O 96: Metallic Nanowires on Semiconductor Surfaces

Time: Thursday 15:00–17:45 Location: WIL C107

O 96.1 Thu 15:00 WIL C107

Femtosecond electronic response of photo-excited in situ grown Indium wires — •Mariana Chavez-Cervantes[1], Sven Aeschlimann[1], Hubertus Bromberger[1], Razvan Krause[1], Andrea Cavalleri[1,2], and Isabella Gierz[1] — [1]Max Planck Institute for the Structure and Dynamics of Matter, Hamburg, Germany — [2]Department of Physics, Clarendon Laboratory, University of Oxford, Oxford, United Kingdom

Strong electronic correlations in one-dimensional wires lead to a metal-to-insulator transition at low temperatures. The low-temperature insulating phase is characterized by a complex order parameter with amplitude (size of the band gap) and phase. Photo-doping with femtosecond laser pulses excites carriers across the band gap and leads to an instantaneous reduction of the amplitude of the order parameter followed by amplitude and possibly phase oscillations. We have grown one-dimensional indium wires in situ on a Si(111) substrate and characterized them with low-energy electron diffraction (LEED) and angle-resolved photoemission spectroscopy (ARPES). At room temperature the system exhibits three one-dimensional metallic bands that undergo a complex metal-to-insulator transition at T=110K. We excited the indium wires with intense femtosecond pulses at 1.5eV and probed the response of the electronic structure with time-resolved ARPES at extreme ultraviolet wavelengths. We analyze the dynamics of the complex order parameter and the energy-dependence of the photo-excited population life time.

O 96.2 Thu 15:15 WIL C107

Ginzburg-Landau-Langevin theory for the phase transition in In/Si(111) — •Yasemin Ergün and Eric Jeckelmann — Appelstraße 2, 30167 Hannover

We investigate thermal fluctuations and collective excitations in quasi-one-dimensional charge-density-wave systems using the Ginzburg-Landau (GL) theory. Starting from a microscopic Su-Schrieffer-Heeger-like model for In/Si(111), we generalized the GL theory for grand canonical Peierls transitions. The equilibrium properties and the non-equilibrium dynamics are simulated using the Langevin approach. We calculated the phonon spectrum for the Landau-Langevin theory. We discuss our theoretical results in relation to doping and spectroscopy experiments for In/Si(111). Extending this approach for local fluctuations within a two-dimensional Ginzburg-Landau-Langevin is computationally expensive. We developed a frequency filter for smoothing fluctuations included in the linear response spectrum by finite simulation size and time. Support from the DFG through the Research Unit FOR 1700 is gratefully acknowledged.

O 96.3 Thu 15:30 WIL C107

Pinning of topological solitons at extrinsic defects in a quasi one-dimensional charge density wave — •Samad Razzaq[1], Stefan Wippermann[1], Taehwan Kim[2], and Hanwoong Yeom[2] — [1]Max Planck Inst fuer Eisenforschung GmbH — [2]IBS Center for Artificial Low Dimensional Electronic Systems , University of Pohang

Quasi one-dimensional (1D) electronic systems are known to exhibit exotic physical phenomena, such as, e.g., Jahn Teller distortions, charge density wave (CDW) formation and non-Fermi liquid behavior. Solitonic excitations of the charge density wave ordered ground state and associated topological edge states in atomic wires are presently the focus of increasing attention. We carried out a combined ab initio and scanning tunneling microscopy (STM) study of solitonic and non-solitonic phase defects in the In/Si(111) atomic wire array. While free solitons move too fast to be imaged directly in STM, they can become trapped at extrinsic defects within the wire. We discuss the detailed atomistic structure of the responsible extrinsic defects and trapped solitons. Our study highlights the key role of coupled theory-experimental investigations in order to understand also the elusive fast moving solitons. S. W. gratefully acknowledges financial support from the German Research Foundation (DFG), grant No. FOR1700.

O 96.4 Thu 15:45 WIL C107

Ultrafast Peierls Transition in In/Si(111) Nanowires Probed by trARPES — •C. W. Nicholson[1], A. Lücke[2], M. Puppin[1], L. Rettig[1], R. Ernstorfer[1], W. Gero Schmidt[2], and M. Wolf[1] — [1]Fritz-Haber-Institut, Berlin — [2]Universität Paderborn

Quasi-1D metals on semiconducting substrates, of which In/Si(111) is one of the most interesting and intensively studied systems, promise not only novel 1D physics, but also control over electronic properties and dimensionality. In/Si(111) undergoes a structural transition from a (4x1) to an (8x2) unit cell at around 120 K, concomitant with a metal-to-insulator transition. A recent combined DFT and Raman study [1] points strongly to a Peierls-like scenario, whereby a combination of shear and rotary distortions leads to the opening of band gaps at specific points in the band structure.

Here we investigate the momentum resolved changes of the electronic structure during the ultrafast photoinduced Peierls transition using high-harmonic-driven trARPES with 50 fs time resolution. Starting from the (8x2) phase, we track the evolution of states both above and below the Fermi level following pulsed excitation and observe the transition from (8x2) to (4x1) phases on a 500 fs time scale. By comparison to complementary DFT calculations we analyse the contributions from the expected shear and rotary distortions to the transient electronic band structure. The observation of coherent phonon oscillations at 2.4 THz provides further insights into the many-body interactions in the system.

[1] E. Jeckelmann et al. Phys. Rev. B, 93, 241407(R) (2016)

O 96.5 Thu 16:00 WIL C107

Tuning of 1D Plasmon properties on Si(hhk)-Au by adsorbates — •Zamin Mamiyev, Timo Lichtenstein, Christoph Tegenkamp, and Herbert Pfnür — Institut für Festkörperphysik, Leibniz Universität Hannover, Hannover, Germany

Gold-induced atomic wires on Si(hhk) surfaces possess intriguing properties of collective electron excitations which are strongly responsive to the electronic state and also to structural motifs. The modification and control of plasmonic excitations in metallic nanowires are of particular interest due to their fundamental and technological importance. In this work, the effect of O$_2$ and H$_2$ adsorption on the plasmons in arrays of single [Si(557)-Au] and double chains of gold [Si(553)-Au] have been examined by Electron Energy Loss Spectroscopy with high resolution both in energy and momentum. Theoretical results show that oxygen and hydrogen atoms bind preferably not to the Au chains directly, but to adjacent Si-honeycomb chains (Si-HC) and Si-adatom rows (The latter exist only in Si(557)-Au). The Si-HC turns out to be mostly responsible for the plasmonic changes. While atomic H reduces the plasmon frequency on Si(553)-Au, as predicted theoretically, adsorbed oxygen leaves it unchanged, whereas a frequency increase is found to be induced by oxygen in Si(557)-Au, indicating an enhanced electron density in the partially filled surface band(s). Comparing the oxygen results on Si(553)-Au and Si(557)-Au, both the structural motifs (double vs. single chain), as well as electronic distribution across the terraces play a role. These effects still need further detailed consideration in order to separate them clearly.

O 96.6 Thu 16:15 WIL C107

Analysis of the electronic and atomic structure of Pb/Si(557) by polarization dependent two-photon photoemission — •Abdul Samad Syed[1], Vesna Miksic-Trontl[1], Manuel Ligges[1], Ping Zhou[1], Herbert Pfnür[2], Christoph Tegenkamp[2], and Uwe Bovensiepen[1] — [1]Universität Duisburg-Essen, Fakultät für Physik und Zentrum für Nanointegration (Cenide), 47048 Duisburg — [2]Leibniz-Universität Hannover, Institut für Festkörperphysik, Appelstrasse 2, 30167 Hannover

The local structure of atomic wires Pb/Si(557) is determined (i) by the macroscopic quasi one dimensional symmetry imposed by the vicinal cut substrate and (ii) local arrangement of Pb atoms on the Si terraces. We analyze the electronic structure by angle-resolved two-photon photoemission (2PPE) as a function of light polarization and find a dichroism in the 2PPE intensity for opposite electron momenta along the terraces k_x and $-k_x$. Considering earlier work [1] on Pb/Si(111) which concluded on the coexistence of the H3 and T4 symmetry in the $\sqrt{3}\times\sqrt{3}$ reconstruction, the observed polarization dependent dichroism suggests a combination of three and six fold symmetry of the Pb arrangement on Si(557) in agreement with a compressed structure along the Si terrace.

Funding by the DFG through FOR 1700 is gratefully acknowledged.

[1] A. Baumann, E. Speiser, S. Chandola, J. Räthel, P. Kratzer, S. Sakong, C. Tegenkamp, N. Esser (2016).

O 96.7 Thu 16:30 WIL C107

Spin correlations in the Si(553)-Au nanowire system — •Bernd Hafke[1], Tim Frigge[1], Tobias Witte[1], Boris Krenzer[1], Julian Aulbach[2], Ralph Claessen[2], Jörg Schäfer[2], and Michael Horn-von Hoegen[1] — [1]Universität Duisburg-Essen, Lotharstr. 1, 47057 Duisburg — [2]Universität Würzburg, Physikalisches Institut and Röntgen Center for Complex Material Systems (RCCM), 97074 Würzburg

Deposition of 0.5 ML Au on Si(553) at 650 °C results in the formation of Au double-strand chains per Si terrace with a twofold periodicity along the wire. These metallic wires are structurally terminated by Si step edge atoms, which exhibit a three-fold periodicity of half-filled dangling bonds of the Si atoms along the steps. Theory predicts an antiferromagnetic spin ordering of every third Si step edge atom [1]. The long-range interaction of the two-fold and three-fold periodicity is investigated by spot-profile analysis in LEED at a sample temperature of 80 K. The strict two-fold periodicity of the Au atoms is not correlated between adjacent wires as concluded from the streak like intensity in LEED. In contrast, the threefold ordering of the Si spins exhibit a clear ordering perpendicular to the Au wires. A modification of the structure model [2] explains the structural correlation between adjacent Si step edge atoms. The resulting frustrated structure indicates the formation of a 2D spin-liquid in this system [2].

[1] S. C. Erwin and F. J. Himpsel, Nature Commun. **1**, 58 (2010).
[2] B. Hafke, *et al.* PRB **94**, 161403(R) (2016).

O 96.8 Thu 16:45 WIL C107

The electronic structure of rare earth silicide nanowires on Si(001) — •Stephan Appelfeller, Martin Franz, Hans-Ferdinand Jirschik, and Mario Dähne — Institut für Festkörperphysik, TU Berlin, Hardenbergstr. 36, 10623 Berlin

Trivalent rare earths are known to form silicide nanowires on Si(001). Based on the chemical similarity of the rare earths and the similar appearance of the nanowires in scanning tunneling microscopy, it is generally assumed that the nanowires have the same atomic structure for all rare earths. On the other hand, angle resolved photoemission spectroscopy (ARPES) studies of Gd and Dy silicide nanowires disagree with each other in the observed band structure, even though both studies indicate an one-dimensional dispersion [1,2]. Here, we report on ARPES experiments on Y and Tb silicide nanowires. Their electronic structure is quasi-one-dimensional, showing only small oscillations of the Fermi contours. Furthermore, the disagreement in the literature data is resolved by the observation of strong matrix element effects in our data, in which all the bands described in the literature are observed indicating that the nanowires have the same electronic properties and, consequently, also the same atomic structure.

This work was supported by the DFG (FOR1700, project E2). We kindly acknowledge the support of K. Horn and coworkers, C. Papp, and of BESSY II (HZB Berlin), where the photoemission experiments were carried out at the beamline UE56/2 PGM-1.

[1] H. W. Yeom et al., Phys. Rev. Lett. **95**, 205504 (2005).
[2] M. Wanke et al., Phys. Rev. B **83**, 205417 (2011).

O 96.9 Thu 17:00 WIL C107

Strain induced quasi-one dimensional structure of rare earth silicides on Si substrates — Frederic Timmer[1], Robert Oelke[1], Christof Dues[2], Simone Sanna[2], Wolf Gero Schmidt[2], Martin Franz[3], Stephan Appelfeller[3], Mario Dähne[3], and •Joachim Wollschläger[1] — [1]Fachbereich Physik, Universität Osnabrück, Germany — [2]Lehrstuhl für Theoretische Physik, Universität Paderborn, Germany — [3]Institut für Festkörperphysik, Technische Universität Berlin, Germany

One dimensional (1D) systems have attracted a lot of attention since their physical properties are distinctively different from structures of higher dimensionality. Recently, a new class of quasi-1D systems based on rare earth silicides has attracted attention. Here, we report on combined studies on quasi-1D structures by scanning tunneling microscopy (STM), spot profile analysis of low-energy electron diffraction (SPA-LEED) and density functional theory (DFT).

Depositing rare earth elements as Dy or Tb at elevated temperature on Si(111), a $2\sqrt{3} \times \sqrt{3}$ superstructure is observed. This structure is attributed to the formation of periodically arranged Si vacancies in different silicide layers. The complex structure of this superstructure with buckled surface layer, $\sqrt{3} \times \sqrt{3}$ superstructure in the first subsurface layer $2\sqrt{3} \times \sqrt{3}$ superstructure in the second subsurface layer can only be analyzed applying the different techniques used here. The anisotropic character of this structure is emphasized by the formation of periodically arranged domain boundaries. The width of the silicide domains formed in two domains is roughly two unit cells.

O 96.10 Thu 17:15 WIL C107

Infrared Spectroscopy of Charge Carrier Excitation in Metallic Nanowires on the Atomic Scale — Annemarie Pucci and •Fabian Hötzel — Kirchhoff Institute for Physics, Heidelberg University, Germany

Atomic chains, as for example gold superstructures on vicinal silicon surfaces, may show infrared resonances that can be attributed to plasmonic excitations in nanowires of a finite length of the order of 100 nm. The appearance of the resonances clearly indicates the metallic character of the atomic chains. The quantitative analysis of the spectral weight and the resonance position yields the data on the nanowire conductivity and complementary information on the electronic band structure. Conductivity changes upon doping can be directly seen in the infrared spectra. Furthermore, as we have recently found out, the plasmonic resonances are sensitive to the changes of the polarization of the silicon step edges with temperature.

O 96.11 Thu 17:30 WIL C107

Functionalization of Si(553)-Au surface with hydrogen and small organic molecules — •Julian Plaickner[1], Sandhya Chandola[1], Eugen Speiser[1], Svetlana Suchkova[1], Norbert Esser[1], and Simone Sanna[2] — [1]Schwarzschildstrasse 8, 12489 Berlin — [2]Warburger Str. 100, 33098 Paderborn

Atomic metallic chains deposited on vicinal Si substrates form templates for the growth of hybrid molecule-solid nanostructures. The advantage of these structures is the possibility to vary the substrate geometry and the metallic element. We investigate the adsorption of toluene-3,4-dithiol molecules on hydrogen-passivated Si(553)-Au surfaces as model system/process. Hydrogen is able to drive a reversible metal-insulator transition on the Si(553)-Au surface and is also changing the adsorption geometry of organic molecules, extending the functionalization possibilities of the surface in organic electronics and biosensing.

We are using a set of polarization-sensitive optical techniques, such as Raman Spectroscopy (RS), Reflection Anisotropy Spectroscopy (RAS) and Infrared Spectroscopic Ellipsometry (IRSE). Our approach consists in establishing a direct connection between optical spectra and surface structure via ab-initio calculations. Optical fingerprints allow us to gain information on structural and electronic properties of the system.

The plan for the future is the realization of highly ordered molecular array geometries and the understanding of charge transfer between molecules and atomic wires. This will open possibilities for further functionalization through modification of terminal groups of molecules.