MA 20: Magnetocaloric effects (joint session MA/TT)

Time: Tuesday 9:30–12:45 Location: EB 407

MA 20.1 Tue 9:30 EB 407

A DFT and Monte Carlo approach to simulating the magnetocaloric effect in magnetovolume-coupled materials — •Nuno Fortunato[1,2], João Amaral[2], Gercsi Zsolt[3], João Gonçalves[2], Vitor Amaral[2], Hongbin Zhang[1], Oliver Gutfleisch[1], Vitalij Pecharsky[4], Karl Sandeman[5], and Lesley Cohen[5] — [1]TU Darmstadt, Germany — [2]CICECO, Universidade de Aveiro, Portugal — [3]Physics, Trinity College Dublin, Ireland — [4]Ames Laboratory, United States — [5]Department of Physics, Imperial College London, United Kingdom

Magnetic refrigeration is an emergent technology promising for eco-friendly and more energy efficient refrigeration applications, using the magnetocaloric effect (MCE). Magnetovolume effects contribute significantly to the MCE, however the estimation of MCE with magnetovolume effects remains a challenge. In this work, we simulate the MCE using a microscopic model solved by Monte Carlo methods that evaluate the thermodynamic density of states. The magnetic interaction (J_{ij}) between local moments is considered a function of volume (v), together with external field (H) and lattice volume terms: $H = -\frac{1}{2}\Sigma J_{ij}(v)S_i.S_j + \frac{1}{2}Kv^2 - HM$, where K is compressibility.

Simulation results are compared with the experimental data of Gd, the typical benchmark material for room-temperature magnetic cooling applications. We show that such a simple model quantitatively reproduces experimental data for the MCE and the magnetostriction. This work paves the way to a 'ground-up', fast computational approach to optimize and search for magnetic refrigerant materials.

MA 20.2 Tue 9:45 EB 407

Spin dynamics of magnetocaloric compounds under magnetic field investigated with inelastic neutron scattering measurements — •Nikolaos Biniskos[1,2], Karin Schmalzl[1], Stephane Raymond[2], and Thomas Brückel[3] — [1]Forschungszentrum Jülich GmbH, Jülich Centre for Neutron Science at ILL, 71 avenue des Martyrs, 38000 Grenoble, France — [2]Univ. Grenoble Alpes, CEA, INAC, MEM, 38000 Grenoble, France — [3]Forschungszentrum Jülich GmbH, Jülich Centre for Neutron Science (JCNS-2) and Peter Grünberg Institut (PGI-4), JARA-FIT, 52425 Jülich, Germany

The magnetocaloric effect (MCE) is a temperature or entropy change of a material subject to a variation of magnetic field and is the basic principle of magnetic refrigeration. This technique is considered as promising for a more environmentally friendly and efficient use of energy. However, the microscopic mechanisms at play are to be revealed and the key ingredients are to be identified in order to design new materials. In order to understand the fundamental driving force of the MCE, a microscopic study of magnetism with inelastic neutron scattering (INS) measurements is necessary. To this aim, the spin dynamics of MnFe4Si3 and Mn5Si3, that exhibit the direct and inverse MCE, respectively, have been investigated with INS measurements under different magnetic fields and temperatures. It is evidenced that the inverse MCE of Mn5Si3, the cooling by adiabatic magnetization, is associated with field induced spin-fluctuations, contrary to the usual suppression of fluctuations by a magnetic field that is observed in the direct MCE of MnFe4Si3 [1]. [1]N. Biniskos et al., Phys. Rev. B 96 104407 (2017).

MA 20.3 Tue 10:00 EB 407

Element-specific view on La(FeSi)$_{13}$ — •Katharina Ollefs[1], Markus E. Gruner[1], Fabrice Wilhelm[2], Andrei Rogalev[2], Ilya Radulov[3], Alexandra Terwey[1], Benedikt Eggert[1], Maria Krautz[4], Konstantin Skokov[3], Werner Keune[1], Oliver Gutfleisch[3], and Heiko Wende[1] — [1]Faculty of Physics and CENIDE, University of Duisburg- Essen, Germany — [2]European Synchrotron Radiation Facility, Grenoble, France — [3]Functional Materials, Technical University Darmstadt, Darmstadt, Germany — [4]Institute for Complex Materials, IFW Dresden, Dresden, Germany

Due to its large magneto-caloric effect, the itinerant electron metamagnet La(FeSi)$_{13}$ is of great interest for its potential use in solid state refrigeration. In order to better understand the magnetic interactions in this material and how they change at the transition, we have performed x-ray absorption measurements. X-ray magnetic circular dichroism measurements in the low temperature phase at the Fe K-edge and La L$_{2,3}$-edges reveal not only a magnetic moment on Fe but also a sizable magnetic moment in the 5d states of La. Magneto-optical sum-rule analysis and DFT calculations indicate an anti-parallel alignement of the Fe and La spin moment and a small orbital moment on La also anti-parallel to spin moment. Disentangling the different magnetic moment contributions in La(FeSi)$_{13}$ may reveal additional sources for hysteresis and might shed light on the thermodynamic role of the particular magnetic degrees of freedom.

Funding by the DFG (SPP1599) is acknowledged.

MA 20.4 Tue 10:15 EB 407

Dynamic effects of the magneto-elastic phase transition in a Fe$_2$P-type magnetocaloric alloy — •Maximilian Fries[1], Pfeuffer Lukas[1], Tino Gottschall[1,2], Franziska Scheibel[1,3], Konstantin Skokov[1], Youri Skourski[2], Mehmet Acet[3], Michael Farle[3], Jochen Wosnitza[3], and Oliver Gutfleisch[1] — [1]Institut für Materialwissenschaft, Technische Universität Darmstadt, 64287 Darmstadt — [2]Hochfeldlabor Dresden (HLD-EMFL), Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden — [3]Fakultät für Physik und CENIDE, Universität Duisburg-Essen, 47057 Duisburg

Magnetic refrigeration could be an efficient alternative refrigeration technology if operated at high cycling frequencies [1]. In order to investigate if the magnetocaloric materials are applicable in a high-frequency cooling device we measured the adiabatic temperature change ΔT_{ad} of a Fe$_2$P-type alloy [2] under different field-change rates ranging from 0.93 Ts^{-1} in a permanent-magnet-based Halbach setup to 2700 Ts^{-1} in pulsed fields. We observed that a field-rate independent second-order like phase transition always overlaps with the first-order phase transition leading to a non-saturating behavior of ΔT_{ad} even in fields up to 20 T. By measurements under different field pulse rates we show that the first-order phase transition cannot follow the fast field changes, resulting in a distinct field-dependent hysteresis of ΔT_{ad}.

[1] O. Gutfleisch et al., Philosophical Transactions of the Royal Society A 374 (2016) 20150308. [2] M. Fries et al., Acta Materialia 132 (2017) 222

MA 20.5 Tue 10:30 EB 407

Decoupling of the magnetostructural transition in magntocaloric La-Fe-Si alloys — •Yanyan Shao[1,2], Konstantin Skokov[2], Francois Guillou[3], Dmitriy Yu Karpenkov[2], Mingxiao Zhang[1], Oliver Gutfleisch[2], and Jian Liu[1] — [1]Ningbo Institute of Material Technology and Engineering, CAS, 315201 Ningbo, China — [2]Material Science, TU Darmstadt, 64287 Darmstadt, Germany — [3]European Synchrotron Radiation Facility, 38000 Grenoble, France

The giant magnetocaloric effect occurs when a magnetic material undergoes a first-order magnetic transition, which usually involves the coupling of magnetic and lattice contributions [1]. In order to investigate in detail the evolution of the magnetostructural phase transition, both magnetocaloric (dT(H)) and magnetovolume (dV(H)) effects in La1.7Fe11.6Si1.4 alloy were measured simultaneously. We observed that under isothermal conditions, only heat transfer occurs first, whereas the structural transition takes place in higher fields, where the heat transfer is already in progress or almost completed. The shift between the magnetic and structural transitions is 0.27 T, which clearly indicates a decoupling effect. The decoupling effect was also confirmed by X-ray absorption (lattice contribution) and by magnetic circular dichroism (change in magnetic system). We will discuss different reasons for the decoupling effect. [1]V. K. Pecharsky et al., Physical Review Letters. 91 (2003) 197204.

MA 20.6 Tue 10:45 EB 407

Correlation of microstructural and magnetic properties of Mn-Fe-P-Si magnetocaloric compounds — •Lukas Pfeuffer[1], Maximilian Fries[1], Enrico Bruder[1], Tino Gottschall[2], Semih Ener[1], Léopold Diop[1], Thorsten Gröb[1], Konstantin Skokov[1], and Oliver Gutfleisch[1] — [1]Fachbereich Materialwissenschaft, TU Darmstadt, 64287, Darmstadt, Germany — [2]Dresden High Magnetic Field Laboratory, Helmholtz-Zentrum Dresden-Rossendorf, 01328, Dresden, Germany

Mn-Fe-P-Si alloys of Fe2P-type are very promising candidates for magnetocaloric applications. Extensive studies dealing with the optimization of the chemical composition have been published in recent years. However, the microstructure and its effect on the thermomagnetic properties are rarely discussed in literature. For this reason, we processed Mn-Fe-P-Si samples using a powder-metallurgical approach and characterized their microstructure and magnetocaloric behaviour. SEM, EDX, EBSD and XRD studies display small amounts of a cubic secondary phase showing a distinct phosphorous depletion and a characteristic arrangement at the triple junctions of the Fe2P grains. A shift in saturation magnetization, transition temperature and isothermal entropy change as a function of the secondary phase fraction can be observed. A significant influence of the metal/non-metal ratio on the above mentioned properties could be investigated. Additionally, all the prepared samples reveal a virgin effect shown thermomagnetically and with temperature dependent optical microscopy.

MA 20.7 Tue 11:00 EB 407

Influence of substitutions, hydrostatic pressure and magnetic field on the MnNiGe system — •Andreas Taubel, Tino Gottschall, Maximilian Fries, Tom Faske, Konstantin P. Skokov, and Oliver Gutfleisch — TU Darmstadt, Institute of Material Science, Alarich-Weiss-Str. 16, 64287 Darmstadt, Germany

An enhancement in the energy efficiency of cooling devices for household refrigeration and air conditioning can provide worldwide savings in energy and CO_2 emissions. An alternative to conventional gas compression refrigerators is solid state based magnetocaloric cooling with the potential of increased energy efficiency. The MM'X materials family provides promising magnetocaloric effects with sharp phase transitions for the MnNiGe and MnCoGe systems.

We studied the isostructural substitutions of Fe for Mn and Si for Ge, which enhance the ferromagnetic character of the low temperature phase, allow for a precise tuning of the transition temperature and reduce the amount of expensive Ge in the compounds. Since a magnetic field shifts the transition temperature by 1 K T^{-1}, the phase transition cannot be induced completely in small fields. We directly measured a maximum adiabatic temperature change of 1.3 K for the first magnetic field application of 1.93 T [1]. Therefore, the large sensitivity towards hydrostatic pressure (72 K GPa^{-1}) enables an additional stimulus to induce the phase transition more efficiently for Fe- and Si-substituted (Mn,Fe)Ni(Ge,Si) compounds.

This work was supported by DFG (Grant No. SPP1599).

[1] A. Taubel et al., J. Phys. D: Appl. Phys. 50, 464005 (2017)

15 minutes break

MA 20.8 Tue 11:30 EB 407

Exploring three-dimensional temperature gradients in magnetic tunnel junctions: Anomalous Nernst effect — Ulrike Martens[1], Torsten Huebner[2], Henning Ulrichs[3], Oliver Reimer[2], Timo Kuschel[2], Ronnie Tamming[4], Chia-Lin Chang[4], Raanan Tobey[4], Andy Thomas[5], Markus Münzenberg[1], and •Jakob Walowski[1] — [1]Universität Greifswald, Greifswald, Germany — [2]Bielefeld University, Bielefeld, Germany — [3]Universität Göttingen, Göttingen, Germany — [4]University of Groningen, Groningen, The Netherlands — [5]IFW Dresden, Institute for Metallic Materials, Dresden, Germany

We measure the anomalous Nernst effect (ANE) generated on a nanometer length scale by micrometer sized temperature gradients in magnetic tunnel junctions (MTJs). The ANE is extracted by analyzing the influence of in-plane temperature gradients on the tunnel magneto-Seebeck effect (TMS) in in-plane magnetized MTJs based on CoFeB electrodes with uniaxial magnetic anisotropy and an MgO tunnel barrier. The direction controlled temperature gradients are created by a focused laser spot. The spatial extent of the measured effects is defined by the MTJ size, while the spatial resolution is given by the laser spot size and the step size of its lateral translation. The measurement method is highly sensitive to low voltages and yields an ANE coefficient of $K_N \approx 1.6 \cdot 10^{-8} \, \frac{\mathrm{V}}{\mathrm{TK}}$ for CoFeB. At such sensitivity, the generated ANE effect allows to expand the MTJs' functionality from simple memory storage to nonvolatile logic devices and opens new application fields e.g. direction dependent temperature sensing.

MA 20.9 Tue 11:45 EB 407

Anomalous Nernst effect in carbon doped Mn_5Ge_3 and Mn_5Si_3 thin films — •Sasmita Srichandan, Sihao Deng, and Christoph Sürgers — Karlsruhe Institute of Technology, Physikalisches Institut, PO Box 6980, 76049 Karlsruhe, Germany

Carbon doped Mn_5Ge_3 shows enhanced magnetic properties compared to pure Mn_5Ge_3 which makes $Mn_5Ge_3C_x$ suitable for spintronics applications. The magnetotransport properties of ferromagnetic Mn_5Ge_3, $Mn_5Ge_3C_{0.8}$ and $Mn_5Si_3C_{0.8}$ systems have been previously investigated [1]. In this present work, the thermal-magnetotransport properties, in particular the anomalous Nernst effect (ANE), have been experimentally investigated in thin films of $Mn_5Ge_3C_{0.8}$, $Mn_5Si_3C_{0.8}$ and Mn_5Ge_3 on Ge (111). The ANE coefficients for all the films show the same positive sign at high temperatures until at about 100 K the sign changes to negative for $Mn_5Ge_3C_{0.8}$ and Mn_5Ge_3 films but not for $Mn_5Si_3C_{0.8}$ film. This behavior follows the same change of sign behavior previously observed in the anisotropic magnetoresistance ratio and ordinary Hall coefficient for these films. The change of sign of the ANE is the direct consequence of the Mott relation in our ferromagnetic films [2] even if the sign of the anomalous Hall coefficient remains unchanged. In addition, a possible contribution from the spin Seebeck effect to the transverse thermo-voltage has been addressed.

[1] C. Sürgers et al. Phys. Rev. B **90**, 104421(2014)
[2] T. Miyasato et al. Phys. Rev. Lett. **99**, 086602(2007)

MA 20.10 Tue 12:00 EB 407

An experimental design to measure the spin Nernst effect — •Sandra Gottwals[1], Thierry Crozes[2], and Georg Schmidt[1,3] — [1]Martin-Luther-Universität Halle-Wittenberg, Institut für Physik, Fachgruppe Nanostrukturierte Materialien, Halle — [2]Institut Néel, CNRS, Grenoble — [3]Martin-Luther-Universität Halle-Wittenberg, Interdisziplinäres Zentrum für Materialwissenschaften, Halle

Like the spin Hall effect to the ordinary Hall effect the spin Nernst effect compares to the Nernst effect. A thermal gradient in a material with sufficient spin orbit coupling generates a spin current and spin accumulation perpendicular to the gradient. We are developing a setup to measure the resulting spin accumulation and magnetic moment using micro SQUIDs. The sample design is rather complex because it needs at least two micro SQUIDs to measure the spin accumulation on two opposite sides of a Pt layer together with superconducting stripes to measure the local temperature. On top of these a Pt layer and a heater with the necessary electrical insulation need to be processed. We present the results and current status of our development. On all superconducting structures the critical current needs to be measured simultaneously.

MA 20.11 Tue 12:15 EB 407

A tool for detecting complex magnetic configurations — •Alexander Fernández Scarioni[1], David Schroeter[2], Xiukun Hu[1], Sibylle Sievers[1], Dirk Menzel[2], Stefan Süllow[2], and Hans W. Schumacher[1] — [1]Physikalish-Technische Bundesanstalt (PTB), Braunschweig, Germany — [2]Institut für Physik der Kondensierten Materie, TU Braunschweig, Germany

The anomalous Nernst effect (ANE) is a simple and powerful tool to detect the average magnetization in a single nanowire. Using this simple thermoelectrical measurement one can precisely track the position and motion of a single Domain Wall in a metallic nanowire with perpendicular magnetization anisotropy with a resolution below 20 nm [1]. This makes the ANE a candidate for detecting the magnetization in nanowires made of complex materials such as the ones that show a Dzyaloshinskii-Moriya Interaction (DMI), even also single skyrmions in nanowires. We are going to show thermoelectric ANE measurements on a nanowire with DMI were we can identify the different components of the magnetization.

[1] P. Krzysteczko et al., Phys. Rev. B. 95, 220410(R) (2017)

MA 20.12 Tue 12:30 EB 407

Magneto-Seebeck Tunneling Across a Vacuum Barrier — •Cody Friesen and Stefan Krause — Department of Physics, University of Hamburg, Jungiusstr. 11A, 20355 Hamburg, Germany

The tunneling magneto-Seebeck (TMS) effect has been intensively studied both for its potential applications in e.g. waste heat recycling in electronics, and for the insights it can provide into fundamental solid state phenomena. This effect has been measured in planar junctions [1] and, as will be described in this talk, can also be measured using spin-polarized scanning tunneling microscopy (SP-STM).

The experiments were performed at low temperatures ($T = 50\,\mathrm{K}$) and in UHV conditions, on the Fe/W(110) multilayer system [2], using a laser-heated bulk Cr tip and active bias compensation. The non-collinear spin structures present in this sample system, and the atomic-scale lateral resolution of SP-STM, allowed for the imaging of a continuous range of relative tip-sample magnetization orientations.

Here, as in planar junctions, the measurement of the temperature gradient between electrodes is a significant challenge. We have estimated the tip-sample temperature difference using a linear thermal tip expansion model. To verify this, we have also directly predicted the Seebeck coefficient S using tunneling bias spectroscopy. We found these approaches to be in good agreement, suggesting a convenient spectroscopic approach to determining S on the atomic scale, even in the absence of a temperature gradient.

[1] M. Walter *et al.*, Nat. Mater. **10**, 10 (2011).
[2] S. Meckler *et al.*, Phys. Rev. Lett. **103**, 15 (2009).