TT 116: Spintronics (incl. Quantum Dynamics) (jointly with MA, HL)

Time: Friday 9:30–12:00 Location: EB 202

Invited Talk TT 116.1 Fri 9:30 EB 202

Antiferromagnetic spintronics — •Tomas Jungwirth — Institute of Physics v.v.i., ASCR, Prague, Czech Republic

Atiferromagnets (AFMs) have for decades played a passive role in conventional spin-valve structures where they provide pinning of the reference ferromagnetic layer. This implies that on one hand, incorporation of some AFM materials in common spintronic structures is well established. On the other hand, limiting their utility to a passive pinning role leaves a broad range of spintronic phenomena and functionalities based on AFMs virtually unexplored. Apart from the insensitivity to magnetic fields and the lack of stray fields, AFMs are common among metals, semiconductors, and insulators and can have orders of magnitude shorter spin-dynamics timescales, to name a few immediate merits of the foreseen concept of AFM spintronics. Several non-relativistic and relativistic spin-transport phenomena have been proposed for AFMs to complement or replace ferromagnets in active parts of spintronic devices. We will focus on the theory of relativistic phenomena and their utility in experimental AFM magneto-resistors, memories, and structures in which AFMs are employed to control ferromagnets electrically.

J. Zelezny et al., Phys. Rev. Lett. 113 (2014) 157201 I. Fina et al., Nature Commun. 5 (2014) 4671 X. Marti et al., Nature Mater. 13 (2014) 367 P. Wadley et al., Nature Commun. 4 (2013) 2322 B.G. Park et al., Nature Mater. 10 (2011) 347

TT 116.2 Fri 10:00 EB 202

Stability of a single spin against readout — •Christoph Hübner[1], Benjamin Baxevanis[1,2], Alexander A. Khajetoorians[3,4], and Daniela Pfannkuche[1] — [1]I. Institute for Theoretical Physics, Hamburg University, Hamburg, Germany — [2]Lorentz Institute, Leiden University, Leiden, The Netherlands — [3]Institute of Applied Physics, Hamburg University, Hamburg, Germany — [4]Institute of Applied Physics, Radboud University Nijmegen, Nijmegen, The Netherlands

A magnetic atom or cluster is extremely sensitive to interactions with a scanning tunneling microscope (STM), that is used to read and write the magnetic state [1]. On the other hand the symmetry of the substrate allows magnetic adatoms to retain their magnetization for minutes, which is extremely long on an atomic time scale [2]. We systematically study this protection against magnetization fluctuations in the presence of a magnetic field and scattering with electrons from the STM and substrate with a non-equilibrium master equation. A combination of spin and substrate symmetry is proposed that produces a stable magnetic orientation even in the presence of a magnetic field [3]. Additionally characteristic features are presented that allow to deduce the spin and substrate symmetry by measurement.

[1] A. A. Khajetoorians et al., Science 339, 55 (2013)
[2] T. Miyamachi et al., Nature 503, 242 (2013)
[3] C. Hübner et al., Phys. Rev. B 90, 155134 (2014)

TT 116.3 Fri 10:15 EB 202

Electric field as a tool for tuning quantum entanglement in supported clusters — •Oleg O. Brovko, Oleg V. Farberovich, and Valeri S. Stepanyuk — Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany

Electric field has been recently gaining in reputation as a versatile tool for tuning adsorption, electronic and magnetic properties of nanostructures. In the present contribution we show that using this tool it is also possible to tune quantum entanglement of spins in small clusters on metallic surfaces. Relying on a combination of ab initio and Heisenberg-Dirac-Van Vleck quantum spin Hamiltonian calculations we show by the example of a typical transitional metal dimer (Mn) on Ag(001) surface, that in an inherently unentangled system, electric field can "switch on" the entanglement and change its critical temperature parameter by orders of magnitude. The physical mechanism allowing such rigorous control of entanglement by electric field is shown to be the field- induced change in the internal coupling of the supported nanostructure.

TT 116.4 Fri 10:30 EB 202

Transmission through correlated Cu_nCoCu_n heterostructures — •Liviu Chioncel[1], Cristian Morari[2], Ivan Runger[3], Andrea Drogetti[3], Andreas Oestlin[4], Ulrich Eckern[5], and Andrei Postnikov[6] — [1]Theoretical Physics III, Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, D - 86135 Augsburg, Germany — [2]National Institute for Research and Development of Isotopic and Molecular Technologies, 65-103 Donath, RO-400293 Cluj Napoca, Romania — [3]School of Physics and CRANN, Trinity College, Dublin 2, Ireland — [4]Department of Materials Science and Engineering, Applied Materials Physics, KTH Royal Institute of Technology, Stockholm SE - 100 44, Sweden — [5]Theoretical Physics II, Institute of Physics, University of Augsburg, D - 86135 Augsburg, Germany — [6]LCP-A2MC, Institute Jean Barriol, University of Lorraine 1, Bd Arago, F - 57078 Metz, France

We study the effects of local electronic interactions and finite temperatures upon the transmission across the Cu_4CoCu_4 metallic heterostructure in a combined density functional and dynamical mean field theory. We show that the total transmission at the Fermi level is reduced as the electronic correlations are taken into account via a local but dynamic self-energy, whereby such a reduction is more pronounced in the minority spin channel. Consequently, the spin polarization of the transmission increases. Our results also demonstrate that the enhancement in spin contrast is in mainly driven by interaction rather than finite temperature fluctuations.

TT 116.5 Fri 10:45 EB 202

Tricky details of tunnel magnetoresistance — •Christian Franz, Michael Czerner, and Christian Heiliger — I. Physikalisches Institut, Justus Liebig University, Giessen, Germany

The basic mechanism responsible for the large TMR in coherent tunnel junctions has already been clarified in the first publications [1,2]. These predictions initiated a broad investigation continuing for more than a decade. Nevertheless, the quantitative understanding of TMR is still incomplete. In particular, the agreement between experiments and calculations remains deficient. The reason for these shortcomings is a complicated interplay of many effects, several of which are not yet fully understood.

We contribute by investigating several effects in great detail using advanced *ab initio* methods [3]. In particular, we discuss the effects of disorder, several interface resonance states and bulk states of different materials. These effects are illustrated by the example of $Fe_{1-x}Co_x$ alloys as ferromagnetic layers [4] which show substitutional disorder for finite concentrations, a complicated concentration dependence of the interface resonance states and variety of bulk states which become available via band filling.

[1] W.H. Butler, X.-G. Zhang, T.C. Schulthess, J.M. MacLaren, Phys. Rev. B 63, 054416 (2001)
[2] J. Mathon, A. Umerski, Phys. Rev. B 63, 220403 (2001).
[3] C. Franz, M. Czerner, C. Heiliger, J. Phys.: Condens. Matter 25, 425301 (2013).
[4] C. Franz, M. Czerner, C. Heiliger, Phys. Rev. B 88, 094421 (2013).

TT 116.6 Fri 11:00 EB 202

Electronic transport in carbon nanotube quantum dots functionalized with magnetic molecules — •Carola Meyer[1,2], Claire Besson[1,2], Michael Schnee[1,2], Henrik Flötotto[3], Robert Frielinghaus[1,2], Lothar Houben[2,4], Paul Kögerler[2,3], and Claus M. Schneider[1,2] — [1]Peter Grünberg Institut, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]JARA - Fundamentals of Future Information Technologies, Germany — [3]RWTH Aachen University, Institute for Inorganic Chemistry, 52074 Aachen, Germany — [4]Ernst Ruska-Center for Microscopy and Spectroscopy with Electrons, Forschungszentrum Jülich, 52425 Jülich, Germany

Transport devices built from individual functionalized carbon nanotubes (CNTs) show great potential for instance in spintronics applications. We graft magnetic complexes to CNTs [1]. The route for the CNT functionalization is very general, based on ligand exchange, and can be applied for different molecules, in particular SMMs. We present first quantum transport measurements on individual functionalized CNTs that prove only weak distortion of the electron wave function by the covalent functionalization. The g-factor of the chemically modified CNT quantum dot (QD) is much smaller compared to pristine CNT QDs indicating spin interaction between the QD and the attached molecules. A clear random telegraph signal is recorded de-

pending on the states of the QD. Origin of timescale and energy of the signal are discussed. [1] Meyer, C. et al., Phys. Status Solidi B 249, 2412(2012)

TT 116.7 Fri 11:15 EB 202

Spin transport and its gate-induced modulation in non-degenerate Si at room temperature — •Masashi Shiraishi[1], Tomoyuki Sasaki[2], Yuichiro Ando[1], Makoto Kameno[1], Hayato Koike[2], Toshio Suzuki[3], and Tohru Oikawa[2] — [1]Kyoto Univ., Japan — [2]TDK Corporation, Japan — [3]AIT, Akita Prefectural Industrial Center, Japan

Si spintronics has been collecting tremendous attention, because of its long spin lifetime and achievement of spin transport at room temperature (RT) [1,2]. In the course of our study in Si spintronics, we have revealed that the so-called 3-terminal method [3] cannot completely preclude spurious signals [4], which is now widely recognized [5-7]. Here, we introduce some methods enabling to avoid detection of spurious signals, and report on reliable RT spin transport in non-degenerate n-type Si and gate-induced modulation of spin signals [8]. This is the first experimental demonstration of spin MOSFET at RT, which can pave a way to establish spin-based logic systems.

[1] T. Suzuki, T. Sasaki, M. Shiraishi et al., Appl. Phys. Express 4, 023004 (2011). [2] E. Shikoh, M. Shiraishi et al., Phys. Rev. Lett. 110, 127201 (2013). [3] S. Dash et al., Nature 462, 491 (2009). [4] Y. Aoki, M. Shiraishi et al., Phys. Rev. B86, 081201(R) (2012). [5] O. Txoperena et al., Appl. Phys. Lett. 102, 192406 (2013). [6] T. Uemura et al., Appl. Phys. Lett. 101, 132411 (2012). [7] O. Txoperena, H. Dery et al., Phys. Rev. Lett. 113, 146601 (2014). [8] T. Sasaki, M. Shiraishi et al., Phys. Rev. Applied 2, 034005 (2014).

TT 116.8 Fri 11:30 EB 202

Spin transfer by pure spin current at magnetic interfaces — •Wei Chen[1], Manfred Sigrist[2], Jairo Sinova[3], and Dirk Manske[1] — [1]Max Planck Institute for Solid State Research, Stuttgart — [2]ETH-Zurich, Zurich, Switzerland — [3]Johannes Gutenberg University-Mainz, Mainz

We present a microscopic theory for the spin transfer torque, spin pumping, spin mixing conductance, and Onsager relation caused by the pure spin current in the normal metal/ferromagnetic insulator bilayer (such as Pt/YIG) and normal metal/ferromagnetic metal/oxide trilayer (such as Pt/Co/AlO_x). The spin Hall effect in the normal metal generates a pure spin current which, upon quantum tunneling into the ferromagnet, causes the magnetization dynamics. The field-like and damping-like component of these spin-transfer quantities are expressed in terms of characteristic energy scales such as the insulating gap and $s-d$ hybridization, which are applicable to a wide range of materials, hence the result can guide the search for materials that have a particular function in spin transport.

TT 116.9 Fri 11:45 EB 202

Spin pumping experiments in Gadolinium Iron Garnet/Pt thin films — Johannes Lotze[1], •Kathrin Ganzhorn[1], Stephan Geprägs[1], Francesco Della Coletta[1], Rudolf Gross[1,2,3], and Sebastian T. B. Goennenwein[1,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, TU München, Garching, Germany — [3]Nanosystems Initiative Munich, München, Germany

Magnetically compensated rare earth garnets, such as Gadolinium Iron Garnet ($Gd_3Fe_5O_{12}$, GdIG), exhibit a pronounced temperature dependence of the sublattice magnetizations, leading to a magnetization compensation temperature $T_{\mathrm{comp,\ M}}$. The investigation of spin currents in GdIG/Pt heterostructures thus can give important insight into the processes involved in the spin current generation in ferrimagnetic insulator/Pt bilayers. Temperature dependent spin Seebeck effect experiments have recently been performed in GdIG/Pt thin film samples [1], revealing two sign changes of the spin Seebeck voltage, a first one at $T_{\mathrm{comp,\ M}}$ and a second one at a lower temperature. We have performed microwave heating induced spin Seebeck together with spin pumping measurements as a function of temperature in doped GdIG/Pt heterostructures. Our experiments confirm the temperature dependent evolution of the spin Seebeck voltage reported in Ref. [1]. We critically discuss this evolution and compare it to the temperature dependence of the spin pumping voltage observed.

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[1] S. Geprägs *et al.*, arXiv 1405.4971 (2014)