MA 36: Spincaloric Transport II (jointly with TT)

Time: Thursday 9:30–12:15 Location: HSZ 04

MA 36.1 Thu 9:30 HSZ 04

6000 % tunnel magneto-Seebeck effect under applied bias — •Alexander Boehnke[1], Marius Minikel[2], Marvin Walter[2], Vladylsav Zbarsky[2], Karsten Rott[1], Andy Thomas[1], Markus Münzenberg[2], and Günter Reiss[1] — [1]Thin Films and Physics of Nanostructures, Bielefeld University, Germany — [2]I. Physikalisches Institut, Georg-August-Universität Göttingen, Germany

Recently, significantly different values of the tunnel magneto-Seebeck effect (TMS) [1-5] have been reported when the material system of the magnetic tunnel junction (MTJ) is changed. Ab initio calculations shine first light on the origin of these differences, as they propose a strong influence of the lead material on the TMS [6]. We applied an additional bias voltage V_{Bias} to MTJs while measuring the TMS.

This well-defined tuning of the electrodes' Fermi level positions allows to compare the bias voltage dependence of the TMS with the theoretical predictions. We demonstrate drastically changing TMS ratios of up to 6000 % generated by the variation of the bias voltage. At certain values of V_{Bias}, an on/off behavior of the Seebeck voltage is found when the magnetization alignment of an MTJ is reversed. These findings are in good agreement with the ab into calculations [6].

[1] M. Walter et al. (2011). Nat. Mater., 10(10), 742.
[2] N. Liebing et al. (2011). Phys. Rev. Lett., 107(17), 177201.
[3] W. Lin et al. (2012). Nat. Commun., 3, 744.
[4] N. Liebing et al. (2013). Appl. Phys. Lett., 102(24), 242413.
[5] A. Boehnke et al. (2013). Rev. Sci. Instrum., 84(6), 063905.
[6] C. Heiliger et al. (2013). Phys. Rev. B, 87(22), 224412.

MA 36.2 Thu 9:45 HSZ 04

Thin film studies of the spin Seebeck effect in insulating ferrimagnets — •Andreas Kehlberger[1], Gerhard Jakob[1], Ulrike Ritzmann[2], Denise Hinzke[2], Ulrich Nowak[2], Mehmet Onbasil[3], Dong Hun Kim[3], Caroline A. Ross[3], Matthias Benjamin Jungfleisch[4], Burkard Hillebrands[4], and Mathias Kläui[1] — [1]University of Mainz, D-55099 Mainz — [2]University of Konstanz, D-78457 Konstanz — [3]Massachusetts Institute of Technology, USA MA-02139 — [4]Technische Universität Kaiserslautern, D-67663 Kaiserslautern

One of the most basic and still unresolved questions is the origin of the spin-Seebeck effect (SSE) in magnetic insulators. Recent studies focused on the investigation of the dependence of the SSE on material parameters in bulk material [1], while for applications thin films are more appropriated. We study the longitudinal SSE (LSSE) in thin film garnets grown by PLD, which allows us to probe the dependence of the SSE on magnetic material parameters as well as on the thickness of the ferromagnetic material, revealing a relevant length scale for the LSSE in the order of 100 nm in YIG. A comparison with the magnetoresistance allows us to estimate its contributions and to identify the genuine origin of the SSE in the bulk of the YIG [2]. Beyond YIG, we study other garnets at variable temperatures to determine the SSE dependence on the dominating sub-lattice that governs the effective magnetic moment in a ferrimagnet [3]. [1] K. Uchida et al., Phys. Rev. B 87, 104412 (2013) [2] A. Kehlberger et al., arXiv:1306.0784 (2013) [3] Y. Ohnuma et al., Phys. Rev. B 87, 014423 (2013)

MA 36.3 Thu 10:00 HSZ 04

Magnonic spin currents and the spin Seebeck effect — •Ulrike Ritzmann, Denise Hinzke, and Ulrich Nowak — Universität Konstanz

In ferromagnetic insulators spatial temperature gradients can lead to a magnon accumulation [1]. Furthermore, it was shown that the measured voltage of the longitudinal spin Seebeck effect increases with film thicknes, saturating on a characteristic length scale [2].

We perform atomistic spin model simulation with the stochastic Landau-Lifshitz-Gilbert equation to investigate the relevant length scales for magnon accumulation. Supported by an analytical description we first calculate the characteristic length scale of magnon propagation in the vicinity of a temperature step [3]. Then we explore magnon propagation in a linear temperature gradient and determine the mean propagation length of the magnons [2]. Our main finding is that the magnon accumulation at the cold end of the temperature gradient first increases with the the length scale of the temperature gradient and then saturates when reaching the length scale of the magnon propagation. These results can explain the saturation of the longitudinal spin Seebeck effect [2] and can help to understand recent measurements regarding the temporal evolution of the spin Seebeck effect [4].

[1] K. Uchida et al, Nat. Mater. 9, 894 (2010)
[2] A. Kehlberger et al.,arXiv:1306.0784
[3] U. Ritzmann et al., submitted
[4] M. Agrawal et al., arXiv:1309.2164

MA 36.4 Thu 10:15 HSZ 04

Temporal evolution of the longitudinal spin Seebeck effect — •Vitaliy Vasyuchka[1], Milan Agrawal[1,2], Alexander Serga[1], Akihiro Kirihara[1,3], Philipp Pirro[1], Thomas Langner[1], Frank Heussner[1], Benjamin Jungfleisch[1], Andrii Chumak[1], Evangelos Papaioannou[1], and Burkard Hillebrands[1] — [1]FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz — [3]Smart Energy Research Laboratories, NEC Corporation, Tsukuba, Japan

The spin Seebeck effect (SSE) is one of the most fascinating phenomena in the contemporary period of spin caloritronics. Further advancements in industrial applications like temperature gradient sensors and thermal spin-current generators require an in-depth understanding of this effect. We developed an experimental approach where we studied the temporal evolution of the SSE in YIG/Pt bilayer structures in the longitudinal configuration. Our findings reveal that this effect is a submicrosecond fast phenomenon governed by the temperature gradient and the thermal magnons diffusion in the magnetic material. A comparison of our experimental results with the thermal-driven magnon-diffusion model shows that the temporal behavior of the SSE depends on the time development of the temperature gradient in the vicinity of the YIG/Pt interface. The effective thermal-magnon diffusion length for our YIG/Pt system is estimated to be around 500 nm.

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MA 36.5 Thu 10:30 HSZ 04

Thermally driven domain wall motion — •Frank Schlickeiser, Ulrike Ritzmann, Denise Hinzke, and Ulrich Nowak — University Konstanz, 78457 Konstanz, Germany

The existence of thermally driven domain wall (DW) motion caused solely by magnonic spin currents was forecast on the basis of computer simulations [1]. Recently, this effect has been measured in a magnetic insulator [2]. A deeper understanding of this effect is of great interest, since it potentially opens the door for new ways to control and manipulate domain structures in spintronic devices.

We present an analytical calculation of the DW velocity as well as the Walker threshold within the framework of the Landau Lifshitz Bloch equation [3] describing the dynamics of the thermally averaged spin polarization on micromagnetic length scales. We demonstrate analytically that the temperature gradient leads effectively to a spin transfer torque where the domain wall is mainly driven by the temperature dependence of the exchange stiffness, or — in a more general picture — by the maximization of entropy. We find a linear dependence of the averaged DW velocity on the temperature gradient in agreement with the experiment [2]. The approximations in our analytical calculation are verified by numerical simulations.

We acknowledge financial support by the DFG through SFB 767.

References: [1] D. Hinzke and U. Nowak, Phys. Rev. Lett. 107, 027205 (2011), [2] W. Jiang et al., Phys. Rev. Lett. 110, 177202 (2013), [3] D. A. Garanin, Phys. Rev. B 55, 3050 (1997).

15 min. break

MA 36.6 Thu 11:00 HSZ 04

Spin disorder effect on the spin-caloric transport properties in magnetic nanostructures from first principles — •Roman Kováčik, Phivos Mavropoulos, Daniel Wortmann, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

An important contribution to the thermoelectric and spin-caloric transport properties in magnetic materials at elevated temperatures is the formation of a spin-disordered state due to the local moment fluctuations. This effect has not been largely investigated so far. We focus on various magnetic nanostructures, motivated by the miniaturization of spintronics devices and by recent suggestions that magnetic nanostructures can lead to extraordinary thermoelectric effects due to quantum confinement [1]. The electronic structure of the studied systems is calculated within the multiple scattering screened Korringa-Kohn-Rostoker Green function (KKR-GF) framework [2]. The Monte-Carlo methodology is used to simulate the effect of temperature induced spin disorder and the transport properties are evaluated from the transmission probability obtained using the Landauer-Büttiker approach for the ballistic transport within the KKR-GF framework [3]. We find qualitative and quantitative changes in the thermoelectric and spin-caloric coefficients in the case that spin-disorder is included in the calculation. Support from the DFG (SPP 1538) is gratefully acknowledged.

[1] N. Vu *et al.*, APEX 4, 015203 (2011).
[2] N. Papanikolaou *et al.*, JPCM 14, 2799 (2002), also see: kkr-gf.org.
[3] Ph. Mavropoulos *et al.*, PRB 69, 125104 (2004).

MA 36.7 Thu 11:15 HSZ 04

Spin caloric transport in alloys from first-principles — •Sebastian Wimmer, Diemo Ködderitzsch, Kristina Chadova, and Hubert Ebert — Ludwig-Maximilians-Universität, München, Deutschland

A fully relativistic implementation of the Korringa-Kohn-Rostoker coherent potential approximation (KKR-CPA) band structure method [1] in conjunction with Kubo's linear response theory is employed to investigate various transport properties of bulk transition metal alloys. Special emphasis is put on spin-orbit coupling induced phenomena of thermo(-magneto)-electric transport in para- as well as ferromagnetic systems such as spin and anomalous Nernst effects and the anisotropy of the Seebeck effect [2,3]. These transverse and longitudinal responses to a temperature gradient are compared to their respective (magneto-)electric counterparts, the spin and anomalous Hall effects and the anisotropic magnetoresistance. For the transverse effects a decomposition into intrinsic and extrinsic (skew scattering and side-jump) contributions is performed, based on vertex corrections and scaling laws.

[1] H. Ebert, D. Ködderitzsch, and J. Minár, Rep. Prog. Phys. **74**, 096501 (2011).
[2] S. Wimmer, D. Ködderitzsch, K. Chadova, and H. Ebert, PRB **88**, 201108(R) (2013).
[3] S. Wimmer, D. Ködderitzsch, and H. Ebert, arXiv:1311.2498 [cond-mat.mtrl-sci] (2013).

MA 36.8 Thu 11:30 HSZ 04

Static proximity investigations on Pt/$NiFe_2O_4$ and Pt/Fe bilayers using x-ray resonant magnetic reflectivity — •Timo Kuschel[1], Christoph Klewe[1], Jan-Michael Schmalhorst[1], Florian Bertram[2], Olga Schuckmann[3], Tobias Schemme[3], Joachim Wollschläger[3], Arunava Gupta[4], Gerhard Götz[1], Daniel Meier[1], and Günter Reiss[1] — [1]Bielefeld University, Germany — [2]Lund University, Sweden — [3]Osnabrück University, Germany — [4]University of Alabama, Tuscaloosa Alabama, USA

When Pt is used to detect spin currents in an attached magnetic film via the inverse spin Hall effect, parasitic charge based effects can be induced due to spin polarization in Pt generated by static proximity. For example, in spin caloritronics the anomalous Nernst effect (ANE) can contribute to the longitudinal spin Seebeck effect (LSSE) signal when an out-of-plane temperature gradient is applied. In case of Pt/YIG Lu et al. [1] observed a spin polarization in Pt via XMCD, while Geprägs et al. [2] found no evidence for static proximity in Pt/YIG. Recently, we have observed the LSSE in $NiFe_2O_4$ (NFO) thin films [3]. Now, we used x-ray resonant magnetic reflectivity (XRMR) to exclude the ANE. XRMR is interface sensitive and therefore, mainly independent of the Pt thickness, which makes it preferable over XMCD. For Pt/Fe we clearly detect an XRMR signal of some %, while for Pt/NFO we can exclude any effect within our detection limit of $< 0.05\,\%$.

[1] Y. M. Lu et al., Phys. Rev. Lett. 110, 147207 (2013)
[2] S. Geprägs et al., Appl. Phys. Lett. 101, 262407 (2012)
[3] D. Meier et al., Phys. Rev. B. 87, 054421 (2013)

MA 36.9 Thu 11:45 HSZ 04

Thermally induced spin accumulation at Al/Co_2TiSi and Al/Co_2TiGe contacts — •Voicu Popescu, Benjamin Geisler, and Peter Kratzer — Faculty of Physics, University Duisburg-Essen, Duisburg, Germany

Spin injection from a ferromagnet in a semiconductor subtrate can be accomplished either by applying an external voltage or a temperature gradient. In the latter case, one exploits the Seebeck effect, with the temperature gradient across the contact directly resulting in a difference in chemical potentials in the two spin channels due to the spin-dependence of the Seebeck coefficient.

The magnetic Heusler alloys Co_2TiSi or Co_2TiGe exhibit half-metallic ferromagnetism in their ideal $L2_1$ crystal structure, with a potentially high degree of spin polarization of the injected current. As such, they recommend themselves for integrated spin injectors in combination with the closely lattice-matched Al contact layer.

We investigate the possibility of employing Al/Co_2TiX/Al (X=Si,Ge) trilayers as thermally driven spin injectors by means of first-principles calculations of the electronic structure and of the thermoelectric transport properties. Our results show that the spin-dependent Seebeck effect is sensitive to the atomic structure of the Heusler/Al interface. In particular, for a thin Co_2TiSi or Co_2TiGe layer terminated by a TiSi or TiGe atomic plane, the thermal spin accumulation is found to be of the same order of magnitude as the conventional, effective Seebeck coefficent.

MA 36.10 Thu 12:00 HSZ 04

Influence of heat flow directions on Nernst effects in Py/Pt bilayers — •Daniel Meier[1], Daniel Reinhardt[1], Maximilian Schmid[2], Christian H. Back[2], Jan-Michael Schmalhorst[1], Timo Kuschel[1], and Günter Reiss[1] — [1]University of Bielefeld, D-33501 Germany — [2]University of Regensburg, D-93040 Germany

We investigated the voltages obtained in a thin Pt strip on a Permalloy film which was subject to in-plane temperature gradients and magnetic fields. The voltages detected by thin W-tips or bond wires showed a purely symmetric effect with respect to the external magnetic field which can be fully explained by the planar Nernst effect (PNE). To verify the influence of the contacts measurements in vacuum and atmosphere were compared and gave similar results. We explain that a slightly in-plane tilted temperature gradient only shifts the field direction dependence but does not cancel out the observed effects. Additionally, the anomalous Nernst effect (ANE) could be induced by using thick Au-tips which generated a heat current perpendicular to the sample plane. The effect can be manipulated by varying the temperature of the Au-tips. These measurements are discussed concerning their relevance in transverse spin Seebeck effect measurements.