# O 52: Nanostructures at surfaces: Wires, tubes

Time: Wednesday 15:00–17:15 Location: WIL B122

O 52.1 Wed 15:00 WIL B122

**Surface and Interface Characterization of III-V Semiconductor Nanowires** — •Rainer Timm, Martin Hjort, Edvin Lundgren, Lars Samuelson, and Anders Mikkelsen — The Nanometer Structure Consortium, Dept. of Physics, Lund University, Sweden

III-V Semiconductor Nanowires have attained strong interest due to their unique properties and tremendous possibilities for device application. They are characterized by an extreme surface-to-volume ratio, so that their surface properties or interface properties in core-shell nanowire heterostructures are crucial for the entire device behavior.

Recently, we have obtained first atomically resolved images of different InAs nanowire surfaces using scanning tunneling microscopy (STM) [1]. Here, we combine STM and scanning tunneling spectroscopy (STS) measurements to directly link local structural and electronic properties of InAs and InP nanowire heterostructures.

A promising application of InAs nanowires are high-speed metal-oxide-semiconductor (MOS) devices [2]. The exact chemical composition of the nanowire-oxide interface is crucial for the MOS device performance. We have therefore studied the reduction of the native oxide on InAs upon deposition of high-k dielectric thin films and the resulting interface properties using X-ray photoemission spectroscopy for planar InAs substrates [3] as well as for InAs nanowires. A clear reduction of various oxide states is observed, also depending on nanowire crystal structure and InAs surface orientation.

[1] E. Hilner *et al.*, Nano Lett. **8**, 3978 (2008). [2] S. Roddaro *et al.*, APL **92**, 253509 (2008). [3] R. Timm *et al.*, APL **97**, 132904 (2010).

O 52.2 Wed 15:15 WIL B122

**Photochemical tuning of the conductivity of DNA-platinum cluster chains** — •Christiane Schuster[1], Thomas Härtling[2], Lukas Eng[3], and Michael Mertig[1] — [1]Technische Universität Dresden, Professur für Physikalische Chemie, Mess- und Sensortechnik, 01062 Dresden — [2]Fraunhofer Institute for Non-Destructive Testing, 01109 Dresden — [3]Institut für Angewandte Photophysik, Technische Universität Dresden, 01062 Dresden

We present a self-assembly based method for the fabrication of conductive DNA-based nanowires. By means of chemical functionalization, DNA molecules were engineered into the gaps of $3-5\,\mu$m wide Au finger electrode arrays. Photo-induced metal deposition was then applied to grow about 5 nm Pt clusters along the molecules. At this stage, the resulting discontinuous cluster chains showed no electrical conductivity. Hence, we "welded" the Pt clusters by further photo-induced deposition of gold into the interparticle gaps and finally obtained continuous, electrically conducting nanowires. The photochemical reduction of gold takes place from a $HAuCl_4$ solution and is catalyzed by the platinum clusters. Exploiting this catalytic activity, we obtain high spatial selectivity of the photo-induced deposition process far below the diffraction limit. Experiments were carried out on an inverted microscope, using a laser for inducing the reduction reaction, and a white-light illumination for monitoring the deposition process. The wires were analyzed by atomic force microscopy and conductivity measurements which proofed the high spatial selectivity of the method as well as the electrical quality of the wires.

O 52.3 Wed 15:30 WIL B122

**One-dimensional Mn atom chains templated on a Si(001) surface** — •Sigrun A. Köster[1], James H. G. Owen[1], François Bianco[1], Alex M. P. Sena[2], David R. Bowler[2], and Christoph Renner[1] — [1]University of Geneva, Switzerland — [2]University College London/London Centre of Nanotchnology, UK

Single-atom chains on a wide gap substrate are a very attractive embodiment of a truly one-dimensional system to explore the remarkable physical properties emerging in such low dimensions. We present self-assembled single-atom Mn chains on a Si(001) surface with Bi nanolines, which serve to increase greatly the average length of the Mn chains. They grow perpendicular to the Si(001) dimer rows, at densities which can be adjusted by means of the growth parameter. High resolution scanning tunneling microscopy (STM) micrographs are in perfect agreement with density functional theory (DFT), providing detailed insight into the chain structure. We further discuss low temperature STM spectroscopy and spin dependent DFT modeling suggesting Mn-chains are indeed a suitable candidate to observe electronic and magnetic properties in one-dimension experimentally.

O 52.4 Wed 15:45 WIL B122

**The In/Si(111)-(4×1)/(8×2) surface – A fascinating model system for 1D conductors** — •Stefan Wippermann, Simone Sanna, and Wolf Gero Schmidt — Lehrstuhl für Theoretische Physik, Universität Paderborn, D-33095 Paderborn

One-dimensional (1D) electronic systems are currently intensively investigated for both fundamental and technological reasons. The ordered array of In nanowires that self-assembles at the Si(111) surface is an extremely popular model system for such 1D electronic systems. It shows an intriguing temperature-induced metal-insulator (MI) transition below 120K from (4×1) to (8×2) translational symmetry. The low-temperature (LT) ground state of the nanowires as well as the driving force and mechanism of the phase transition remain controversial, however.

Here we present an overview of recent *ab initio* optical response and free-energy calculations [1] that allow for the unambiguous determination of the ground-state geometry. Soft shear and rotary phonon modes are shown to describe the structural transformation between the LT and the room-temperature (RT) geometry. The MI transition is explained as a triple-band Peierls instability. The phase transition is caused by the subtle interplay between the lower total energy of the insulating (8×2) ground state and the larger vibrational and electronic entropy of the less tightly bound and metallic RT (4×1) phase.

[1] S Wippermann *et al.* PRL **98**, 026105 (2007) + PRL **100**, 106802 (2008) + PRL **102**, 226805 (2009) + PRL **105**, 126102 (2010)

O 52.5 Wed 16:00 WIL B122

**Comparative Study of the Growth of Nonacosan-10-ol Wax Tubules of Lotus (Nelumbo nucifera) Leaves on Gold (111) and HOPG Surface** — •Sujit Kumar Dora and Klaus Wandelt — Institute for Physical and Theoretical Chemistry, University of Bonn, Wegelerstr. 12, D-53115, Bonn, Germany

A comparative study of self-assembly of nonacosan-10-ol tubules derived from lotus (Nelumbo nucifera) leaves on gold (111) and HOPG surface is presented. Even though the average time period of tubule formation is ≈ 2-3 hours, however, the orientation of tubules differed on both substrates. On HOPG, a vertical orientation of tubules was found whereas on gold (111) tubules are arranged in a horizontal fashion with respect to the surface. Taking into account the surface properties of HOPG and gold (111) where both are nonpolar, crystalline as well as hydrophobic, the different orientation of tubules on these surfaces clearly indicated that none of the surface properties are responsible for the tubule orientation. This also provokes another question whether HOPG is a good material to mimic natural surfaces.

O 52.6 Wed 16:15 WIL B122

**Growth behaviour of Ge nanowires grown homoepitaxially by means of MBE** — •Jan Schmidtbauer, Roman Bansen, Torsten Boeck, and Thomas Teubner — Leibniz Institute for Crystal Growth, 12489 Berlin, Germany

Germanium has gained renewed interest within recent years for aggressively scaled Si CMOS as well as Si photonics technologies. The reasons are given by the facts that: (*i*) Ge is compatible with Si process technology, (*ii*) it has higher hole concentration and mobility compared to many III-V semiconductor materials and (*iii*) its band gap value matches the wavelength of typical telecommunication infrastructure. With respect to the later application we investigated germanium nanowires as promising structures for low-band-gap photonics devices compatible with Si CMOS process technologies.

We studied the influence of different types of Ge substrates on growth direction, growth rate and shape of MBE grown Ge nanowires. In particular, homoepitaxial growth of the nanowires was compared using (100), (110) and (111) oriented germanium substrates. In all cases, the experiments revealed preferential growth in ⟨110⟩ direction. A clear dependency of the growth rate on the inclination of nanowires towards the surface normal was shown. This growth behaviour is explained by different amounts of material that contribute to nanowire growth through direct impingement on the sidewalls of the nanowire. To understand the nature of the preferential growth in ⟨110⟩ direc-

tion TEM studies are presented. Furthermore, a model is proposed to explain this behaviour.

O 52.7 Wed 16:30 WIL B122

**Template-Fabrication of Highly Ordered MnO2 One-Dimensional Nanostructure Arrays and their Device Applications as Super-Capacitors** — •Fabian Grote[1,2], Jingjing Xu[1,2], Huaping Zhao[1,2], and Yong Lei[1,2] — [1]Institute of Materials Physics, University of Muenster — [2]Center for Nanotechnology, Muenster 48149, Germany

MnO2 is a promising candidate for future applications in super-capacitors, especially for nano-structured MnO2 that might result in a high specific capacitance of the super-capacitor. Moreover, it is highly desirable to prepare highly ordered arrays of MnO2 nanostructures so that the properties (e.g., electrochemical property) can be controlled. Recently, using anodic alumina membranes as templates, we fabricated regular arrays of MnO2 one-dimensional nanostructures, including nanotubes and nanowires. The morphology and microstructures of the synthesized nanostructures were characterized by scanning electron microscopy and transmission electron microscopy. Electrochemical properties of the highly ordered MnO2 nanostructure arrays were investigated for super-capacitor application.

O 52.8 Wed 16:45 WIL B122

**Tin dioxide nanowire gas sensor for detection of the toxic gases CO, H2S and SO2** — •Elise Brunet[1], Christian Griessler[1], Giorgio Mutinati[1], Stephan Steinhauer[1], Anton Koeck[1], Christian Edtmaier[2], and Wolf-Dieter Schubert[2] — [1]AIT Austrian Institute of Technology GmbH, Health & Environment Department, Nano Systems, Vienna, Austria — [2]Institute of Chemical Technologies and Analytics, Vienna University of Technology, Vienna, Austria

Metal oxide-based gas sensors rely on changes of electrical conductance due to interactions between the surrounding gas and the sensing layer. This sensing layer is most commonly a polycrystalline tin dioxide (SnO2) thin film. However, single crystalline SnO2 nanowires have higher chemical resistance and thermal stability and are therefore of great interest for highly sensitive gas detecting devices. We present nanosensors based on single crystalline SnO2 nanowires, which are very sensitive to the highly toxic gases CO, H2S and SO2. A SnO2 thin film is deposited by spray pyrolysis on a SiO2/Si substrate and further tempered 1h at 900°C in Ar-atmosphere resulting in the growth of single crystalline SnO2 nanowires. The sensing performance of the nanowire sensor is presented. Exposure to 260ppm CO leads to a sensitivity of 1.5% at 300°C. In presence of 1,5ppm H2S the highest sensitivity of 25% is obtained at 250°C and the sensor response to 27ppm SO2 reaches a sensitivity of 8% at 400°C. The specific responses achieved from the nanowire sensor at different temperatures are crucial for a selective detection of the toxic gases CO, H2S and SO2.

O 52.9 Wed 17:00 WIL B122

**Synthesis, characterization and gas sensing applications of CuO nanowires** — •Stephan Steinhauer[1], Elise Brunet[1], Christian Griessler[1], Marcus Milnera[1], Giorgio Mutinati[1], Anton Köck[1], Christian Edtmaier[2], Wolf-Dieter Schubert[2], Christian Gspan[3], and Gerald Kothleitner[3] — [1]Health & Environment Department, Nano Systems, AIT Austrian Institute of Technology GmbH, Vienna, Austria — [2]Institute of Chemical Technologies and Analytics, Vienna University of Technology, Vienna, Austria — [3]Institute for Electron Microscopy and Fine Structure Research, Graz University of Technology, and Centre for Electron Microscopy Graz, Graz, Austria

A powerful strategy to improve sensor performance of metal oxide based gas sensors is the implementation of single-crystalline nanowires as sensing elements due to the high surface to volume ratio. Thermal oxidation is a convenient solution for growth of single-crystalline cupric oxide (CuO) nanowires with high aspect ratios. SEM and TEM analysis showed different growth characteristics when varying the oxidation temperature, the oxygen concentration, the relative humidity and the substrate. Single-crystalline CuO nanowires with lengths between 0.5 micrometer and 40 micrometer and diameters from 20 nanometer to 120 nanometer have been fabricated. In particular, high-aspect ratio CuO nanowires have been employed as gas sensing elements and their sensitivity to carbon monoxide and hydrogen sulfide has been successfully demonstrated. For hydrogen sulfide, the nanowire gas sensor is even able to detect a concentration as low as 1 ppm.