O 12: Nanostructures at Surfaces II (Wires, Tubes)

Time: Monday 14:15–17:30 Location: H36

O 12.1 Mon 14:15 H36

Spin-Split Bands in a One-Dimensional Chain Structure — •Ingo Barke, Fan Zheng, Tilman Rügheimer, and Franz Himpsel — Dept. of Physics, University of Wisconsin Madison, 1150 University Ave, Madison, WI 53706, USA

Gold atom chains on vicinal Si(111) surfaces exhibit an unusual doublet of one-dimensional half-filled bands, whose origin has remained uncertain. The splitting is identified by angle-resolved photoemission as a spin splitting induced by the spin-orbit interaction (Rashba effect), in agreement with a theoretical prediction by Sánchez-Portal et al. [1]. This interaction leads to a characteristic pattern of avoided band crossings at a superlattice zone boundary [2]. Two out of four crossings are avoided, with a mini-gap $E_G = 85$ meV and a k-offset of 0.05 Å^{-1}. The finding solves a long-standing puzzle about the origin of split bands observed in a whole class of atomic chains and is essential for the analysis of their fractional electron count.

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[1] D. Sánchez-Portal, S. Riikonen, and R. M. Martin, Phys. Rev. Lett. 93, 146803 (2004).

[2] I. Barke, Fan Zheng, T. K. Rügheimer, and F. J. Himpsel, Phys. Rev. Lett. 97, 226405 (2006).

O 12.2 Mon 14:30 H36

Switching between 1d and 2d by complete and incomplete Fermi nesting in Pb chains grown on Si(557) — •C. Tegenkamp[1], H. Pfnür[1], T. Ohta[2], J.L. McChesney[2], E. Rotenberg[2], and K. Horn[3] — [1]Institut für Festkörperphysik, Leibniz-Universität Hannover, 30167 Hannover, Germany — [2]ALS, Lawrence Berkley National Laboratory, Berkley, CA. 94720, USA — [3]FHI der Max-Planck Gesellschaft, 14195 Berlin, Germany

As shown recently by STM and LEED, the adsorption of 1ML Pb at low temperatures on Si(557) followed by annealing to 640K leads to the formation of Pb-chains with an interachain spacing of d=1.5nm. The closely packed Pb film on the micro-Si(111) facets forms locally a $\sqrt{3} \times \sqrt{3}$ structure, which shows in addition a 10-fold periodicity along the $[1\bar{1}0]$ direction. Conductivity measurements below 78K have shown that electronic transport occurs only along the chain direction, whereas insulating behavior is found in the perpendicular direction. Above 78K, the sytsem switches into a 2d-regime, i.e. activated transport is found in both directions. Using angle resolved photoemission (ARPES), we explored the origins of the quasi one-dimensional (1d) conductance found below 78K. The interchain distance is reflected directly by Umklapp structures in the $[11\overline{2}]$ direction close to E_F. As ARPES reveals further, ordering into the chain structure below 78K results in complete Fermi nesting in the $[11\overline{2}]$ direction and in energy reduction by band filling. The domain structure along the chains forms split-off valence bands with mesoscopic λ_F, responsible for the 1d conductance without further instabilities at low temperatures.

O 12.3 Mon 14:45 H36

Optical anisotropy of buried metallic nanowires — •Karsten Fleischer, Julie Jacob, Sandhya Chandola, and John F McGilp — Trinity College Dublin, School of Physics, Dublin 2, Ireland

Arrays of metallic nanowires frequently show strong optical anisotropies in the infrared due to conductance differences along and perpendicular to the main wire axis. We utilize reflectance anisotropy spectroscopy (RAS) and second harmonic generation (SHG) to investigate Ag nanowires on vicinal Si(111) surfaces and the influence of the offcut angle on the properties of the Ag wires. In a second step the Ag structures are capped with amorphous Si in order to investigate the conductivity of buried nanowires which are stable under ambient conditions.

O 12.4 Mon 15:00 H36

Screening of electric field by a two-dimensional surface nanostructure — •Josef Mysliveček, Anna Stróżecka, Neelima Paul, and Bert Voigtländer — Institut für Bio- und Nanosysteme (IBN 3), and Center of Nanoelectronic Systems for Information Technology (CNI), Forschungszentrum Jülich, 52425 Jülich, Germany

A monolayer of Ge embedded in Bi-terminated Si(111) surface can form two-dimensional surface nanostructures like nanowires and nanorings [1]. We study the electronic properties of these nanostructures by scanning tunneling spectroscopy. Both the Bi-terminated Si(111) surface and the Ge areas feature a surface bandgap. On the Ge areas, however, the bandgap is smaller due to an electron state localized in the Ge-Si interface at an energy above the bulk valence band maximum [2]. We show that the electric field of the STM tip can depopulate this electron state creating a positive surface charge layer located on the Ge areas. Thus, the Ge areas screen the external electric field more efectively than the clean Bi-terminated Si(111) surface. This can be used e.g. to locally prevent the field-induced inversion of carriers in the subsurface region and to influence the surface conductivity on the nanoscale.

[1] M. Kawamura, N. Paul, V. Cherepanov, B. Voigtländer, *Phys. Rev. Lett.* **91**, 096102, 2003.

[2] R.H. Miwa, T.M. Schmidt, P. Venezuela, *Phys. Rev. B* **72**, 125403, 2005.

O 12.5 Mon 15:15 H36

Pt Nanowires on Ge(001): A Real- and K-Space Investigation — •Marc Wisniewski, Jörg Schäfer, Florian Sandrock, and Ralph Claessen — Universität, Würzburg, Germany

Electron confinement to one dimension is expected to reveal new phenomena due to the reduced electronic degrees of freedom. The possibility of charge density waves or a potential collapse of the Fermi liquid picture are key scenarios associated with such conditions. A highly one-dimensional model system is thus most desirable. In this respect, a number of quasi-one-dimensional metallic reconstructions on semiconductors, so-called nanowires, have been identified in the last years. A little explored class of noble metal nanowires are formed by self-organized platinum chains on the Ge(001) surface. These wires have a diameter of only one atom on their top, thereby representing single-atom chains. For clarifying their real space structure, scanning tunneling microscopy was performed at very low voltages and currents. In fact, the nanowires can be imaged in the millivolt regime, suggestive of a metallic behavior. A dimerization is seen at high tunneling bias. The various dimers are indicative of building blocks in the embankment, rather than a charge density wave. To obtain further evidence on the electronic properties near the Fermi level, angle-resolved photoemission studies are currently underway. A report on the key features of the electronic strucutre will be presented.

O 12.6 Mon 15:30 H36

Surface enhancend infrared absorption (SEIRA) on single gold nanowires — •Frank Neubrech[1], Gerhard Fahsold[1], Thomas Cornelius[2], Shafqat Karim[2], Javier Aizpurua[3], Reinhard Neumann[2], and Annemarie Pucci[1] — [1]Kirchhoff-Institut für Physik, Universität Heidelberg — [2]Gesellschaft für Schwerionenforschung, Darmstadt — [3]Donostia International Physics Center, San Sebastian

We perform surface enhanced infrared (IR) absorption of adsorbates on single gold nanowires using synchrotron light at the ANKA beamline (Forschungszentrum Karlsruhe). The examined nanowires with diameter of about 100nm are prepared by electrochemical deposition in polymeric etched ion track membranes and transferred onto infrared-transparent substrates (e.g. ZnS, CaF2). Performing spectroscopic IR-microscopy we observed antenna-like plasmon resonances for a few micrometer long nanowires. For a demonstration of SEIRA on single gold nanowires we used an octadecanthiol (ODT) monolayer as adsorbate. For wires with resonances in the 3 μm range we observe significant absorption bands at 2850 cm^{-1} and 2919 cm^{-1}, corresponding to the CH stretching vibrations of ODT. In the case of gold wires with antenna resonance at much higher resonance wavelength CH stretching vibrations could not be observed. The appearance of the absorptions bands is interpreted as an indication of local field enhancement due to the presence of the nanowire.

O 12.7 Mon 15:45 H36

Template-guided formation of cobalt chains on Au(110) — •Martin Ziegler, Jörg Kröger, Nicolas Néel, Patrick Schmidt, and Richard Berndt — Institut für Experimentelle und Angewandte

Physik der Universität Kiel

We report on an ultra-high vacuum low temperature scanning tunnelling microscopy experiment which aimed at fabricating cobalt chains on a metal surface. To this end we employed the (1×2) reconstructed topmost layer of a Au(110) surface as a template to guide cobalt deposition. Scanning tunnelling microscopy reveals chain-like adsorbate assemblies which are oriented along the missing row direction of the surface reconstruction.

O 12.8 Mon 16:00 H36

Electronic properties of self-organized bi-atomic Fe chains on Ir(001) — •Matthias Menzel, André Kubetzka, Kirsten von Bergmann, Matthias Bode, and Roland Wiesendanger — Institut für Angewandte Physik, Universität Hamburg,

The clean Ir(001) surface layer rearranges in a quasi-hexagonal structure, thereby forming a (5×1) reconstruction. As previously shown by Hammer *et al.* [1], this Ir(001)-(5×1) surface is an ideal template for the self-organized formation of one-dimensional nanostructures, such as Fe chains, which may exhibit extraordinary electronic properties like endstates [2], i.e. the zero-dimensional analogon to surface states, or confinement states [3].

We have studied the structural and electronic properties of Fe/Ir(001) using scanning tunneling microscopy (STM) and spectroscopy (STS). At submonolayer coverage our growth studies confirm the results of Ref. [1]. In addition, we find a transition from anisotropic (≤ 2 ML) to isotropic growth (≥ 3 ML) at higher coverages. Low-temperature STS data obtained on bi-atomic Fe chains reveal the existance of pronounced endstates but give no evidence for confinement states.

[1] L. Hammer *et al.*, Phys. Rev. B, **67**, 125422 (2003)
[2] J. Crain *et al.*, Science, **307**, 703 (2005)
[3] S. Fölsch *et al.*, Phys. Rev. Lett., **92**, 056803 (2004)

O 12.9 Mon 16:15 H36

Tunable Quantum Wires: New Horizons in Plasmonics — •Dominic Zerulla[1], Stephanie Rehwald[2], Michael Berndt[1,2], Frank Katzenberg[3], Stephan Schwieger[4], Erich Runge[4], and Klaus Schierbaum[2] — [1]UCD Dublin, Physics, Dublin 4, Ireland — [2]Heinrich-Heine-Universität Düsseldorf, D-40225 Düsseldorf — [3]Universität Dortmund, FB Bio-und Chemieingenieurwesen, D-44227 Dortmund, — [4]Technische Universität Ilmenau, Theor. Physik I, D-98684 Ilmenau

Here we report on the excitation of surface plasmon polaritons (SPP's) on a periodical arrangement of quantum wires with tunable periodicity. The ability to vary its two-dimensional lattice constant results in an additional degree of freedom, permitting excitation of SPP's for any combination of wavelength and angle of incidence within the tuning range of the system. Moreover it allows crucial questions on a fundamental level to be answered by shedding light on the characteristic localization properties of SPP's. Planar waveguides and photonic crystal structures are being intensively investigated as primary solutions for integrated photonic devices. However, there is an alternative approach to the manufacturing of highly integrated optical devices with structural elements smaller than the wavelength, which nevertheless enables strong guidance and manipulation of light - the use of metallodielectric nanostructures in conjunction with SPP's. This approach is now branded as "the next big step" in nanotechnology. Our novel design opens new vistas in the development of novel methodologies in spectroscopy including plasmonic sensors and chips.

O 12.10 Mon 16:30 H36

A Route to Generate Clean Nanostructures with Arbitrary Shapes on Silicon by Electron-Beam Induced Deposition (EBID) — •Michael Schirmer, Thomas Lukasczyk, Hubertus Marbach, and Hans-Peter Steinrück — Lehrstuhl für Physikalische Chemie II, Universität Erlangen-Nürnberg, Egerlandstraße 3, D-91058 Erlangen, Germany

EBID is a technique with a high potential for the fabrication of nanostructures on different surfaces. By utilizing a highly focussed electron beam, precursor molecules are locally cracked, resulting in the deposition of the non-volatile molecule fragments. A lithography package enables the fabrication of spatially well defined ultra-small deposit structures of arbitrary shapes. The distinct approach of this paper is to use a high resolution UHV electron column (resolution < 3 nm), integrated in an ultra-high vacuum (UHV) apparatus, in order to avoid contaminations due to residual gases in the chamber. For the fabrication of metallic nanostructures on silicon substrates, various organometallic precursors, in particular transition metal carbonyls, were used. Iron pentacarbonyl, $Fe(CO)_5$, turned out to be a suitable precursor for clean EBID deposits. The resulting iron nanostructures exhibit a very high purity, which was determined by local Auger electron spectroscopy. On clean Si(111) and Si(100) surfaces, discontinuous iron structures are observed, which consist of small dots with a size of < 10 nm. Auger measurements indicate that these EBID deposits grow on a composite layer, which homogeneously covers the silicon substrates.

O 12.11 Mon 16:45 H36

Local crystal structure of iron oxide nano particles synthesized form ferritin — •Michael Krispin, Marcus Preisinger, Peter Pfalzer, and Siegfried Horn — Lehrstuhl für Experimentalphysik II, Universität Augsburg, D-86135 Augsburg

We have investigated the size dependence of the local crystal structure of nanosized iron oxide by extended x-ray absorption fine structure (EXAFS) at the iron K-edge. Hematite (α-Fe_2O_3) nanoparticles of different diameters were produced by thermal treatment of horse spleen ferritin molecules and remineralized apo-ferritin molecules, respectively. The structure of these particles was compared to α-Fe_2O_3 and γ-Fe_2O_3 nanopowder references. The Fourier transformed EXAFS spectra of the nanoparticles differ significantly from hematite and maghemite reference spectra and change systematically as a function of particle diameter, signalling a corresponding evolution of the structure. We show that the Fe-O bond length decreases with decreasing diameter of the particles and with decreasing particle density. This is explained by a core-shell model, in which the fraction of a γ-Fe_2O_3 like particle shell increases while the α-Fe_2O_3 core decreases with decreasing particle size.

O 12.12 Mon 17:00 H36

Self-Organized growth of highly ordered metal-nanodots on C/W(110) — •Martin Gabl, Clemens Deisl, Norbert Memmel, and Erminald Bertel — Institute of Physical Chemistry, University of Innsbruck, Austria

The growth of Ag nanostructures on W(110) and C/W(110) is studied by LEED and STM. Whereas on clean W(110) and on the R(15x3) surface large Ag islands are formed, on the R(15x12)-C/W(110) surface the growth of Ag nanodots is observed. The R (15x12) carbon structure serves as a stable periodic template with a nanoscale unit mesh of 14Å x 31Å, which is replicated by the Ag nanodots. Most critical for the fabrication of a regular nanostructure array is the perfect preparation of the R(15x12)-C/W template. Interestingly, it forms more readily in the interior of large terraces, while small terraces tend to stay free of carbon. This implies a crucial role of steps in the C budget of the surface, most probably due to step-enhanced diffusion of carbon into the bulk. At optimum silver coverage (0.12 ML) the Ag nanodots show a narrow size distribution with most islands consisting of hexagonally shaped 7-atom clusters. However, clusters of this size are also observed at slightly higher silver coverages, if deposition temperatures around 500K are used. In this case excess silver agglomerates on terraces with a locally reduced carbon coverage. This implies that the 7-atom clusters are particularly stable, defining a *magic island size*. The present work was supported by the Austrian Science Fund (FWF) and the West-Austrian Initiative for Nano-Networking (WINN).

O 12.13 Mon 17:15 H36

Electron wave-vector quantization in nanostructures — •Sebastian Wedekind[1], Guillemin Rodary[1], Dirk Sander[1], Hui Liu[2], Hongwu Zhao[2], Larissa Niebergall[1], Valeri Stepanyuk[1], Patrick Bruno[1], and Jürgen Kirschner[1] — [1]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle/Saale, Germany — [2]Institute of Physics, Chinese Academy of Science, Beijing, China

We use hexagonal vacancy islands on Cu(111) to study electron confinement in a nanostructure. Scanning tunneling microscopy shows that these monolayer deep depressions are often of almost perfect hexagonal shape and have a size of up to 24 nm. Low temperature scanning tunneling spectroscopy and ab initio based theory reveal electron wave-vector quantization due to electron confinement in the nanostructure. A Fourier transformation of the spatial modulation pattern of the local density of states (LDOS) indicates the quantization of the electron wave-vector within the nanostructure, which gives rise to a discontinuous, staircase-like dispersion relation. Our experimental and theoretical results show that each step of the dispersion relation corresponds to an extremum of the LDOS. The sequence of extrema identifies the complete eigenstate spectrum of the confined system.