O 99: Scanning Probe Methods III

Time: Friday 10:30–13:00 Location: GER 38

O 99.1 Fri 10:30 GER 38

Sensing the spin environment at atomic dimensions — •Shichao Yan[1], Deung-Jang Choi[1], Jacob Burgess[1], Steffen Rolf-Pissarczyk[1], and Sebastian Loth[1,2] — [1]Max Plank Institute for the Structure and Dynamics of Matter, Hamburg — [2]Max Planck Institute for Solid State Research, Stuttgart

Electronic pump-probe spectroscopy is a versatile tool to study dynamic processes in tunnel junctions with nanosecond time resolution. We apply this technique to low temperature scanning tunneling microscopy and study spin dynamics of Fe nanostructures. Regular patterns of Fe atoms can be assembled with the tip of the STM on a copper nitride surface on Cu(100) and studied individually. The spin relaxation time of Fe trimers is found to be extremely sensitive to variations in their spin environment. We use this sensitivity to sense the presence of another spin. By attaching one transition metal atom to the STM tip and approaching it to the Fe trimer on the surface we deduce the coupling strength between the magnetic atoms. In addition, by monitoring minute changes of the Fe trimer's spin relaxation time, the magnetic state of long-lived spin chains can be sensed even at several nanometers distance.

O 99.2 Fri 10:45 GER 38

Magnetic force microscopy sensors with multi-component stray field sensitivity — •Christopher Friedrich Reiche[1], Silvia Vock[1], Bernd Büchner[1,2], and Thomas Mühl[1] — [1]Leibniz-Institut für Festköper- und Werkstoffforschung IFW Dresden — [2]Institut für Festkörperphysik, Technische Universität Dresden

Magnetic force microscopy (MFM) is a powerful tool for mapping the spatial distribution of one component of a magnetic stray field gradient. We employ iron filled carbon nanotubes as monopole-like magnetic tips [1] for quantitative MFM. Our advanced sensor design enables us to consecutively perform quantitative measurements of one in-plane and the out-of-plane stray field component with the same sensor [2]. By developing novel sensor concepts we not only improve the in-plane sensitivity of our sensors but also expand their scope of application. Furthermore, we investigate the applicability of our sensors to general scanning force microscopy methods.

[1] F. Wolny, T. Mühl, U. Weissker, K. Lipert, J. Schumann, A. Leonhardt, and B. Büchner, Nanotechnology 21, 435501 (2010)

[2] T. Mühl, J. Körner, S. Philippi, C. F. Reiche, A. Leonhardt, and B. Büchner, Appl. Phys. Lett. 101, 112401 (2012)

O 99.3 Fri 11:00 GER 38

Electron-phonon coupling of hot and low-energy electrons studied with SP-STM — •Anika Schlenhoff, Stefan Krause, and Roland Wiesendanger — Institute of Applied Physics, University of Hamburg

Heat dissipation in electronic devices influences their performance and reliability. As dimensions approach the nanoscale, understanding thermal phenomena on a local scale becomes crucial. In spin-polarized scanning tunneling microscopy (SP-STM) the atom-size probe tip allows for a very local current injection. By changing the tip-sample distance, the current can be varied by orders of magnitude.

In our experiments, we inject low-energy tunneling electrons at $U = 200\,\mathrm{mV}$ and hot field-emitted electrons at $U = 5\,\mathrm{V}$ into a superparamagnet, consisting of about 50 iron atoms on a W(110) substrate [1]. In both cases, increasing the current significantly rises its thermal switching frequency, indicating considerable Joule heating. Astonishingly, for the same power a lower effective temperature increase of the nanomagnet is observed for the hot field-emitted electrons. Our experiments reveal that the Joule heating depends not only on the power but also on the electron energy. The results will be discussed in terms of different relaxation mechanisms for the respective electron energies. Within a simple model taking the heat flow from the nanomagnet to the substrate into account [2], we quantify the electron-phonon coupling for the hot and the low-energy electrons.

[1] A. Schlenhoff *et al.*, Phys. Rev. Lett. **109**, 097602 (2012).

[2] W. A. Little, Can. J. Phys. **37**, 334 (1959).

O 99.4 Fri 11:15 GER 38

Determination of the electron-phonon coupling in ultra-thin Pb films with STM — Michael Schackert[1], Tobias Märkl[1], •Jasmin Jandke[1], Martin Hölzer[2], Sergey Ostanin[2], Eberhard K.U. Gross[2], Arthur Ernst[2,3], and Wulf Wulfhekel[1] — [1]Karlsruhe Institut of Technology, Physikalisches Instiut, Wolfgang-Gaede Straße 1, 76131 Karlsruhe, Germany — [2]Max Planck Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle, Germany — [3]Wilhelm-Ostwald Institut für Physikalische und Theoretische Chemie, Linnéstraße 2, Universität Leipzig, 04103 Leipzig, Germany

In conventional superconductors, Cooper pairs form due to electron-electron interaction via virtual phonon exchange. A central quantity in this process is the effective phonon spectrum, also known as Éliashberg function which determines the superconducting properties of the material. Using scanning tunneling microscopy (STM) below 800 mK in UHV we found a new method to locally determine the Éliashberg function directly by performing the inelastic tunneling spectroscopy in the normal state. As a first model system we investigated thin Pb islands on Cu(111), wich are in the normal-state due to the proximity effect and therefore the STM-ITS signal is not superposed by the signature of the SC gap. We find a pronounced dependence of the electron-phonon coupling on the island thickness which is in good agreement with ab initio calculations.

O 99.5 Fri 11:30 GER 38

Scanning force and Kelvin probe force microscopy studies of vicinal Si(111) with atomic resolution — •Carmen Pérez León, Holger Drees, Michael Marz, and Regina Hoffmann-Vogel — Karlsruher Institut für Technologie (KIT), Physikalisches Institut and DFG-Center for Functional Nanostructures (CFN), D-76131 Karlsruhe

Stepped well-ordered surfaces can be used as nanotemplates for the fabrication of one-dimensional nanostructures. Vicinal Si(111) surfaces inclined towards the $[\bar{1}\bar{1}2]$ direction contain steps with the height of one and three interplanar distances at temperatures below 870°C [1]. With increasing miscut angle the amount of triple steps also increases [1,2]. For an angle of 10 °, only triple steps appear between regularly spaced (111) terraces with a width equal to that of a cell of the Si(111)-7×7 surface structure [2]. We have investigated the atomic structure of the 10 °-miscut vicinal Si(111) surface with with frequency-modulation scanning force microscopy (FM-SFM) and Kelvin probe force microscopy (KPFM) at room temperature. Although measurements of step edges are challenging for SFM and KPFM, we have obtained atomic resolution of the structure and the surface potential distribution on the triple step between the Si(111)-7×7 terraces.

[1] S. A. Teys, K. N. Romanyuk, R. Zhachuk and B. Z. Olshanetsky, Surf. Sci. **600**, 4878 (2006).

[2] A. Kirakosian, R. Bennewitz, J. N. Crain, Th. Fauster, J.-L. Lin, D. Y. Petrovykh and F. J. Himpsel, Appl. Phys. Lett. **79**, 1608 (2001).

O 99.6 Fri 11:45 GER 38

Kelvin Probe Force Microscopy Studies of Lead Islands on Si(111) — •Thomas Späth[1], Carmen Pérez León[1], Michael Marz[1], Hilbert v. Löhneysen[1,2], and Regina Hoffmann-Vogel[1] — [1]Karlsruher Institut für Technologie (KIT), Physikalisches Institut and DFG-Center for Functional Nanostructures (CFN), D-76131 Karlsruhe — [2]Karlsruher Institut für Technologie (KIT), Institut für Festkörperphysik, D-76021 Karlsruhe

Quantum size sffects (QSE) become pronounced when the thickness of a metal film approaches the de Broglie wavelength of the confined electrons. QSE lead to an oscillatory behavior of many physical properties as a function on the thickness of the metallic film. We have studied the influence of the QSE on the work function of Pb islands on Si(111). Pb was evaporated in ultra-high vacuum at room temperature on the Si(111)-7×7 surface. The height and local work function of the islands were simultaneously characterized by non-contact atomic force microscopy and Kelvin probe force microscopy. To prevent dewetting, the measurements were performed at approx. 110 K. The observed height of the islands ranges between four and nine monolayers. The local work-function difference shows an even-odd oscillatory dependence on the island's height, in good agreement with calculations [1] and previous results [2]. The amplitude of the oscillation decreases with increasing film thickness.

[1] C. M. Wei and M. Y. Chou, Phys. Rev. B **66**, 233408 (2002).

[2] J. Kim, S. Y. Qin, W. Yao, Q. Niu, M. Y. Chou, and C. K. Shih, Proc. Natl. Acad. Sci. USA **107**, 12761 (2010).

O 99.7 Fri 12:00 GER 38

Modifying the atomic structure of a single Pb layer by STM — •Michael Caminale[1], Augusto A. Leon Vanegas[1], Agnieszka Stepniak[1], Hirofumi Oka[1], Dirk Sander[1], and Jürgen Kirschner[1,2] — [1]MPI-Halle — [2]MLU Halle-Wittenberg

The highly complex atomic structure of one single layer of Pb on Si(111) has been extensively investigated in the past by scanning tunneling microscopy (STM) [1-2]. It has been shown that in a narrow coverage interval of 0.1 ML the system exhibits a quasi-infinite number of structural phases constructed hierarchically with an increasing atomic density. This is ascribed to the existence of two competing unit cells for the Pb atoms, respectively identified as $\sqrt{3} \times \sqrt{3}$ (10.44 atoms/nm^2) and $\sqrt{7} \times \sqrt{3}$ (9.4 atoms/nm^2). The combination of these leads to a rich set of phases [2]. We report the manipulation of a structural phase of Pb/Si(111) by STM-induced structural manipulation at 380 mK. A reversible modification of the atomic arrangement on a scale from 15×15 nm^2 to 80×80 nm^2 is achieved by exploiting the tip-surface interaction by two different strategies: (i) by the application of a milliseconds-long voltage pulse for a constant tunneling current; (ii) by a milliseconds-long ramping of the tip-surface distance for a constant bias value. Combined atomically resolved STM and tunneling spectroscopy measurements give a structural and electronic characterization of the phase change. The results are discussed in view of tip-surface interactions, mass transfer and surface atomic diffusion.

[1] D. R. Heslinga et al. Phys. Rev. Lett. 64, 1589 (1990). [2] M. Hupalo et al. Phys. Rev. Lett. 90, 216106 (2003).

O 99.8 Fri 12:15 GER 38

The role of Si trimers in the Si/Pt(111) surface alloy — •M. Švec[1], M. Ondráček[1], P. Hapala[1], P. Merino[2], P. Mutombo[1], M. Vondracek[1], S. Polyak[1], V. Chab[1], M. Blanco-Rey[3], P. de Andres[3], J. A. M. Gago[3], and P. Jelinek[1] — [1]FZÚ AVČR, Praha CZ — [2]CAB-INTA, Madrid ES — [3]ICMM-CSIC, Madrid ES

Silicon is deposited onto crystalline Pt and the resulting structure is investigated in a great detail. An ensemble of surface-science techniques (STM-AFM, ARUPS, SRPES, LEED-IV) is employed to characterize the system and to deduce an atomistic model for the complex geometry of the Si-(r19xr19)R23.4°/Pt(111) structure. Theoretical simulations achieve a very good agreement with the experimental techniques and corroborate beyond any doubt that it is a surface alloy. Generality of the model is briefly discussed, based on similarities found in analogous systems. These findings render unlikely any formation of silicene or germanene on Pt(111) and other noble metal surfaces.

O 99.9 Fri 12:30 GER 38

Current driven forces in molecular junctions — Zsolt Majzik, Prokop Hapala, Ondrej Krejci, Martin Setvin, and •Pavel Jelinek — Institute of Physics, Academy of Sciences of the Czech Republic, Prague, Czech Republic

We performed simultaneous nc-AFM/STM measurements over acetophenon molecule deposited on Si(100) p-doped surface in an upright position. Simultaneously tunnelling current and frequency shift as function of tip-sample distance and bias voltage allows us to identify presence of new current driven force acting in molecular junction. In far distance regime, we observe well-known parabolic dependence of frequency shift on applied voltage due to long-range electrostatic force. In close distance regime, the new attractive force emerges at positive bias voltage. What more the force changes sign with further tip approach. We will discuss the origin of the force and the sign change with distance.

O 99.10 Fri 12:45 GER 38

Investigations of the surface structure of Pt and Fe/Pt by PAES, XPS and STM — •Samantha Zimnik[1,2], Christian Piochacz[1,2], Sebastian Vohburger[2], and Christoph Hugenschmidt[1,2] — [1]Technische Universität München, Physik Department,Lehrstuhl E21, James-Franck-Straße, D-85748 Garching, Germany — [2]Technische Universität München, Forschungs-Neutronenquelle Heinz Maier-Leibnitz, Lichtenbergstraße 1, D-85748 Garching, Germany

The characterization of the elemental composition of surfaces is of high importance for the understanding of many surface processes such as surface segregation or oxidation. These processes may significantly affect the macroscopic properties of thin films or nano particles such as the magnetization in the system Fe/Pt. Positron annihilation induced Auger Electron Spectroscopy (PAES) is a powerful technique to gather information about the elemental composition of only the topmost atomic layer of a sample. The positron beam facility NEPOMUC at the research reactor Heinz Maier-Leibnitz delivers a high-intensity positron beam with an intensity of 10^9 e^+/s. Thus, time-dependent PAES becomes possible and enables an in-situ observation of the surface segregation process.

The upgraded surface spectrometer at NEPOMUC uses the complementary techniques PAES, XPS and STM for a comprehensive surface analysis and enables the characterization of the elemental composition and the surface topology. Recent studies on the surface of Pt and Fe/Pt with PAES, XPS and STM will be presented.