Optical properties of Sn-doped CdS nanowires

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we find that the luminescence decay time can be well fitted with a bi-dent PL measurements, indicates the successful incorporation of Sn DAP transition, which was proven by power- and temperature dependent DLE and DAP (donor-acceptor pair) transitions were investigated to state about the optical properties. The occurring DAP transition, which was proven by power- and temperature dependent PL measurements, indicates the successful incorporation of Sn into the CdS NWs.

Tailoring CdS nanowire laser resonators — •ROBERT RÖDER1, SEBASTIAN GEBURT2, ANDREAS JOHANNES1, MARKUS GLÄSER2, ALOIS LUGSTEIN2, and CARSTEN RONNING1 — 1Institut für Festkörperphysik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, D-07743 Jena — 2Institut für Festkörperelektronik, TU Wien, Floragasse 7, A-1040 Wien

The nanophotonics research for the development of on-chip optical components has to be intensified due to the forthcoming limits of conventional electronic integrated circuits. Semiconductor nanowires mark the physical size limit of a multimode photonic laser system. Thus, they are promising for concentrating these limits via optical data transmission and processing. The green spectral range around 2.4 eV is made accessible by high quality VLS synthesized cadmium sulfide nanowires (CdS NW) acting as Fabry-Pérot laser resonators with a remarkable low threshold of 10 kW/cm² at room temperature. The resulting task for the processing of CdS nanowasers with reproducible properties remains in defining the resonator: The mode spacing can be adjusted by reducing the cavity length. The reflectivity of the guided modes can be selectively attached to semiconductor surfaces with the help of a focused ion beams (FIB) and a focused laser beam.

Luminescence decay dynamics of colloidal CdSe quantum dots in different environments — •MICHAEL DIEZ2, STEPHANIE BLEY1, DONGCHAO HOU1, SEBASTIAN RESCH2, SIEGFRIED WALDVOGEL2, JÜRGEN GUTOWSKI3, and TOBIAS VOSS4 — 1Institute of Solid State Physics, Semiconductor Optics, University of Bremen, 28359 Bremen, Germany — 2Institute of Organic Chemistry, Johannes Gutenberg University Mainz, 55128 Mainz, Germany

The functionalization of semiconductor surfaces with colloidal quantum dots has gained substantial interest because of its wide application in optical sensing and energy harvesting. The quantum dots can be selectively attached to semiconductor surfaces with the help of linker molecules. We have studied the luminescence decay dynamics of colloidal CdSe quantum dots functionalized with α-mercaptoalkanoic acid in different environments. As optical excitation source we use a frequency-doubled Ti:sapphire laser (Δτ = 350 nm, Δf = 60 fs, f = 82 MHz and l_{exc} = 12 μm). We detect the luminescence signal with a streak camera and an attached spectrometer (Δf ≤ 2 ps, Δλ < 0.2 nm). For colloidal CdSe quantum dots in aqueous solution, we find that the luminescence decay time can be well fitted with a bi-exponential decay (shorter decay time t1 ≈ 200 ps, longer decay time t2 ≈ 3 ns). Furthermore, we discuss the importance of surface and bulk states for the observed biexponential decay and study the change of t1 and t2 for quantum dots attached to different oxide surfaces. The observed results will allow for the optimization of quantum dot properties for specific optoelectronic applications.

Growth of GaAs nanowires using the ANKA portable MBE system — •JEAN-WOLFGANG HORNUNG1, EMMANOUIL DIMAKIS2, PHILIPP SCHROTH3, LUTZ GERLHAAR4, and TILLO BAUMBACH1 — 1Karlsruhe Institute of Technology, Institute for Photon Science and Synchrotron Radiation, Karlsruhe, Germany — 2Paul-Drude-Institut für Festkörperphysik, Berlin, Germany

We present results on first growth experiments with the portable Molecular Beam Epitaxy (MBE) system of ANKA performed at the PDI in Berlin. This system enables the growth of nanostructures in the (In,Ga)As-material system and in-situ monitoring of growth processes using synchrotron radiation at various synchrotron radiation facilities such as ANKA, ESRF, PETRA III. The properties of such NWs are of great importance for the fabrication of high performance electronic devices such as vertical transistors and solar cells.

Structural and resistive switching properties of SrTiO3 deposited by RF sputtering — •BENJAMIN ROESSLER, JURKA RENSBERG, FRANK SCHMIDL, and CARSTEN RONNING — Institut für Festkörperforschung, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, D-07743 Jena, Germany

Stromium titanate (SrTiO₃) exhibits bipolar resistive switching between a high- and a low-resistance state when applying an appropriate electric field. The possibility to deposit SrTiO₃ at room temperature by magnetron sputtering on silicon substrates without buffer layers makes it one of the promising candidates for future nonvolatile data memory applications. Therefore, we deposited polycrystalline SrTiO₃ films on p-Si(100) as well as n-Si(110) at room temperature with a fixed oxygen-to-argon content ratio of 1:2. The microstructure as well as the crystalline quality of the films was analyzed using cross-sectional electron microscopy and X-ray diffraction analysis. For both substrates

HL 27: Joint Poster Session: Functionalized semiconductor nanowires (DS, jointly with HL); Resistive switching (DS, jointly with DF, KR, HL)

Time: Monday 17:00–20:00
Location: Poster B1

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a broad grain size distribution was found for the as-deposited films. To improve the crystalline quality post-deposition annealing was performed up to temperatures of 1000°C. In this contribution we discuss the structural changes and electrical properties of SrTiO₃, i.e. the resistive switching properties as a function of the annealing temperature.

HIL 27.7 Mon 17:00 Poster B1
Memory Effects in Resistive Ion-beam Modified Oxides — •S. Gemming¹,², D. Blaschke¹,², K. Potzger¹, P. Zahn¹, A. Bocquart², H. Schmitt², T. Mikolajczik¹, S. Slesazeck¹, H. Wylezich³, B. Arendtöwitzer³, D. C. Mievin³, S. Rentrop⁴, R. Dittmann⁵, K. Skaja⁵, R. Waser⁵, J. Rensberg⁵, C. Ronning³, N. A. Spaldin⁷, and D. Basov⁸ — ¹HZ Dresden-Rossendorf, D-01314 Dresden — ²TU Chemnitz, D-09107 Chemnitz — ³TU Dresden — D-01062 Dresden — ⁴TU Bergakademie Freiberg, D-09596 Freiberg — ⁵FZ Jülich, D-52425 Jülich — ⁶Friedrich Schiller University Jena, D-07743 Jena — ⁷ETH Zürich, CH-8092 Zürich, Switzerland — ⁸UC San Diego, La Jolla CA 92039-0354, USA.

The Virtual Institute ‘Memrix’ establishes a joint research initiative in the field of ion-tailored oxide-based memristive elements, to be pursued within a novel and unique combination of core competences from the Helmholtz centers Dresden-Rossendorf and Jülich and their university partners in Dresden, Freiberg, Jena, San Diego, and Zürich. A major aim is to implement memristive elements in the concept of the ultimate future non-volatile memory cell with a resistance set directly by electric currents. The Virtual Institute aims at stepping beyond the established layer-by-layer control of intrinsic defects during the synthesis methods.

HIL 27.8 Mon 17:00 Poster B1
Transmission X-ray microscopy of resistively switched epitaxial Fe-doped SrTiO₃ MIM structures — •Holger Wasmund¹, Annemarie Köhl², Peter Guttmann², Katja Henzel², Stephan Werner², Sebastian Schmelzer³, Regina Dittmann³, and Rainer Waser¹ — ¹FZ Jülich, PG1-7, Germany — ²HZB, Institute for Soft Matter and Functional Materials, Germany.

There exists strong experimental evidence that the resistance change in transition metal oxides is caused by a valency change on a nanoscale. Transmission X-ray microscopy exhibit the potential of observing bulk spectral information of the sample with a spatial resolution of 25nm unlike other methods which exclusively probe the surface e.g. XPS. One central issue in TXM probe preparation is the sample thickness which should not exceed 100nm. As a first approach we studied polycrystalline STO devices on SiN membranes which were switched in two different resistive states. To analyse epitaxial grown STO devices we prepared SRO/STO/Pt MIM structures on top of NGO substrates with an intermediate sacrificial layer by pulsed laser deposition and sputtered Pt electrodes. A chromium adhesion layer and a carbon film were deposited on top of the stack in order to serve as a carrier foil followed by a selective etching step of the sacrificial layer to release the specimen from the substrate. XAS spectra measurements at the Ti L edge and the Fe L edge for electrode pads in different resistive states were realized at the U41 beamline at Bessy II. We observed significant changes in the Ti spectra which are indications for a valency change in a filament like region.

HIL 27.9 Mon 17:00 Poster B1
Adaptive Robot learning via (simulated) memristive Elements — •Marius Schirmacher and Andy Thomas — Bielefeld University, Bielefeld, Germany

Memristors are new circuit elements that fill the gap in relations between the circuit variables flux φ and charge q. Like their name consisting of Memory and Resistor presumes, they are resistors with memory. The resistance depends on the current i(t) that was applied to an element earlier. This behavior is similar to the synapse of a living nerve cell and therefore networks of memristors can be used as neuronal networks in hardware circuits.

To visualize the learning process of such a memristive neuronal network we used a Lego Mindstorms NXT robot and designed an interface for using memristors that can be connected to the NXT’brick. We also designed a circuit board that is simulating memristive behavior. The Software written in Java allows several different learning tasks.

HIL 27.10 Mon 17:00 Poster B1
Thermal conductivity measurements using the Raman shift method — •Simon Filser, Benedict Stoib, Martin Stutzmann, and Martin S. Brandt — Walter Schottky Institut, Technische Universität München, Am Coulombwall 4, 85748 Garching

With the aim to determine the in-plane thermal conductivity of laser-sintered thin films of SiGe nanoparticles [1], we study the applicability of a contactless optical method employing the temperature-dependent frequency shift of the LO phonon of the SiGe nanoparticles. For Raman spectroscopy, as a measure for the local temperature, we present our results on a variety of model systems such as, e.g., bulk Si, free-standing Si films and rectangular cantilevers validating the method. The pressure-dependent influence of parasitic thermal conduction through the ambient atmosphere is studied, indicating a small effect for single crystalline material, but a significant contribution for the macro-porous laser-sintered system studied here. Free-standing samples of laser-sintered Si nanoparticle thin films were fabricated either by scanning electron microscope-based micro-manipulation or via a liquid-transfer technique. The results of Raman mapping of such membranes are consistent with the sample morphology and provide insight into the thermal transport.


HIL 27.11 Mon 17:00 Poster B1
A real space method for third-order IFCs and phonon re- sistance — •Michael Bachmann, Michal Czerny, Robert Henrich, and Christian Heiliger — I. Physikalisches Institut, Justus Liebig-Universität, D-35392 Giessen, Germany

We present a real space method to obtain third-order phonon anharmonicities from first principles calculations. The anharmonic interatomic force constants (IFCs) of third order are determined from a real space method involving small displacements of atoms inside a supercell. We calculate the anharmonic IFCs from force fields due to the displaced atoms using the Vienna Ab Initio Simulation Package (VASP). We determine the third-order anharmonicities of the potential for the case of silicon (Si). From these the phonon relaxation times for Si are obtained for different phonon branches.

HIL 27.12 Mon 17:00 Poster B1
Phonon Transport in Si-Isotope-Multilayer — •Michael Bachmann, Michael Czerny, Robert Henrich, and Christian Heiliger — I. Physikalisches Institut, Justus Liebig University Giessen, D-35392, Germany

In thermoelectrics the maximum achievable efficiency is linked to the material parameters by the so called figure of merit. There are in principle four different material parameters, which can be divided into three electronic parameters and one phononic parameter. The three electronic parameters are the electric conductivity, the Seebeck coefficient, and the thermal conductivity of the electrons. The phononic parameter is the thermal conductivity of the lattice. In silicon the electronic parameters are suitable for thermoelectric applications, but the high lattice thermal conductivity prevents the application of pure silicon. In Si-Ge- or Si-Ge-based materials, which are a promising structure, where the lattice thermal conductivity can be decreased and the electronic parameters remain unaffected. We present phonon transport calculations based on an atomistic Greens function method for Si/SiGe/Si and Si/SiGe/Si-Isotope-multilayers. These results show that a periodic arrangement of the layer-system cannot decrease the phonon thermal conductivity substantially, whereas a random arrangement of the layer-system can lead to a strong decrease in the phonon conductivity.

HIL 27.13 Mon 17:00 Poster B1
Glancing Angle Deposited Silicon Germanium Nanostru- ctures for Electronic Applications — •Christoph Grüner and Bernd Krauschenbach — Leibniz-Institut für Oberflächenmodifizierung, Pernomserstraße 15, D-04318 Leipzig, Germany

Obtaining control over the physical properties of semiconductors is a big challenge for future electronics. The use of nanostructures can provide this control, since quantum mechanical and surface effects become important. Nanostructured thin films can show higher optical absorption or reduced reflection, higher thermal resistivity and altered electrical properties compared to bulk material. Most preparation techniques for such structures, like etching or VLS growth, are limited by a small window of usable materials or process conditions. With Glancing Angle Deposition (GLAD) it is possible to produce nanostructures from a wide range of materials and with highly customizable shapes, such as slanted and vertical wires, spirals or zig-zag

Monday
structures. In this technique a highly oblique incidence of deposited material causes small obstacles to cast shadows during the high vacuum deposition, so that areas behind them do not receive material. This leads to the growth of a highly porous thin film. The shape of the individual structures can be influenced by a controlled substrate rotation. We present silicon germanium GLAD heterostructures with different shapes, a varying germanium distribution and adjustable doping. We also show some approaches to prepare electrical contacts to nanostucture arrays for device integration.

A Rubinov [1], we study the conversion efficiency of thermoelectric materials characterized by the dimensionless figure of merit \( zT = \frac{\sigma T}{\kappa} \). Hence, to gain large \( zT \) values, it is mandatory to have a high electrical conductivity \( \sigma \), a large Seebeck coefficient \( \alpha \) and a low thermal conductivity \( \kappa \). Several configurations have been proposed to this end. First, the pillars is ballistic in a temperature range at least up to 150 K and the 3-omega method we verified that the thermal transport through the gap, thermal transport through the pillars can be studied. Using nanostructure arrays for device integration.

We fabricate GaAs nanopillars with typical lengths between 4-8 nm and diameters of about 100 nm using molecular beam epitaxy [1]. The pillars are linked to a GaAs substrate on one end and to a GaAs layer of variable thickness at the other end. The epitaxial growth of the pillars is ballistic in a temperature range at least up to 150 K and the 3-omega method we verified that the thermal transport through the gap, thermal transport through the pillars can be studied. Using nanostructure arrays for device integration.

Transport through nano sized pillars [2]. A Rubinov [1], we study the conversion efficiency of thermoelectric materials characterized by the dimensionless figure of merit \( zT = \frac{\sigma T}{\kappa} \). Hence, to gain large \( zT \) values, it is mandatory to have a high electrical conductivity \( \sigma \), a large Seebeck coefficient \( \alpha \) and a low thermal conductivity \( \kappa \). Several configurations have been proposed to this end. First, the pillars is ballistic in a temperature range at least up to 150 K and the 3-omega method we verified that the thermal transport through the gap, thermal transport through the pillars can be studied. Using nanostructure arrays for device integration.

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Thermoelectric power factor and full ZT characterization of Bi2Te3-nanowires [3] were investigated using a TCNP (Thermoelectric characterization platform) which allows the determination of the Seebeck coefficient \( S \), the conductivity \( \sigma \) and the thermal conductivity. The NW is deposited between 2 thin Au and few Si-cantilevers. On each cantilever, 2 Pt-electrodes are arranged serving as microheater and thermometer. The calibration of the TCNP is discussed. In the temperature range 4.2K \( < T < 300K \), the conductivity and the thermopower were measured. The function \( \sigma(T) \) corresponds to a rather metallic behaviour. The thermopower exhibits a maximum near 200 K. For a conductivity of nearly 1000S/cm the thermopower \( S(300K) \) varied between -35 \( \mu \)V/K and -70 \( \mu \)V/K. Experiments to determine the thermal conductivity are discussed.

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Weekend temperature dependence of thermal boundary conductance for epitaxial Bi(111) films on Si(001) [4]. We investigated the thermoelectric properties of BiSb thin films in the thickness range between 50 nm and 500 nm. For the determination of the thermoelectric properties we measured the Seebeck-coefficient and the thermal and electrical conductivity to obtain the figure of merit for these films. We deposited between 2 thin Au and few Si-cantilevers. On each cantilever, 2 Pt-electrodes are arranged serving as microheater and thermometer. The calibration of the TCNP is discussed. In the temperature range 4.2K \( < T < 300K \), the conductivity and the thermopower were measured. The function \( \sigma(T) \) corresponds to a rather metallic behaviour. The thermopower exhibits a maximum near 200 K. For a conductivity of nearly 1000S/cm the thermopower \( S(300K) \) varied between -35 \( \mu \)V/K and -70 \( \mu \)V/K. Experiments to determine the thermal conductivity are discussed.

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terms were recorded. The transient drop of spot intensity is explained in terms of the Debye-Waller effect and reflects the instant heating and subsequent cooling of the Bi films. The thermal boundary conductance of the interface is then determined from the exponential cooling of the film. We show that the thermal boundary conductance increases by more than 35% if the substrate temperature is increased from 80 K to 300 K. This is not explained by numerical simulations of the heat transport using temperature dependent parameters. For the 120 nm thick Bi-film a bi-exponential intensity is observed and explained by diffusion in the film and across the interface.

**HL 27.20 Mon 17:00 Poster B1**

**Structural and electrical properties of thermoelectric Fe$_{x}$Co$_{1-x}$Sb$_{3}$ thin films** — **AYHAM DALLA, MARCUS DANIEL, ANDREAS LIEBHIC, FABIAN GANS, GUNTER BODES, AND MANFRED ALBRECHT** — Chemnitz University of Technology, Institute of Physics

Increasing interest in efficiency enhancement of existing energy sources led to an extended research in the field of thermoelectricity. A suitable thermoelectric material like CoSb$_3$ is characterized by a high power factor and a low thermal conductivity. To control and improve the power factor a targeted electrical doping is necessary to achieve charge carrier densities up to 10$^{20}$ cm$^{-3}$. In case of CoSb$_3$ controlled doping can be obtained by a partial substitution of Co by Fe atoms. In this study, 30 nm thick Fe$_{x}$Co$_{1-x}$Sb$_{3}$ films have been deposited via MBE onto thermally oxidized Si(100) substrates at room temperature. The samples were post-annealed in ultra-high vacuum for one hour at 450°C. Two sample series with varying Fe content (0 < x < 0.5) were fabricated, a Sb rich (x = 3.3) and a Sb deficient series (x = 2.5). The composition was verified by RBS and the XRD analysis confirmed CoSb$_3$ as major phase. A systematic decrease of the extracted lattice parameter with increasing Fe content indicated the substitution of Co by Fe atoms. The electrical characterization was performed in a temperature range between 4 K and 300 K. Both series show an increase in charge carrier concentration with increasing Fe content, and thus a decrease in resistivity. The temperature dependence of the resistivity revealed for both sample series a change from semiconducting to metallic behaviour at a critical charge carrier concentration.

**HL 27.21 Mon 17:00 Poster B1**

**Measurement setup for simultaneous determination of electrical conductivity, Hall coefficient and Seebeck coefficient.** — **KOLLE, J. DEKKER, D. HARDE*, T. DASSAGUTHA, T. PURNASKI, AND E. MÜLLER** — DLR, Institute of Materials Research, Cologne

Thermoelectric materials can convert heat directly into usable electrical energy. An important aim in thermoelectric research is to find and optimize suitable materials and improve their performance to get higher efficiency. For a complete characterization it is in general required to do several different measurements in different apparatus which can be challenging and time consuming. Therefore we developed a measurement system that can measure three of the thermoelectric key quantities (electrical conductivity, Seebeck- and Hall coefficient) simultaneously from room temperature up to 1000K, which is a typical temperature region for many potential applications of these materials. All three quantities are coupled via the charge carrier concentration and therefore a simultaneous measurement is important for a deep insight in the charge carrier transport in the sample. This is particularly important for thermally instable materials, where consecutive measurements can easily lead to misinterpretations. Four sheathed thermocouples arranged in a van der Paw geometry are pressed by small springs on a round sample for electrical contact. This special arrangement allows for the electrical measurements, while the thermocouples allow for a determination of the Seebeck coefficient if an additional temperature gradient is applied. We will discuss technical details, features and limitations of the setup.

**HL 27.22 Mon 17:00 Poster B1**

**Anomalous enhancement of the thermoelectric figure of merit by V co-doping in SrTiO$_3$** — **UDO SCHWINGENSCHÖGL AND MOESUMI UPADHYAY-KHALILY** — KAUST, PSE Division, Thuwal, Saudi Arabia

The effect of V co-doping in Nb-SrTiO$_3$ and Pr-SrTiO$_3$ is studied by full-potential density functional theory. While in Nb-SrTiO$_3$ a high carrier density counteracts a high thermoelectric figure of merit, the trend is inverted by V co-doping. A similar but even more pronounced effect is found in Pr-SrTiO$_3$. The mechanism leading to this behavior is explained in terms of a local spin-polarization introduced by the V ions. Our results indicate that magnetic co-doping can be a prominent tool for improving the thermoelectric figure of merit.


**HL 27.23 Mon 17:00 Poster B1**

**The effect of interfaces on the thermoelectric properties of laterally microstructrued ZnO-based thin-films** — **DAVID HARTUNG, FLORIAN GATHER, ACHIM KRONENBERGER, MARTIN EICKHOPF, BRUNO K. MEYER, AND PETER J. KRAR** — I. Physikalisches Institut, Justus-Liebig-University, Heinrich-Buff-Ring 16, 35392 Giessen

A series of samples was laterally microstructured with a self-aligned pattern transfer method consisting of alternating stripes of ZnO grown by molecular-beam epitaxy and radio-frequency sputtered Ga-doped ZnO stripes. The MBE-grown ZnO thin film samples were laterally microstructured by photolithography followed by ion-beam etching in order to obtain different lateral arrangements of stripes of defined interface geometry. In a second step the free regions between the stripes of MBE-grown ZnO were sputtered with Ga-doped ZnO. A lift-off step completes the micro-fabrication of a planar alternating ZnO/ZnO:Ga bar structure on each sample. Throughout the series the bar width and hence the number of interfaces was kept constant, but the interface profile was varied yielding different interface lengths and geometries. We measured in-plane as a function of temperature the Seebeck coefficient $S$ and the electrical conductivity $\sigma$ of the samples with the transport direction perpendicular to the stripe direction. The measured data were compared to simulated data using an empirical network model.

**HL 27.24 Mon 17:00 Poster B1**

**Thermoelectric properties of ZnO$_{1-x}$S$_x$ thin films** — **FLORIAN GATHER, ACHIM KRONENBERGER, PETER J. KRAR, AND BRUNO K. MEYER** — I. Physikalisches Institut, Justus-Liebig-University, Heinrich-Buff-Ring 16, 35392 Giessen

We investigated the thermoelectric properties of rf-sputtered ZnO$_{1-x}$S$_x$ thin films on sapphire substrates. Due to its good availability and its non-toxicity, ZnO is a promising candidate for thermoelectric applications. The electric conductivity $\sigma$, the Seebeck coefficient $S$, and carrier concentrations of a series of hydrogen doped samples and aluminum doped samples respectively were determined in in-plane direction over a wide temperature range. For the investigation of the influence of the sulphur concentration $x$ on the thermal conductivity $\kappa$ we employed the 3-omega method on a series of undoped thin-films. The measurements reveal a reduced $\kappa$ in cross-plane direction of the samples containing sulphur compared to zinc-oxide samples. Using Raman spectroscopy we found indications for local phonon modes of oxygen in zinc-sulfide and of sulphur in zinc-oxide, respectively. These local phonon modes cause the reduction of $\kappa$ observed in the experiments. Both sample series are compared in terms of crystal quality and grain size using XRD-analysis and atomic force microscopy.