MA 29: Caloric Effects in Magnetic Materials

Time: Thursday 9:30–11:45 Location: H47

MA 29.1 Thu 9:30 H47

"Giant" magnetocaloric effects for 2nd order phase transition near 20 K: a study on rare-earth Laves phases for hydrogen liquefaction — •Wei Liu[1], Franziska Scheibel[1], Tino Gottschall[2], Eduard Bykov[2], Konstantin Skokov[1], and Oliver Gutfleisch[1] — [1]Funktionale Materialien, Technische Universität, TU Darmstadt, Germany — [2]Hochfeld- Magnetlabor Dresden, Helmholtz-Zentrum Dresden-Rossendorf, Germany

Hydrogen will play a key role for building a climate-neutral society, where renewables are the major energy sources [1]. Liquid hydrogen is essential for efficient storage and transport of hydrogen, but expensive due to the low efficiency of traditional gas-compression refrigeration [2]. As an emerging and energy-saving technology, magnetocaloric gas liquefaction can be an a "game-changer". Here we report a noticeable, but unaddressed feature for magnetocaloric hydrogen liquefaction using rare-earth-based intermetallic alloys: magnetocaloric effect of a 2nd order magnetocaloric materials can become "giant" when the Curie temperature TC is near the hydrogen boiling point of 20 K. Based on our study on rare-earth Laves phases for hydrogen liquefaction and a comprehensive literature review, we summarized two phenomenological rules for a rare-earth-based intermetallic series: (1) magnetic entropy change increases with decreasing TC; (2) adiabatic temperature change decreases firstly with decreasing TC but increases in cryogenic temperature range. These findings are well interpreted by a mean-field approach. Our studies can guide the materials design for hydrogen liquefaction.

MA 29.2 Thu 9:45 H47

Magnetocaloric effect in Tb_3Ni studied in high magnetic fields for cryogenic applications — •T. Niehoff[1,2], T. Gottschall[1], C. Salazar Mejia[1], A. Herrero[3], A. Oleaga[3], A.F. Gubkin[4], and J. Wosnitza[1,2] — [1]Dresden High Magnetic Field Laboratory (HLD-EMFL), HZDR, Dresden, Germany — [2]Technische Universität Dresden, Dresden, Germany — [3]Universidad del País Vasco, Bilbao, Spain — [4]Ekaterinburg, Russia

Tb_3Ni exhibits a large variety of temperature and magnetic-field dependent phase transitions in a temperature range of 3 to 90 K. This gives rise to a very competitive conventional magnetocaloric effect and an inverse magnetocaloric effect at very low temperature. These properties make this material an interesting candidate for magnetic refrigeration applications in the gas liquefaction temperature range. In this work, we present a comprehensive analysis of the magnetocaloric effect in a Tb_3Ni single crystal in pulsed magnetic fields up to 50 T and by heat capacity measurements in static fields.

MA 29.3 Thu 10:00 H47

Direct measurements of the adiabatic temperature change of holmium for cryogenic applications — •E. Bykov[1,2], T. Gottschall[1], Y. Skourski[1], C. Salazar Mejia[1], J. Wosnitza[1,2], M. D. Kuz'min[3], Y. Mudryk[4], D. L. Schlagel[4], and V. Pecharsky[4,5] — [1]1Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, Dresden, Germany — [2]Technische Universität Dresden, Dresden, Germany — [3]Aix-Marseille Université, IM2NP, Marseille, France — [4]Ames Laboratory, U.S. Department of Energy, Iowa State University, Ames,USA — [5]Department of Materials Science and Engineering, Iowa State University, Ames, USA

Rare-earth elements and their intermetallic compounds are interesting candidate materials for magnetic cooling at and below room temperature. Holmium demonstrates one of the largest magnetic moment in the lanthanide series and possesses other unusual magnetic properties. This metal exhibits numerous magnetic phase transitions as the temperature and/or magnetic field vary. Its Néel temperature accounts for $T_N = 132$ K, and its Curie temperature is $T_C = 20$ K resulting in a strong magnetocaloric effect in a large temperature window. This fact makes holmium a promising single-stage refrigerator material in an AMR (active magnetic regenerator) scheme for the liquefaction of natural gas and hydrogen. In this work, we present a comprehensive analysis of the magnetocaloric effect in a holmium single crystal in high magnetic fields up to 60 T.

MA 29.4 Thu 10:15 H47

Anomalous Nernst effect in ferromagnetic τ-MnAl thin films — •Daniel Scheffler[1], Helena Reichlova[1], Sebastian Beckert[1], Torsten Mix[2], Thomas G. Woodcock[2], Sebastian T. B. Goennenwein[3], and Andy Thomas[1,2] — [1]Technische Universität Dresden — [2]Leibniz Institute for Solid State and Materials Research Dresden (IFW Dresden) — [3]University of Konstanz

τ-MnAl is a ferromagnetic compound with high uniaxial magnetocrystalline anisotropy. In single crystalline films, the anomalous Hall effect and the tunnel magnetoresistance effect have been investigated, the magneto-thermal transport properties of τ-MnAl films are unknown. Given the unique anisotropy, this material could allow for a robust spontaneous anomalous Nernst effect generated by a thermal gradient applied in the film plane.

We have sucessfully grown single crystalline τ-MnAl thin films via co-sputtering. X-ray diffraction and DC magnetometry confirm a good structural quality and strong perpendicular magnetic anisotropy. We observe a robust anomalous Hall effect with a coercivity of 1 T in magneto-transport measurements. In the same device, a defined thermal gradient can also be applied in the sample plane, resulting in a clear anomalous Nernst effect response.

We will present results from our magneto-transport and magneto-thermopower experiments, which in particular allow to quantify the anomalous Nernst effect coefficient. Our results show that τ-MnAl in thin film form is an interesting material for spin-caloritronic research and devices.

MA 29.5 Thu 10:30 H47

Magnonic to electronic spin current conversion in a quantum dot hybrid system with magnetic insulator — •Emil Siuda and Piotr Trocha — Faculty of Physics, Institute of Spintronics and Quantum Information, Adam Mickiewicz University, ul. Uniwersytetu Poznańskiego 2, 61-614 Poznań, Poland

One of the challenges of further miniaturization of electronic components is managing heat generated due to the Joule heating and other effects. While magnonics offers a way to reduce generation of the waste heat in the device it is still impossible to get rid of it entirely. Hence a way of converting heat to useful electric power is desirable.

We investigate a hybrid system which utilizes a temperature gradient to produce a magnon current and converts it to a spin electronic current. The considered system consists of a quantum dot coupled to the two ferromagnetic insulators or one ferromagnetic insulator and one ferromagnetic metal. This work focuses on the influence of energy-dependent density of states and many-body magnon interactions in the magnonic reservoirson the thermally induced spin transport through the system. Energy-dependent density of states is crucial for boson-like particles, especially in the low energy limit where the lowest momentum states dominate the tranport. Thus, in the present work we consider explicit energy dependence of the density of states for the magnonic reservoirs. Moreover, taking into account many-body magnon interactions leads to a temperature-dependent density of states of magnons which results in temperature-dependent couplings of the dot to the magnonic reservoirs.

MA 29.6 Thu 10:45 H47

Magneto-thermal transport in non-collinear antiferromagnetic thin films — •Sebastian Beckert[1], João Godinho[2,4], Freya Johnson[3], Jozef Kimák[4], Eva Schmoranzerová[4], Zbyněk Šobáň[2], Kamil Olejník[2], Jan Zemen[5], Joerg Wunderlich[6], Petr Němec[4], Dominik Kriegner[1,2], Lesley F. Cohen[3], Andy Thomas[1,7], Sebastian T. B. Goennenwein[8], and Helena Reichlová[1,2] — [1]TU Dresden — [2]IoP ASCR Prague — [3]Imperial College London — [4]Charles University — [5]Czech TU — [6]University of Regensburg — [7]IFW Dresden — [8]University of Konstanz

Understanding the interplay between topological properties and transport phenomena in non-collinear antiferromagnets is important for exploiting their unconventional characteristics in spintronics. Non-collinear antiferromagnets can exhibit phenomena previously known to be exclusive to ferromagnets, such as the anomalous Hall Effect (AHE) or the anomalous Nernst effect (ANE).

We experimentally study magneto-thermal transport in a Mn_3NiN thin film antiferromagnet. In our films the spins are arranged in the (111) plane, resulting in a component of the Hall vector in both out-of plane and in-plane direction. This makes Mn_3NiN an ideal candidate for a systematic study of magneto-thermal transport phenomena. We will present measurements of ANE, AHE, magnetoresistance and magneto-Seebeck effect measured in a single device. We will compare the amplitudes of the magneto-thermal transport coefficients and discuss them in context of the Mott relation.

MA 29.7 Thu 11:00 H47

Multicaloric all-d-metal Ni-Co-Mn-Ti Heusler alloys: Heat treatment optimization and arrested martensitic transformations — •Benedikt Beckmann[1], Andreas Taubel[1], Lukas Pfeuffer[1], David Koch[1], Tino Gottschall[2], Franziska Scheibel[1], Konstantin P. Skokov[1], and Oliver Gutfleisch[1] — [1]TU Darmstadt, Institute of Material Science, 64287 Darmstadt, Germany — [2]Dresden High Magnetic Field Laboratory (HLD-EMFL), Helmholtz-Zentrum Dresden-Rossendorf, Dresden 01328, Germany

Ni-Mn-based Heusler alloys display precisely tunable first-order martensitic transformations and are promising candidates for multicaloric cooling applications [1]. In our work, all-d-metal $Ni_{50-x}Co_xMn_{50-y}Ti_y$ Heusler alloys, showing an enhanced mechanical stability, are analyzed in detail [2]. A systematic heat treatment optimization results in a tailored microstructure and leads to large isothermal entropy changes up to 38 $J(kgK)^{-1}$ and adiabatic temperature changes up to -3.8 K for the first field application in moderate magnetic field changes of 2 T. The contradictory role of the magnetic entropy contribution [3], which leads to arrested martensitic transformations in $Ni_{50-x}Co_xMn_{50-y}Ti_y$ inverse magnetocaloric Heusler alloys, is discussed in detail.

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[1] T. Gottschall *et al.*, Nat. Mater. 17, 929-934 (2018)
[2] A. Taubel *et al.*, Acta Mater. 201, 425-434 (2021)
[3] T. Gottschall *et al.*, Phys. Rev. B 93, 184431 (2016)

MA 29.8 Thu 11:15 H47

Magnetocaloric effect of Gd - an realistic ab-initio study — •Rafael Vieira[1,2], Olle Eriksson[1,3], Torbjörn Björkman[2], and Heike C. Herper[1] — [1]Department of Physics and Astronomy, Uppsala University, Box 516, SE-75120 Uppsala, Sweden — [2]Physics, Faculty of Science and Engineering, Åbo Akademi University, FI-20500 Turku, Finland — [3]School of Science and Technology, Örebro University, SE-701 82 Örebro, Sweden

We present a computational approach to evaluate field-dependent entropy of magnetocaloric materials from ab-initio calculations. Taking hcp Gd as a test system, we fully characterize the entropy associated with the magnetocaloric effect by including the entropy's electronic, lattice, and magnetic contributions.

The 2nd order nature of the ferromagnetic (FM)→paramagnetic (PM) transition in Gd implies considering intermediate states of magnetic disorder. We describe the properties of these intermediate states as weighted averages of the properties of the FM and PM phases, with mixing weights defined by the magnetization of the system at a given temperature, to which we use the results from the Monte Carlo simulations. This approach allows a realistic system description, bringing the total entropy variation in agreement with reported measurements.

We find, as expected that the magnetic entropy is the dominant entropy. However, we also observe that the lattice contribution has a role in total entropy variation.

MA 29.9 Thu 11:30 H47

Eletrochemical corrosion study of La(FeSi)13H1,5 in diverse chemical environments — •Ulysse Rocabert[1], Falk Munch[2], Maximilian Fries[2], Benedict Beckmann[1], Konrad Loewe[3], Hugo Vieyra[3], Matthias Katter[3], Alexander Barcza[3], Wolfgang Ensinger[1], and Oliver Gutfleisch[1] — [1]Technische Universität Darmstadt — [2]MagnoTherm Solutions GmbH — [3]Vacuumschmelze GmbH & Co

Hydrogenated La(FeMnSi)13 alloys represent a promising material class for magnetocaloric cooling at ambient temperatures, but contain highly oxophilic elements and are chemically sensitive. The development of protection strategies ensuring long-term stability is required and so analysis focused on Linear sweep voltammetry as the main analytical tool were performed in preferably buffered electrolytes with pH values reaching from moderately acidic to strongly alkaline to study different passivation strategies.