HL 36: Focus Session: Functionalized semiconductor nanowires I (DS, jointly with HL)

Nanowires are filamentary crystals with a diameter ranging from few to hundred nanometers. Thanks to their special morphology and geometry, they are at the base of many applications that can revolutionize this century's technology. For this to become a reality, fundamental studies on the growth and properties are essential. This focus session presents the latest developments and discoveries in the area of nanowires, with a special focus on semiconductor materials. (Organizers: Margit Zacharias, U. Freiburg; Tobias Voss, U. Bremen; Anna Fontcuberta i Morral, EPFL)

Time: Tuesday 9:30–12:45 Location: H8

Invited Talk HL 36.1 Tue 9:30 H8

Nanowire photovoltaics with absorption beyond the ray optics limit. — •Magnus T Borgström — Solid state physics, Lund University, Lund, Sweden

Semiconducting nanowires have been recognized as promising materials for high-performance electronics and optics where optical and electrical properties can be tuned individually. The feasibility of III-V nanowire integration with existing silicon processing technology due to the small footprint between the silicon substrate and the nanowire material has further sparked that interest. For NWs to provide the new architecture for next generation photovoltaics there is a strong need to take complete control over synthesis. By optimizing growth conditions with respect to tapering we created nanowire-InP nanowire based solar cells using Au seed particles for growth. The nanowires were processed as-grown with a transparent top contact to create 1x1 square mm devices, with about 4 million nanowires contacted on each device. The solar cells were investigated under 1 sun (AM 1.5) illumination, and the devices show efficiencies higher than 10% and conversion of the solar irradiation into photocurrent beyond the ray optics limit.

Invited Talk HL 36.2 Tue 10:00 H8

Crystal structure control in nanowires — •Erik Bakkers — Eindhoven University of Technology, Den Dolech 2, 5612 AZ Eindhoven, The Netherlands — Delft University of Technology, Lorentzweg 1, 2600 CL Delft, The Netherlands

Important semiconductors like Si, Ge and GaP have an indirect bandgap when having the (normal) cubic crystal structure. It has been predicted that when these materials crystallize in a hexagonal structure that they can have a direct bandgap. But, these materials have never been controllably made with the pure wurtzite structure. Nanowires can be grown in other crystal structures than known in the bulk, offering new routes to tailor the optical and electronic properties. The nanowire growth mechanism will be discussed and the fabrication of the pure hexagonal form will be investigated. Here, we exploit these possibilities and discuss control of the crystal structure of nanowires and investigate the optical properties. Finally, we demonstrate the direct nature of the bandgap of wurtzite materials.

Topical Talk HL 36.3 Tue 10:30 H8

Spectral and spatial overlap of oxide quantum wells and whispering gallery modes — •Marius Grundmann — Universität Leipzig, Insitut für Experimentelle Physik II

We present the fabrication of zinc oxide nano- and microwires and the epitaxial growth of oxide heterostructures and quantum wells around the zinc oxide cores in radial direction. (Mg,Zn)O/ZnO and (Cd,Zn)O/ZnO QWs are compared and found to not exhibit quantum confined Stark effect, as expected for the non-polar growth directions. Due to the hexagonal cross-section, the ZnO wires exhibit whispering gallery resonances. The spectral and spatial overlap of the quantum wells with the whispering gallery modes is achieved in various geometries. The coupling of exciton and photon modes will be discussed.
This work was conducted together with C.P. Dietrich, M. Lange, T. Böntgen and M. Stölzel and financially supported by DFG in the framework of FOR1616 and by ESF.

Coffee break (15 min)

Topical Talk HL 36.4 Tue 11:15 H8

Semiconducting Nanowire Heterostructures on Silicon - From Growth to Devices — Heinz Schmid, Kirsten Moselund, Cedric Bessire, Pratyush Das Kanungo, Philipp Mensch, Siegfried Karg, Mattias Borg, Volker Schmidt, and •Heike Riel — IBM Research - Zurich, Rüschlikon, Schweiz

Bottom-up grown nanowires (NWs) are very attractive materials for direct integration of III-V semiconductors on Si thus opening up new possibilities for the fabrication and design of electronic and optoelectronic devices. The NW geometry allows the growth of abrupt heterostructures with large lattice mismatch and offers an ideal geometry for field-effect transistors (FETs) from an electrostatics perspective. These characteristics are especially important for tunnel FETs (TFETs) which today are being considered the most promising steep-slope devices. TFETs can achieve a subthreshold swing of less than 60 mV/dec and are thus attractive for low-voltage operation thereby offering significant power dissipation savings. We present our results on the fabrication and characterization of vertical InAs-Si heterojunction nanowire (NW) Esaki tunnel diodes and TFETs with InAs as low bandgap source. InAs NWs are grown on Si <111> by selective area epitaxy within e-beam patterned SiOx openings by MOCVD where the doping level is controlled in-situ. Furthermore, a new approach based on nanotube templates has been developed to grow axial III/V nanowire homo- and hetero-structures on silicon with high quality. The device fabrication will be discussed and the latest electrical results of tunnel diodes and TFETs will be presented.

Topical Talk HL 36.5 Tue 11:45 H8

III-nitride nanowires: From growth phenomena to light-emitting diodes — •Raffaella Calarco — Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin, Germany

Epitaxy in the form of freestanding vertical nanowires offers compared to planar layers the advantage that the interface between adsorbate and substrate is very small and that strain caused by lattice mismatch can elastically relax at the free sidewalls. Hence, dissimilar materials can be combined in high structural quality, and arguably the most relevant case is the growth of III-V compound semiconductors on Si substrates. We grow GaN nanowires on Si substrates by molecular beam epitaxy (MBE) and investigate nanowire properties that are essential for optoelectronic applications. Light emitting diodes (LEDs) have been fabricated using ensembles of free-standing (In, Ga)N/GaN NWs grown on Si substrates in the self-induced growth. Several characterization techniques indicate that the electroluminescence of such LEDs is governed by the differences in the individual current densities of the single-NW LEDs operated in parallel, i.e. by the inhomogeneity of the current path in the ensemble LED. In addition, the optoelectronic characterization leads to the conclusion that these NWs exhibit N-polarity and that the (In, Ga)N quantum well states in the NWs are subject to a non-vanishing quantum confined Stark effect. LEDs require NW ensembles with very homogeneous properties. Here, we present our selective area growth strategy for the synthesis of high-quality GaN NWs on prepatterned Si(111) substrates.

Topical Talk HL 36.6 Tue 12:15 H8

3D GaN nanorods: fabrication, properties, applications — •Andreas Waag, Johannes Ledig, Xue Wang, Milena Erenburg, Jana Hartmann, Lorenzo Caccamo, Matin Mohajerani, Manal Ali Deeb, Jiandong Wei, Martin Hoffmann, Hao Shen, and Hergo-Heinrich Wehmann — TU Braunschweig

GaN nanorods and 3D columns recently attracted a lot of attention since they are expected to be an exciting new route towards light engines for solid state lighting. In contrast to a planar thin film technology, a completely 3-dimensional nano- or microrod approach gives more freedom in the device design. E.g., a core-shell design of LEDs based on 3D GaN offer a dramatically enhanced active area per wafer footprint, since the active area is scaling with height of the 3D structures. High quality core-shell devices will have a tremendous impact on LED technology. However, there are also challenges related to a 3D device approach. Conventional planar characterization as well as processing techniques can no longer be used. In addition, the growth windows in epitaxy have to be modified in order to enhance vertical growth rates and reduce planar growth rates. Quite often, this leads to growth modes, which are far away from the ones regularly used for high efficiency planar LEDs. This talk will give an overview on the state of the art of our 3D GaN research, particularly focusing on MOCVD growth and 3D characterization. Potential advantages and challenges of this exciting new strategy towards low cost high efficiency solid state lighting will also be discussed.