the integer quantum Hall effect.

[1] D.H. Cobden, C.H.W. Barnes, and C.J.B. Ford, Phys. Ref. Lett. **82**, 4695 (1999)

HL 58.18 Di 16:30 Poster TU F

Storing of arbitrary light pulses in resonant 1D photonic crystals — •Martin Schaarschmidt, Jens Förstner und Andreas Knorr — Institut für Theoretische Physik, Technische Universität Berlin, Germany

The considered 1D photonic crystal consists of semiconductor planes with localized excitons spaced at $\lambda/2$. The excitons couple dynamically to a propagating light pulse. Stationary (trapped) field distributions of this coupled system are numerically observed for resonant excitation inside the resonant photonic band gap. Within slowly varying envelope approximation analytic solutions based on the Maxwell-Bloch-Equations for these trapped light pulses are presented. It is shown that pulses of nearly arbitrary shape and intensity can exist as zero-velocity pulses inside an active photonic crystal. The preparation of a whole class of these pulses is demonstrated. In a similar system consisting of an InGaAs multiple quantum well with free excitons such solutions could not be found[1].

[1]Linear and nonlinear pulse propagation in a multiple-quantum-well photonic crystal, PRB 70 075306 (2004)

HL 58.19 Di 16:30 Poster TU F

Resonance Fluorescence of Semiconductor Quantum Dots: Signatures of the Electron-Phonon Interaction — •Kwang Jun Ahn, Jens Förstner, and Andreas Knorr — Institut für Theoretische Physik, AG Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Hardenbergstr.36 PN7-1, 10623 Berlin

Compared to an atom in vacuum, which is considered as an isolated quantum optical system, excitons in semiconductor quantum dots are embedded in a complex solid state environment and interact with phonons. We investigate the influence of acoustic phonons on incoherent photon emission. The equations of motion of the density matrix are derived for the coupled system of quantum dot electrons, phonons and photons using the correlation expansion up to second order. The corresponding resonance fluorescence spectra are calculated depending on pulse duration and temperature. The appearance of sideband broadening by electron-phonon interaction in the spectrum depends on the pulse duration compared to the typical electron-phonon scattering time. In addition, nonclassical signatures of the emitted light are discussed.

HL 58.20 Di 16:30 Poster TU F

Aharonov-Anandan phase and the quasistationarity of driven quantum systems — •Alex Matos-Abiague and Jamal Berakdar — Max-Planck Institut für Mikrostrukturphysik,

We derive necessary and sufficient conditions for the quasistationarity of a time-dependent quantum system and point out the relationship between the degree of quasistationarity, the Fubini-Study metric, and the Aharonov-Anandan geometric phase. As an illustration we analyze the dynamical localization of an electron in a double quantum well as well as the sustainability of field-induced orientation of polar molecules.

HL 58.21 Di 16:30 Poster TU F

Spontaneous Emission in Photonic Crystals: Experiment vs. Calculation — •Michael Barth and Frank Cichos — Photonics and Optical Materials, Institute of Physics, Chemnitz University of Technology

We have performed single-domain spectroscopy and time-resolved measurements on dye molecules and CdSe-nanoparticles in three-dimensional photonic crystals. The high spatial resolution of our microscopy setup provides an excellent basis for probing the local optical density of states (LDOS) in these crystals. The measurements are supplemented by corresponding numerical calculations of the LDOS, incorporating anisotropy effects and the spatial distribution of the emitters. It is found experimentally as well as theoretically, that, while the total radiative lifetime may stay nearly unaffected, strong modifications of the radiation pattern can be achieved in certain frequency ranges. We show that these effects depend sensitively on the ordering-quality of the crystal domains and the spatial position of the emitters.

HL 58.22 Di 16:30 Poster TU F

Nanophotonic Applications of Silicon Carbide — •Bettina Friedel and Siegmund Greulich-Weber — Universität Paderborn, Department Physik, Paderborn

3D photonic crystals for the visible spectrum are preferably prepared from sub-micron-spheres made from silica or organic materials which by self-organization form colloidal crystals. However, these crystals are fragile and exhibit a low refractive index and thus are not suitable for photonic devices. Infiltration of the interparticle voids with materials of appropriate refractive index, followed by removal of the spheres, leads to inverted opals for which a complete photonic bandgap is expected. A number of materials have been infiltrated, however not all are suitable for the visible range and in addition mechanically stable enough. We prefer infiltration by sol-gel routes because of its easy and time-saving application at low cost. Most infiltrates are rather porous and therefore do not feature the expected effective refractive index. We will discuss sol-gel wide-bandgap semiconductors, especially SiC, as possible infiltrates. In view of future photonic applications in-situ tuning of photonic properties becomes necessary, which might be realized by 'electronic' doping of the semiconductor material. Thus practical doping procedures for sol-gel semiconductor materials are additional requirements.

HL 58.23 Di 16:30 Poster TU F

Photonic Crystal Microwave Resonators for Magnetic Resonance Applications — •A. von Rhein, E. von Rhein, M. Wanjek, and S. Greulich-Weber — Universität Paderborn, Department Physik, Warburger Straße 100, 33098 Paderborn

Electron paramagnetic resonance and multiple resonance techniques like electron nuclear double resonance and optically detected magnetic resonance are powerful tools for the investigation of defects in solids. Recently high frequency sources (100 GHz) at reasonable costs became available for magnetic resonance (MR) spectroscopy providing higher spectral resolution and in principle higher sensitivity compared to lower frequencies. Usually the microwave absorption due to the MR signal is measured using a microwave bridge balanced by a microwave resonator containing the sample. At high frequencies the resonator becomes rather small which requires the development of new resonator designs. Especially for optical detection of MR optical access to the sample is needed which at high frequencies only allows the use of Fabry-Perot resonators, which provide relatively small quality factors. We present new resonator designs on the basis of photonic crystals also suitable for low frequency MR providing additional features not known from conventional resonators.

HL 58.24 Di 16:30 Poster TU F

II-VI/III-V semiconductor optical cavities fabricated by chemical etching, selective growth or FIB — •J. Lupaca-Schomber[1], B. Daniel[1], M. Hetterich[1], D. Tröndle[1], H. Kalt[1], F. Perez-Willard[2], J. Hawecker[2], and D. Gerthsen[2] — [1]Institut für Angewandte Physik and Center for Functional Nanostructures (CFN), Universität Karlsruhe, D-76131 Karlsruhe, Germany — [2]Laboratorium für Elektronenmikroskopie and CFN, Universität Karlsruhe, D-76128 Karlsruhe, Germany

We present three different methods for the production of (sub-) micrometer optical cavities with pyramidal shape made of II-VI/III-V semiconductors. One method is the selective etching (H_3PO_4:H_2O_2:H_2O solution) of an AlAs/GaAs structure. The AlAs sacrificial layer controls the lateral etching rate and influences the cross-sectional profile of the GaAs pyramidal objects. Another possibility is the selective growth of self-organized CdSe/ZnSe structures on pre-patterned GaAs (001) surfaces. Growth was performed by molecular beam epitaxy (MBE). A more direct method is Focussed Ion Beam (FIB). Structures in CdSe/ZnSe multiple quantum wells were prepared by this technique using a Ga ion beam without the necessity of further process steps. All samples were examined for their optical quality using μ-PL.

HL 58.25 Di 16:30 Poster TU F

Control of colloidal crystal growth by external fields — •E. von Rhein, O. Gudi, and S. Greulich-Weber — Universität Paderborn, Department Physik, Warburger Straße 100, 33098 Paderborn

Since the introduction of the concept of a photonic crystal much effort has been targeted at producing 3D photonic crystals working in the visible wavelength range. The most promising way is by self-assembly of monodisperse sub-micron spheres made of silica or organic materials resulting in fcc and hcp colloidal crystals. However, the large scale fabrication and thus their application in photonics suffer from the reproducible growth of defect-free extended bulk crystals. Commonly used 'natural' sedimentation is unacceptably slow and often results in low crystal quality showing cracks and stacking faults or reveals a disordered bulk below an apparently ordered surface. In literature there are several examples, where additional external fields such as electric or acoustic fields were applied, which to a certain extent enhanced the crystal quality. However, the reproducibility of such experiments depends on many parameters like the chemical composition of the spheres, the solvent, the density ratio of spheres and solvent, and many more. To have control of all this parameters during crystal growth is one of our current projects. We will present details of our computer controlled crystal growth experiments using specific external fields.

HL 58.26 Di 16:30 Poster TU F

Fabrication of templates and 3D nanostructuring of positive photoresists — •Sven Passinger, Carsten Reinhardt, and Boris Chichkov — Laserzentrum Hannover e.V., Hollerithallee 8, 30419 Hannover

So far, two-photon polymerization technique has been applied for the fabrication of photonic crystal structures only in negative photoresists. These materials have relatively low refractive index and, due to their high chemical stability, it appears difficult to use them as templates for the realization of high refractive index replicas.

In this contribution, positive photoresist S1813 (which can be easily removed) is used for the first time for the fabrication of photonic crystal templates. 3D nanostructuring of positive photoresist by two-photon irradiation technique is studied. We will report on resolution limits, first 3D photonic crystal structures fabricated by these methods, and their properties.

HL 58.27 Di 16:30 Poster TU F

Photoprocessable polymer opals — •Birger Lange and Rudolf Zentel — Institute of Organic Chemistry, Department of Chemistry and Pharmacy, University of Mainz, Duesbergweg 10-14, D-55099 Mainz

Progress in electronics and photonics can be seen in the development of new materials, which broadens our ability to manipulate electron and photon transport respectively. Photonic crystals are a new class of materials first discussed in 1987. Eli Yablonovitch and Sajeev John introduced the idea of controlling light and its emission with photonic crystalline materials. For a good control of light we need first a photonic crystal, this is here accomplished by the synthesis of monodisperse colloids from the acid labile polymer poly-tert.-butyl-methacrylate and a subsequent crystallization into polymer opals. Second we need the possibility to structure the photonic crystals, this could be achieved by loading the colloids with photoacid generator before crystallization. Irradiation with UV-light followed by baking and development with aqueous base allows subsequent patterning of the opaline films. This chemical approach makes it possible to use the self-assembly of this colloids (opal formation) to form a large scale periodic structure, and introduce optical defects with UV-lithography.

HL 58.28 Di 16:30 Poster TU F

Active and passive doped microstructured and photonic crystal fibres: — •Jens Kobelke, Johannes Kirchhof, Kirsten Gerth, Kay Schuster, Klaus Mörl, Claudia Aichele, and Hartmut Bartelt — Institut für Physikalische Hochtechnologie e.V., Albert-Einstein-Strasse 9, D-07745 Jena, Germany

The rapid development of novel designs of microstructured optical fibres (MOFs) and photonic crystal fibres (PCFs) as well as various material concepts open up improved technical implementations for fibre functionality: e.g. for fibre lasers, amplifiers, frequency filters, switching modules. We prepared and investigated high silica based MOFs with holey structure and with germanium and phosphorus doping. The aim of this design is to enlarge the possibility of tailoring the fibre properties, e.g. pulse dispersion and mode field shape. Novel types of laser fibres have been prepared by doping the core of PCFs with rare-earth elements. Such fibres are typically composed of a double-clad structures for efficient pumping. In current fibres the numerical aperture and the thermal stability are limited by the coating material. Its thermal behaviour typically reduces the power stability in longitudinal pumped ytterbium doped high power fibre lasers. We prepared different types of ytterbium doped PCFs with an air cladding in order to overcome this power limitation. The air cladding results in optical decoupling from the fibre coating and allows higher pump power levels compared with conventional polymer coated laser fibres due to an increase of the numerical aperture by a factor of about 2. The results of first laser tests show the high potential for power upgrading of this novel laser fibre concept.

HL 58.29 Di 16:30 Poster TU F

Realisation of a high efficiency gas sensing device — •Daniel Pergande[1], Torsten M. Geppert[1,2], Andreas von Rhein[1], Stefan L. Schweizer[1], Ralf B. Wehrspohn[1], Thomas Beyer[3], Iliyana Hinkov[3], and Armin Lambrecht[3] — [1]Universität Paderborn, Dept. Physik, Warburger Str. 100, 33098 Paderborn, Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle, Germany — [3]Fraunhofer-Institut für Physikalische Messtechnik, Heidenhofstr. 8, 79110 Freiburg

We present the conception of a gas sensor as a application of a 2D photonic crystal (PC). The PC consists of a membrane made of electrochemical etched pores in Silicon. The gas measurement makes use of the light absorption of the gas. Due to the effect of low group velocities a stronger interaction of the light with the gas is achieved. So the detection distance required for a certain sensitivity can be drastically decreased. One obtains a significant minituarisation of the device. The PC has to be designed according to the absorption frequency of the gas(in this case alcohol). This occures by the variation of the diameter and the pitch of the pores. A novel taper concept will be introduced and the fabrication of the device will be described.

HL 58.30 Di 16:30 Poster TU F

Focusing microwaves with a concave lens based on a 2D photonic crystal — •E. Foca[1], S. Frey[1], F. Daschner[1], V.V. Sergentu[2], J. Carstensen[1], R. Knöchel[1], I.M. Tiginyanu[2] und H. Föll[1] — [1]Faculty of Engineering, Christian-Albrechts-University, Kiel, Germany — [2]LLDSP, Technical University of Moldova, Chisinau, Moldova

Photonic crystals (PC) can be considered as optically homogenous materials for the long wave length limit, thus they can be ascribed an effective electric permittivity, and an effective refractive index. However, it is more complicated when the radiation wavelength is comparable with the PC irregularities. Even in this regime there remain frequency regions where the PC can be attributed an effective refractive index.

We present a new method to find the effective refractive index of a PC in non-trivial regimes, especially for the case of $0 < n_{eff} < 1$. We prove the correctness of our calculations by designing and measuring a concave lens with a $0 < n_{eff} < 1$ in the microwave regime. For such a case the lens focuses the radiation and we measured that this is indeed the case. We show a good correlation between the theoretical predictions and measured data and a good focusing quality of the lens. We estimate the focusing power of the lens in terms of the transmission coefficient that reaches values as high as 40 for frequencies close to 7.5 GHz, which is extremely good since nearly no other tool for focussing of microwaves exists.

HL 58.31 Di 16:30 Poster TU F

Selective Thermal Emitters in 2D Photonic Crystals — •B. Gesemann, M. Milbradt, A. von Rhein, S.L. Schweizer, and R.B. Wehrspohn — Universität Paderborn, Department Physik, Warburger Str. 100, 33098 Paderborn

We study the fabrication and optical properties of thermal emitters placed directly into the holes of a 2D-Photonic Crystal. The influence of the photonic band structure and DOS on the emission characteristics of the emitter is analyzed theoretically. For the realisation, we use Fe_2O_3 nanoparticles as inductive heaters which are selectively infiltrated into 2D macroporous silicon photonic crystals. We present structural and optical characterisation of the infiltration.

HL 58.32 Di 16:30 Poster TU F

High quality opals from organic-inorganic material — •Jianhui Ye and Rudolf Zentel — Department of Chemistry, University of Mainz, Duesbergweg 10-14, D-55099 Mainz

An attractive feature of synthetic opals, in comparison with their natural counterparts, arises from the possibility to use the lattice of sphere as a template that can be infiltrated with a variety of ferroelectric, nonlinear, and photorefractive materials. This permits the preparation of diverse materials compositions for optoelectronic applications. The photonic crystal properties of such diverse materials compositions are strongly dependent (I) on the quality of the initial opal and (II) on the filling factor of the opaline voids. We use high quality polymer opals as template and infiltrate with an organic-inorganic monomer (ORMOCER). This monomer can be photopolymerized within the opaline voids leading to "perfect" replica structure with filling factor above 90%. This is different from inorganic materials prepared by chemical vapor deposition or a sol-gel process.

HL 58.33 Di 16:30 Poster TU F

Photonic bandgap in two-dimensional octagonal quasi-periodic lattice — •Dmitry Chigrin and Johann Kroha — Physikalisches Institut, Universität Bonn, Nussallee 12, 53155 Bonn

A systematic study of a photonic bandgap formation in two-dimensional octagonal quasi-periodic lattice of dielectric rods is presented. Photonic bandgap maps are obtained for different dielectric constants and radiuses of rods for both fundamental polarizations. It is shown that for fairly high dielectric constant of rods, complete photonic bandgaps in both fundamental polarizations can overlap leading to a full bandgap. It is also shown, that in the case of TM polarization the first complete photonic bandgap remains open down to very small dielectric constants. The threshold dielectric constant can be as small as $\varepsilon = 1.6$. Possible optoelectronic applications of two-dimensional octagonal photonic quasi-crystals are discussed. The physical mechanisms of the photonic bandgap formation in a quasi-periodic lattice are addressed. Finite-difference time-domain and plane wave expansion methods were used for density of states and band structure calculations, respectively.

HL 58.34 Di 16:30 Poster TU F

Durchstimmbare Lasertätigkeit in ein- und zweidimensionalen photonischen Kristallen — •Stroisch Marc[1], Gerken Martina[1], Lemmer Uli[1], Forberich Karen[2] und Gombert Andreas[3] — [1]Lichttechnisches Institut, AG Visuelle Informationstechnik und Optoelektronik, Universität Karlsruhe — [2]Freiburger Materialforschungszentrum, Universität Freiburg — [3]Fraunhofer Institut für Solare Energiesysteme ISE, Freiburg

Organische Photonische Kristall-Laser lassen sich durch das Aufbringen von organischen Farbstoffen auf ein mikrostrukturiertes Substrat herstellen. Die Durchstimmbarkeit der Laserwellenlänge erfolgt dabei durch die Variation der Schichtdicke, der chemischen Zusammensetzung und der Gitterperiode des Substrates. Durch die Kombination der drei Elemente ist es mögliche den sichtbaren Spektralbereich abzudecken. Unterschiedliche Lasergitter (Linien-, Kreuz- und Hexagonalgitter) beeinflussen zudem Laserparameter wie die Abstrahlcharakteristik, die Laserschwelle und die Modenform der Laser. Als optisch aktive Materialien werden nach dem Spiro-Konzept verknüpfte organische Farbstoffe (Oligomere) und handelsübliche Laserfarbstoffe verwendet. Die experimentelle Charakterisierung erfolgt durch winkel- und wellenlängenabhängige Detektion der spontanen Emission, der stimulierten Emission und der Transmission.

HL 58.35 Di 16:30 Poster TU F

Ultraschnelles optisches Schalten in dreidimensionalen Photonischen Kristallen aus Silizium — •C. Becker[1], S. Linden[1], M. Wegener[1,2], N. Tetreault[3], V. Kitaev[3], G. von Freymann[3] und G. A. Ozin[3] — [1]Institut für Nanotechnologie, Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft — [2]Institut für Angewandte Physik, Universität Karlsruhe — [3]Department of Chemistry, University of Toronto

Photonische Kristalle weisen vielversprechende Möglichkeiten zur Realisierung von optischen Schaltelementen auf. Verantwortlich hierfür ist die Existenz einer teilweisen oder kompletten Photonischen Bandlücke, deren spektrale Position vom Brechungsindex abhängt. Eine ultraschnelle optisch induzierte Veränderung des Brechungindex ermöglicht daher interessante Schaltprozesse. Es gab in der Vergangenheit diesbezüglich nur wenige Experimente, die auf resonanter Erzeugung freier Ladungsträger beruhten und daher lange Relaxationszeiten hatten.[1]

Wir haben in einem Anrege-Abfrage-Experiment mit zwei voneinander unabhängigen optisch parametrischen Verstärkern invertierte Silizium-Opale untersucht, deren Bandlücke im nahen Infrarot liegt. Die Variation des Brechungsindex kann jedoch auch durch nichtresonante Effekte verursacht werden. Bei diesen Prozessen, insbesondere beim optischen Kerr-Effekt, sind die Relexationszeiten wesentlich kürzer. In der Analyse der Daten wurde ein besonderes Augenmerk auf die Unterscheidung der verschiedenen resonanten und nichtresonanten nichtlinearen Effekte gerichtet.

[1] S. W. Leonard et al., PRB, **66**, 161102 (2002)

HL 58.36 Di 16:30 Poster TU F

Integration of three-dimensional photonic crystals onto structured silicon wafers — •Jianhui Ye[1], Rudolf Zentel[1], Sanna Arpiainen[2], and Jouni Ahopelto[2] — [1]Department of Chemistry, University of Mainz, Duesbergerweg 10-14, D-55099 Mainz — [2]VTT Centre for Microelectronics, P.O. Box 1208, FIN-02044 VTT

The strong research effort devoted to photonic crystals is motivated by their potential to build a generation of optoelectronic devices of reduced size, combining high integration, and high-speed processing. Advanced photonic circuits will need complex architectures, which can be achieved by using structured silicon substrates as a container, onto which high-quality photonic crystals of controlled size and shape have to be grown.

We report on crystallization of silica spheres of diameter 900 nm on structured silicon wafers with the help of a "drawing apparatus". The crystallization can, thereby, be directed exclusively to the lower lying parts. We optimize the conditions of the crystallization and obtain opals of good quality on patterned substrates, i.e.: (I) good infilling of the structures, flat top surface; (II) 3D order; and (III) absence of cracking. The influence of the complex pattern on the quality of the opals will be discussed.

HL 58.37 Di 16:30 Poster TU F

Larger bandgaps of photonic crystals fabricated by holographic lithography can be realized by the beam design — •Xiulun Yang[1] and L.Z. Cai[2] — [1]Institute of Applied Physics, University of Bonn — [2]Department of optics, Shandong University, 250100, P. R. China

The existence of photonic band gaps (PBGs) is the most important property and the basis of many applications of photonic crystals (PhCs). One of the fundamental tasks of PBG engineering is how to obtain and maximize a PBG for a given structure. A unique feature of the PhCs produced by the holographic method is that the shape and size of the resultant element spots, referred to as atoms of the structure, take the form of the equal- intensity surfaces of the interference field. Naturally they vary with the beam design and the choice of the threshold intensity, and they are usually different from the regular shapes like a cylinder or a sphere reported before. Therefore a more specific PBG study of the PhCs of this kind considering their special atom shape and size becomes necessary. In our recent work we have taken two-dimensional triangular and square lattices as an example to investigate the PBG property of holographically recorded PhCs, and shown that the holographic method gives us a new freedom for PBG engineering. This work was supported by BMBF(13N8340), DFG (SPP1113), the National Natural Science Foundation of China (50173015 and 60177002), foundation NSFC/RGC of China (50218001), and the China Postdoctoral Foundation.

HL 58.38 Di 16:30 Poster TU F

Negative refraction in 2d square lattice photonic crystals at millimetre waves — •Rados Gajic[1], Ronald Meisels[2], Friedemar Kuchar[2], Javad Zarbakhsh[3], and Kurt Hingerl[3] — [1]Institute of Physics, University of Belgrade, Yugoslavia — [2]Institute of Physics, University of Leoben, Austria — [3]Christian Doppler Laboratory, Institute for

We investigated the negative refraction of microwaves in a 2D photonic crystal (PhC) made of alumina rods in air. The experiments were performed in the 26 – 40 GHz range. Negative refraction was experimentally verified of the TM mode for the Gamma-M surface of the crystal in the range 35 to 37 GHz for an incidence of 45 degree. In addition we studied collimation and self-focusing effects in our PhC.

The refraction of an incident beam was determined by measuring the lateral displacement of the beam by a plane parallel slab made from the PhC. The beam was collimated using a pyramidal horn. The intensity distribution after the slab was scanned using an open-ended waveguide connected to a power meter.

Experimental findings are in agreement with calculations determining the direction of the beam as that of the group velocity which is obtained from the equifrequency contours (from band structure calculations). In addition real space FDTD simulations of the beam propagation were also found to validate the experiments.

HL 58.39 Di 16:30 Poster TU F

Tuning of the defect mode in a three dimensional photonic crystal made of macroporous silicon and a liquid crystal — •Guido Mertens[1], Sven Matthias[2], Ralf Wehrspohn[1], and Heinz Kitzerow[1] — [1]Faculty of Science, University of Paderborn, Warburger Str. 100, 33098 Paderborn — [2]Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle

Variations of the refractive index can be utilized in order to shift the stop band in photonic crystals. We report on investigations of three-dimensional macroporous silicon structures which are filled with a liquid crystal. The sample contains a two-dimensional array of pores with periodically varying diameter. A plane with constant pore diameter embedded between two three-dimensional structures with varying pore diameter forms a micro resonator. FTIR measurements indicate a defect mode that can be shifted by changing the temperature. In transmission, a peak at the wavelength 7.184 micrometers appears in the centre of the second stopband, which can be attributed to a localised defect mode. Filling the structure with the liquid crystal 5CB (Merck) causes a red-shift of the stopband. Together with the stopband, the wavelength of the defect state is shifted by 191 nm to the larger wavelength 7.375 micrometers at 24 centigrades. An additional shift by 20 nm to a wavelength of 7.395 micrometers is caused when the liquid crystal is heated from the nematic phase (24 centigrades) to the isotropic phase (40 centigrades). These results are in qualitative agreement with theoretical calculations based on a transfer matrix model.

HL 58.40 Di 16:30 Poster TU F

Photonic Crystal Waveguides Based On The Insulator-On-Silicon-On-Insulator Material System — •Cécile Jamois[1,2], Christian Hermann[2], Alexey Milenin[1], Torsten Geppert[1,3], Kosmas Tsakmakidis[2], Ralf Wehrspohn[3], and Ortwin Hess[2] — [1]Max-Planck Institut für Mikrostrukturphysik, Weinberg 2, 06108 Halle (Saale) — [2]Advanced Technology Institute, University of Surrey, Guildford, Surrey, GU2 4LE, UK — [3]Department Physik, Nanophotonische Materialien, Universität Paderborn, Warburgerstr. 100, 33098 Paderborn

In this paper, we discuss the properties of planar photonic crystal (PPC) waveguides in the insulator-on-silicon-on-insulator (IOSOI) material system. IOSOI-based PPCs are very attractive, since they are compatible with the standard silicon technology and offer a high light confinement, due to the high vertical index contrast and to the vertical symmetry of the structure. Using FDTD simulations as well as a plane-wave method (MIT package) we study the properties of PPCs based on IOSOI and put into evidence intrinsic loss mechanisms associated with the planar nature of PPCs, which may restrict their application range. Next, we discuss the consequences of these loss mechanisms on the properties of waveguides made in IOSOI-based PPCs, and propose solutions to the possible restrictions on the device functionalities. The experimental fabrication of these waveguides is achieved by F-based ICP etching through a Cr mask, which is patterned by e-beam lithography and Cl-based RIE. Optical measurements on the fabricated structures are performed and compared to the theoretical predictions.

HL 58.41 Di 16:30 Poster TU F

Purcell effect of colloidal semiconductor nanocrystals in microcavities — •Robert M. Kraus[1], Pavlos G. Lagoudakis[1], Dmitry Talapin[2], Andrey L. Rogach[1], John M. Lupton[1], Jochen Feldmann[1], and Horst Weller[2] — [1]Lehrstuhl für Photonik und Optoelektronik, Ludwig-Maximilians-Universität München — [2]Institut für Physikalische Chemie, Universität Hamburg

The theory of cavity quantum electrodynamics focuses on the fundamental questions of light matter interaction. Photon confinement in a planar microcavity geometry changes the photon mode density. An emitter embedded in the cavity has a modified spontaneous emission rate depending on its spectral and spatial overlap with the cavity mode. In our case the emitters are colloidal semiconductor nanocrystal quantum dots. Due to their polydispersity they exhibit a spectrally broad emission. A suitable resonator was built by a dielectric Bragg reflector and a silver mirror separated by a 200nm thick polymer/nanocrystal layer. By tuning the layer thickness one can choose the emission wavelength within the spectra of the nanocrystals. Q-factors of up to 300 demonstrate the excellent controllability of the fabrication process. Time resolved fluorescence decay measurements reveal an intriguing dependence of the spontaneous emission rate on temperature and Q-factor.

HL 58.42 Di 16:30 Poster TU F

DLTS-Untersuchungen an III-V-Halbleitern für Solarzellen — •Severin Müller[1,2], Frank Dimroth[2], Sascha van Riesen[2] und Andreas W. Bett[2] — [1]Freiburger Materialforschungszentrum, Universität Freiburg, Stefan-Meier-Strasse 21, 79104 Freiburg — [2]Fraunhofer ISE, Heidenhofstrasse 2, 79110 Freiburg

Voraussetzung für einen hohen Wirkungsgrad einer Solarzelle ist, dass die durch Lichteinstrahlung im Halbleiter erzeugten Minoritätsladungsträger eine hohe Lebensdauer erzielen. Rekombinieren diese bevor sie den p/n-Übergang erreicht haben, tragen sie nicht zum Strom der Zelle bei. Dabei wirken tief in der Bandlücke des Halbleiters liegende Defekte als besonders effektive Rekombinationszentren. Diese gilt es daher zu verringern. Am Fraunhofer ISE werden GaAs-basierende Schichtstrukturen für Solarzellen mittels MOVPE (metallorganische Gasphasenepitaxie) auf GaAs- und Ge-Substraten abgeschieden. Insbesondere das Material GaInNAs ist als Mittelzelle einer Kaskadensolarzelle auf Germanium-Substraten von besonderen Interesse. Bisher wurden mit diesem Material allerdings nur geringe Solarzellenwirkungsgrade erzielt, was auf eine geringe Diffusionslänge bzw. Lebensdauer zurückzuführen ist. Mittels DLTS-Messungen (Deep-level transient spectroscopy) können tiefe Rekombinationszentren identifiziert werden. Somit besteht die Möglichkeit, unterschiedliche Wachstumsbedingungen zu bewerten und sie zu optimieren. Ergebnisse dieser Arbeiten werden vorgestellt.

HL 58.43 Di 16:30 Poster TU F

Optimierung von Tunneldioden in III-V Mehrfach-Solarzellen — •Wolfgang Guter[1], Frank Dimroth[1], Matthias Meusel[1,2] und Andreas Bett[1] — [1]Fraunhofer ISE, Heidenhofstrasse 2, 79110 Freiburg — [2]RWE Space Solar Power GmbH, Theresienstr. 2, 74072 Heilbronn

Solarzellen mit mehreren *p-n* Übergängen eröffnen neue Möglichkeiten für die Steigerung des Wirkungsgrades bei Solarzellen, da jede Teilzelle einem speziellen Band des Sonnenspektrums angepasst werden kann. Um monolithisch aufeinander gewachsene Zellen elektrisch miteinander zu verbinden, wünscht man sich optisch transparente, hoch leitfähige Schichten, welche den Wirkungsgrad nicht schmälern; sogenannte *Intercell Ohmic Contacts* (*IOCs*). Eine wichtige Realisierung eines *IOC* ist die Interband-Tunneldiode (*TD*) nach Esaki. Speziell in Konzentratorsystemen, welche Solarzellen aus *III-V* Halbleitern auch auf der Erde wirtschaftlich machen, werden in den Zellen hohe Stromdichten von etwa $15\,A/cm^2$ erreicht. Diese Arbeit befasst sich mit der Optimierung von Tunneldioden in *GaInP/Ga(In)As/Ge*-Tripelzellen bezüglich hoher Tunnelstromdichten. Numerische Simulationen der Bandstruktur und Ausheil-Experimente an *MOVPE* (metall-organische Gasphasenepitaxie) gewachsenen Tunneldioden zeigen den Einfluss der die *TD* umgebenden Barriereschichten auf Bandverbiegung, Dotierstoffdiffusion und Tunnelverhalten.

HL 58.44 Di 16:30 Poster TU F

Local characterisation of multicrystalline silicon solar cells with the front metal grid on grain boundaries — •Viktor Schlosser[1], Rita Ebner[2], and Johann Summhammer[2] — [1]Institut für Materialphysik, Universität Wien — [2]Atominstitut der Österreichischen Universitäten, Wien

Light beam induced current mapping (LBIC) is used to investigate large area solar cells. Multicrystalline silicon solar cells were equipped with a front metal grid which was applied onto the grain boundaries. The LBIC experimental set up works with two fibre coupled luminescence diodes at centre wavelengths of 650 nm and 870 nm respectively. The two LEDs were driven by the same current and individually intensity modulated. By the use of two Lock In amplifiers the total light generated current from the device was split into its two components. A feed back loop for the LED current was used to maintain a constant LBIC signal of the red LED. The current caused by the infrared LED was recorded as a function of the light spot position on the solar cell. By this method the contribution of many of the surface's electrical and optical inhomogenities to the LBIC were eliminated. The scanned signal merely is altered by the local bulk properties of the carriers. The results made on cells under different operating conditions will be presented and discussed.

HL 58.45 Di 16:30 Poster TU F

Radiative recombination coefficient in crystalline silicon above room temperature — •Sebastian Meier, Rudolf Brüggemann, Saioa Tardon, and Gottfried Heinrich Bauer — Institute of Physics, Carl von Ossietzky University Oldenburg, Germany

Typical operating temperatures of solar cells are in the temperature range above room temperature. In these devices radiative recombination is one of the recombination channels that determine the excess carrier density and luminescence efficicency. We concentrate on radiative recombination in crystalline silicon for which some discrepancy exists in the literature on the values for the rate coefficient B(T) of radiative recombination. Trupke et al. [1] reviewed this discrepancy and determined B(T) in the temperature range between 77 K and 300 K from relative photoluminescence measurements that were calibrated with literature data of the absorption coefficient. In order to extend the temperature range reported in the literature, we determined B(T) for crystalline silicon between room temperature and 393 K from absolute photoluminescence measurements on crystalline silicon wafers passivated with thin amorphous silicon films. For temperatures below room temperature good agreement is found between data from [1] and the present values. Above room temperature B(T) is almost independent of temperature with a value around 3.9×10^{-15} cm^3 s^{-1}.

[1] T. Trupke et al., J. appl. Phys. 94 4930 (2003).

HL 58.46 Di 16:30 Poster TU F

Transmissionselektronenmikroskopie und hochauflösende Röntgendiffraktometrie an GaInP/GaInAs/Ge Heterostrukturen für Tripel Solarzellen — •Jan Schöne[1,2], Erdmann Spiecker[1], Wolfgang Jäger[1], Frank Dimroth[2] und Andreas W. Bett[2] — [1]Technische Fakultät der CAU Kiel, Kaiserstrasse 2, 24143 Kiel — [2]Fraunhofer ISE, Heidenhofstrasse 2, 79110 Freiburg

Eine maximale Effizienz von sogenannten Stapelsolarzellen aus III-V-Halbleitern mit 3 pn-Übergängen wird mit einer metamorphen Struktur aus GaInP/GaInAs/Ge erzielt. Hierzu ist es notwendig, gitterfehlgepasste Materialien mit einem Mismatch bis zu 2% auf das Ge-Substrat aufzuwachsen. Bei gitterfehlgepasstem Wachstum entstehen Spannungen, die ab einer gewissen Schichtdicke durch den Einbau von Fehlpassungsversetzungen relaxieren. Neben diesen Versetzungen entstehen auch sogenannte Fadenversetzungen (threading dislocations). Diese Versetzungen stellen starke Rekombinationszentren für Minoritätsladungsträger dar und wirken sich daher negativ auf die Diffusionslängen der Ladungsträger aus. Durch das Aufwachsen von geeigneten Pufferschichten zwischen den gitterfehlgepassten Schichten wird die Gitterkonstante stufenweise oder kontinuierlich angepasst. Die Wachstumsbedingungen während des Pufferschichtwachstums haben einen wesentlichen Einfluss auf die Qualität der anschließend gitterangepasst abgeschiedenen Solarzellenstruktur. Ergebnisse von Analysen der Versetzungsnetzwerke mittels Transmissionselektronenmikroskopie und der Restspannungen mittels hochauflösender Röntgendiffraktometrie werden vorgestellt.

HL 58.47 Di 16:30 Poster TU F

Local partial density of states in CuInS2 upper valence band determined by x-ray emission spectroscopy-evidence for In 5p contribution — •L. Zhang[1], I. Konovalov[2], D. Wett[2], M. Nagel[1], D. Schulze[2], R. Szargan[2], and T. Chassé[1] — [1]Institut für Physikalische und Theoretische Chemie, Universität Tübingen, Auf der Morgenstelle 8, 72076 Tübingen, Germany — [2]Wilhelm-Ostwald-Institut für Physikalische und Theoretische Chemie, Universität Leipzig, Linnéstrasse 2, 04103 Leipzig, Germany

The Cu L2,3, In M4,5 and S L1 soft x-ray emission spectra of single crystalline CuInS2 were measured using synchrotron radiation as excitation source at ROSA endstation of U41-PGM beamline in BESSY. These spectra reflect the local partial density of states (LPDOS) of Cu 3d, In 5p and S 3p valence states, and they correspond to the features in the total density of states of the upper valence band represented in the valence band photoelectron spectrum. A density functional calculation of the LPDOS confirms two components occurring in both S 3p and In 5p partial density of states. From the similarity of the positions and the intensity ratios of these two components, an admixture of In 5p states to the S 3p states in the upper valence band was suggested.

HL 58.48 Di 16:30 Poster TU F

Nichtinvasive Charakterisierung fabrikationsbedingter Defekte in Solarzellen — •D. Ragusch[1], J. Beyer[2], E. Cikos[3], D. Drung[2], S. Rolle[1] und Th. Schurig[2] — [1]Technische Fachhochschule Wildau, Bahnhofstr. 15745 Wildau — [2]Physikalisch-Technische Bundesanstalt, Abbestr. 2-12, 10587 Berlin — [3]University Skopje, Macedonia

Das in [1] vorgestellte Messsystem zur berührungslosen Detektion von Fotostromverteilungen und Defekten in Solarzellen, basierend auf der SQUID-Photoscanning Methode [2], wurde von uns im Hinblick auf eine fabrikationsbegleitende Kontrolle weiterentwickelt.

Die Frontseite der zu untersuchenden Solarzelle wird mittels einer geeigneten und amplitudenmodulierten Lichtquelle abgetastet. Die von den Fotoströmen verursachten magnetischen Felder werden von einer Induktionsspule detektiert. Die Ausgangsspannung der Spule wird frequenzselektiv und phasenempfindlich gemessen. Aus diesen Messdaten können Rückschlüsse auf Defekte der Solarzelle gezogen werden.

Um die Eignung des Messsystems für den industriellen Einsatz zu verbessern, wurde die optische Anregung und die Sensorik auf den schnellen Nachweis typischer Defekte, wie Kontaktierungsfehler und Brüche zugeschnitten. Der Messaufbau und die gewonnen Ergebnisse werden vorgestellt.

[1] D.Ragusch et al., Poster, DPG Frühjahrstagung 2002

[2] J.Beyer et al., IEEE Trans.Appl.Supercond., Vol.11, pp. 1162-1167, March 2001

HL 58.49 Di 16:30 Poster TU F

InP-based III-V solar cells — •H.-J. Schimper, Z. Kollonitsch, K. Möller, U. Seidel, U. Bloeck, K. Schwarzburg, F. Willig, and T. Hannappel — Hahn-Meitner-Institute, Glienicker Str. 100, 14109 Berlin, Germany

New materials were introduced for multi junction solar cells based on the lattice constant of InP, in particular GaAsSb (E_{gap} = 0.75eV) and InAlGaAs (E_{gap} = 1.15eV). These materials were grown via metalorganic vapor phase epitaxy (MOVPE) using the alternative precursors TBP and TESb.

The new absorber materials were compared with the more established materials InGaAs (E_{gap} = 0.75eV) and InGaAsP (E_{gap} = 1.15eV). The values of short-circuit current and open-circuit voltage achieved with the new GaAsSb pn-solar cells were in the same range as the best InGaAs pn-cells. The substitution of Ga by Al in InAlGaAs leads to III-V-compounds lattice matched to InP(100) with band gaps between 0.75eV < E_{gap} < 1.5eV. A pn-junction solar cell was prepared from $In_{0.53}Al_{0.26}Ga_{0.21}As$ with E_{gap} = 1.15eV and compared to the InGaAsP (E_{gap} = 1.15eV) cell. It will be shown that the latter cell with 26% Al reached an internal quantum efficiency close to that of the InGaAsP cell.

HL 58.50 Di 16:30 Poster TU F

Growth and Characterization of 3C-SiC thin films on Si substrates — •Rakesh Sohal, Karsten Henkel, Klaus Müller, and Dieter Schmeisser — Angewandte Physik Sensorik, BTU Cottbus

This work reports on the growth and characterization of cubic silicon carbide thin films. A cold wall low pressure chemical vapour deposition (LPCVD) system has been used to grow the cubic silicon carbide. The two step method, carbonization and subsequent growth, has been used to grow good quality 3C-SiC thin films. The composition and structure of deposited thin films have been analysed by Fourier Transform Infrared Spectroscopy (FTIR), XPS and X-Ray Diffractometry (XRD). The structural quality of the films has been optimized as a function of substrate temperature during carbonization and growth. X-rays diffraction measurements shows that the grown layers are highly oriented crystalline cubic silicon carbide.

HL 58.51 Di 16:30 Poster TU F

Oxide-free transfer of silicon layers in UHV — •Alin Mihai Fecioru, Stephan Senz, and Ulrich Michael Gösele — Max-Planck-Institut für Mikrostrukturphysik, 06120 Halle

We combine ultrahigh vacuum (UHV) wafer bonding with hydrogen implantation in order to transfer single crystal silicon layers on (100) and (111) silicon substrates. The smart-cut procedure used for SOI fabrication requires SiO_2 to SiO_2 bonding followed by a high temperature annealing step. Unlike the smart-cut approach, we were able to achieve direct transfer without the involvement of any oxide layers by means of UHV bonding. Hydrogen desorption was done in-situ, by 248 nm excimer laser pulses with energy densities around 300 mJ/cm^2. TEM investigations were performed in order to confirm that our interfaces are smooth and oxide-free. The electrical properties were characterized by temperature-dependent current-voltage (I-V) measurements correlated with deep level transient spectroscopy (DLTS) measurements, showing the presence of interface and bulk electrically active defects which alter the device performance to some extent. A high temperature annealing step following the splitting procedure improves both the interface properties and the smoothness of the transferred layer.

HL 58.52 Di 16:30 Poster TU F

Preparation and Characterization of FeS films — •Ganhua Fu[1], Angelika Polity[1], Wilhelm Kriegseis[1], Dietmar Hasselkamp[1], Bruno K. Meyer[1], Boris Mogwitz[2], and Jürgen Janek[2] — [1]I.Physikalisches Institut, Justus-Liebig-Universität Giessen, Heinrich-Buff-Ring 16, D-35392, Giessen — [2]Physikalisch-Chemisches Institut, Justus-Liebig-Universität Giessen, Heinrich-Buff-Ring 58, D-35392, Giessen

Bulk FeS exhibits a metal-semiconductor transition at 420 K. Below 420 K, it is a semiconductor with troilite structure, while it transforms into a poor metal with NiAs-type structure above 420 K, accompanied by a change of two orders of magnitude in electrical conductivity. In this work, FeS films on float glass were prepared by RF reactive sputtering. The structure and morphology of the layers were studied by X-ray diffraction (XRD) and scanning electron microscopy (SEM), respectively. Rutherford back-scattering spectroscopy (RBS) and secondary ion mass spectroscopy (SIMS) were used to determine the compositon of the films. In addition, the effects of the growth parameters, such as power and substrate temperature, on the structure of FeS films were investigated. It's found that the films show substrate temperature dependent preferred orientation, which varies from (112) plane to (110) plane with the decline of substrate temperature from 773 K down to 473 K.

HL 58.53 Di 16:30 Poster TU F

Electrical properties of semiconducting PZT films on gold surfaces — •F. Müller[1], J. Yukecheva[2], A.-D. Müller[1], and M. Hietschold[1] — [1]Chemnitz University of Technology, Institute of Physics, Solid Surfaces Analysis Group, 09107 Chemnitz — [2]630092 Novosibirsk State Technical University (NSTU), Karl Marx avenue 20, Novosibirsk, Russia

PZT (lead zirconium titanat) is mainly known as ferroelectric material with a high dielectric permittivity and bistable polarization states, which leads to its application in actuators, nonvolatile memories and pyroelectric infrared sensors. Besides this, PZT is a semiconducting material with a band gap of 3.5 eV. The electrical investigation of the semiconducting properties, however, is difficult, because the typical dependencies are hidden behind the larger ferroelectric effects. In this work, we have shown that it is possible to prepare PZT thin films, which are semiconductive and not ferroelectric. The electrical properties of these films have been studied with various methods. From C(V)-curves, it was derived that the prepared PZT films are p-doped. The stability of the material was investigated with time dependent current spectroscopy.

HL 58.54 Di 16:30 Poster TU F

Focused ion beam implantation of magnetic ions — •Alexander Melnikov, Safak Gök, Sinan Ünlübayir, Rolf Wernhardt, Dirk Reuter, and Andreas Wieck — Ruhr-Universität Bochum, Lehrstuhl fr Angewandte Festkrperphysik, Universittsstrasse 150, D-44780 Bochum

For focused ion beam (FIB) implantation of magnetic ions, liquid metal ion sources (LMIS) with long operation times were developed on the basis of appropriate binary and ternary alloys. Alloys such as AuCrGe, AuDyGe, AuDySi, AuErSi, AuFeGe, AuGdSi, AuGeMn, AuGeNi, AuHoSi, AuSiTb, CoDy, DyNi, and HoNi were used to obtain Cr, Mn, Fe, Co, Ni, Gd, Tb, Dy, Ho and Er ions. The mass spectra were analyzed for the developed sources. As an example, FIB implantation of Mn was investigated. Lines with width about 200 nm were implanted with doses $2\times10^{11}-2\times10^{14}cm^{-2}$ in a $GaAs/Al_xGa_{1-x}As$ heterostructures (HEMTs) with two-dimensional electron and two-dimensional hole systems, respectively. Subsequent rapid thermal annealing was performed with typical temperatures of $750°C$ during 30 s. Transport properties through such lines have been investigated as function of magnetic fields up to 5 T in the temperature range from 4.2 to 300 K.

HL 58.55 Di 16:30 Poster TU F

Fabrication of closed single-walled semiconductor microtubes — •T. Kipp, S. Mendach, H. Welsch, Ch. Heyn, D. Heitmann, and W. Hansen — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg

The epitaxial lift-off of pseudomorphically strained semiconductor bilayers results in the formation of cylindrical microtubes [1]. These three-dimensional objects have extremely smooth surfaces and thus, they are promising candidates for the realization of novel high-Q optical resonators for light guided along the cylinder perimeter.

Applying the conventional preparation process, microtubes have the shape of rolled-in carpets. Here, we report on a novel technique to prepare closed single-walled microtubes. We define two starting edges on two opposite sides of a thickness modulated strained InGaAs/GaAs mesa and provide both starting edges with unstrained tines. During the final selective etching step the mesa bends up from both starting edges and the straight tines of the opposite sides interlock centrically resulting in a closed single-walled semiconductor tube. Due to its steadiness and the fact that all parameters of the forming tubes can be tuned precisely this interlocking mechanism is a key point for the realization of closed pathways along the perimeter of semiconductor tubes for photons, but possibly also for electrons.

[1] V.Ya. Prinz *et al.*, Physica E **6**, 828 (2000).

HL 58.56 Di 16:30 Poster TU F

Strukturelle und optische Eigenschaften von β-$FeSi_2$-Filmen auf Si(100) und MgO(100) — •Kirill Trounov[1], Marco Walterfang[1], Werner Keune[1] und Vasyl Kravets[2] — [1]Angewandte Physik, Universität Duisburg-Essen, 47048 Duisburg — [2]Experimentalphysik, Universität Duisburg-Essen, 47048 Duisburg

Seit einigen Jahren sind Fe-Disilizide von Interesse für Anwendungen in der Silizium-Technologie. Viele Untersuchungen haben sich aufgrund seines direkten Bandübergangs von 0.85 eV (1.46 μm), der sich nahe am Absorptionsminimum von Glasfasern befindet, auf das halbleitende β-$FeSi_2$ konzentriert, welches aufgrund seiner besonderen Eigenschaften als potentieller Kandidat für den Bau von optischen Detektoren bis in den infraroten Wellenlängenbereich gilt. Der große Brechungsindex von β-$FeSi_2$ (5.6) gegenüber dem von Si (3.5) macht die β-$FeSi_2$/Si Doppel-Heterostruktur interessant für LEDs.

β-$FeSi_2$-Filme wurden auf Si(100)- oder MgO(100)-Substraten molekularstrahlepitaktisch hergestellt und mößbauerspektroskopisch (^{57}Fe-CEMS) sowie mittels Röntgenbeugung untersucht. Dabei wiesen β-$FeSi_2$-Filme auf Si(100) eine geringfügig bessere strukturelle Qualität auf als auf MgO(100). Mittels IR-Transmissionsspektroskopie wurde für den Bandabstand der β-$FeSi_2$-Phase ein Wert von 0.85 eV (auf Si(100)) bzw. 0.90 eV (auf Mg(100)) ermittelt. Für dickere β-$FeSi_2$-Filme (> 1500 Å) wurden in den IR-Spektren für Energien unterhalb des Bandabstandes Oszillationen in den Transmissionskurven beobachtet.

Gefördert durch die Deutsche Forschungsgemeinschaft (Ke 273/17-1).

HL 58.57 Di 16:30 Poster TU F

Electrical transport investigation of platinum salt nanowires — •J. M. Becker[1], L. Ren[2], M. Wark[2], and R. Haug[1] — [1]Institute of Solid State Physics, Nanostructure Group, Hannover — [2]Institute of Physical Chemistry, Hanover

The investigation of electrical transport properties and the growth mechanism of platinum salt $[Pt(NH_3)_4][HCO_3]_2$ nanowires will be presented. These nanowires have a thickness of $50 - 100$ nm and a length of 500 $nm - 2.5$ μm. Electrical contacts (Cr/Au) are fabricated by using e-beam lithography and vacuum evaporation. The current-voltage characteristic shows a ohmic behavior at room temperature. This can be related to a metallic structure of these platinum salt nanowires, which means that delocalized states exist at room temperature in growth direction of the wires. The unit cell (space group P 4/m b m) of the platinum salt was determined by using X-ray diffraction.

HL 58.58 Di 16:30 Poster TU F

Infrared behaviour and plasmon properties of single metal nanowires — •Torsten Kolb[1], Maria Eugenia Toimil Molares[2], Thomas Cornelius[2], Florian Kost[1], Robert Lovrincic[1], Reinhard Neumann[2], Annemarie Pucci[1], and Gerhard Fahsold[1] — [1]Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227, D-69120 Heidelberg — [2]Gesellschaft für Schwerionenforschung (GSI), Planckstraße 1, D-64291 Darmstadt

We investigate the IR-optical properties of single metal (Cu) nanowires. The wires were prepared by template directed growth of Cu in etched ion tracks in polycarbonate membranes. We dispersed these wires on IR-transparent substrates by dissolving the membranes. For IR spectroscopy we used the synchrotron radiation source ANKA at the Forschungszentrum Karlsruhe. Investigations of broadband IR-optical properties in the range from 600 cm^{-1} to 6000 cm^{-1} of single nanowires were done by performing IR-microscopy in transmission with an IR-beam of about 8.3 micrometer width. For few-micrometer long Cu wires we observed antenna-like plasmon resonances dependent on size and shape of the wires. By varying polarisation of the incident beam we proved that an electric field component parallel to the wire is necessary for an excitation of these resonances.

Project ist supported by DFG (SPP 1165)

HL 58.59 Di 16:30 Poster TU F

Investigation of lateral Stark effect in InAs-quantum dots — •Victorina Stavarache[1], Dirk Reuter[1], Andreas D. Wieck[1], Matthias Schwab[2], Ruth Oulton[2], and Manfred Bayer[2] — [1]Angewandte Festkörperphysik, Ruhr- Universität Bochum, Univesitätsstr.150, 44780 Bochum — [2]Experimentelle Physik II, Universität Dortmund, Otto-Hahn Strasse 4, 44221 Dortmund

We have investigated the effect of an in-plane (lateral) electric field on self-assembled InAs-quantum dots (QDs) by photoluminescence (PL) and time-resolved spectroscopy measurements. For this, we have fabricated in-plane p-i-n diode structures by implanting Si^{2+} ions (n-type region) and Be^{+} ions (p-type region). The width of the intrinsic region was $2 - 3\mu m$ which results in an electric field higher than $\sim 10^5 Vm^{-1}$.

Time resolved PL spectroscopy has been performed on a sample with a relatively high QD density ($10^{10} cm^{-2}$). The PL intensity decreases with increasing reverse bias as the radiative lifetime increases with increasing electrical field. To observe the change in the emission wavelength as function of the applied electric field (lateral Stark-effect), we have also fabricated devices with low QD density ($10^8 - 10^9 cm^{-2}$). This may also lead to perform single dots spectroscopy. The results will be discussed.

HL 58.60 Di 16:30 Poster TU F

Nanolithography on AlGaAs-GaAs heterostructures by Atomic Force Microscope — •Kevin Rachor, Steffen Groth, Christian Heyn, Detlef Heitmann, and Can-Ming Hu — Institut für Angewandte Physik , Universität Hamburg, Jungiusstr. 11, 20355 Hamburg

We have explored two different techniques to pattern AlGaAs-GaAs heterostructures with a two dimensional electron gas (2DEG) confined 35 nm below the surface by AFM: (i) The "dynamical ploughing", where the AFM tip scribes a pattern into a very thin photoresist on top of the sample and the pattern is transferred by wet chemical etching into the AlGaAs. (ii) We have also performed local anodic oxidation with a bias voltage between tip and sample. Both methods yield a depletion of the 2DEG underneath, respectively, the etched or the oxidized lines. We fabricate ballistic quantum point contacts (QPC's) with geometrical width between 50 and 150 nm. Conductance measurements at 4.2 K are performed, which can demonstrate the formation of 1D subbands in the QPC's by varying the electron density using a top gate.

HL 58.61 Di 16:30 Poster TU F

Ionenimplantation von N+ und Al+ in ZnO Nanodrähte — •Sven Müller, Daniel Stichtenoth, Daniel Schwen, Christine Borchers und Carsten Ronning — II. Physikalisches Institut, Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany

ZnO Nanodrähte, die mit Hilfe eines einfachen CVD-Prozesses hergestellt wurden, wurden mittels Ionenimplantation dotiert. Dabei wurden die Elemente N+ (als Akzeptor) oder Al+ (als Donator) mit einer Energie von 25 keV eingesetzt. Die strukturellen Veränderungen innerhalb der Nanodrähte nach der Ionenimplantation wurden mit hoch-auflösender TEM untersucht. Sowohl Punktdefekte als auch ausgedehnte Defekte wurden lokalisiert, die nach Anlassen auf 800°C nahezu komplett ausgeheilt werden konnten. Die optische Aktivierung der implantierten Atome wird auf diesem Poster anhand von parallel durchgeführten PL/CL-Messungen diskutiert.

HL 58.62 Di 16:30 Poster TU F

Growth Direction of Epitaxially Grown Silicon Nanowires — •Volker Schmidt, Stephan Senz, and Ulrich Gösele — Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany

We found that silicon nanowires grown epitaxially on Si (100) via the vapor-liquid-solid growth mechanism change their growth direction from <111> to <110> at a crossover diameter of approximately 20 nm. A model is proposed for the explanation of this phenomenon. We suggest that the interplay of the liquid-solid interface energy with the silicon surface energy is responsible for the change of the growth direction. For large diameters the direction with the lowest interface energy is dominant, while for small diameters the surface energy of the silicon nanowire determines the preferential growth direction. In addition, results concerning the growth of silicon nanowires with other catalyst materials than gold will be presented.

HL 58.63 Di 16:30 Poster TU F

GaN Nanowhiskers: Epitaxial Growth — •Thomas Richter[1], Ralph Meijers[1], Raffaella Calarco[1], Toma Stoica[1,2], and Hans Lüth[1] — [1]Institute of Thin Films and Interfaces (ISG1) and CNI - Centre of Nanoelectronic Systems for Information Technology, Research Center Jülich, 52425 Jülich, Germany — [2]INCDFM, Magurele, POB Mg7, Bucharest, Romania

The study of GaN-based nanostructures, whose electrical and optical characterization is at its infancy, can help to elucidate the link among structural, optical and electrical features, allowing for a deeper understanding of the physical mechanisms controlling the material behavior in these nanostructures.

In our experiments, GaN nanocolumns are reproducibly grown by

plasma-assisted molecular beam epitaxy on Si(111). The nanocolumns density and diameter (10-150 nm) are controlled by means of the III/V ratio. The substrate temperature during growth is chosen between 770^0C and 800^0C. For higher growth temperatures higher Ga fluxes are needed to reach the same growth rate, due to the Ga desorption process. In our experiments we did not change the nominal III/V ratio but the growth temperature, which results in different stoichiometry and deposition rates. The signature of a tapering process can be observed.

The GaN-nanocolumns have been studied and characterized by means of XRD, TEM, Raman spectroscopy, photo- and cathodo- luminescence. A correlation between growth parameter and defects has been found.

HL 58.64 Di 16:30 Poster TU F

Size Reduction of Silicon / Silicon Dioxide Nanowires — •Florian M. Kolb, Herbert Hofmeister, Margit Zacharias, and Ulrich Gösele — Max-Planck-Institut für Mikrostrukturphysik, 06120 Halle (Saale)

Nanowires consisting of a crystalline silicon core and an amorphous silicon dioxide shell can be obtained by combining thermal evaporation of silicon monoxide with the vapor-liquid-solid (VLS) process. The resulting nanowires show silicon core diameters between 15 nm and 75 nm and lengths up to several micrometers. In order to reach the quantum size regime even smaller diameters are necessary. It is possible to remove the oxide shell and further reduce the silicon core by a thermal dry oxidation step. We will present results on how the thickness of the oxide shell depends on the duration and temperature of the oxidation process as well as the core diameter. In addition, we observe the formation of silicon nanocrystals embedded in silicon dioxide nanowires after the oxidation process. A model for the Rayleigh instability-based formation of these nanocrystals will be presented and the results will be compared to morphological instabilities that can be observed during the growth of the nanowires.

HL 58.65 Di 16:30 Poster TU F

Gas-source C Predeposition and Ge Dot Formation on Si(001): Effects of Anneal Temperature for Hydrogen Desorption — •Takeshi Murata, Yuzuru Narita, and Maki Suemitsu — CIR, Tohoku University, Aoba, Aramaki, Aoba-ku, Sendai 980-8578 Japan

Self-assembled Ge dots on Si(001) surface attract much attention for their possible applications in electronics and optoelectronics. Knowing that submonolayer C predeposition is effective in minimizing and densifying the Ge dots and that gas-source processings are much favored in actual device fabrications, we have conducted Ge dot deposition with C predeposition using monomethylsilane (MMS) and germane as the C and Ge source, respectively. While the Ge growth temperature was fixed at 500C, the anneal temperature for hydrogen desorption after MMS adsorption was varied for 500, 700 and 900C. The dots were a mixture of mounds and domes, with the former being most densified after annealed at 500C. Infrared absorption spectroscopy in multiple-internal-reflection geometry as well as reflection-high-energy-electron-diffraction observation have shown that C atoms from MMS molecules diffuse into the subsurface below 500C and nucleate as SiC at around 900C. These results indicate importance of uniform distribution of C atoms in the subsurface in obtaining densified Ge dots on Si(001).

HL 58.66 Di 16:30 Poster TU F

Formation of Ge dots on Si(111)-7x7 surface and effects of C predeposition using monomethylsilane — •Yuzuru Narita, Masashi Sakai, Takeshi Murata, and Maki Suemitsu — Center for Interdisciplinary Research, Tohoku University, Aramaki aza-Aoba, Aoba-ku, Sendai 980-8578, Japan

Germanium (Ge) dots are promising as a new material for Si-based opto-electronic integrated circuits (OEICs). To reduce the size of the Ge dots on Si, carbon (C) predeposition prior to Ge deposition has recently proved itself. Most of previous studies, however, have used solid-source MBE for both C and Ge depositions, which may be problematic when applied in practical use. Also, few studies have ever been made on Si(111)-7x7 surface, which could nevertheless affect the adsorption and diffusion of Ge atoms and therefore be a possible template for dot alignment. In this study, we have formed Ge dots on Si(111)-7x7 surface by using germane and monomethylsilane (MMS) as Ge and C sources, respectively. By exposing the Si(111)-7x7 surface at RT to 80-L MMS flux and by desorbing the surface hydrogen with an anneal at 900C for 1 min, the subsequent dot density increased about two orders of magnitude and the dot size decreased by a factor of six as compared to the case without the C predeposition. From the Raman-scattering microscopy, the Ge dots formed with C predeposition using MMS are found to be nearly dislocation-free.

HL 58.67 Di 16:30 Poster TU F

Low-ohmic contacts to two-dimensional electron gases in GaAs/AlGaAs heterostructures — •S. Raiser[1], U. Graumann[2], M. Fleischer[1], J. Schmid[2], S. Jauerneck[1], J. Weis[2], and D.A. Wharam[1] — [1]Institut für Angewandte Physik, Universität Tübingen, Auf der Morgenstelle 10, D-72076 Tübingen — [2]Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, D-70569 Stuttgart

The reliable contacting of two-dimensional electron gases is an essential prerequisite for the low-temperature characterisation of heterostructure-devices. In the past it has often been difficult to produce high quality ohmic contacts. For the low-resistance ohmic contacts presented here we use standard AuGe/Ni/Au-metallisation with significantly different parameters than conventional recipes. We are now able to produce low-ohmic contacts with perfect reliability. The quality of the contacts has been investigated with respect to processing parameters such as the thickness of the metallisation layers, alloying temperature, and alloying time. The dependence of the contact geometry has been examined, whereby a dependence upon the orientation with respect to the crystallographic direction has been found. Initial studies of the contact structure have been performed using electron microscopy.

HL 58.68 Di 16:30 Poster TU F

Growth of highly homogeneous InGaAs islands on GaAs using a stressor layer technique — •H. J. Krenner, D. Heiss, D. Schuh, M. Bichler, G. Abstreiter, and J. J. Finley — Walter Schottky Institut and Physik Department,TU Muenchen, Am Coulombwall 3, D-85748 Garching, Germany

We present a detailed study of single and multi-layer structures containing self-assembled InGaAs islands on GaAs. Growth parameters were optimized in order to observe a transition to low QD surface densities for optical single QD spectroscopy. As a stressor layer we introduced a highly strained 3nm InGaAs quantum well 10nm below the islands. We observe a pronounced blue-shift of the QD emission and furthermore in improved homogeneity resulting in a narrower linewidth (FWHM $<$ 20meV). We attribute these effects to altered growth conditions on the strained surface. First studies of multi-layer structures indicate that this novel stressor layer technique enables preparation of a well defined strained surface for the first QD layer. The buffer thickness between the following QD layers can be set to achieve similar strain conditions for each layer. This is the opposite approach compared to proposed strain-reduction layers since it takes advantage of island growth on strained substrates to achieve homogeneous ensembles. Variation of In-content and buffer layer thicknesses gives rise to a versatile technique which is particularly attractive to grow active media for laser applications.

HL 58.69 Di 16:30 Poster TU F

$CoSi_2$ nanowires synthesized by FIB — •L. Bischoff, B. Schmidt, and C. Akhmadaliev — Research Center Rossendorf, Dresden

Nanowires and chains of nanoparticles are of emerging interest in nanoelectronics, nano-optics and plasmonics as well as for their monolithic integration into microelectronic devices. $CoSi_2$ is a promising material due to its CMOS-compatibility microelectronics technology. Two fabrication methods of $CoSi_2$ -nanowires by using ion beam synthesis (IBS) with Focused Ion Beams (FIB) technique are presented. In a first approach, an oxide layer, structured by sputtering with a focused Ga^+ ion beam, have been used as an implantation mask for large area homogeneous Co^+ implantation. Alternatively, a mass separated FIB of cobalt ions, emitted from a $Co_{36}Nd_{64}$ alloy liquid metal ion source, is applied for a direct writing IBS process. Implantation into Si with doubly charged Co^+ ions emitted from the Co source allows ion energies up to 60 keV, which result in $CoSi_2$ nanostructures buried in silicon. The processes of damaging and annealing of the substrate due to extremely high current density of the FIB were investigated. The fabrication of nanowires down to 30 nm diameter has been demonstrated.

HL 58.70 Di 16:30 Poster TU F

Elektrische Charakterisierung einzelner Silizium und Silizium/Germanium Heterostruktur- Nanodrähte — •Frank Fleischer, Jan Bauer, Luise Schubert, Peter Werner und Margit Zacharias — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle

Für die angestrebte technologische Verwendung von Nanomaterialien ist die elektrische Charakterisierung einzelner Nanoobjekte unumgänglich. Die Kontaktierung einzelner Nanodrähte wurde mit Hilfe eines Nanomanipulators im SEM mittels Pt/Ir-Spitzen von rund 60nm realisiert. Es wurden die elektrischen Eigenschaften einzelner freistehender als auch liegend angeordneter Si und Si/Ge Nanodrähte gemessen.

Es wurde eine Methodenkombination aus der Rasterelektronenmikroskopie und EBIC (electron beam induced current) angewandt, um Grenzregionen unterschiedlicher Bandstrukturen direkt sichtbar zu machen, z. B. zwischen semi-isolierenden bzw. dotierten Nanodrähten und dem Substrat. Die Messungen werden am Beispiel von Drähten mit einem Durchmesser kleiner 200nm demonstriert.

HL 58.71 Di 16:30 Poster TU F

Atomistic Computer Simulations on Ion Beam Synthesis and Decay of $CoSi_2$ Nanowires — •Lars Röntzsch and Karl-Heinz Heinig — Research Center Rossendorf, Institute of Ion Beam Physics and Materials Research, Dresden

Nanowires (NWs) and chains of nanocrystals (NCs) embedded in dielectrics or semiconductors are intensively studied regarding their potential application in nanoelectronics. $CoSi_2$ nanostructures in Si are particularly interesting because of the full compatibility of $CoSi_2$ with CMOS technology.

Here, we present predictive atomistic computer simulations on the ion beam synthesis of $CoSi_2$ NWs in Si and their decay into chains of $CoSi_2$ NCs which are applicable as plasmon waveguides. In order to simulate the Co implantation, the binary collision codes TRIDYN and TRIM were adapted to the particular experimental situation of a finely-focused Co ion beam of 50nm in width. The resulting 3D implantation profile serves as input for a kinetic lattice Monte-Carlo code by means of which nucleation and growth of $CoSi_2$ precipitates and their coalescence into a $CoSi_2$ NW are described. From an evolutionary viewpoint, NW synthesis and decay proceed on different time scales. The NW decay into a NC chain (Rayleigh instability) is driven by the minimization of interfacial free energy. In this regard, it will be demonstrated that the orientation of the Co implantation profile to the single crystalline Si matrix influences the stability of the synthesized $CoSi_2$ NW. Since the system energetically favors the $CoSi_2(111)/Si(111)$ interface, driving faceting forces may occur which accelerate the NW decay into a NC chain.

HL 60 Hauptvortrag Zahn

Zeit: Mittwoch 10:00–10:45 Raum: TU P270

Hauptvortrag HL 60.1 Mi 10:00 TU P270

Chemistry and Electronic Properties of Metal Interfaces to Organic Semiconductors — •Dietrich R.T. Zahn — Institut für Physik, TU Chemnitz, D-09107 Chemnitz

Metal contacts to organic semiconductors play a decisive role for the performance of organic based devices such as organic light emitting diodes, organic field effect transistors or organic solar cells. In particular when a metal is deposited onto an organic substrate, severe disruption of the interface may occur as a result of chemical reactions of the metal with organic molecules and/or diffusion of the metal into the organic layer. Here, the interaction of metals of different reactivity (Ag, In, Mg) with a variety of perylene derivatives as model molecules is probed employing in situ Raman spectroscopy. The results reveal that this technique allows an extreme interface sensitivity to be achieved via surface enhanced Raman scattering. The degree of reactivity and indiffusion can be derived from the analysis of the evolution in scattering by internal vibrational modes of the molecules and phonon-like external modes of the molecular crystal. The Raman investigations are complemented by synchrotron based photoemission and near-edge X-ray absorption fine structure measurements. These clarify that the reactivity of the molecules is highly depended on the molecular structure. In the case of the perylene derivatives the molecular endgroups, i.e. anhydride or different imides, control the interaction of the metals with the molecules.

HL 61 Organische Halbleiter

Zeit: Mittwoch 10:45–13:15 Raum: TU P270

HL 61.1 Mi 10:45 TU P270

Photoresponse of conjugated polymer/fullerene based Organic Field-Effect Transistors — •Nenad Marjanović, Birendra Singh, Serap Günes, Helmut Neugebauer, and Niyazi Serdar Sariciftci — Linz Institute for Organic Solar Cells (LIOS), Physical Chemistry, Johannes Kepler University Linz, Austria

Results on photoresponsive organic field-effect transistors (photOFETs) fabricated on ITO glass substrates using conjugated polymer/fullerene bulk heterojunction and bilayer concepts will be presented. Measurements in the dark with LiF/Al source and drain top contacts show dominantly n-type transistor behaviour. Under AM1.5 illumination, an increase in drain-source current Ids by five orders of magnitude is observed, whereas Ids becomes independent on the gate voltage. The results suggest that a photodoping effect (creation of a large free carrier concentration from a photoinduced charge transfer at the conjugated polymer/fullerene heterojunction upon illumination) is strongly dominating over the gate effect.

HL 61.2 Mi 11:00 TU P270

On the determination of the Transport Mechanism in Organic Semiconductors from the Field-Effect Mobility — •Gernot Paasch, Nabin Baran Manik, and Thomas Lindner — IFW Dresden

The field-effect mobility is determined by the gate voltage dependence of the drain current for low drain voltage. Based on fitting analytical expressions to the measured dependencies on the gate voltage and on temperature, it has been claimed that there is a one-to-one correspondence to the transport mechanism: Either hopping in a Gaussian distribution of states, or in an exponential distribution (allegedly as an approximation for the first one in some energy interval), or transport of mobile carriers above a mobility edge in the presence of exponentially distributed traps below the edge (essentially the so-called a-Si model). A critical reexamination of these procedures shows that (i) the data used to prove the assumption of hopping in exponentially distributed states can be described also with the a-Si model. (ii) The respective models should not only describe the field-effect mobility but also the subthreshold and saturation currents. (iii) Full 2D numerical simulation with the a-Si model are reported and compared (for the small drain voltage limit) to the analytic approximation. (iv) Connections with the Einstein relation and with the transition from non-degenerate to degenerate statistics are clarified.

HL 61.3 Mi 11:15 TU P270

Space Charge Layers in Organic Semiconductors with Gaussian or Exponential Density of States — •Susanne Scheinert[1] and Gernot Paasch[2] — [1]TU Ilmenau — [2]IFW Dresden

Space charge layers (SCL) in MOS structures are decisive for the operation of field effect transistors (FET). For many organic semiconductors, transport takes place as hopping in Gaussian or exponentially distributed states. However, existing theoretical descriptions of SCL suppose a density of states other than a Gaussian or an exponential. We present results of a simulation study for a thin semiconducting layer e.g. on a metal substrate and the MOS structure as the basic module of the FET. From the calculated distributions of concentration, field and potential, and the

semiconductor capacitance as a function of either the surface potential or an applied gate voltage detailed, conclusions are drawn. Of special importance are: (i) the bulk Fermi energy and hence the flat band voltage depend strongly on the distribution, (ii) for broader distributions the accumulation layer becomes thinner, (iii) this can lead to an apparent contribution to a surface dipole, (iv) the total areal charge, which determines the FET current, is almost the same as that one of a delta shaped distribution if the flat band voltage shift is considered appropriately.

HL 61.4 Mi 11:30 TU P270

Transport properties of ultra thin thiophene based thin film transistors — •T. Muck and V. Wagner — School of Engineering and Science, International University Bremen, Campus Ring 8, D-28759 Bremen, Germany

The aim of this study was to determine the properties of thin organic layers within a field-effect transistor geometry. Transport properties of standard OFETs are known to be crucially influenced by the first monolayer (ML). Deposition of the active material was performed by organic molecular beam deposition in ultra high vacuum. As organic semiconductor various thiophene derivatives, e.g. dihexylquaterthiophene (DH4T) were analyzed. These DH4T films were prepared at elevated temperatures (90 °C) to achieve a growth in the smectic phase of DH4T. Electrical measurements were performed on these growing liquid crystal films. By characterizing the organic transistors at different film thicknesses in the monolayer range we observe a steplike behavior of the charge mobility. Charge transport starts at approx. 0.6 ML and the field-effect mobility shows a quadratic increase for increasing coverage due to percolation of DH4T monolayers. Saturation is observed while completing the first ML. We interpret this behavior with the growth mode of DH4T analyzed by AFM imaging and compare this with Monte-Carlo simulations. The deposition of the second monolayer influences the mobility first by worsening due to non-percolated islands and a subsequent improvement while closing the second monolayer. Additional monolayers do not increase the performance. These data allow the determination of the transport layer thickness, which is given mainly by the first two monolayers.

HL 61.5 Mi 11:45 TU P270

Electronic Properties of a Metal/Organic/GaAs Heteroestructure — •Henry Méndez, Ilja Thurzo, Mihaela Gorgoi, Cristian Iacovita, Gianina Gavrila, and Dietrich R.T. Zahn — Institut für Physik, Reihenheiner Str.70 D-09107 Chemnitz, Germany

Devices based on a metal/organic/GaAs heterostructure were prepared under UHV conditions and their electrical properties studied *in situ*. Hydrogen plasma treated GaAs(100) (H^+GaAs) and the perylene derivative dimethyl-3,4,9,10-perylenetetracarboxylic diimide (DiMe-PTCDI) were used as inorganic substrate and organic material, respectively. Silver contacts were then deposited through a shadow mask. The electronic transport properties were investigated by UPS, IV, CV and QTS techniques. A barrier height of (0.83 ± 0.05) eV for the reference Ag/H^+GaAs diode was deduced from IV characteristics. Organic modification of the reference diode with DiMe-PTCDI leads to a decrease in the effective barrier height with increasing thickness of the molecular film. The electrical measurements show that at the interface LUMO of DiMe-PTCDI lies below the CBM of GaAs(100). This is confirmed by IPES measurements on a DiMe-PTCDI layer deposited on H^+GaAs. The transport mechanism through the device is discussed considering the Fermi level alignment at the organic/inorganic interface and the role of interfacial and bulk trap levels. All the information is taken into account when simulating IV characteristics of the organic modified device.

HL 61.6 Mi 12:00 TU P270

Optimisation of contacts for downscaling of organic thin-film transistors — •M. Leufgen[1], U. Bass[1], M. Michelfeit[1], T. Borzenko[1], G. Schmidt[1], J. Geurts[1], L. W. Molenkamp[1], and P. Mackie[2] — [1]Universität Würzburg, Physikalisches Institut (EPIII), Am Hubland, D-97074 Würzburg, Germany — [2]Avecia Ltd., PO Box 42, Hexagon House, Blackley, Manchester M9 8ZS, UK

When downscaling the channel length of organic thin-film transistors (OTFTs), the conductance is increasingly governed by the electrical contact resistance. We verified this behaviour for DH4T-based bottom-contact OTFTs with different contact metals (Au/Ti, Pd). The electrical behaviour of the Au contacts was hampered by the Ti adhesion layer, while the Pd contacts, although electrically superior, suffered from insufficient mechanical stability.
We report two alternative strategies to overcome these drawbacks: (i)For Au/Ti, we developed a two-layer resist technique for UV lithography. The resulting undercut guarantees smooth and homogeneous metal contact edges, confirmed by SEM, and an improved Au/DH4T-contact. (ii)Sputtered Pt contacts have the necessary adhesion on SiO_2 and a good contact to the organic layer. In this context we optimised an e-beam lithography process, resulting in an undercut in the resist combined with a sub-100 nm resolution for large area structures (channel width of several 100 μm). Operating devices were fabricated both by vacuum deposition of DH4T and by spin cast deposition of diluted semiconducting polymers.

HL 61.7 Mi 12:15 TU P270

Structural properties of thin P3HT/PCBM-films for organic solar cells — •Tobias Erb[1], Uladzimir Zhokhavets[1], Gerhard Gobsch[1], Sofiya Raleva[2], Bernd Stühn[2], Pavel Schilinsky[3], Christoph Waldauf[3], and Christoph Brabec[3] — [1]Institute of Physics, Ilmenau Technical University, 98684 Ilmenau, Germany — [2]Institute of Solid Physics, Darmstadt Technical University, 64289 Darmstadt, Germany — [3]Konarka Technologies GmbH, Paul-Gossen-Str. 100, 91052 Erlangen, Germany

We have investigated thin P3HT/PCBM - (poly[3-hexylthiophene 2,5 diyl]/[6,6]-phenyl C61 butyric acid methyl ester) films, which are widely used as an active layer in plastic solar cells. Their structural properties were studied by X-ray diffraction in grazing incidence geometry. The size and the orientation of crystalline P3HT-nanodomains within the films were determined. Contrarily, PCBM crystallites were not detected in thin films. Upon annealing, the P3HT-crystallinity is increased, whereas PCBM crystallites were not found.

With these results the raise of the optical absorption and spectral photocurrent in low photon energy region can be explained. In addition, the efficiency of P3HT/PCBM solar cells is also significantly increased upon annealing.

HL 61.8 Mi 12:30 TU P270

Ultrafast transient absorption spectroscopy of perylene derivatives — •E. Engel[1], K. Schmidt[2], D. Beljonne[2], J.-L. Brédas[2], K. Leo[1], and M. Hoffmann[1] — [1]Institut für Angewandte Photophysik, TU Dresden, 01062 Dresden, Germany, www.iapp.de — [2]School of Chemistry and Biochemistry, Georgia Institute of Technology, Atlanta, Georgia 30332-0400, USA

The perylene derivatives N,N'-dimethylperylene-3,4,9,10-dicarboximide (MePTCDI) and 3,4,9,10-perylene-tetracarboxylic dianhydride (PTCDA) are paradigmatic and widely investigated organic semiconductors. Quantitative statements about excitonic relaxation processes require a thorough understanding of the optical transitions involved in time-resolved experiments.

We investigated matrix (SiO_2) isolated molecules and thin films of MePTCDI and PTCDA by means of ultrafast pump-probe spectroscopy. A broad femtosecond white-light continuum was used to record high resolution transient absorption spectra between 1.2 eV and 2.7 eV above the lowest excited state energy. Excited state contributions below the onset of linear absorption exhibit two pronounced peaks. The observed peaks in the monomer (around 1.85 eV and 1.3 eV, respectively) can be clearly correlated to numerical spectra obtained by a highly correlated quantum chemical MRD-CI calculation technique.

HL 61.9 Mi 12:45 TU P270

COMPARATIVE ELECTROABSORPTION STUDIES ON ORGANIC SEMICONDUCTOR DEVICES WITH VARIOUS INTERFACIAL LAYERS — •Christoph Lungenschmied[1], Markus Scharber[2], Helmut Neugebauer[1], and Serdar Sariciftci[1] — [1]Linz Institute for Organic Solar Cells (LIOS), Johannes Kepler University Linz, Altenbergerstr. 69, 4040 Linz, Austria — [2]Konarka Austria, Gruberstr. 40-42, 4020 Linz, Austria

Electroabsorption spectroscopy in reflection geometry was used to probe the electric field induced changes in the transmission of thin organic semiconducting films sandwiched between asymmetric contacts. The photoactive layer of the investigated devices consisted of a soluble polyphenylene vinylene derivative, namely MDMO-PPV, spin cast on ITO coated glass substrates and covered with an Al layer as top electrode. The change in the transmission (ΔT) due to the Stark effect was monitored using a modulation technique at various applied DC voltages (VDC). It is observed, that $\mid \Delta T \mid$ goes to zero at positive VDC (ITO is +), indicating that the internal electric field is cancelled by the externally applied field.

This VDC was found to change by introducing interfacial layers. When using the same device setups in photovoltaic studies the maximum open circuit voltage (VOC) qualitatively follows the same trend. A possible correlation of the internal electric field with photovoltaic device parameters will be described.

HL 61.10 Mi 13:00 TU P270

Fullerene/Silicon Hybrid Heterojunction diodes — •G. J. Matt[1], T. Fromherz[2], and N.S. Sariciftci[1] — [1]Linz Institute for Organic Solar Cells (LIOS), Johannes Kepler University Linz, Austria — [2]Institute for Semiconductor and Solid State Physics, Johannes Kepler University, Austria

Fullerene based diodes on p-Si substrates are presented. Rectification up to 10^5 at $\pm 1V$ is observed with broad spectral resolved photo-current in UV-Vis. Device parameter as the idealitay factor and the nature of the electronic structure at the Fullerene/Silicon heterojunction are discussed.

HL 62 Photonische Kristalle IV

Zeit: Mittwoch 10:45–13:30 Raum: TU P164

HL 62.1 Mi 10:45 TU P164

A novel technique for near-field mapping of photonic crystal eigenmodes — •F. Intonti[1], C. Ropers[2], M. Colocci[1], C. Lienau[2], P. Bettotto[3], and L. Pavesi[3] — [1]LENS, 50019 Sesto Fiorentino (FI), Italy — [2]Max-Born-Institut für Nichtlineare Optik und-Kurzzeitspektroskopie, 12489 Berlin — [3]Università di Trento, 38100 Trento, Italy

Photonic crystals (PCs) are predicted to drastically influence the light propagation (1) and these predictions are currently actively tested by experiments. Most studies probe the band structure by analyzing amplitudes of scattered electromagnetic waves (2) and thus provide only indirect microscopic information about the optical modes of the PC. Near-field optical microscopy allows for a direct spatial imaging of these modes. So far, however, only few near-field studies have been reported, mainly due to inherent experimental difficulties.

Here, we report a novel, efficient and easy-to-use technique for near-field mapping of PC eigenmodes. The technique is based on non-metalized dielectric near-field probes and can be applied in a wide wavelength range from 400 to > 2000 nm. Experiments at λ=1.55 μm, probing the the local reflectance from periodically ordered air pores in a crystalline silicon matrix, demonstrate an optical resolution of less than $\lambda/5$ and are well reproduced by numerically solving the PC master equation.

HL 62.2 Mi 11:00 TU P164

Ultrafast light transmission and subradiant damping in plasmonic crystals — •C. Ropers[1], D. J. Park[2], G. Stibenz[1], G. Steinmeyer[1], D. S. Kim[2] und C. Lienau[1] — [1]Max-Born-Institut für Nichtlineare Optik undKurzzeitspektroskopie, 12489 Berlin — [2]School ofPhysics, Seoul National University, Seoul 151-742, Korea

Surface-bound electromagnetic waves on metals, surface plasmon polaritons (SPP), will play an important role in novel photonic structures, promising an unprecedented amount of light control on the nanoscale. Periodic arrays of subwavelength slits and holes in metallic films serve as important SPP model systems. Here, the SPP lifetime is generally limited to few tens of femtoseconds by the strong SPP coupling to far-field radiation, limiting their use in new photonic elements such as nano-resonators or waveguides. Here, we discuss a novel approach for tailoring the radiative damping in metallic nanohole arrays. Amplitude and phase-resolved transmission experiments with ultrashort, 10 fs light pulses demonstrate a more than 15-fold increase in radiative SPP lifetime to more than 200 fs, induced by the coherent coupling between different SPP resonances. In close analogy to the famous subradiant damping in radiatively coupled atomic systems [1], the formation of antisymmetric coupled SPP eigenmodes leads to this pronounced damping suppression. In plasmonic systems, the spatial structure of the SPP eigemodes can directly be imaged by near-field microscopy, providing insight into the microscopic origin radiative coupling phenomena.

[1] R. H. Dicke, Phys. Rev. **93**, 99 (1954)

HL 62.3 Mi 11:15 TU P164

Microwave modelling of disorder in photonic crystal slab waveguides — •Jan Brosi, Christopher Poulton, and Wolfgang Freude — Institut für Hochfrequenztechnik und Quantenelektronik, Universität Karlsruhe, Engesserstr. 5, D-76128 Karlsruhe

Disorder due to imperfect fabrication processes of photonic crystals is unavoidable and has a significant effect on the loss of photonic crystal waveguides.

We studied the influence of positional and radial disorder of the air holes in a high-index triangular lattice photonic crystal slab with line defect. For the experimental investigation, we used a microwave model, where the frequency was downscaled by a factor of 20,000 to 10 GHz and the dimensions of the structure were upscaled by the same factor. This way, ideal structures could be fabricated and well-defined disorder introduced. From the measurements, amplitude and phase data could be obtained, and the results were compared to numerical results.

HL 62.4 Mi 11:30 TU P164

Giant Purcell Effect for InGaAs self-assembled Quantum Dots in Photonic Crystal Microcavities — •A. Kress, F. Hofbauer, N. Reinelt, M. Kaniber, G. Böhm, and J. J. Finley — Walter Schottky Institut, TU München, 85748 Garching, Germany

We present investigations of the coupling of InGaAs self-assembled quantum dots (QD) to localised optical modes in 2D photonic crystal defect microcavities, where a very strong enhancement of the light-matter interaction in the weak coupling regime was directly measured.

Our samples consist of thin active GaAs membranes into which a layer of QDs are incorporated. The photonic crystal cavities are formed by single missing hole defects in an etched 2D hexagonal lattice of air holes. Finally the membranes are fabricated by removing a sacrificial AlAs layer in a wet etching process.

The investigated cavity modes have Q-factors of >2500 and mode-volumes $V < (\lambda/n)^3$. Up to a 50x enhancement of the emission intensity is observed for QDs on-resonance with the cavity modes suggesting the presence of significant cavity QED phenomena. Time resolved luminescence measurements reveal a shortening of the spontaneous emission lifetime by a factor ∼20, for single QDs inside our cavities on-resonance with the optical modes compared with QD emission outside any cavity. Furthermore, over a spectral range of >40nm we obtain factor >2 longer excitonic lifetimes for QDs inside these cavities but off-resonance with optical modes.

HL 62.5 Mi 11:45 TU P164

Disorder in metallic photonic crystal slabs — •Dietmar Nau[1], Anja Schönhardt[1], Harald Giessen[1], André Christ[2], and Jürgen Kuhl[2] — [1]Institut für Angewandte Physik, Universität Bonn, Wegelerstraße 8, D-53115 Bonn — [2]Max-Planck-Institut für Festkörperforschung, Heisenbergstraße 1, D-70569 Stuttgart

It is well known that the optical properties of gold nanostructures can be tailored by arranging them periodically on top of a dielectric waveguide material [1]. This effect can be explained by the formation of a new quasi-particle, a so-called waveguide-plasmon polariton [2]. In this work we present a detailed study of the influence of disorder in these structures. Samples with a controlled amount and type of disorder are fabricated. We vary the positions of the nanostructures with respect to the original grid. We consider frozen-phonon disorder, where the nanostructures are shifted similar to phonons in a solid, and another model with far-field disorder. The models are characterized in detail by their two-particle correlation functions, and the optical properties of the different structures are determined. We find that the linear optical properties are changed dramatically. The modulation in the extinction due to the polariton formation decreases for increasing disorder. Also, the bandstructure is influenced. Disorder causes the splitting of the bands to decrease due to a reduced spatial overlap of the wavefunctions of plasmon and waveguide mode. Different disorder models influence the specific optical properties in different ways.

[1] S. Linden et al., Phys. Rev. Lett. 86, 4688 (2001) [2] A. Christ et al., Phys. Rev. Lett. 91, 183901 (2003)

HL 62.6 Mi 12:00 TU P164

Designing and Engineering of High-Q Photonic Crystal Defect Cavities — •F. Hofbauer, A. Kress, N. Reinelt, H. J. Krenner, M. Bichler, D. Schuh, and J. J. Finley — Walter Schottky Institut, TU München, 85748 Garching, Germany

We present investigations and calculations on localized light states in 2D photonic crystal defect cavities (PCDC). Our results enable us to control the spectral position of photonic modes inside the photonic bandgap and engineer their Q-factors.

Our samples consist of thin GaAs membranes into which a layer of InGaAs self assembled QDs are incorporated. The 2D photonic crystals consist of an etched hexagonal lattice of air holes. The defect cavities are either formed by a line of three missing holes (L3)[1] or by one missing hole and the redistribution of the six surrounding holes (Y1)[2].

Controlling the spectral position of single photonic modes over a range of ∼200nm in different PCDC together with 3D simulations of the PCDC enables us to tune and select the position of cavity modes relative to the photonic bandgap. Our investigations demonstrate a one order of magnitude change of the Q-factor for these designed photonic modes. The fine-tuning of the different PCDC designs enabled us to obtain Q-factors up to 8000 and mode-volumes less than $0.5(\lambda/n)^3$.

[1] Y. Akahane et al., Nature, 425, 944 (2003)
[2] J. Vučković and Y. Yamamoto, APL 82, 2374 (2003)

HL 62.7 Mi 12:15 TU P164

Spontaneous parametric scattering of microcavity polaritons in momentum space — •Wolfgang Langbein — Department of Physics and Astronomy, Cardiff

We measure the spontaneous parametric emission from a semiconductor microcavity after resonant pulsed coherent excitation. Resolving the emission in time and two-dimensional momentum space, the underlying scattering processes, which were theoretically treated by Ciuti *et al.*, Phys. Rev. B **63**, 041303 (2001), are validated. The predicted figure-8 shaped distribution of the final states of the parametric scattering is observed. We find a narrowing of the momentum distribution with time, which is a feature of memory effects in the scattering due to parametric correlation. Additionally, the influence of higher-order scattering and pump depletion are observed in the experiment.

HL 62.8 Mi 12:30 TU P164

Structure and Properties of Low-n Mesoporous Silica Films for Optical Applications — •Denan Konjhodzic[1], Helmut Bretinger[1], Siegmund Schröter[2], and Frank Marlow[1] — [1]Max-Planck-Institut für Kohlenforschung, D-45470 Mülheim an der Ruhr — [2]Institut für Physikalische Hochtechnologie, D-07745 Jena

The properties and structure of the mesoporous silica films are investigated. Because of their ultra low refractive index (n = 1.14), these films are used as optical waveguide supports especially for 2D photonic crystals. The films are synthesized by a template-modified sol-gel process using triblock copolymers. A significant dependence of the formed structure on the processing conditions has been revealed allowing an appreciable structure tuning. One set of processing conditions allows the reproducible synthesis of low-n films. They are optically clear, mechanically and chemically resistant, very smooth, and sufficiently thick (1000 nm) with the pore size of 8 nm. Under other processing conditions, a novel sustained lamellar structure remaining stable upon calcination was synthesized.

The films were characterized by angular-dependent interferometry, small angle x-ray scattering, transmission electron microscopy and atomic force microscopy. Onto these films, 2D photonic crystals of different materials, such as polymers (PMMA/DR-1)[1], niob pentoxide and tantal pentoxide have been fabricated. The first investigations of such Ta2O5 and ferroelectric PZT films will be presented.

[1] M. Schmidt et al., Appl. Phys. Lett. 85, 16 (2004)

HL 62.9 Mi 12:45 TU P164

A new optical method to investigate the director field of liquid crystals appearing in a photonic crystal template — •Heinz Kitzerow[1], Heinrich Matthias[1], Thorsten Röder[1], Sven Matthias[2], Ralf Wehrspohn[1], and Stephen Picken[3] — [1]Faculty of Science, University of Paderborn, Warburger Str. 100, 33098 Paderborn — [2]Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle — [3]Delft University of Technology, Dept Material Science and Technology, Julianalaan 136, Delft 2628 BL, The Netherlands

Photonic crystals can be actively tuned by filling these porous structures with liquid crystals. We report on results using fluorescence confocal polarizing microscopy (FCPM) to examine the director field of liquid crystals confined to modulated micrometer pores. The photonic crystal was filled with a glass-forming liquid crystalline polymer and cooled below the glass transition temperature to conserve the director field. After removing the photonic crystal template, we studied the remaining liquid crystal rods by FCPM. Evidences of a spatially periodic director field containing a lattice of disclination rings are found.

HL 62.10 Mi 13:00 TU P164

Nonlinear optical tuning demonstrated on 2D photonic crystals — •Stefan L. Schweizer[1], Ralf B. Wehrspohn[1], Hong W. Tan[2], Henry M. van Driel[2], and Ulrich Gösele[3] — [1]Dept. Physik, Universität Paderborn — [2]Dept. of Physics, University of Toronto — [3]Max-Planck-Institut für Mikrostrukturphysik, Halle

Optical switching can be achieved by changing the refractive index. For this nonlinear optical effects are used. We used pump and probe reflectivity experiments with 130fs laser pulses. Both the Kerr effect and the Drude effect shifting the band edges of a stop gap of a photonic crystal are identified. The Drude effect (based on real carriers) shows a fast rise time but a slow fall time whereas the Kerr effect (virtual carrier excitation) has a very fast rise and fall response. On the other hand the Kerr effect is limited to high pump light intensities.

HL 62.11 Mi 13:15 TU P164

Interplay between Auger and ionisation processes in nanocrystal quantum dots — •Robert Kraus[1], Pavlos Lagoudakis[1], Dmitry Talapin[2], Andrey L. Rogach[1], John M. Lupton[1], Jochen Feldmann[1], and Horst Weller[2] — [1]Lehrstuhl für Photonik und Optoelektronik, Ludwig-Maximilians-Universität München — [2]Institut für Physikalische Chemie, Universität Hamburg

A detailed understanding of the radiative and non-radiative decay channels in semiconductor nanocrystal quantum dots (NQDs) is necessary for tuning their fluorescence dynamics in photonic structures. In photonically confined systems it is particularly important to know if there is an influence of increased excitation density on the decay dynamics, as such an intrinsic effect may mark extrinsic changes in lifetime due to photonic confinement [1]. As a first step we present here spectrally resolved fluorescence decay measurements on CdSe/ZnS core/shell NQDs embedded in a polystyrene matrix. We show that there is an monotonic increase of the fluorescence decay rate with excitation power in the high excitation density regime. Our results suggest that Auger recombination accelerates ionisation processes that lead to the formation of dark, non-emissive nanocrystal states. A detailed kinetic model is proposed in the quantised Auger regime describing these experimental observations and providing an estimate of the Auger assisted ionisation rates. We conclude that great caution has to be exerted when employing NQDs as light sources under photonic confinement due to their intrinsic field strength dependence of the fluorescence decay. [1] P. Lodahl *et al.*, Nature **430**, 654 (2004)

HL 63 Ultrakurzzeitphänomene

Zeit: Mittwoch 10:45–13:30 Raum: TU P-N201

HL 63.1 Mi 10:45 TU P-N201

Theory of two photon photo emission at semiconductor surfaces — •Norbert Bücking, Andreas Zeiser, and Andreas Knorr — Nichtlineare Optik und Quantenelektronik, PN 7-1, Institut für Theoretische Physik, TU Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

Recent time resolved Photoemission experiments on InP surfaces yield spectra with a two peak shape and a characteristic decay rate of 200 fs. This shape implies the existence of a surface band energetically close to the bulk conduction band, coupled through many particle interaction.

A system of four bands, including bulk valence, bulk conduction, surface conduction and free electrons is set up to dynamically model electronic transitions at the surface. Density matrix formalism is used to calculate the dynamics of the transitions and the population inside the bands [1]. By this approach, the experimental two peak spectra can be reproduced and it is shown that the measured decay rates may be obtained by the choice of realistic parameters.

[1] A. Zeiser, N. Bücking, J. Götte, J. Förstner, P. Hahn, W. G. Schmidt and A. Knorr, "Dynamics of the phonon-induced electron transfer between semiconductor bulk and surface states", phys. stat. sol (b) **241**,No. 12, R60-R62, (2004)

HL 63.2 Mi 11:00 TU P-N201

Ultrafast spin-preserving carrier capture into InGaAs/GaAs quantum dots — •S. Trumm[1], M. Wesseli[1], A. Laubereau[1], M. Betz[1], H. J. Krenner[2], A. Kress[2], D. Schuh[2], and J. J. Finley[2] — [1]Physik-Department E11, TU München, 85748 Garching — [2]Walter-Schottky-Institut, TU München, 85748 Garching

The carrier capture and relaxation processes in an ensemble of self assembled InGaAs/GaAs quantum dots (QDs) are studied in a two-color femtosecond transmission experiment. Carriers are injected resonantly into the wetting layer (WL) by a 100 fs pump pulse centered at 1.51 eV. The transmission changes of both the band edge of the WL at 1.45 eV and the excited states of the QDs at 1.38 eV are detected. This nonlinear optical response directly reveals the population of the corresponding states.

For low pump intensities the population of the WL decays with a time constant of 4 ps. In parallel, the occupation of the QD p-shell builds up giving rise to the interpretation of this time scale as carrier capture time. Interestingly, this capture time does not depend on the excitation density as long as it is small as compared to the number of electronic states available in the QDs. Moreover, exploiting the selection rules for circularly polarized excitation and probe pulses, we find a predominantly spin-preserving nature of the capture process. These results suggest a phonon mediated scattering process to govern the capture of carriers into the QDs. This finding may be an important ingredient for the optimization of modern quantum dot lasers.

HL 63.3 Mi 11:15 TU P-N201

Observation of THz collective oscillations of ballistic electrons in wide heterostructure potential wells — •M. Betz[1], M. Eckardt[2], A. Schwanhäusser[2], S. Trumm[1], F. Sotier[1,3], L. Robledo[2], S. Malzer[2], T. Müller[4], K. Unterrainer[4], A. Leitenstorfer[1,3] und G. H. Döhler[2] — [1]Physik-Department E11, TU München — [2]Institut für technische Physik, Universität Erlangen — [3]Fachbereich Physik, Universität Konstanz — [4]Institut für Festkörperelektronik, Universität Wien

Parabolic shaped potential wells of a width between 120 nm and 250 nm are defined in a band gap engineered p^+-n-p^+ heterostructure. After femtosecond photoinjection of carriers near the boundary of the well, electrons are found to coherently oscillate across the well with the classical harmonic oscillator frequency of a few THz instead of performing the intuitively expected unidirectional relaxation towards the bottom of the well. Most strikingly, the coherence of this periodic electron motion is maintained despite multiple phonon scattering events. This novel transport is predicted by detailed Monte Carlo simulations and verified analyzing the femtosecond transmission of the heterostructure as well as by directly detecting the THz radiation emitted by the oscillating electron-hole dipole. Decreasing the well width, this semi-classical ballistic transport regime is expected to converge towards a quantum-beat regime.

HL 63.4 Mi 11:30 TU P-N201

Ultrafast phase-resolved spectroscopy on semiconductor multiple-quantum-well Bragg structures in different light-matter interaction regimes — •Tilman Höner zu Siederdissen[1], Nils C. Nielsen[1], Jürgen Kuhl[1], and Harald Giessen[2] — [1]Max-Planck-Institut für Festkörperforschung, 70569 Stuttgart — [2]Institut für Angewandte Physik, Uni Bonn, 53115 Bonn

We present phase-resolved pulse propagation measurements on semiconductor multiple-quantum-well Bragg structures allowing us to study the transition between different light-matter interaction regimes. Our experiments cover the range from linear excitation to the breakdown of the photonic band gap, on to self-induced transmission and self-phase modulation. The complete knowledge of the output pulse properties including the phase characteristics is used to clearly identify the involved linear and nonlinear effects. An improved fast scanning cross-correlation frequency-resolved optical gating (XFROG) setup is applied to retrieve the pulse phase with an excellent signal to noise ratio.

HL 63.5 Mi 11:45 TU P-N201

Nonlinear transmission and pump-and-probe experiments on ZnSe/ZnSSe heterostructures — •Iryna Kudyk[1], Ilja Rückmann[1], Jürgen Gutowski[1], Stefan Schumacher[2], Gerd Czycholl[2], and Frank Jahnke[2] — [1]Institut für Festkörperphysik, Universität Bremen, POB 330440, D-28334 Bremen — [2]Institut für Theoretische Physik, Universität Bremen, POB 330440, D-28334 Bremen

The energy position of polariton modes in the optical spectra of semiconductor nanostructures depends on the layer thickness due to quantization of the electron-hole motion. Therefore, ZnSe nanostructures with layer thicknesses of about 20 nm are appropriate objects for studies of polariton effects. The polariton modes in a 20 nm ZnSe layer are initially characterised with linear transmission spectroscopy. Furthermore, the polariton and biexcitonic properties are investigated in nonlinear transmission and in pump-and-probe experiments. 110 fs pulses are generated by a frequency-doubled mode-locked Ti:sapphire laser. The spectral position of the pulses is adjusted to exclusively excite the hh1 to hh3 polariton modes and the corresponding biexciton. For the experiments the polarization state of the excitation pulses is chosen to be either linear or circular by use of Pockelscells. In nonlinear transmission experiments with linear polarization of the excitation pulses as well as in pump-and-probe experiments with contra-circular polarization the biexciton with a binding energy of 4.3 meV is clearly observed. The presented experimental results are in good agreement with numerical calculations based on a microscopic theory.

HL 63.6 Mi 12:00 TU P-N201

Projection operator formalism for temporal relaxation phenomena in nanostructures — •Nikolaos Gortsas and Andreas Knorr — Institute for Theoretical Physics, Nonlinear Optics and Quantum Electronics, Technical University Berlin, Germany

By the use of projection operator techniques (POT) we investigate temporal relaxation phenomena in semiconductor nanostructures. POT provide powerful tools to derive close and local master equations of open quantum systems, which allow a systematic description of the non-Markovian features of the dynamics of open quantum systems. We are going to present applications of this theory for quantum dots and intersubband transitions with emphasis on the coupling of the electronic system to a reservoir of phonons.

HL 63.7 Mi 12:15 TU P-N201

Terahertz microscopy of charge carrier distributions — •F. F. Buersgens[1], H.-T. Chen[2], and R. Kersting[1,2] — [1]Physics Department, University of Munich, 80799 Munich, Germany — [2]Department of Physics, Rensselaer Polytechnic Institute, Troy, NY 12180, U.S.A.

Our recent development of an apertureless THz scanning near-field optical microscope (THz-SNOM) allows for submicron spatial resolutions and suggests a broad variety of novel applications in semiconductor technology [1,2]. For example, this technique may be used for the detection of charge carrier distributions in a field effect transistor or for the contactless characterization of nano-electronic building blocks. In this contribution we will demonstrate that apertureless THz-microscopy can be used to

detect electron distributions on a microscopic scale. The basic mechanism is that a metallic probe allows to map the THz permittivity of the surface, which depends on the electron density in the region under the probing tip. By applying a potential between the needle and the semiconductor the electron density can be locally controlled. We show first evidence that THz microscopy is capable to detect electron populations in n-doped GaAs structures that consist only of about 1000 electrons.

[1] H.-T. Chen et al. Appl. Phys. Lett. 83, 3009 (2003)
[2] H.-T. Chen et al. Phys. Rev. Lett. in press (2004)

HL 63.8 Mi 12:30 TU P-N201

Dynamic polarization filtering in strained *M*-plane GaN films — •T. Flissikowski[1], K. Omae[1], P. Misra[1], O. Brandt[1], H. T. Grahn[1], K. Kojima[2], and Y. Kawakami[2] — [1]Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5–7, 10117 Berlin, Germany — [2]Department of Electronic Science and Engineering, Kyoto University, Kyoto 615-8510, Japan

We have observed dynamic polarization filtering in anisotropically strained *M*-plane GaN films on γ-$LiAlO_2$. The in-plane polarization anisotropy, resulting from the anisotropic strain, leads to a static polarization filtering due to the much larger absorption coefficient for light polarized perpendicular to the c-axis $\alpha_\perp$ in comparison to $\alpha_\parallel$ [1,2]. In order to investigate dynamic polarization filtering in these films, a polarization sensitive, femtosecond pump-and-probe technique is used in connection with a micro-optical setup in order to bleach $\alpha_\perp$. In this case, the effective static polarization rotation of the probe toward the c-axis can be almost canceled by the pump pulse. The amplitude of this dynamic filtering strongly depends on the photoexcited carrier density as well as on the hole redistribution between the upper two valence bands. The time scale of this dynamic filtering is mostly determined by the carrier recombination time. Furthermore, the pump-induced changes in $\alpha_\perp$ and $\alpha_\parallel$ can also alter the refractive indices $n_\perp$ and $n_\parallel$. Consequently, the ellipticity of the outgoing light beam is investigated during dynamic filtering.

[1] P. Misra *et al.*, Appl. Phys. Lett. **83**, 4327 (2003).
[2] P. Misra *et al.*, J. Appl. Phys. **96**, 1. Dec. (2004).

HL 63.9 Mi 12:45 TU P-N201

High-intensity THz radiation pulses from a scalable photoconductive device — •Stephan Winnerl, André Dreyhaupt, Marcel Krenz, Dominik Stehr, Thomas Dekorsy, and Manfred Helm — Forschungszentrum Rossendorf, Institute of Ion Beam Physics and Materials Research, P.O. Box 510119, D-01314 Dresden, Germany

Photoconductive emitters are an attractive way for impulsive generation of THz radiation. There are two main categories, namely large-aperture emitters and interdigitated electrodes coupled to antennas. Large-aperture emitters have the advantage of a large active area, while interdigitated structures provide high electric fields for efficient acceleration of photogenerated carriers. We present a large-aperture emitter consisting of an interdigitated metal-semiconductor-metal (MSM) structure, which combines both advantages. A second metallization layer, which is electrically insulated from the first one, blocks the optical excitation in every second period of the MSM structure, resulting in an unidirectional acceleration of carriers in the device. Focussing fs optical pulses with an average power of $100mW$ from a Ti:sapphire oscillator on the emitter lead to THz field amplitudes of up to $85V/cm$ ($U_{bias} = 65V$). Excitation with unfocussed radiation from a $1kHz$ repetition rate Ti:sapphire amplifier system (average power $10mW$) provided THz field amplitudes of $6kV/cm$ ($U_{bias} = 23V$). In case of the excitation with the Ti:sapphire amplifier system a pronounced nonlinear behavior of the THz field amplitude with respect to both the excitation density and the bias electric field was observed.

HL 63.10 Mi 13:00 TU P-N201

Coupling two quantum dots: Förster or direct dipole interaction? — •Christoph Lienau[1], Thomas Unold[1], Kerstin Müller[1], Thomas Elsaesser[1], and Andreas D. Wieck[2] — [1]Max-Born-Institut für Nichtlineare Optik undKurzzeitspektroskopie, 12489 Berlin — [2]Ruhr-Universität Bochum, 44870 Bochum

A variety of theoretical ideas for quantum dot (QD) based implementations of quantum logic have been discussed over the last years. Most of these schemes rely on short-range dipole-dipole couplings between neighboring QDs. On the experimental side, however, fairly little is known about such interactions, as they are often difficult to probe in ensemble studies.

Here, we report a combined experimental and theoretical study of dipolar interactions between two individual quantum dots. Ultrafast laser pulses are used to coherently control exciton states in a single quantum dot [1] and perform single-exciton Rabi rotations. Manipulation of this QD strongly modifies the energy spectrum of an adjacent QD - Rabi oscillations are also observed in the nonlinear response of the second QD. The theoretical analysis indicates that unlike in atomic systems the coupling between the quantum dots arises mainly from permanent excitonic dipole moments, whereas quasi-resonant (Förster) energy transfer is weak. Since such a coupling is readily controllable by means of external electric fields, new possibilities for realizing QD-based quantum logic with ultrafast laser pulses emerge.

[1] T. Guenther et al., Phys. Rev. Lett. **89** 057401 (2002), **92** 157401 (2004).

HL 63.11 Mi 13:15 TU P-N201

Coherent atomic motions in a semiconductor superlattice studied by femtosecond x-ray diffraction — •Matias Bargheer[1], Nikolai Zhavoronkov[1], Yuri Gritsai[1], J. C. Woo[2], Dai-Sik Kim[2], Michael Woerner[1], and Thomas Elsaesser[1] — [1]Max-Born-Institut, Berlin — [2]Seoul National University, Seoul, Korea

We report on the first nondestructive femtosecond x-ray diffraction measurements of minute reversible structural changes in a nanostructured solid. As a prototype sample representative for a larger class of inorganic and organic nanostructures, we directly measured coherent lattice plane motions with sub-picosecond and sub-picometer accuracy in a GaAs/AlGaAs superlattice [1]. The spatially periodic femtosecond excitation of the lowest subband in the wells of the superlattice results in coherent lattice motions with a 3.5 ps period, directly monitored by a novel kHz femtosecond-XRD setup. Small changes $\Delta R/R = 0.01$ of weak Bragg reflexes ($R = 0.005$) are detected. Phase and amplitude of the XRD signal demonstrate the displacive excitation of zone-folded longitudinal acoustic phonons as the dominant mechanism for strong excitation. This results is in contrast to all optical pump-probe experiments on the same material in the weak excitation regime which was shown to be impulsive Raman excitation [2]. [1] Bargheer et al. "Coherent Atomic Motions in a Nanostructure Studied by Femtosecond X-ray Diffraction", Science 2004 (in print). [2] A. Bartels et al. Phys. Rev. Lett. 82, 1044 (1999).

HL 64 Photovoltaik II

Zeit: Mittwoch 10:45–13:30 Raum: TU P-N202

HL 64.1 Mi 10:45 TU P-N202

Wirkungsgrad von Solarzellen mit Fluoreszenzkollektoren — •Gerda C. Gläser, Florian Einsele, Uwe Rau und Jürgen H. Werner — Institut für Physikalische Elektronik, Universität Stuttgart, Pfaffenwaldring 47, 70569 Stuttgart, Germany

Fluoreszenzkollektoren benutzen Farbstoffe zur Konversion von hochenergetischen Photonen der Solarstrahlung in niederenergetische Photonen. Bei der Frequenzkonversion werden die Photonen in der Farbstoffschicht in eine beliebige Richtung emittiert. Das Konversionsvermögen des Kollektors ist abhängig von den Absorptions- und Emissionseigenschaften des Farbstoffes. Die Reflexionseigenschaften und die geometrische Anordnung von Kollektorschicht und Solarzelle bestimmen den Grad der Konzentration des Systems. Die Art des verwendeten Kollektors hängt von der Bandlücke und dem Aufbau der Solarzelle ab. Monte-Carlo-Simulationen des Lichtweges dienen dazu, den Konzentrationsgrad und die Effizienz unterschiedlicher Systemgeometrien zu berechnen. Trotz des Konzentrationseffektes ist der maximale Wirkungsgrad bei rein strahlender Rekombination niedriger als der Shockley-Queisser Wirkungsgrad ohne Konzentration. Unsere Ergebnisse zeigen, dass in realen Fluoreszenzkollektoren ein optimaler Konzentrationsgrad existiert, der zum maximalen Wirkungsgrad führt.

HL 64.2 Mi 11:00 TU P-N202

Laser doped crystalline silicon solar cells — •A. Esturo-Breton, M. Ametowobla, J.R. Köhler, and J.H. Werner — Institut für Physikalische Elektronik, Universität Stuttgart

We report on a laser doping technique that creates pn-junctions for crystalline silicon solar cells. Here, spin on coating of a phosphorous containing liquid serves as a doping precursor on 0.35 Ωcm p-type crystalline silicon wafers. A Nd:YVO4 pulsed laser scans the sample. Each pulse melts a thin silicon layer and phosphorous atoms diffuse into the molten silicon before the molten layer recrystallizes again. An increase of the laser pulse energy density increases the emitter thickness and reduces the sheet resistance of the emitter and blue response of the cell. PC1D simulations indicate that the decrease of the blue response of the cells with increasing pulse energy density is a result of the increase of the emitter thickness. Secondary Ion Mass Spectroscopy (SIMS) measurements prove that overlap between the laser pulses reduces the phosphorous concentration at the surface. The result is an increased contact resistivity between metal and semiconductor and, therefore higher series resistance of the solar cells.

HL 64.3 Mi 11:15 TU P-N202

Modellierung der elektrischen und optischen Eigenschaften dünner Siliciumsolarzellen — •Willi Brendle, Christopher Berge, Markus B. Schubert und Jürgen H. Werner — Institut für Physikalische Elektronik, Universität Stuttgart, Pfaffenwaldring 47, 70569 Stuttgart, Germany

Oberflächenverluste spielen bei dünnen Solarzellen eine entscheidende Rolle. Zur Analyse und Optimierung der elektronischen Parameter unserer dünnen einkristallinen Siliciumsolarzellen setzen wir das Simulationsprogramm PC1D [1] ein. Die Variation der Leerlaufspannug als Funktion der Zelldicke erlaubt Rückschlüsse auf die Rekombination photogenerierter Ladungsträger an der Bauelementrückseite. Die Modellierung des Lichteinfangs mit SUNRAYS [2] liefert eine Abschätzung des maximal möglichen Wirkungsgrades unserer Solarzellen. Der Vergleich der Modellrechnungen mit experimentellen Ergebnissen gibt Anhaltspunkte zur weiteren Verbesserung unserer Zellen.

[1] P. A. Basore, D. A. Clugston, PC-1D, University of New South Wales, Sydney, Australia (1997).

[2] R. Brendel, *SUNRAYS: A versatile solar cell ray tracing program...*, in *Proc 12th EU Photovoltaic Solar Energy Conf.*, eds. R. Hill, W. Palz, und P. Helm (H. S. Stephens, Bedford, 1994), p. 1339.

HL 64.4 Mi 11:30 TU P-N202

Comparison of dopant sources for laser doped crystalline silicon — •M. Ametowobla, A. Esturo-Breton, J.R. Köhler, and J.H. Werner — Institut für Physikalische Elektronik, Universität Stuttgart

Laser doping of crystalline silicon is a fast and effective method to produce abrupt pn-junctions with one side being highly doped. This approach replaces furnace diffusion for the emitter fabrication of crystalline silicon solar cells. For this purpose we deposit phosphorous and boron containing liquid doping precursor layers by spin on, spray on, roll on and inkjet processes. Alternatively, we investigate sputtering of boron or phosphorous atoms onto the silicon surface to obtain precursor layers. The deposition method and laser processing parameters affect dopant concentration and homogeneity, as well as junction depth. Junction depth depends mainly on the laser energy density, whereas doping efficiency is mostly influenced by the effective dopant concentration in the precursor layer and its thickness. Consequently, sputtered precursor layers result in the highest dopant concentrations, and require less laser energy than liquid precursor layers.

HL 64.5 Mi 11:45 TU P-N202

Poly-crystalline Si thin-film solar cells on glass: Low-temperature epitaxial thickening of seed layers — •Björn Rau[1], Juliane Klein[1], Jens Schneider[1], Ina Sieber[1], Stefan Gall[1], Michael Stöger-Pollach[2], Peter Schattschneider[2], and Walther Fuhs[1] — [1]Hahn-Meitner-Institut Berlin, Abt. Silizium-Photovoltaik, Kekuléstr. 5, D-12489 Berlin — [2]Technische Universität Wien, Institut für Festkörperphysik, Wiedner Hauptstr. 8-10, A-1040 Wien, Austria

The epitaxial thickening of poly-Si seed layers on low-cost substrates like glass is of great interest for the realisation of the photo-active absorber layer of a poly-Si thin-film solar cell. The use of glass substrates limits all process temperatures to temperatures below the softening point of the glass (<650 ^{o}C).

Here, we report on the epitaxial growth of Si at temperatures below 600 ^{o}C on polycrystalline seed layers using electron-cyclotron resonance chemical vapor deposition (ECRCVD). The seed layers were prepared by aluminum-induced crystallization (AIC) of amorphous Si on glass substrates. The quality of the ECRCVD-grown films depends strongly on the orientation of the seed layer grains; a (100) preferential orientation is favourable for epitxial thickening.

Structural and electronic properties of the epitaxial layers are discussed in view to their use in solar cell structures. First solar cell test structures were prepared. Open circuit voltages of above 280 mV were achieved.

HL 64.6 Mi 12:00 TU P-N202

Dispersive Optical Structures for Tandemsolarcells — •A. Bielawny[1], P.T. Miclea[1], S.L. Schweizer[1], R.B. Wehrspohn[1], and S. Glunz[2] — [1]University of Paderborn, Department of Physics, Warburger Str. 100, D-33098 Paderborn — [2]Fraunhofer Institute for Solar Energy Systems, Department: Solarcells - Materials and Technology, Heidenhofstr. 2, D-79110 Freiburg

Photovoltaic tandem solarcells are currently being developed and produced with great efficiencies but at high technological cost. The optical concept of spectrum splitting comes with the advantage of compatibility to all types of cells. Although additional optical efforts are to be made, external photon management can be achieved to fit different pv-cell combinations no matter which bandgaps involved or how the cells connect. We present an experimental set-up to compare spectral beamsplitters and dispersive media and the results obtained from measurements on a GaInP/GaInAs-system matched by means of a dielectric mirror. Initial measurements with bulk colloidal Photonic Crystals as next generation spectral splitting components are presented and possible applications in photovoltaics being discussed.

HL 64.7 Mi 12:15 TU P-N202

Strukturelle, Optische und Elektronische Eigenschaften von reaktiv-gesputteren $CuInS_2$ Dünnschichten und Solarzellen — •T. Unold, T. Enzenhofer und K. Ellmer — Hahn-Meitner Institut, Berlin

Wir untersuchen $CuInS_2$ Dünnschichten die direkt in einem Schritt durch reaktives Sputtern von Cu und In in H_2S/Ar Athmosphäre hergestellt werden. Um den Vergleich mit sonst üblichen sequentiellen und Koverdampfungsprozessen zu ermöglichen wurden auch Solarzellen im HMI Standardprozess hergestellt. REM Messungen zeigen dass mit unserer Methode ein kolumnares Wachstum möglich ist, mit Korndurchmessern im Mikrometerbereich. Raman Messungen zeigen dass für Substrattemperaturen T_s unterhalb 450C eine Cu−Au Fehlordnung existiert, während diese für $T_s > 450$C nicht nachweisbar ist, selbst bei Indium-arm gewachsenen Schichten. In der Tat ist es uns gelungen Zellen aus In-arm gewachsenen Absorberschichten mit nahe 6% Wirkungsgrad herzustellen, verglichen mit 8% für unsere besten Cu-reich gewachsenen Schichten. PL Messungen lassen auf eine sehr ähnliche Defektstruktur wie bei sequentiell oder durch Koverdampfung hergestellten Schichen schliessen. Dies bedeutet dass der Ionenbeschuss während des Sputterprozesses nicht zu einer stark veränderten Defektstruktur führt.

HL 64.8 Mi 12:30 TU P-N202

ESTIMATION OF INTERFACE DEFECT DISTRIBUTION IN A-SI:H/C-SI HETEROSTRUCTURES — •Saioa Tardon, Gottfried H. Bauer, and Rudolf Brueggemann — Institut fuer Physik, Carl-von-Ossietzsky Universitaet Oldenburg, AG GRECO, 26111 Oldenburg

According to Planck's generalized law, photon flux emitted from matter is related to the splitting of the quasi-Fermi levels. We have recorded room temperature photoluminescence yield from p-doped crystalline silicon wafer structures after each step of solar cell processing such as rear contact and hetero-interface preparation and translated into the splitting of quasi-Fermi energies. Numerical simulations of identical structures and measurement conditions have been performed in order to fit the calculated pl-yields to experimental ones. An interfacial defect layer with a Gaussian distribution has been considered at the hetero junction and the energy position of the peak $E_p - E_V$ has been varied from 0.2 to 0.9 eV. The energetic position of interface defects strongly influences band bending, the occupation of dangling bonds, and consequently the splitting of quasi-fermi levels and final maximal open circuit voltage of a-si:H/c-Si heterojunction solar cells.

HL 64.9 Mi 12:45 TU P-N202

Bestimmung der Gitterkonstanten epitaktischer $CuIn_{1-x}Ga_xS_2$ Filme auf Si(111) mittels Synchrotronstrahlung — •Janko Cieslak[1], Jürgen Kräusslich[2], Thomas Hahn[1], Frank Wunderlich[2], Heiner Metzner[1], Jens Eberhardt[1], Udo Reislöhner[1], Mario Gossla[1] und Wolfgang Witthuhn[1] — [1]Institut für Festköperphysik, Friedrich Schiller Universität Jena, Max-Wien-Platz 1, 07743 Jena — [2]Institut für Optik und Quantenelektronik, Friedrich Schiller Universität Jena, Max-Wien-Platz 1, 07743 Jena

Es wurden epitaktische $CuIn_{1-x}Ga_xS_2$ Filme unterschiedlicher Ga-Anteile x mittels Molekularstrahlepitaxie auf Si(111) Substraten abgeschieden. Aufgrund der bzgl. Si kleineren Gitterkonstante a von $CuGaS_2$ und größeren Gitterkonstante von $CuInS_2$ ist eine perfekte Gitteranpassung für das quaternäre System $CuIn_{1-x}Ga_xS_2$ zu erwarten. An der Europäischen Synchrotron Strahlungsquelle in Grenoble konnten die Gitterkonstanten der epitaktischen Filme mittels Röntgenbeugung präzise bestimmt werden. Der Ga-Anteil x, bei denen Gitteranpassung eintritt wurden ermittelt und hat aufgrund des tetragonalen Kristallsystems für die Gitterkonstanten a und c unterschiedliche Werte. Abweichungen der Gitterkonstanten zu Literaturwerten von Einkristallen sowie der Einfluß metastabiler Ordnungstypen werden diskutiert.

HL 64.10 Mi 13:00 TU P-N202

Analysis of the recombination processes at silicon based heterojunctions by surface photovoltage transient technique — •A. Laades, C. Schubert, R. Stangl, K. v. Maydell, K. Kliefoth, M. Schmidt, and W. Fuhs — Hahn-Meitner-Institut Berlin, Silizium-Photovoltaik, Kekuléstr. 5, D-12489 Berlin

We have studied the decay dynamics of photoinduced excess carriers in silicon heterojunctions with different surface passivation procedures by means of time-resolved surface photovoltage technique. In this method excess carriers are generated by a short laser pulse and their annihilation is monitored through the time decay of the light-induced change in surface potential. The characteristic time constants of the different decay modes correlate well with interface parameters such as interface recombination velocity, effective lifetime and trap-emission times. The primary advantage of the present technique compared to the conventional minority carrier investigation methods is the direct probing of the influence of band bending on the interface recombination. Using silicon substrates with different resistivities, we have shown that with decreasing band bending the recombination at the interface prevails over volume recombination. By decreasing the interface state density or increasing band bending, the time constant in the initial part of the transient, where the excess carrier concentration still exceeds the equilibrium concentration, increases considerably. This is explained by a decrease in the surface recombination velocity, leading to a dominance of volume recombination. In this case, an effective minority carrier lifetime can be extracted from low injection part of the transient.

HL 64.11 Mi 13:15 TU P-N202

Band alignment at the CdS/Cu(In,Ga)S_2 interface in thin film solar cells — •L. Weinhardt[1], O. Fuchs[1], D. Gross[1], G. Storch[1], E. Umbach[1], N.G. Dhere[2], A.A. Kadam[2], S.S. Kulkarni[2], and C. Heske[3] — [1]Experimentelle Physik II, Universität Würzburg — [2]Florida Solar Energy Center, Cocoa, USA — [3]Dept. of Chemistry, University of Nevada, Las Vegas, USA

While the Se-based part of the Cu(In,Ga)$(S,Se)_2$ thin film solar cell family has reached cell efficiencies above 19%, the S-based systems are today still limited to 13%. In principle, cells based on $CuInS_2$ should be superior to $CuInSe_2$ cells because of their optimal band gap of 1.4 eV (compared to 1.0 eV for $CuInSe_2$) and their potentially higher voltage, which reduces the series resistance in a module. However, the open circuit voltage shows a lower increase as would be expected by the larger band gap, the reason for which is speculated to be a non-ideal band alignment at the CdS/$CuInS_2$-interface. To clarify this issue, we have directly determined the conduction and valence band alignment at the CdS/Cu(In,Ga)S_2 interface by using photoelectron spectroscopy and inverse photoemission. We find an unfavorable conduction band offset of -0.45 ($\pm$0.15) eV, which can explain the low open circuit voltage. The results will be discussed in the context of the band alignment at the CdS/CuIn$(S,Se)_2$ derived in earlier measurements.