O 14: Electronic Structure of Surfaces: Magnetism and Spin Phenomena II

Time: Monday 15:00–17:30 Location: WIL C107

O 14.1 Mon 15:00 WIL C107

Exchange Splitting above the Curie Temperature in EuO — •Timm Gerber[1], Markus Eschbach[1], Tristan Heider[1], Ewa Mlynczak[1], Patrick Lömker[1], Pika Gospodaric[1], Mathias Gehlmann[1], Moritz Plötzing[1], Okan Köksal[2], Rossitza Pentcheva[2], Lukasz Plucinski[1,2], Claus M. Schneider[1,2], and Martina Müller[1,2] — [1]Peter Grünberg Institut (PGI-6), Forschungszentrum Jülich GmbH, Germany — [2]Fakultät für Physik and CENIDE, Universität Duisburg-Essen, Germany

The ferromagnetic semiconductor europium monoxide (EuO) is an efficient spin filter and, therefore, an attractive material for fundamental research in the field of spintronics [1,2]. Although EuO is considered to be a Heisenberg ferromagnet, a Stoner-like vanishing of the conduction band's exchange splitting is typically observed [3].

We investigated the electronic structure of EuO by means of spin- and angle-resolved photoemission spectroscopy (spinARPES) complemented by DFT + U calculations. Our spin-resolved data reveals a complex temperature dependence of the occupied density of states which can not be accessed by spin-integrated ARPES measurements [4]. We show that the exchange splitting of the O 2p band persists up to the Curie temperature and even above. Our findings indicate that sizeable short range magnetic order in EuO is present above T_C.

[1] M. Müller et. al., J. Appl. Phys. 105, 07C917 (2009)
[2] A. Schmehl et. al., Nat. Mater. 6, 882 (2007)
[3] M. Freiser et al., Helv. Phys. Acta 41, 832 (1968).
[4] H. Miyazaki et. al., Phys. Rev. Lett. 102, 227203 (2009)

O 14.2 Mon 15:15 WIL C107

Impurity states and ferromagnetic superexchange interactions in the magnetic topological insulator V:(Bi,Sb)$_2$Te$_3$: a combined resonant photoemission and x-ray magnetic circular dichroism study — •Thiago R. F. Peixoto[1], Hendrik Bentmann[1], Sonja Schatz[1], Steffen Schreyeck[2], Martin Winnerlein[2], Charles Gould[2], Karl Brunner[2], Kai Fauth[3], Arthur Ernst[4], Laurens W. Molenkamp[2], and Friedrich Reinert[1] — [1]EP VII, Uni-Würzburg, Germany — [2]EP III, Uni-Würzburg, Germany — [3]EP II, Uni-Würzburg, Germany — [4]Max Planck Institute of Microstrocture Physics, Halle, Germany

Recently we have demonstrated the impurity character of the V 3d density of states (DOS) at V:(Bi,Sb)$_2$Te$_3$ magnetic topological insulator thin films [1], a newly reported quantum anomalous Hall system (QAHS), by resonant photoemission spectroscopy (resPES). Here we used resPES at the Cr $L_{2,3}$ edges to extract the Cr 3d DOS of Cr:(Bi,Sb)$_2$Te$_3$ thin films, another QAHS, and compare with the V 3d states. In addition, we probed x-ray magnetic circular dichroism (XMCD) of the V 3d states, showing a persistent ferromagnetic character up to 50 K. A small opposite XMCD signal was observed at the Sb M_5 edge, evidencing an induced antiparallel magnetic moment at the Sb atom, as recently reported for Cr:(Bi,Sb)$_2$Te$_3$ [2]. The 3d impurity states are expected to mediate a ferromagnetic superexchange interaction, thus contributing to the ferromagnetism in these systems.

[1] T. R. F. Peixoto *et al.*, Phys. Rev. B **94**, 195140 (2016).
[2] M. Ye *et al.*, Nat. Commun. **6**, 8913 (2015).

O 14.3 Mon 15:30 WIL C107

Switchable spin - orbit gaps in a prototypical ferromagnet — •Ewa Mlynczak[1], Markus Eschbach[1], Stephan Borek[2], Jan Minar[2], Jürgen Braun[2], Irene Aguilera[1], Gustav Bihlmayer[1], Sven Döring[1], Mathias Gehlmann[1], Pika Gospodaric[1], Shigemasa Suga[1], Lukasz Plucinski[1], Stephan Blügel[1], Hubert Ebert[2], and Claus M. Schneider[1] — [1]Peter Grünberg Institut, Forschungszentrum Jülich GmbH, 52428 Jülich, Germany — [2]Department Chemie, Ludwig-Maximilians-Universität München, Butenandtstrasse 5-13, 81377 München, Germany

In this contribution we will present results of a recent study of the influence of spin-orbit interaction (SOI) on the electronic properties of a prototypical ferromagnet, Fe(001) [1]. Using high resolution angle-resolved photoemission spectroscopy we demonstrate openings of the SOI - induced electronic band gaps, spin-orbit gaps (SOG), near the Fermi level. The SOG and thus the Fermi surface can be manipulated by changing the remanent magnetization direction. The experimental results are compared with the first-principles calculations and one-step photoemission calculations.

By pinpointing the regions in the electronic band structure where the switchable band gaps occur, we demonstrate the significance of SOI even for elements as light as 3d ferromagnets.

[1].E. Mlynczak et al. 'Fermi surface manipulation by external magnetic field demonstrated for a prototypical ferromagnet' Phys. Rev. X (2016), accepted

O 14.4 Mon 15:45 WIL C107

Spin texture manipulation in the multiferroic Rashba semiconductor GeMn$_x$Te — Juraj Krempasky[1], Stefan Muff[1,2], Jan Minar[3], Nicolas Pilet[1], Peter Warnicke[1], Vladimir Strocov[1], Gunther Springholz[4], and •Hugo Dil[1,2] — [1]Swiss Light Source, Paul Scherrer Institut, Switzerland — [2]Institute of Physics, Ecole Polytechnique Fédérale de Lausanne, Switzerland — [3]Department of Chemistry, Ludwig Maximillian Universität, Germany — [4]Institut für Halbleiter-und Festkörperphysik, Johannes Kepler Universität, Austria

The search for materials with novel functional spin properties has received a prominent place in modern condensed matter physics because of the promise they bear in spinorbitronics and topological quantum phenomena. Multiferroic Rashba semiconductors are expected play an important role in this aspect because they combine a large Rashba-type spin splitting and ferromagnetic order in a manipulatable environment. By using a combination of spectroscopic techniques we could determine the electronic structure and spin properties of Mn-doped GeTe thin films[1,2]. The 3D Fermi surface takes the shape of a gapped spindle torus with just one spin-polarised Fermi sheet. Furthermore, it will be shown that the spin properties can be manipulated by either an electric field, a magnetic field, or optical stimuli. The films remain superconducting even after Mn doping, thus providing all the ingredients for the formation and manipulation of Majorana fermions.

[1,2] J. Krempasky et al. PRB 94, 205111 (2016); J. Krempasky et al. Nature Commun. 7, 13071 (2016).

O 14.5 Mon 16:00 WIL C107

Controlling the Rashba spin texture by adsorption of inorganic molecules — •Rico Friedrich, Vasile Caciuc, Gustav Bihlmayer, Nicolae Atodiresei, and Stefan Blügel — Peter Grünberg Institut (PGI-1) and Institute for Advanced Simulation (IAS-1), Forschungszentrum Jülich and JARA, D-52425 Jülich

We demonstrate from first principles that the spin texture of a surface Rashba system can be controlled by the adsorption of molecules. By making use of physisorbed and chemisorbed inorganic molecules on the BiAg$_2$/Ag(111) surface alloy [1] we show that both the spin-orbit splitting and the spin direction of Rashba-split surface states can be manipulated selectively.

The physisorption of NH$_3$ gives rise to a slightly enhanced outward buckling of the surface Bi which enlarges the magnitude of the Rashba splitting. On the contrary, the weak chemisorption of BH$_3$ defines a strong inward relaxation of the surface Bi. This causes the occupied Rashba split state to shift into Ag bulk states. In addition a new Rashba splitting is created in an unoccupied state upon BH$_3$ adsorption. Most importantly, in contrast to the clean surface [1,2] in case of the BH$_3$-BiAg$_2$/Ag(111) system the out-of-plane spin polarization is significantly larger than the in-plane one.

[1] C. R. Ast *et al.*, Physical Review Letters **98**, 186807 (2007).
[2] G. Bihlmayer *et al.*, Physical Review B **75**, 195414 (2007).

This work is supported by the Volkswagen-Stiftung through the Optically Controlled Spin Logic project and by DFG through SFB 1238 (Project C01).

O 14.6 Mon 16:15 WIL C107

Spin crossover molecules on ferromagnetic FeN layer — •Jinjie Chen and Wulf Wulfhekel — Physikalisches Institut, Karlsruhe Institute of Technology (KIT)

Organic spintronics has become an attractive research field combining spin-based functional devices with the benefits of organic materials. A promising candidate to build organic electronic switches at nanoscale are spin crossover molecules, which display a transition between a low- and a high-spin state upon various external stimuli. Unlike a frozen spin state when deposited on metallic surfaces (Cu(111), Cu(100), Au(111), Ag(111) and Co/Cu(111)), Fe-(phenanthroline)2-(NCS)2 complexes (short Fe-phen) deposited on single ferromagnetic layer of FeN on Cu(100) can be switched between the two spin states at low temperatures. By switching the spin states, also the exchange interaction between individual Fe-phen molecule and FeN layer can be tuned. This work indicates a potential route to manipulating the magnetic properties of a hybrid system.

O 14.7 Mon 16:30 WIL C107

Spin polarization and attosecond time delay in photoemission from spin-degenerate states of Copper, Graphene and BSCCO — •Mauro Fanciulli[1,2], Stefan Muff[1,2], Andrew P. Weber[1,2], Ulrich Heinzmann[3], and Hugo Dil[1,2] — [1]École Polytechnique Fédérale de Lausanne, Switzerland — [2]Paul Scherrer Institut, Villigen, Switzerland — [3]University of Bielefeld, Germany

During the photoemission process from spin-degenerate states of solids, the photoelectron beam can present a spin polarization which originates from the phase of the photoelectron wavefunction and can be measured by spin-resolved photoemission spectroscopy. The binding energy dependence of the spin polarization can then be related to an attosecond time delay of the photoemission process via the Eisenbud-Wigner-Smith half-scattering model.

Our study involves three different solid state physics benchmark materials: Cu(111), quasi-free-standing graphene, and the cuprate superconductor BSCCO. Without any time resolution, our photoemission experiments on Cu(111) with full angular, energy and spin resolution show an attosecond time delay of the sp bulk-derived band. In the experimentally more complicated cases of graphene and BSCCO a sizeable spin polarization is still observed and can be related to the phase and time information.

These results open the way for new developments in spin- and time-resolved photoemission theory and experimental setups, and could help in the understandings of the physics of many different systems of interest.

O 14.8 Mon 16:45 WIL C107

Application of the Ir(100) surface as a spin-filter usingthe azimuthal characteristics of its scattering properties — •Keisuke Hatada[1], Stephan Borek[1], Jürgen Braun[1], Jan Minar[1,2], Erik Schäfer[3], Hans-Joachim Elmers[3], Gerd Schönhense[3], and Hubert Ebert[1] — [1]Ludwig-Maximilians-Universität München — [2]University of West Bohemia Pilsen — [3]Johannes-Gutenberg-Universität Mainz

It has been shown recently that the Ir(100) surface is a promising candidate for the application as spin filter [1]. In our theoretical study we investigated a semi-infinite Ir(100) system with a structural relaxed surface. Using the fully relativistic Korringa-Kohn-Rostoker method we are able to characterize the scattering of spin polarized electrons [2]. The calculations have been done for an energy range from 6 to 15 eV, i.e. for the energy regime of SPLEED (Spin Polarized Low Energy Electron Diffraction). With respect to experimental applications the diffraction patterns have been calculated using a polar angle of incidence of 45 deg. Considering the azimuthal degree of freedom we calculated so-called rotation diagrams beginning at a high symmetry direction of the Ir surface. The use of the azimuthal angle provides an additional possibility to construct spin-filter applications. In combination with external magnetic fields the detection of all components of the spin polarization is possible. Results of our corresponding calculations will be compared to experimental data.

[1] D. Kutnyakhov et al. Ultramicroscopy **130**, 63 (2013)
[2] H. Ebert et al., The Munich SPR-KKR package, version 7.2, 2016

O 14.9 Mon 17:00 WIL C107

Potential Energy Driven Spin Manipulation via a Controllable Hydrogen Ligand — •Peter Jacobson[1], Matthias Muenks[1], Gennadii Laskin[1], Oleg Brovko[2], Valeri Stepanyuk[3], Markus Ternes[1], and Klaus Kern[1,4] — [1]Max Planck Institute for Solid State Research, Heisenbergstr. 1, 70569 Stuttgart, Germany — [2]The Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy — [3]Max Planck Institute of Microstructure Physics, Weinberg 2, 06120, Halle(Saale), Germany — [4]Institut de Physique, École Polytechnique Fédérale de Lausanne, CH-1015, Lausanne, Switzerland

Spin-bearing molecules can be stabilized on surfaces and in junctions with desirable properties such as a net spin that can be adjusted by external stimuli. Using scanning probes, initial and final spin states can be deduced from topographic or spectroscopic data, but the transition mechanism between these states is largely unknown. We address this question by manipulating the total spin of cobalt complexes on a h-BN surface with a H-functionalized scanning probe tip by simultaneously tracking force and conductance. When the additional H ligand is brought close to the CoH, switching between a correlated S = 1/2 Kondo state and a S = 1 state with anisotropy is observed. We show that the total spin changes when the system is transferred onto a new potential energy surface defined by the position of the H in the junction. These results show how and why chemically functionalized tips are an effective tool to manipulate adatoms and molecules, and a promising new method to selectively tune spin systems.

O 14.10 Mon 17:15 WIL C107

Vectorial Multichannel Spin-Polarimetry Using an Ir(001) Imaging Spin Filter — •Erik Schaefer[1], Stephan Borek[2], Jürgen Braun[2], Ján Minár[2,3], Hubert Ebert[2], Katerina Medjanik[1], Gerd Schönhense[1], and Hans-Joachim Elmers[1] — [1]Institut of Physics, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany — [2]Department Chemie, Ludwig-Maximilians-Universität München, Butenandtstraße 5-13, 81377 München, Germany — [3]New Technologies-Research Centre, University of West Bohemia, Univerzitni 8, 306 14 Pilsen, Czech Republic

A newly developed high-performance imaging spin filter system based on a large Ir(001) scattering crystal tackles the issue of previously inefficient spin-resolving photoemission spectrometers. An increase of the effective figure of merit by a factor of over 10^3 in contrast to standard single-channel detectors is presented together with a detailed characterization of the experimental setup. The spin filter efficiency is analyzed by mapping a broad range of scattering energy and azimuthal angle. A high sensitivity to spin-components parallel and perpendicular to the scattering plane is observed under certain scattering conditions. An additional spin rotator element allows the independent determination of the two in-plane components of the spin vector. By combining three or six scattering conditions a vectorial spin analysis becomes possible for both, magnetic and non-magnetic samples.