O 77: Electronic Structure and Spin-Orbit Interaction III

Time: Thursday 16:00–19:15 Location: H33

O 77.1 Thu 16:00 H33

Surface valence states and stoichiometry of non-superconducting and superconducting FeTe films — •Donald Telesca[1,2], Yuefeng Nie[1], Joseph Budnick[1], Barrett Wells[1], and Boris Sinkovic[1] — [1]University of Connecticut — [2]Air Force Research Laboratory

We report the surface electronic structure and stoichiometry of FeTe films following the incorporation of oxygen by three different methods: air exposure, dry oxygen exposure and low temperature oxygen annealing. X-ray photoemission experiments show that oxygen incorporation changes the initial valence state of Fe from 0 to mainly 3+. We also observe that the Te changes valence from initially 0 to mixed 0 and 4+. The rate of valence changes is seen to depend on the method of incorporation. In addition, it is observed that the surface of the FeTe films is left in a Te deficient state following any type of exposure to oxygen.

O 77.2 Thu 16:15 H33

Valence reconstruction at the surface of LaCoO$_3$ thin films studied by resonant x-ray reflectometry — •Jorge E. Hamann-Borrero[1,2], Abdullah Radi[2], Woo Seok Choi[3], Sebastian Macke[4], Ronny Sutarto[5], Feizhou He[5], George A. Sawatzky[2], Ho Nyung Lee[3], and Vladimir Hinkov[4] — [1]IFW-Dresden — [2]University of British Columbia, Vancouver, Canada — [3]Oak Ridge National Laboratory, Materials Science and Technology Division, USA. — [4]Max Planck-UBC Centre for Quantum Materials, Vancouver, Canada — [5]Canadian Light Source, Saskatoon, Canada

The structural and electronic properties of a set of LaCoO$_3$ (LCO) thin films with and without a LaAlO$_3$ capping layer are studied by means of resonant x-ray reflectometry (RXRR) and x-ray absorption spectroscopy. The data analysis was performed using an element and valence specific approach. Our observations show that, whereas the capped film shows homogeneous and undisturbed electronic properties throughout the whole LCO layer, the uncapped sample suffers a valence disproportionation where the film bulk has a Co^{3+} character and a Co^{2+} layer is formed at the film surface. The origin of this reconstruction and its relation to the magnetism is discussed. Our results demonstrate the power of RXRR in studying fine depth resolved electronic properties in thin films.

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O 77.3 Thu 16:30 H33

Direct band structure measurement of a buried two-dimensional electron gas: delta-doped Si(001) — Jill Miwa[1], Michelle Simmons[2], Philip Hofmann[1], and •Justin Wells[3] — [1]Department of Physics and Astronomy, Interdisciplinary Nanoscience Center (iNano), Aarhus University, 8000 Aarhus C, Denmark. — [2]Centre of Excellence for Quantum Computation and Communication Technology, School of Physics, University of New South Wales, Sydney, NSW 2052, Australia. — [3]Department of Physics, Norwegian University of Science and Technology (NTNU), N-7491 Trondheim, Norway

We directly measure the band structure of a buried two dimensional electron gas (2DEG) using angle resolved photoemission spectroscopy. The buried 2DEG forms 2 nm beneath the surface of p-type silicon, because of a dense delta-type layer of phosphorus n-type dopants which have been placed there. The position of the phosphorous layer is beyond the probing depth of the photoemission experiment but the observation of the 2DEG is nevertheless possible at certain photon energies where emission from the states is resonantly enhanced. This permits direct access to the band structure of the 2DEG and its temperature dependence. This material system has been chosen since delta-doped silicon is not only a testing ground for fundamental physics, but has demonstrated recent successes as a platform for the fabrication of atomic-scale devices for quantum computation applications. The measurement concept presented here should be applicable to a wide range of similarly important buried conductive layers.

O 77.4 Thu 16:45 H33

Angle-Resolved Photoemission on the Kondo Surface Alloy CePd$_7$ — •Mattia Mulazzi[1], Christoph Seibel[1], Holger Schwab[1], Kenya Shimada[2], Jiang Jiang[2], and Friedrich Reinert[1,3] — [1]Universität Würzburg, Experimentelle Physik VII, Am Hubland, D-97074 Würzburg, Germany — [2]Graduate School of Science, Hiroshima University, Higashi-Hiroshima 739-8526, Japan — [3]Karlsruhe Institute of Technology KIT, Gemeinschaftslabor für Nanoanalytik, D-76021 Karlsruhe, Germany

This films of the Cerium were evaporated on a Pd(001) substrate an further annealed to obtain a thin surface alloy layer of stoichiometry CePd$_7$, as observed by Auger spectroscopy. From LEED measurements it was possible to determine that the alloy has a $(\sqrt{5}\times\sqrt{5})R26.6^\circ$ reconstruction, commensurate to the Palladium substrate. Photon-energy dependent ARPES measurements crossing the 4d-4f resonance show the presence of a strong peak near the Fermi level, having actually two components, the actual Kondo peak at the Fermi level and the spin-orbit peak at 280 meV binding energy. Resonant and non-resonant Fermi surface maps shows large intensity variations of the Pd bands, when measured at the resonance, a sign of strong hybridization between the conduction and the 4f electrons. While previous work assigns the CePd7 to the class of intermediate valence systems, our work shows that it is actually a Kondo system, with a rather high Kondo temperature.

O 77.5 Thu 17:00 H33

Time-of-flight momentum microscopy with imaging spin filter — •Katerina Medjanik[1], Sergey Chernov[1], Hans-Joachim Elmers[1], Christian Tusche[2], Alexander Krasyuk[2], Jürgen Kirschner[2], and Gerd Schönhense[2] — [1]Institut für Physik, Univ. Mainz — [2]Max Planck-Institut für Mikrostrukturphysik, Halle

Momentum microscopy is a novel approach to study the electronic structure of surfaces using the cathode-lens technique, well-known from PEEM. Whereas a PEEM is optimized for best resolution in real space, momentum microscopy aims at an ultimate resolution in k-space (reciprocal space). Up to now, dispersive spectrometers have been used as energy filter [1]. In this contribution we present first results using time-of-flight (ToF) energy dispersion using a delayline detector, adopting concepts of ToF-PEEM [2]. By setting a ToF condition in the 3D (x,y,t) data sets, we define sections in k-space. We optimized the electron optical design such that for start energies up to 80eV the full half space above the sample surface (more than the first Brillouin zone) is imaged with high k-resolution. Using the imaging reflection-type spin filter [3,4], we were able to obtain spin resolution. The instrument allows highly efficient simultaneous spin filtering of many energy sections through momentum space.

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[1] B. Krömker et al., Rev. Sci. Instrum. 79 (2008) 053702.
[2] G. Schönhense et al., Surf. Sci. 480 (2001) 180.
[3] C. Tusche et al., APL 99 (2011) 032505.
[4] D. Kutnyakhov et al., submitted to Ultramicroscopy.

O 77.6 Thu 17:15 H33

Mapping Image Potential States on Graphene Nanoflakes — Fabian Craes[1], Sven Runte[1], Jürgen Klinkhammer[1], Marko Kralj[2], Thomas Michely[1], and •Carsten Busse[1] — [1]II. Physikalisches Institut, Universität zu Köln, Germany — [2]Institut za fiziku, Zagreb, Croatia

Confinement effects of free electron like image potential states (IPSs) are observed in scanning tunneling spectroscopy (STS) on graphene nanoflakes on Ir(111) acting as potential wells. IPSs are unoccupied surface states energetically residing in an image charge potential between the Fermi and the vacuum level. They show a hydrogen-like spectrum perpendicular to the surface and form a two dimensional electron gas (2DEG) parallel to it.

We analyzed the IPSs by measuring local density of states (LDOS) point spectra as well as maps of the LDOS at selected energies. The spectra strongly depend on the size of the nanostructure as well as on the spatial position on top, indicating lateral confinement. The dominant contribution comes from a state other than the ground state due to parallel momentum transfer in the tunneling process. The confining potential can be tuned by intercalation.

O 77.7 Thu 17:30 H33

Development of a Megahertz high-harmonic light source for time-of-flight photoemission spectroscopy — •Cheng-Tien Chiang[1,2], Michael Huth[1], Alexander Blättermann[2], Jürgen Kirschner[1,2], and Wolf Widdra[2,1] — [1]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120, Halle(Saale), Germany — [2]Institute of Physics, Martin-Luther-Universität Halle-Wittenberg, Von-Danckelmann-Platz 3, D-06120, Halle(Saale), Germany

We developed a tunable laboratory light source for time-of-flight photoemission spectroscopy using high-order harmonic generation at 4 MHz. The harmonics are driven by a commercial Ti-sapphire laser oscillator and generated in a tight-focusing geometry. Photons with energies beyond 20 eV are produced from an argon gas jet, and the intensity of harmonics can be significantly increased by using a xenon jet. With this light source, we demonstrate photoemission experiments at 4 MHz repetition rate on the well-known Cu(111) surface with a characteristic electronic structure [1].

[1] C.-T. Chiang, A. Blättermann, M. Huth, J. Kirschner, and W. Widdra, Appl. Phys. Lett. **101**, 071116 (2012)

O 77.8 Thu 17:45 H33

Femtosecond time-resolved photoemission on 1T-TaS$_2$ in the Mott-insulating state — •Isabella Avigo[1], Simon Freutel[1], Laurenz Rettig[1], Manuel Ligges[1], Lutz Kipp[2], Kai Rossnagel[2], and Uwe Bovensiepen[1] — [1](1)*Universitt Duisburg-Essen, D 47048 Duisburg — [2](2)*Christian-Albrechts-Universitt zu Kiel, D 24118 Kiel

1T-TaS$_2$ is a quasi-two-dimensional transition metal dichalcogenide undergoing a metal-to-insulator transition below 180 K in which a charge density wave (CDW) coexists with a Mott insulating state. Of particular interest is the photoinduced melting of the Mott-Hubbard phase which drives the system in a crossover state [1,2] substantially different from the high temperature metallic state. Femtosecond time- and angle-resolved photoemission measurements were performed in the Mott-insulating phase at different pump fluences from 0.1 to 1 mJ/cm^2. We observe a population of states above the Fermi level (E_F) after pumping and a depletion and broadening of the Lower-Hubbard band (LHB) peak below E_F. From the analysis we carried out we clearly observe different relaxation dynamics of electron population above E_F, which decay in about 350 fs, and the intensity of the lower Hubbard band, recovering in about 900 fs. This points to a possible decoupling of populations above and below E_F and so to an at least non conventional metallic behavior of the photoinduced state.

We acknowledge support by the DFG through BO 1823/2, /4 and the EU under grant agreement 280555 within FP7. [1] Perfetti et al., NJP 10, 053019 (2008) [2] Dean et al., PRL 106, 016401 (2011)

O 77.9 Thu 18:00 H33

Electronic properties of Bi overlayers on Au(111) studied by low-temperature scanning tunneling spectroscopy — •Pin-Jui Hsu, Jeannette Kemmer, Jens Kügel, Tobias Maueurer, and Matthias Bode — Institute of Experimental Physics II, University Würzburg, Am Hubland, 97074 Würzburg, Germany

The Au(111) surface state is the paradigm of a Rashba-Bychkov system which—due to the large atomic spin-orbit coupling—exhibits the largest spin-splitting of all nobel metals [1]. Recent experiments have shown that the Rashba-splitting can be further enhanced by the adsorption of heavy adatoms [2]. In addition, complex spin textures have been predicted around isolated magnetic surface impurities [3]. In this contribution, we present scanning tunneling spectroscopy (STS) data of ultra-thin Bi films grown on Au(111). Our results indicate that the electronic structure strongly depends on the actual Bi coverage and surface structure. While the STS spectrum of the so-called (6×6)-structure observed at a coverage of about 0.5 atomic layers (AL) is almost featureless, the monolayer exhibits a strong peak in the differential conductance at $U = +2.3\,\mathrm{V}$, i.e. in the unoccupied sample states. For a local Bi coverage of 2 AL an asymmetric peak is observed at $U = +0.3\,\mathrm{V}$. We will discuss the potential origin of these electronic features and analyze if they are subject to Rashba-splitting.

[1] S. LaShell *et al.*, Phys. Rev. Lett. **77**, 3419 (1996).
[2] C. R. Ast *et al.*, Phys. Rev. Lett. **98**, 186807 (2007).
[3] S. Lounis, A. Bringer and S. Blügel, Phys. Rev. B **108**, 207202 (2012).

O 77.10 Thu 18:15 H33

Low-temperature superstructure of Au-induced atom chains on high-index silicon surfaces — •J. Aulbach[1], J. Schäfer[1], S.C. Erwin[2], S. Meyer[1], L. Dudy[1], B. Slomski[3], G. Landolt[3], H. Dil[3], and R. Claessen[1] — [1]Physikalisches Institut, Universität Würzburg, Germany — [2]Naval Research Laboratory, Washington DC, USA — [3]Paul Scherrer Institut, Villigen, Switzerland

Self-organized nanowires on high-index semiconductor substrates provide a versatile playground to scrutinize the low-temperature ground state of quasi-one-dimensional systems, such as a charge density wave (CDW) or a Tomonaga-Luttinger liquid. Here we report on Au nanowires on Si(553), where a structural model from density functional theory (DFT) [1] suggests strong spin-orbit coupling for the Au chains. Intriguingly, also antiferromagnetic spin order is proposed for the silicon structure along the terrace edges.

Scanning tunneling microscopy images of Au/Si(553) are found to be in astounding agreement with the structural model [1], including its periodicities. Moreover, tunneling spectroscopy measurements at low temperature indicate the absence of an energy gap. This does not support the picture of two coexisting CDWs, contrary to previous perception. Instead, the local density of states displays a distinctive structure which matches the spin-polarized Si step-edge state predicted by DFT. Finally, we briefly address the spin-orbit coupling in the Au bands using spin- and angle-resolved photoemission, providing direct evidence for a spin-splitting.

[1] S. C. Erwin and F. J. Himpsel, Nature Commun. **1**, 58 (2010).

O 77.11 Thu 18:30 H33

Probing current noise and topography in low-temperature scanning tunneling microscopes at sub-molecular resolution — •Markus Herz, Samuel Bouvron, Elizabeta Ćavar, Mikhail Fonin, and Elke Scheer — Department of Physics, University of Konstanz, 78457 Konstanz

Noise studies have become an active field in mesoscopic physics because they reveal a variety of additional information about electronic correlations [1].

We probe the current noise in low-temperature scanning tunneling microscopes (STM). The measurement setup is modified for extracting the current noise and its spectral density without the necessity of double wiring and performing cross correlation [2] and without going to high frequency measurements [3].

We show simultaneous measurements of the tunneling current and its noise in a low-temperature STM [4] with a very high thermal, mechanical and electronic stability.

In first experiments, the Fano factor $F = 1$ is observed to be a sharp lower limit for the current noise scaling when imaging sub-molecular details of clusters produced on a metallic surface at a tunneling conductance of $\simeq 10^{-4} G_0$, and the noise power is not correlated with the topographic signal.

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[3] R. Chen et al., Phys. Rev. B 85, 235455 (2012)
[4] C. Debuschewitz et al., J. Low. Temp. Phys. 147, 525 (2007)

O 77.12 Thu 18:45 H33

Long range charge transfer and electrostatics at a molecular heterojunction on a metal surface — •Patrick Amsalem[1], Jens Niederhausen[1], Andreas Wilke[1], Georg Heimel[1], Raphael Schlesinger[1], Stefani Winkler[1,2], Antje Vollmer[2], Jürgen P. Rabe[1], and Norbert Koch[1,2] — [1]Humboldt-Universität zu Berlin, Institut für Physik, Berlin, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, BESSY II, Berlin, Germany

Understanding the energy level alignment (ELA) at organic heterostructures grown on conductive electrodes is of major importance for improving organic-based devices. In this work, the ELA at an electron acceptor molecule (C60) / organic spacer (alpha sexithiophene, 6T) / Ag(111) interface is investigated as a function of the 6T thickness (one and two monolayers) by means of photoelectron spectroscopy. The formation of an interface dipole with similar magnitude is found for the two studied systems. Valence band and core level measurements reveal that these interface dipoles result from an integer electron transfer from the metal towards the C60 molecules, through the 6T film [1, 2]. Consistently, the total amount of electrons transferred to the C60 film is found to decrease with increasing 6T thickness. Also, a potential drop within the 6T is observed. These findings are quantitatively addressed by electrostatic considerations to entangle the effect of dipole-dipole interactions and potential drops observed when the interface is formed. [1] P. Amsalem, et al., J. Phys. Chem. C 115, 17503 (2011) [2] J. Niederhausen et al., Phys. Rev. B 86, 081411 (R) (2012)

O 77.13 Thu 19:00 H33

Probing the electronic structure of salt solutions by resonant inelastic soft X-ray scattering — •Sankaranarayanan Nagarajan[1], Frank Meyer[2], Andreas Benkert[2,3], Marcus Bär[4,5], Regan Wilks[4], Wanli Yang[6], Friedrich Reinert[2], Clemens Heske[3,5], Lothar Weinhardt[3,5], and Michael Zharnikov[1] — [1]Angew. Phys. Chemie, Universität Heidelberg — [2]Exp. Phys. VII, Universität Würzburg — [3]Inst. for Photon Science and Synchr. Radiation, Karlsruhe Institute of Technology — [4]Sol. Energy Res., Helmholtz-Zentrum Berlin — [5]Dept. of Chemistry, University of Nevada, Las Vegas — [6]Advanced Light Source, Lawrence Berkeley National Laboratory

Salt addition to water induces changes in the hydrogen bond network. These changes can be monitored by Resonant Inelastic soft X-ray Scattering (RIXS) measurements, which provide information on the electronic structure of solids, liquids, gases, and (here) solutions. In this contribution, we present RIXS maps for the aqueous solutions of KCl and NaCl at different concentrations (from 1M to super-saturated solutions). Both resonant and non-resonant emission spectra derived from these maps are discussed in detail. We find changes in the positions and intensities of characteristic emission peaks as a function of salt concentration. The observed changes are rationalized in terms of structural perturbations induced by the salt, which, in turn, result in a change of the electronic structure.