MA 42: Caloric Effects in Ferromagnetic Materials

Time: Thursday 15:00–17:45 Location: HSZ 04

MA 42.1 Thu 15:00 HSZ 04

Exploring rare earth Laves phases for magnetocaloric hydrogen liquefaction — •Bruno Weise[1], Marvin Hofmann[1,2], Lukas Beyer[1,3], and Tino Gottschall[4] — [1]Leibniz IFW, Dresden, Germany — [2]TU Dresden, Dresden, Germany — [3]TU Bergakademie Freiberg, Freiberg, Germany — [4]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

The replacement of fossil fuels with renewable energies is an integral part of fighting the global climate crisis. Green hydrogen, produced with renewable energies, is one of the most promising energy sources. The unsurpassed high storage density of liquid hydrogen offers great advantages, especially on long transport routes. By magnetocaloric cooling the efficiency of the energy-intensive liquefaction of hydrogen will be increased. RE-X_2 Laves phases, are ideal for low temperature hydrogen liquefaction in the temperature range between 77 and 20 K.

By substitution of individual elements in the RE-X_2 Laves phases the transition temperature can be manipulated, while maintaining the magnetocaloric performance. A substitution series of $DyNi_{2-x}Al_x$ was prepared by arc melting and studied by structural, magnetic and thermodynamic characterization methods. The investigated alloy series $DyNi_{2-x}Al_x$ shows a nonlinear substitution dependency of the Curie Temperature and adiabatic temperature change. In pulsed field measurements a temperature of up to 17 K for 10 T magnetic field pulse was measured. In the present contribution we will evaluate the suitability of the $DyNi_{2-x}Al_x$ rare earth Laves phases for magnetocaloric hydrogen liquefaction.

MA 42.2 Thu 15:15 HSZ 04

Lattice contribution to entropy change at first-order phase transition in Laves phase $DyCo_2$ — •Johanna Lill[1], Benedikt Eggert[1], Jiyong Zhao[2], Benedikt Beckmann[3], Barbara Lavina[2], Michael Hu[2], Konstantin Skokov[3], Tom Toellner[2], Esen E. Alp[2], Katharina Ollefs[1], Oliver Gutfleisch[3], and Heiko Wende[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, Duisburg, Germany — [2]APS, Lemont, Illinois - US — [3]TU Darmstadt, Darmstadt, Germany

Laves phases are promising candidates for facilitating liquefaction, applying the magnetocaloric effect. The Laves phase of $DyCo_2$ undergoes a first-order phase transition around 140 K from a ferromagnetic (at low temperatures) to a disordered magnetic phase (at higher temperatures). The magnetic phase transition accompanies a structural change from cubic to tetragonal symmetry also resulting in a volume discontinuity. The magnetocaloric effect is a change in entropy along a phase transition, which in an adiabatically performed cooling cycle can lead to the desired cooling effect. This effect can be characterized by the amount of entropy change at the first-order phase transition. For magnetocaloric applications and improvement of reversible magnetocaloric effect it is therefore essential to understand the contributions of different subsystems to the overall entropy change. In this presentation, we show experimental data that resolves the Dy-partial lattice entropy of the $DyCo_2$ Laves phase along the first-order phase transition utilizing nuclear resonant inelastic x-ray scattering. We acknowledge financial support from DFG through TRR270 HoMMage.

MA 42.3 Thu 15:30 HSZ 04

Designing a light rare-earth-based material system for magnetocaloric hydrogen liquefaction — •Wei Liu[1], Franziska Scheibel[1], Tino Gottschall[2], Eduard Bykov[2], Konstantin Skokov[1], and Oliver Gutfleisch[1] — [1]TU Darmstadt — [2]Hochfeld-Magnetlabor Dresden, Helmholtz-Zentrum Dresden-Rossendorf, Germany

Hydrogen will play a key role in 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 a "game-changer". However, the high criticalities of the heavy rare-earth elements put a question on the usage of the heavy rare-earth-based magnetocaloric materials in industrial scales, although they show large magnetic entropy and adiabatic temperature changes.[3] On the other hand, the relatively high abundances of light rare-earth elements make their alloys appealing for industrial-scale applications. In this work, based on the analysis of mean-field theory, we propose a method of designing a light rare-earth-based magnetocaloric material system with Ce, Pr, and Nd for hydrogen liquefaction.

MA 42.4 Thu 15:45 HSZ 04

Multicaloric effect and exploited hysteresis in the Heusler alloy Ni-Mn-Sn-Fe-Co — •T. Niehoff[1,2], T. Gottschall[1], C. Salazar Mejia[1], and J. Wosnitza[1,2] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, Dresden, Germany — [2]Institut für Festkörper- und Materialphysik TUD, Dresden, Germany

Today's research on commercial magnetocaloric cooling focuses on reducing the hysteresis of materials with first-order phase transitions. In contrast, this work exploits the width of hystereses to achieve more effective cooling performance with a combination of multiple caloric effects and investigates the coupling between the magnetocaloric and elastocaloric effects. The hysteresis is finetuned by substituting the proper amount of Fe and Co in the Heusler alloy Ni-Sn. To study the material, simultaneous magnetization, strain, and adiabatic temperature changes are compared at a range of different initial temperatures and various uniaxial loads in pulsed magnetic fields up to 50 T.

MA 42.5 Thu 16:00 HSZ 04

Effect of Pt substitution on the reversibility of the magnetocaloric effect in Ni-Pt-Mn-In Heusler alloys — •Parul Devi[1], C. Salazar-Mejia[1], S. Singh[2], and J. Wosnitza[1,3] — [1]High Magnetic Field Laboratory (HLD-EMFL), Helmholtz-Zentrum Dresden-Rossendorf, Germany — [2]School of Materials Science and Technology, Indian Institute of Technology (BHU), Varanasi, India — [3]Institut für Festkörper –und Materialphysik, TU Dresden, Germany

Among different magnetic shape memory Heusler alloys, $Ni_2Mn_{1.4}In_{0.6}$ is one of the most studied system for multiple caloric effects. However, obstacles such as the low-temperature martensitic transition and large thermal hysteresis hinder its technological applications motivating the search for novel materials showing better mechanical properties as well as higher martensitic transition temperature [1 and references within]. Here, we will present the experimental results such as the crystal structure determined by x-ray diffraction, magnetization in static magnetic fields, and the adiabatic temperature change in pulsed magnetic field of quaternary $Ni_{2-x}Pt_xMn_{1.4}In_{0.6}$ ($0 \leq x \leq 0.2$) shape memory alloys. The substitution of Pt affects the geometric compatibility condition without changing the space group symmetry of the austenite and the martensite phase. Around the martensitic transition temperature, a large value of ΔT_{ad} was found in pulsed magnetic fields due to the compatibility of austenite and martensite phase.

[1] K. K. Dubey et al., J. Magn. Magn. Mat. **507**, 166818 (2020).

15 min. break

MA 42.6 Thu 16:30 HSZ 04

Simultaneous measurements of adiabatic temperature change and magnetization in Fe-Ni-Rh. — •Catalina Salazar-Mejia[1], Alisa M. Chirkova[2], Shingo Yamamoto[1], Jochen Wosnitza[1,3], and Tino Gottschall[1] — [1]High Magnetic Field Laboratory (HLD-EMFL), Helmholtz-Zentrum Dresden-Rossendorf, Germany — [2]FH Bielefeld, University of Applied Sciences, Germany — [3]Institut für Festkörper- und Materialphysik, TU Dresden, Germany

We have performed simultaneous measurements of the magnetization and the adiabatic temperature change in an $Fe_{49}Ni_1Rh_{50}$ alloy. The material exhibits an antiferromagnetic (AFM) to ferromagnetic (FM) transition at $T_{tr} \approx 326$ K. Specifically, we have studied the field-induced metamagnetic AFM-FM transition at temperatures well below T_{tr} in high pulsed magnetic fields. Due to the large magnetocaloric effect (MCE) of the material, magnetization measurements in pulsed magnetic fields are not isothermal. Recording the temperature of the sample during the measurement allows not only to characterized the MCE of the material, but to precisely determine the magnetic phase diagram.

MA 42.7 Thu 16:45 HSZ 04

The local magnetic and geometric structure in Mn-doped

La(Fe,Si)$_{13}$ — •Benedikt Eggert[1], Johanna Lill[1], Konstantin Skokov[2], Cynthia Pillich[1], Alexandra Terwey[1], Fabrice Wilhelm[3], Mauro Rovezzi[3], Andrei Rogalev[3], Katharina Ollefs[1], Markus E. Gruner[1], Oliver Gutfleisch[2], and Heiko Wende[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen — [2]Functional Materials, TU Darmstadt — [3]European Synchrotron Radiation Facility

Magnetic cooling has the potential to replace conventional gas compression refrigeration. Materials such as La(Fe,Si)$_{13}$ exhibit a sizeable first-order magnetocaloric effect. For Mn-H doped La(Fe,Si)$_{13}$, it is possible to tailor the phase transition towards room temperature while maintaining first-order character. In this contribution, we discuss the effects of Mn-doping in La(Fe,Si)$_{13}$ on the magnetic moments and the local environment by means of X-ray magnetic circular dichroism and extended X-ray absorption spectroscopy in the hard X-ray regime. Spectroscopic results indicate a reduction of the Fe magnetic moment and an increased structural disorder around the La site, which is not identified for the Fe sites. Furthermore, first-principles calculations reveal energetically unfavourable Mn-Si bonds that lead to a broad distribution of La-Si bond lengths that explain the experimentally observed structural disorder. We acknowledge the financial support through the Deutsche Forschungsgemeinschaft within the framework of the CRC/TRR 270 HoMMage and thank the ESRF for allocating beamtimes at ID12 and BM30.

MA 42.8 Thu 17:00 HSZ 04

Magnetocaloric effect in (La,Ce)(Fe,Si,Mn)$_{13}$ with tunable, low transition temperature — •M. Strassheim[1,2], C. Salazar Mejia[1], J. Wosnitza[1,2], and T. Gottschall[1] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, Dresden, Germany — [2]Institut für Festkörper- und Materialphysik Technische Universität Dresden, Dresden, Germany

The La(Fe,Si)$_{13}$ family is a very promising group of magnetocaloric materials due to their overall good cost-benefit ratio in comparison to alloys based on scarce rare earths such as Gd or Ho. By partly substituting La with Ce and Fe with Mn, the metamagnetic transition can be tuned down to at least 40 K, while maintaining a rather sharp transition to enable a notable magnetocaloric effect. Tuning the magnetocaloric effect down to these temperatures opens up large-scale applications such as the magnetic liquefaction of hydrogen. In this work, we synthesized $(La_{1-z}Ce_z)(Fe_{0.88-y}Mn_ySi_{0.12})_{13}$ with $z = 0 \ldots 0.4$, $y = 0 \ldots 0.04$ and determined the adiabatic temperature change in pulsed magnetic fields. For selected samples, we calculated the magnetic entropy change using isothermal magnetization measurements.

MA 42.9 Thu 17:15 HSZ 04

Rapid bulk sintering and magnetocaloric performance of polycrystalline $Fe_2Al_{1.15-x}B_2Ge_xGa_x$ (x=0, 0.05) MAB phases — •Benedikt Beckmann[1], Tarek El-Melegy[2], David Koch[1], Ulf Wiedwald[3], Michael Farle[3], Fernando Maccari[1], Joshua Snyder[2], Konstantin Skokov[1], Michel Barsoum[2], and Oliver Gutfleisch[1] — [1]TU Darmstadt, Institute of Materials Science, Darmstadt, Germany — [2]Drexel University, Department of Materials Science & Engineering, Philadelphia, PA, USA — [3]University of Duisburg Essen, CENIDE, Duisburg, Germany

Reactive single-step hot-pressing at 1473 K and 36 MPa for 4 h produces dense, bulk, near single-phase, low-cost and low-criticality $Fe_2Al_{1.15}B_2$ and $Fe_2Al_{1.1}B_2Ge_{0.05}Ga_{0.05}$ MAB samples, showing a second-order magnetic phase transition with favorable magnetocaloric properties at room temperature. The maximum isothermal entropy change Δs_T of hot-pressed $Fe_2Al_{1.15}B_2$ in magnetic field changes of 2 and 5 T amounts to 2.5 and 5 J(kgK)$^{-1}$ at 287.5 K and increases by Ge and Ga addition to 3.1 and 6.2 J(kgK)$^{-1}$ at 306.5 K, respectively. The directly measured maximum adiabatic temperature change ΔT_{ad} in magnetic field changes of 1.93 T is improved by the alloy design from 0.9 to 1.1 K. Our criticality assessment shows that hot-pressed Fe-based MAB phases provide a promising compromise between material and processing cost, criticality and magnetocaloric performance around room temperature.

We acknowledge financial support from DFG (CRC/TRR 270, Project-ID 405553726).

MA 42.10 Thu 17:30 HSZ 04

Effect of Pt substitution on the reversibility of the magnetocaloric effect in Ni-Pt-Mn-In Heusler alloys — •Parul Devi[1], C. Salazar-Mejia[1], S. Singh[2], and J. Wosnitza[1,3] — [1]High Magnetic Field Laboratory (HLD-EMFL), Helmholtz-Zentrum Dresden-Rossendorf, Germany — [2]School of Materials Science and Technology, Indian Institute of Technology (BHU), Varanasi, India — [3]Institut für Festkörper –und Materialphysik, TU Dresden, Germany

Among different magnetic shape memory Heusler alloys, $Ni_2Mn_{1.4}In_{0.6}$ is one of the most studied system for multiple caloric effects. However, obstacles such as the low-temperature martensitic transition and large thermal hysteresis hinder its technological applications motivating the search for novel materials showing better mechanical properties as well as higher martensitic transition temperature [1 and references within]. Here, we will present the experimental results such as the crystal structure determined by x-ray diffraction, magnetization in static magnetic fields, and the adiabatic temperature change in pulsed magnetic field of quaternary $Ni_{2-x}Pt_xMn_{1.4}In_{0.6}$ ($0 \leq x \leq 0.2$) shape memory alloys. The substitution of Pt affects the geometric compatibility condition without changing the space group symmetry of the austenite and the martensite phase. Around the martensitic transition temperature, a large value of ΔT_{ad} was found in pulsed magnetic fields due to the compatibility of austenite and martensite phase.

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