O 48: Poster Session - Electronic Structure of Surfaces: Spectroscopy, Surface States

Time: Tuesday 18:15–20:00 Location: P2/EG

O 48.1 Tue 18:15 P2/EG

Rashba-split surface state on Re(0001) investigated by STM — •Johannes Regel[1], Torge Mashoff[1], Jan Minar[2], Jürgen Braun[3], Hubert Ebert[3], and Hans-Joachim Elmers[1] — [1]Institut für Physik, Johannes Gutenberg-Universität, Mainz — [2]University of West Bohemia, Pilsen, Czech Republic — [3]Department Chemie, Ludwig Maximilians-Universität, München

The electronic structure of surfaces differs significantly from the bulk structure. Due to the broken symmetry, surface states and resonances are formed at the surface. A strong spin-orbit coupling, as given for Re, leads to Rashba spin splitting of these states. Although the strong spin momentum coupling should suppress backscattering, Re(0001) shows quantum interference patterns in the proximity of defects and step edges.

We investigate the electronic states of the Re(0001) surface using low temperature scanning tunneling microscopy and spectroscopy. Differential conductivity measurements lead to an energy-dependent analysis of wavelength, phase and damping of the surface states. Additionally, we use molecular beam epitaxy to deposit pseudomorphic submonolayers of Au and Ni and study their influence on the complex reflection coefficient of the surface wave function. The dispersion relations of the surface states are compared with theoretical results and show good agreement.

O 48.2 Tue 18:15 P2/EG

Magnetic adsorbates on W(110): A comparative study of the electronic structure — •Pascal J. Grenz[1], Marcel Holtmann[1], Koji Miyamoto[2], Eike F. Schwier[2], Shiv Kumar[2], Taichi Okuda[2], and Markus Donath[1] — [1]Institute of Physics, Westfälische-Wilhelms-Universität Münster, Germany — [2]Hiroshima Synchrotron Radiation Center, Japan

We used spin- and angle-resolved photoelectron spectroscopy to study the electronic structure of ultrathin Ni and Co films on W(110) and compare the results with those of Fe/W(110) [1]. W(110) exhibits a Dirac-cone-like surface state [2] which is topologically non-trivial and protected by mirror symmetry [3]. Magnetic adsorbates on W(110) are a model system to study the influence of exchange interaction on topologically protected surface states. In this contribution, we show that Co and Ni have a distinctly different influence on the Dirac-cone-like surface state than Fe. Additionally, we investigated the dispersion and spin structure of interface states for sub-monolayer and monolayer coverages of Co/W(110) and Ni/W(110).

[1] K. Honma *et al.*, Phys. Rev. Lett. **115**, 266401 (2015). [2] K. Miyamoto *et al.*, Phys. Rev. Lett. **108**, 066808 (2012). [3] D. Thonig *et al.*, Phys. Rev. B **94**, 155132 (2016).

O 48.3 Tue 18:15 P2/EG

Capability of an ultra-low work function electride material for ion thrusters as neutralizer insert — Fabian Michel[1,2], Daniel Zschaetsch[1,2], Malina Reitemeyer[1,2], •Jurek Lange[1,2], Limei Chen[1,2], Detlev M. Hofmann[1,2], and Peter J. Klar[1,2] — [1]Institue of Experimental Physics I, JLU Giessen, 35392 Giessen — [2]Center for Material Research (ZfM/LaMa), JLU Giessen, 35392 Giessen

Due to its low workfunction for electrons electride materials have many advantages for applications for space flight propulsions. For this reason C12A7:e^- is a promising insert candidate to be used in cold-cathode designs. By tuning the reduction process of C12A7 (12 CaO-7 Al_2O_3) it is possible to achieve electron concentrations up to $10^{21}/cm^3$. The concentrations can be determined by electrical measurements, and complementary by electron paramagnetic resonance (EPR) and Raman spectroscopy. In addition the later give information about impurities in the material. We further correlate the EPR and Raman results to photoelectron spectroscopy (XPS), to obtain a deeper understanding of the material properties. The task of the investigation is to contribute to the improvement of charge neutralizer materials for space applications.

O 48.4 Tue 18:15 P2/EG

The role of the final state in dichroic spin- and angle-resolved photoemission on the Au(111) surface state — •Maximilian Ünzelmann[1], Hendrik Bentmann[1], Tim Figgemeier[1], Raphael Crespo Vidal[1], Thiago R. F. Peixoto[1], Henriette Maass[1], Chul-Hee Min[2], and Friedrich Reinert[1] — [1]Experimentelle Physik 7, Universität Würzburg — [2]Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel

The Shockley surface state of the Au(111) surface is a paradigmatic example for a Rashba-type spin-splitting of two-dimensional electronic states. By means of spin- and angle-resolved photoemission we have investigated the photoelectron spin polarization and the linear dichroism (LD) in dependence on the photoelectron final state. To this end we conducted measurements in a photon-energy range from 18 eV to 30 eV and compare our results to previous findings for the giant Rashba systems $PbAg_2$/Ag(111) and $BiAg_2$/Ag(111) [1]. In all systems the LD changes its sign between energies of roughly 22 eV and 26 eV, likely due to a band gap in the similar final-state band structure of Ag(111) and Au(111). Interestingly, the measured spin polarization of the Shockley surface state is almost constant at these photon energies, in stark contrast to the case of $BiAg_2$ [1]. We will discuss these results by comparing the different influence of inversion symmetry breaking and spin-orbit coupling on the spin-split electronic wave functions.

[1] Bentmann et al., Phys. Rev. Lett. 119, 106401 (2017).

O 48.5 Tue 18:15 P2/EG

Towards ultrafast time-resolved orbital imaging using a ToF-based momentum microscope and photoelectrons extracted by HHG light — •Wiebke Bennecke, Matthijs Jansen, Sabine Steil, Marius Keunecke, David Schmitt, Marten Düvel, Christina Möller, Daniel Steil, and Stefan Mathias — I. Physikalisches Institut, Georg-August-Universität Göttingen

Orbital imaging (OI) is a powerful method to visualize molecular orbitals in molecules-metal interfaces using angle-resolved photoemission spectroscopy (ARPES) data and phase retrieval algorithms [Puschnig *et al., Science* **326**, 702-706 (2009)]. On this poster, we will report on our progress towards a demonstration of time-resolved imaging of optically excited orbitals. OI requires the precise preparation of a few highly ordered monolayers of molecules on a monocrystalline metallic substrate. We achieve this by thermal evaporation from a Knudsen cell in combination with LEED and UV photoemission measurements to verify the sample quality. Our photoemission setup consists of a momentum microscope and a high harmonic generation beamline at 26.5 eV, which yields the full momentum- and energy-dependent photoelectron spectrum of the absorbed molecules in a single measurement. We combine this setup with UV, visible and IR pump beamlines, which allows us to induce a wide range of optical excitations on a femtosecond time scale. The measured time-resolved photoelectron spectra are analysed using a sparsity-driven phase retrieval algorithm, which enables us to visualize the molecular orbitals in real space while requiring only limited prior knowledge of the molecular orbital.

O 48.6 Tue 18:15 P2/EG

Improved numerical reconstruction method for Metastable Induced Electron Spectra of molecules — •Wichard J. D. Beenken[1], Tobias B. Gäbler[2,3], Erich Runge[1], and Stefan Krischok[1] — [1]Technische Universität Ilmenau, Institut für Physik, Ilmenau, Germany — [2]Friedrich-Schiller-Universität Jena, Institut für Angewandte Physik, Jena, Germany — [3]Fraunhofer Institut für Angewandte Optik und Feinmechanik IOF, Jena, Germany

Metastable Induced Electron Spectroscopy (MIES) is arguably the most surface-sensitive spectroscopic method. Thus, it has been used, e.g., to study molecular layers of organic molecules [1] and the composition of ionic liquids [2,3]. Of particular interest are the orientations of the molecules and ions to the surface plane. In order to obtain this information, detailed reconstructions of the MIES spectra based on quantum-chemical calculations of the molecule in combination with a simulation of many trajectories of the impinging metastable helium atoms including shadowing effects are required. The latter makes such an analysis numerically very costly. We present recent progress in the numerical simulation of MIES spectra. [1] J. Günster, G. Liu, V. Kempter, D.W. Goodman, Surf. Sci. 415 (1998) 303-311. [2] T. Ikari, A. Keppler, M. Reinmöller, W.J.D. Beenken, S. Krischok et al., Surf. Sci. Nanotech. 8 (2010) 241-245. [3] A. Ulbrich, M. Reinmöller, W.J.D. Beenken, S. Krischok, Chem. Phys. Chem. 13 (2012) 1718-1724.

O 48.7 Tue 18:15 P2/EG

Revisiting the Quantum Corral with combined atomic force and scanning tunneling microscopy — •Fabian Stilp, Julian Berwanger, Nadine Mundigl, and Franz Josef Giessibl — University of Regensburg, 93040 Regensburg, Germany

Cu(111) exhibits a surface state that is scattered by adsorbates, defects and step edges, leading to pronounced interference patterns visible by scanning tunneling microscopy (STM) [1]. In 1993, Crommie et al. [2] confined these surface state electrons into a circular symmetric Quantum Corral with a diameter of about 15 nm assembled from 48 single Fe adatoms. They investigated the Bessel-type eigenstates with scanning tunneling microscopy and tunneling spectroscopy [2]. Afterwards, also elliptic, square and triangular Quantum Corrals [3] were created which lead e.g. to the observation of Quantum Mirages [4]. While STM is only able to image the Quantum Corral's states close to the Fermi level, atomic force microscopy (AFM) probes all occupied states. We revisit Quantum Corrals with combined STM and AFM using monoatomic metal and CO-terminated tips, probing whether the eigenstates of the Quantum Corral also lead to signatures in the AFM signal.

[1] Crommie et al. Nature **363**, 524 (1993)
[2] Crommie et al. Science **262**, 218 (1993)
[3] Crommie et al. Physica D **83**, 98 (1995)
[4] Manoharan et al. Nature **403**, 512 (2000)

O 48.8 Tue 18:15 P2/EG

Influence of strong spin-orbit coupling in strong electron correlated Bi/Sb:CeAg$_x$ on Ag(111) — •Hendrik Bostelmann-Arp, Katharina Kissner, Simon Müller, and Friedrich Reinert — Experimental Physics VII, Julius Maximilians University of Würzburg, 97074 Würzburg

Correlated electron systems show unique ground state properties. Ce-based compounds play a particular role in the investigation of strong correlation effects due to the single 4 f-electron occupation. At low temperatures the interaction of strongly localized 4 f-electrons with itinerant conduction electrons can lead to distinct features in the electronic structure such as the Kondo-Resonance and the formation of a hybridization band gap at the Fermi edge. The hybridization gap at the Fermi level is connected to the possibility of realising a Topological Kondo-Insulator by introducing additional elements with strong spin-orbit coupling [1].
In order to understand the influence of strong spin-orbit coupling on correlated systems we present results on the Kondo-System CeAg$_x$ on Ag(111) alloyed with elements showing strong spin-orbit coupling i.e. Bi or Sb. We study the electronic structure by means of Angle Resolved and X-Ray photoemission spectroscopy (ARPES and XPS). Furthermore changes in the geometric surface structure are studied by Low Energy Electron Diffraction (LEED). [1] M. Dzero, et al.,Phys. Rev. Lett. 104, 106408 (2010)

O 48.9 Tue 18:15 P2/EG

eMIL: advanced emission Mössbauer Spectrometer — •Dmitry Zyabkin[1], Ulrich Vetter[1], Fredericus Linderhof[2], and Peter Schaaf[1] — [1]Ilmenau University of Technology, Gustav-Kirchhoff-Str. 5, 98693 Ilmenau, Germany — [2]Department of Experimental Physics, Palacký University in Olomouc, 17. Listopadu 12, Olomouc, Czechia

Mssbauer spectroscopy is one of the most powerful methods to locally probe structural and electronic properties in condensed matter. The method allows to analyse and quantify various atomic surroundings, magnetic states, in-field magnetic arrangements of magnetic moments and coordination symmetry [1]. This current work presents a contemporary design of an advanced emission Mössbauer Spectrometer (eMS) eMIL equipped with a parallel-plate avalanche counter. The setup is based on an emission geometry and provides numerous advantages over conversion electron, common emission or transmission Mössbauer spectroscopy. eMIL is designed to measure hyperfine interactions in solids under various exposures. The implemented design overcomes limitations and improves performance and handling. In the current revision the implantation chamber is supplied with an UV extension - allowing to perform studies of photo-catalytic materials under external light exposure. A specifically designed motorised lid-samples-holder is fully automatised, and makes it possible to study up to 4 samples loaded in a magazine within a temperature range up to 1100 K and to perform angular-dependence-measurements in high vacuum.

[1] Gütlich *et al*, Mössbauer Spectroscopy, Springer (2010)

O 48.10 Tue 18:15 P2/EG

Ordered and disordered Tellurium surface alloys on Ag(111) and Cu(111) — •Andreas Raabgrund, Maximilian Ammon, Tilman Kisslinger, Lutz Hammer, and M. Alexander Schneider — Lehrstuhl für Festkörperphysik, Universität Erlangen-Nürnberg, D-91058 Erlangen, Germany

The formation of (surface) metal alloys using Te achieved a lot attention lately, e.g. for photovoltaics [1] or for spintronics [2]. In this work the Te surface alloys on Cu(111) and on Ag(111) were studied by low temperature STM, STS, LEED (all at 80 K) and DFT. Evaporation of $\Theta = 1/3$ ML Te leads to the formation of a $(\sqrt{3} \times \sqrt{3})R30°$ superstructure on Ag(111) [3] and a $(2\sqrt{3} \times \sqrt{3})R30°$ superstructure on Cu(111), respectively. By reducing the Te coverage we observe for both substrates patches of a disordered phase instead of a phase separation into ordered structure and clean surface. The reduced order below 1/3 ML Te coverage manifests itself as an increased background signal in LEED and is shown by STM to arise from a disordered Te lattice. Investigating those surface alloys by STS shows for both ordered structures a strong signal above the Fermi energy with onsets at 0.6...0.7 eV for AgTe and at 1.3...1.4 eV for CuTe, respectively. These features are also found by DFT and are the result of the longe-range order since they are absent on the disordered structures.

[1] Ibers J., Nat. Chem. 1, 508 (2009)
[2] Eremeev et al., Phys. Rev. Lett. 108, 246802 (2018)
[3] Liu et al, J. Phys. Chem. Lett. 2019, 10, 1866-1871 (2019)

O 48.11 Tue 18:15 P2/EG

Angle-resolved photoemission spectroscopy measurements from thin film manganites — •Jonas Pöhls, Marten Düvel, Cinja Seick, Vitaly Bruchmann-Bamberg, Jan Philipp Bange, Marco Merboldt, Henrike Probst, Marius Keunecke, Sabine Steil, Daniel Steil, and Stefan Mathias — 1st Physical Institute, University of Göttingen

Strongly correlated oxide perovskites, e.g. the manganite $La_{1-x}Sr_xMnO_3$ (LSMO), have a very rich magnetic phase diagram [1]. This is closely linked with the electronic structure of the material. Angle-resolved photoemission spectroscopy (ARPES) provides an opportunity to study this structure. Due to the surface sensitivity of this technique, the study of thin films produced by metalorganic aerosol deposition (MAD) in atmosphere is challenging. We have developed a two-step cleaning process to prepare the samples in UHV for the ARPES studies. For this purpose we simulate in a first step the conditions during the production in the MAD for cleaning. In the second step we use a reaction with ozone to remove the remaining adsorbates. We will present our setup and discuss the influence of our cleaning process on the material properties. Furthermore, first photoemission data on the band structure of MAD-grown manganites will be presented.

[1] Moshnyaga et al., Ann. Phys. 523, 652 (2011)

O 48.12 Tue 18:15 P2/EG

Designing High Energy Resolution Laser-Based Tunable Pump and Probe ARTOF Workstations — Alexander Forsman, •Viktor Jonsson, Luca Piazza, Magnus H. Berntsen, Jonas Weissenrieder, and Oscar Tjernberg — Materials Physics, KTH Royal Institute of Technology, Electrum 229, SE-16440 Kista, Stockholm, Sweden

We present recent upgrades of a laser-based angle-resolved time-of-flight spectrometer including our plans to move our system to modern facilities, add time-resolving capabilities and radically improve the optical design. The current system is driven by a 45W fiber laser 300 fs pulses at 1030 nm. The 9^{th},15^{th} and 21^{st} harmonic is generated in an argon-gas jet, separated by a horizontal groove grating and focused by 2 toroidal mirrors to around 0.1mm at the sample position. We demonstrate an energy resolution of 20 meV at space charge limited flux. In the new lab a Tangor Amplitude laser will generate 500 fs to 2 ps pulses for the probe while feeding the fiber laser which will after an optical parametric amplification act as a tunable pump at wavelengths from 200 to 1000 nm. The new optical design relies on movable narrow bandwidth spherical mirrors inside a monochromator. Instead of using filters to separate the $5 \cdot 10^{-11}$ vacuum from the much lower 10^{-6} vacuum in the monochromator we use sets of turbo pumps and a XIA differential pump to enable a free path for the XUV to the sample position. Our new system will increase the flux making it feasible to probe using the additional 27^{th} harmonic.