O 18: Spin-orbit interaction

Time: Monday 16:00–17:30 Location: A 060

O 18.1 Mon 16:00 A 060

Detection of the spin-orbit splitting at the β–Bi/Si(111)-$\sqrt{3}\times\sqrt{3}$ surface by scanning tunneling spectroscopy — •Patrick Reissner, Paolo Sessi, and Matthias Bode — Physikalisches Institut, Experimentelle Physik II, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

The $\sqrt{3}\times\sqrt{3}$ reconstruction formed by the adsorption of Bi on the Si(111) surface has been recently reported to show a giant Rashba-Bychkov (RB) effect. Photoemission studies have highlighted its complex band structure consisting of multiple spin split bands with non-trivial spin texture [1]. Nevertheless a microscopic characterization is still missing. Here, we report on a combined STM/STS study of Bi/Si(111) performed at cryogenic temperature. We show how it is possible, by means of STS, to locally detect the strength of the RB-splitting. Concerning occupied states, our results are in agreement with previously reported experiments. For unoccupied states, not accessible by standard photoemission techniques, we also observe spectroscopic features that are assigned to RB spin split states. Finally, by taking advantage of the high spatial resolution of STM, the influence of defects on the local density of states is discussed.

[1] K. Sakamoto *et al.*, PRL **103** , 156801 (2009)

O 18.2 Mon 16:15 A 060

Tl/Si(111) - Rotation of the Rashba spin perpendicular to the surface - The unoccupied electronic structure — •Sebastian D. Stolwijk[1], Kazuyuki Sakamoto[2], Anke B. Schmidt[1], Peter Krüger[3], and Markus Donath[1] — [1]Physikalisches Institut, Westfälische Wilhelms-Universität Münster — [2]Graduate School of Advanced Integration Science, Chiba University, Japan — [3]Institut für Festkörpertheorie, Westfälische Wilhelms-Universität Münster

Tl/Si(111) exhibits an occupied Rashba-split surface state with a peculiar spin structure in reciprocal space [1]. Along the $\bar{\Gamma}\bar{K}$ direction of the hexagonal two-dimensional surface Brillouin zone the spin polarization is rotating from the normal Rashba direction to the direction perpendicular to the surface. This is due to a spin frustration at the $\bar{K}$ point and can be simply understood as a consequence of the 2D symmetry of the hexagonal system. Our spin-resolved inverse photoemission study reveals an unoccupied spin-orbit split surface state along $\bar{\Gamma}\bar{K}$ with the same out-of-plane rotation of the spin polarization. Remarkably, at the $\bar{K}$ point the two spin components are split in energy by more than 0.5 eV, whereas the lower surface band approaches the Fermi level. This gives rise to a nearly complete spin polarization at E_F. As the out-of-plane spin polarization is always negative for $\bar{K}$ and positive for $\bar{K}'$, interesting transport properties can be expected. Our results are supported and discussed on the basis of calculations within the LDA and the GW approximation including spin-orbit coupling.

[1] K. Sakamoto et al., Phys. Rev. Lett. **102**, 096805 (2009)

O 18.3 Mon 16:30 A 060

Manipulating the Rashba-type spin splitting of Pb quantum well states through interface engineering and the substrate charge density — •Bartosz Slomski[1,2], Gabriel Landolt[1,2], Jürg Osterwalder[2], and J. Hugo Dil[1,2] — [1]Swiss Light Source, Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland — [2]Physik-Institut, Universität Zürich, CH-8057 Zürich, Switzerland

Using spin and angle resolved photoemission spectroscopy we show how the Rashba-type spin splitting in Pb quantum well states [1] can be controlled either by changing the metal-substrate interface or the donor concentration of the n-type Si(111) substrate. Replacing the wetting layer from Pb to Bi reduces the Rashba constant by 50% [2], whereas an increase of the donor concentration by a factor of 20 enhances the constant by almost 50%. Both findings are explained in terms of a modified charge distribution close to the Pb nuclei [3] mediated by the metal-substrate interfaces. Especially the dependency of the Rashba constant on the substrate charge density opens the possibility to manipulate the Rashba effect through an external gate voltage and thus to realize a spin-based field effect transistor as proposed by Datta and Das [4].

[1] J.H. Dil, et al. Phys. Rev. Lett. 101, 266802 (2008)
[2] B. Slomski, et al. PRB 84, 193406 (2011)
[3] G. Bihlmayer, et al. Surf. Sci. 600, 3888 (2006)
[4] S. Datta, et al. Appl. Phys. Lett. 56, 7 (1990)

O 18.4 Mon 16:45 A 060

Quasi-two-dimensional electron gas under in-plane magnetic field and gate electric field in the presence of Rashba and Dresselhaus spin-orbit interactions — •Enver Nakhmedov[1,2], Oktay Alekperov[2], and Reinhold Oppermann[1] — [1]Institut für Theoretische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [2]Institute of Physics, Azerbaijan National Academy of Sciences,H. Cavid str. 33, AZ1143 Baku, Azerbaijan

Interplay of Rashba- and Dresselhaus spin-orpit interactions with the orbital and Zeeman effects of an in-plane magnetic field and gate electric field is studied in a quasi-two-dimenstional electron gas with finite thickness. It is shown that subsidiary valleys arise in the energy-momentum spectrum under particular values of the SO coupling constants, the magnetic field and the Lande factor, which may display a negative differential conductivity and the Gunn effect. Anticrossing and gaps yield multiple extrema in the energy spectrum, indicating in the ballistic conductance as pulsed projections on the energy plateaus.

We show that out-of-plane equilibrium spin current appears under in-plane magnetic field. In the absence of the magnetic field, the average values of the in-plane components of the spin current are shown to coincide with the well-known results obtained for a strictly 2D electron gas, revealing a cubic dependence on the SO coupling constants. In-plane magnetic field contribute new terms to the in-plane components of the spin-current too. The out-of-plane component of the spin current vanishes completely with the magnetic field, and depends quadratically or linearly on the SO coupling constants.

O 18.5 Mon 17:00 A 060

Empty bulk state with a Rashba-type spin-polarization observed on Au(111) — •Sune N. P. Wissing, Anna Zumbülte, Christian Eibl, Anke B. Schmidt, and Markus Donath — Physikalisches Institut, Westfälische Wilhelms-Universität Münster, Germany

Recently, we demonstrated the potential of spin- and angle-resolved inverse photoemission for investigating Rashba phenomena by following the well-known Rashba-split surface state of Au(111) beyond the Fermi level.

Here, we report on the first measurements of a Rashba-type spin polarization in unoccupied bulk states on Au(111). We observe a downward-dispersing spectral feature with strong spin polarization. This feature is attributed to a transition between sp-like bulk states. We will discuss the origin of the observed spin polarization, also in view of recent theoretical and experimental results concerning Rashba splitting in bulk states [1,2].

[1] A. Kimura *et al.*: Phys. Rev. Lett. **105**, 076804 (2010)
[2] E. E. Krasovskii and E. V. Chulkov: Phys. Rev. B **83**, 155401 (2011)

O 18.6 Mon 17:15 A 060

Three-Dimensional Spin Rotations at the Fermi Surface of the Metallic Surface System Au/Ge(111) — •Philipp Höpfner[1], Jörg Schäfer[1], Andrzej Fleszar[2], Jan Hugo Dil[3,4], Bartosz Slomski[3,4], Werner Hanke[2] und Ralph Claessen[1] — [1]Experimentelle Physik 4, Universität Würzburg — [2]Theoretische Physik 1, Universität Würzburg — [3]Swiss Light Source, Villigen PSI, Switzerland — [4]Physik-Institut, Universität Zürich, Switzerland

Adatom-induced $(\sqrt{3}\times\sqrt{3})$-reconstructions at semiconductor surfaces have attracted significant scientific interest in the past. This is due to the manifold of intriguing low-dimensional properties contained therein, ranging from correlated Mott-Hubbard physics to superconducting surface states. Moreover, as a result of space inversion symmetry-breaking at the solid-vacuum interface, a Rashba-type spin-orbit coupling may lead to a lift of the spin degeneracy in the surface states. A significant spin-splitting in metallic surface states at a semiconductor surface would offer the perspective to manipulate spins electronically.

Here, we present a fully three-dimensional analysis of the spin-properties in the metallic surface system Au/Ge(111) by both spin-resolved photoelectron spectroscopy and advanced density-functional modeling. Contrary to a conventional Rashba situation, the spin texture exhibits strong out-of-plane spin components following a three-fold symmetry. Moreover, the observation of additional radial spin components shows the complexity of the spin-orbit interaction in

Au/Ge(111), and reveals an interplay with Dresselhaus-like spin-orbit effects as a result of the crystalline anisotropies.