MA 44: Spininjection / Spin currents in heterostructures

Time: Thursday 15:00–18:00 Location: H31

MA 44.1 Thu 15:00 H31

room temperature spin transport in n-type Ge — •Masashi Shiraishi[1], Sergey Dushenko[1,2], Yuichiro Ando[1], Teruya Shinjo[1], and Maksym Myronov[3] — [1]Kyoto University, Japan — [2]Osaka University, Japan — [3]Univ. Warwick, UK

After the success of room temperature (RT) spin transport in Si [1,2] and RT operation of spin MOSFET using Si [3,4], the next milestone in semiconductor spintronics was set to realization of RT spin transport in Ge because carrier mobility of Ge is larger than that in Si. Much effort has been dedicated for the realization, the temperature range of the spin transport in Ge was limited below 225 K when an electrical method was used [5,6]. We introduced the other potential method for spin injection and transport in semiconductor, i.e., dynamical spin pumping. In this presentation, we report on RT spin transport in n-type Ge, where spin diffusion length is estimated to be ca. 600 nm [7]. Temperature dependence of the spin diffusion length tells us that the spin relaxation is induced by impurity scattering. The detail is discussed in the presentation.

[1] T. Suzuki, M. Shiraishi et al., Appl. Phys. Express 4, 023003 (2011). [2] E. Shikoh, M. Shiraishi et al., Phys. Rev. Lett. 110, 127201 (2013). [3] T. Sasaki, M. Shiraishi et al., Phys. Rev. Applied 2, 034005 (2014). [4] T. Tahara, M. Shiraishi et al., Appl. Phys. Express 8, 113004 (2015). [5] Y. Zhou et al., Phys. Rev. B84, 125323 (2011). [6] K. Kasahara et al., Appl. Phys. Express 7, 033002 (2014). [7] S. Dushenko, M. Shiraishi et al., Phys. Rev. Lett. 114, 196602 (2015).

MA 44.2 Thu 15:15 H31

Charge neutral tunneling spectroscopy using spin Hall effect — •Wei Chen and Manfred Sigrist — ETH Zurich, Switzerland

When charge current passes through a normal metal that exhibits spin Hall effect, spin accumulates at the edge of the sample in the transverse direction. We predict that the accumulated spin can quantum tunnel through an insulator or vacuum to reach a metallic or insulating magnet without transferring charge, realizing the spintronic analog of field emission. This quantum tunneling of spin causes a spin-transfer torque, and implies a new type of charge neutral tunneling spectroscopy that can probe the magnetic excitation of a bulk insulator or a metallic thin film in a noninvasive manner. [1] W. Chen, M. Sigrist, J. Sinova, and D. Manske, Phys. Rev. Lett. 115, 217203 (2015).

MA 44.3 Thu 15:30 H31

Electrical Spin Injection into an Inverted 2DEG Structure — •Martin Buchner, Thomas Kuczmik, Martin Oltscher, Mariusz Ciorga, Josef Loher, Dieter Schuh, Tobias Korn, Christian Schüller, Dominique Bougeard, Dieter Weiss, and Christian Back — Department of Physics, Regensburg University, 93053 Regensburg, Germany

In 1990 Datta and Das proposed a novel transistor concept, which utilizes the electron's spin as a new degree of freedom [1]. The current modulation arises from spin precession, which originates from the Bychkov-Rashba-term of spin-orbit-interaction. One key ingredient for the experimental realization of the device is spin injection into a two-dimensional electron gas (2DEG), which turned out to be a challenging task.

In this study, we demonstrate spin injection into a high mobility 2DEG, investigated by means of scanning Kerr microscopy at the cleaved edge of the sample. In detail, we investigate samples with the 2DEG confined at an (Al,Ga)As/GaAs interface; ferromagnetic (Ga,Mn)As contacts are used as spin aligners. Former investigations on these structures have shown a strong enhancement of the nonlocal voltage signal for certain bias conditions [2]. We probe the spatial distribution of the spins with the aid of a diode laser directly underneath the injecting contact. Hanle depolarization gives a measure for the spin lifetimes.

[1] S. Datta, B. Das, Appl. Phys. Lett. 56, 665 (1990).
[2] M. Oltscher et al., Phys. Rev. Lett. 113, 236602 (2014).

MA 44.4 Thu 15:45 H31

Skew-scattering Anomalous and Spin Hall effects in $L1_0$-ordered FePt alloys — •Bernd Zimmermann, Nguyen H. Long, Phivos Mavropoulos, Stefan Blügel, and Yuriy Mokrousov — Peter Grünberg Institut & Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

The Spin Hall effect (SHE) and inverse SHE are of fundamental importance for spinorbitronics, as they are the main source of spin current generation and detection. Intimately related is the anomalous Hall effect (AHE), which in addition appears in magnetic materials. New insights into the common underlying mechanisms can be anticipated from a combined study of both. Here, we turn our attention to the $L1_0$-ordered FePt alloy and determine by *ab-initio* calculations the disorder-induced skew-scattering contribution to AHE and SHE. We investigate the role of different antisite-defects, such as Pt atoms occupying Fe sites (and vice versa) where the stoichiometry deviates from the 1:1 ratio, or where the ideal stoichiometry remains but nearest-neighbor Fe and Pt atoms switch sites and form a dimer. Our results reveal that Fe-antisite defects show the largest Hall angles of about 1%, which is of the same order of magnitude as experimentally measured Hall angles [1]. On the contrary, Hall angles for Pt-antisite defects are smaller in magnitude and of different sign. As we show, the effect of FePt-dimers can only be addressed by explicit *ab-initio* calculations, while the approximative Matthiessen rule greatly fails.

[1] K.M. Seemann *et al.*, Phys. Rev. Lett. **104**, 076402 (2010).

MA 44.5 Thu 16:00 H31

Spin-Hall magnetoresistance and spin Seebeck effect in non-collinear magnetic insulators — •Aisha Aqeel[1], Nynke Vlietstra[1], Jeroen A. Heuver[1], Gerrit E. W. Bauer[2,3], Beatriz Noheda[1], Bart J. van Wees[1], and Thomas T. M. Palstra[1] — [1]Zernike Institute for Advanced Materials, University of Groningen, The Netherlands — [2]Institute for Materials Research and WPI-AIMR, Tohoku University, Sendai, Miyagi 980-8577, Japan — [3]Kavli Institute of NanoScience, Delft University of Technology, Lorentzweg 1, 2628 CJ Delft, The Netherlands

Recently, the spin-Hall Magnetoresistance (SMR) and the spin Seebeck effect (SSE) have attracted much interest in the field of spintronics. However, these effects have been studied only for collinear magnetic systems. The nature and sensitivity of these effects in non-collinear magnetic insulators is still unknown. Here, we present a study of the SMR and the SSE in a non-collinear magnetic insulator $CoCr_2O_4$ (CCO) with Pt contacts. $CoCr_2O_4$ (CCO) is a spinel with a collinear ferrimagnetic state below $T_c = 94$ K and non-collinear magnetic phases at lower temperatures. Through lock-in detection technique, we show the existence of the SMR and the SSE in different magnetic phases. We observe a large enhancement in SMR and SSE in the non-collinear phase of the CCO, which indicates that the interaction between spins at the Pt|CCO interface is more efficient in the non-collinear magnetic state. Our results show that the spin transport at the Pt|CCO interface is sensitive to different magnetic phases but cannot be explained solely by the bulk magnetization.

15 min. break

MA 44.6 Thu 16:30 H31

Spin-pumping and Inverse Spin-Hall-effect in Strontium ruthenate grown on Yttrium Iron garnet — •Tim Richter[1], Maximilian Paleschke[1], Martin Wahler[1], Frank Heyroth[2], Hakan Deniz[3], Dietrich Hesse[3], and Georg Schmidt[1,2] — [1]Fachbereich Physik, Martin-Luther-Universität Halle Wittenberg, Halle(Saale), Germany — [2]Interdisziplinäres Zentrum für Materialwissenschaften, Halle(Saale), Germany — [3]Max-Planck-Institut für Mikrostrukturphyik, Halle(Saale), Germany

Ferromagnetic oxides recently gained importance due to their application in spintronics. They can exhibit an extraordinary high spin polarization, which can be used for highly efficient tunneling magnetoresistance but also for spin pumping and inverse spin Hall effect invastigations. Especially $Y_3Fe_5O_{12}$ (YIG - ferrimagnetic oxide at room temperature) is a prototypical source for spin pumping because its insulating nature and exceptionally low damping greatly facilitate the experiments. YIG is used for many investigation of ISHE using metals or polymers as a spin sink. Here we show an all-oxide heterostructure consisting YIG as a source and $SrRuO_3$ as a spin sink. Both materials were grown in situ with PLD. Although YIG is grown in a garnet structure and SRO naturally in a perovskite structure, we observe spin-pumping in SRO by FMR-measurements. Even the ISHE in SRO can be detected. We will present results from structural characterization including TEM and electron diffraction as well as from FMR and ISHE measurements. These results open up new possibilities for all oxide heterostructures with different crystal systems in spintronics.

MA 44.7 Thu 16:45 H31

Switchable spin-current in a non-magnetic-metal/ferroelectric tunnel junction — Andrea Neroni, Daniel Wortmann, Stefan Blügel, and •Marjana Ležaić — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

The Rashba effect produces a crystal-momentum dependent spin-splitting of the electronic bands. As a consequence of the inversion symmetry breaking, it is often observed at the surfaces, due to the potential gradient in the direction normal to the surface. In bulk, the splitting is present in some structures with the appropriate symmetry breaking. For example, it was shown [1, 2] that the effect could be observed in ferroelectrics containing heavy elements (such as GeTe).

Using Density Functional Theory calculations, we study a tunnel junction consisting of non-magnetic metallic leads and GeTe as the barrier material. We show that the Rashba-like splitting of the GeTe bands causes a momentum and spin-dependence of the electron-current tunneling probabilities and propose a device which exploits this dependence to obtain a switchable spin-current that can be controlled by the polarization direction of the ferroelectric barrier [3].

We acknowledge the support by Helmholtz Young Investigators Group Programme VH-NG-409.

[1] D. Di Sante et al., Adv. Mater. **25**, 509 (2013). [2] M. Liebmann et al., Adv. Mater. DOI: 10.1002/adma.201503459 (2015) [3] A. Neroni, PhD Thesis, RWTH Aachen

MA 44.8 Thu 17:00 H31

Boltzmann-equation model for spin-dependent transport on ultrashort timescales — •Dennis Michael Nenno and Hans Christian Schneider — Physics Department and Research Center OPTIMAS, University of Kaiserslautern, 67663 Kaiserslautern

Spin-polarized currents have been shown to play an important role in ultrafast demagnetization [1,2,3].

We use a spin-resolved Boltzmann equation to simulate charge and spin dynamics in an iron/gold hetero-structure. The excitation conditions are modeled after the ultrashort laser excitation as in Ref. [1].

The dynamical equation is solved using numerical methods originally applied in plasma physics in a reduced phase space in order to limit the computational cost. Scattering effects are included at the level of the relaxation time approximation. This calculation accounts for microscopic effects such as a k-dependent excitation and deviations from the equilibrium distribution. We study the influence of different excitation spectra injected from the ferromagnetic iron layer into the adjacent nonmagnetic gold slab and their influence on the resulting spin and charge dynamics. In additon, we compare the results with the macroscopic wave-diffusion equations for spin and charge transport [3].

[1] A. Melnikov *et al.*, Phys. Rev. Lett. 107, 076601 (2011).
[2] M. Battiato, K. Carva, and P. M. Oppeneer, Phys. Rev. B 86, 024404 (2012).
[3] S. Kaltenborn, Y. H. Zhu, and H. .C. Schneider, Phys. Rev. B 85, 235101 (2012)

MA 44.9 Thu 17:15 H31

Skyrmions and defects: from pinning to new memory designs — •Jan Müller and Achim Rosch — Institut für Theoretische Physik, Universität zu Köln, Cologne, Germany

In the last few years, magnetic whirls with integer winding number, so-called 'skyrmions', have gained a lot of attention due to their thermal (topological) stability, nanometer scale size, and the ability to be controlled at ultra low current densities. These properties make skyrmions promising candidates for future logic devices and in particular magnetic memory devices. As the most prominent example, the skyrmion racetrack memory has been proposed.

Using numerical and analytical calculations, we investigated the interaction of a single skyrmion with different kinds of single defects. We will present the possible phases of interaction [1]. Finally we will motivate an alternative to the skyrmion racetrack, that is supposed to take care of most of its disadvantages and be a realistic candidate for skyrmion memory devices.

[1] J. Müller and A. Rosch, Phys. Rev. B 91, 054410

MA 44.10 Thu 17:30 H31

Investigation of the spin pumping effect in epitaxially grown Fe/MgO/Pt systems — •Mihalceanu L.[1], Keller S.[1], Conca A.[1], Pliatsikas N.[2], Karfaridis D.[2], Vourlias G.[2], Hillebrands B.[1], and Papaioannou E. Th.[1] — [1]TU Kaiserslautern, Erwin-Schrödinger-Straße 1, 67663 Kaiserslautern — [2]Dep. of Physics, Aristotle University of Thessaloniki, 54124 Thessaloniki, GR

Understanding and improving the generation of spin currents at the interface of thin ferromagnetic (FM)/ non magnetic (NM) and FM/ Insulator (I)/NM stacks provides a challenging opportunity for developing faster data-processing nanoelectronics devices with low energy consumption. Here we investigate the influence of an MgO tunneling barrier in Fe/MgO/Pt systems on the spin pumping effect which is based upon a spin current getting injected from the FM into the NM layer. The injected spin current is detected via the inverse spin Hall effect (ISHE). The signal is analysed by fitting a symmetric and an antisymmetric Lorenzian formula. By means of the spin pumping FMR measurements we demonstrate that an increasing thickness of the MgO interlayer leads to an increased signal of ISHE DC-voltage with a more pronounced dependence of the symmetric part over the antisymmetric one. We correlate our results with structural analysis of the trilayers. Employing X-ray diffraction we show single crystal growth of Pt on top of an MgO interlayer while Fe grows epitaxially on the MgO substrate. X-ray photoemission spectroscopy is also used to reveal the chemical synthesis of the interfaces. Financial support by the Carl Zeiss Stiftung and by the DAAD-PPP GR program are gratefully acknowledged.

MA 44.11 Thu 17:45 H31

Investigation of the unidirectional spin heat conveyer effect in a 200nm thin Yttrium Iron Garnet film — •Olga Wid[1], Jan Bauer[2], Otwin Breitenstein[2], and Georg Schmidt[1,3] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Germany — [2]Max Planck Institute of Microstructure Physics, Halle (Saale), Germany — [3]Interdisziplinäres Zentrum für Materialwissenschaften, MLU Halle-Wittenberg, Germany

In 2013 An et al. have shown that nonreciprocal spin waves, so-called Damon-Eshbach modes, can be used to transport heat. The direction of the heat flow is independent from thermal gradients and can be switched by reversing the applied magnetic field [1]. The measurements reported so far were performed with an infrared camera on YIG films with thicknesses of few micrometers to hundreds of micrometers. We are able to demonstrate the unidirectional spin heat conveyer effect even on a 200nm thin YIG film, using Lock-in thermography [2]. In our measurements we can discern temperature differences smaller than 1 mK. These results are important for measurement of the inverse spin-hall effect (ISHE) and spin caloritronics, showing that small temperature differences can be created even in thin layers when Damon-Eshbach modes are involved. These can easily lead to thermovoltages with exactly the same signature as the ISHE voltage which also reverses sign with the magnetic field [3]. [1] T. An et al., Nat Mater 12, 549 (2013) [2] O. Breitenstein, M. Langenkamp, "Lock-in Thermography: Basics and Use for Functional Diagnostics of Electronic Components", Springer (2003) [3] Z. Qiu, AIP Advances 5, 057167 (2015)