MA 51: Magnetic Shape Memory Alloys (Joint Session with MM)

Time: Friday 9:30–12:30 Location: H 0112

MA 51.1 Fri 9:30 H 0112

A new device for thermography measurements of the adiabatic temperature change — •Lars Helmich, Niclas Teichert, and Andreas Hütten — Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany

Phase transitions in Magnetic Shape Memory Alloys involve an adiabatic temperature change which can be observed by means of infrared thermography. These infrared investigations can be challenging for metallic thin-film samples for several reasons: On the one hand these thin films are grown on certain substrates which provide a large heat sink. Therefore the samples need to be lifted-off from the substrates. On the other hand a metallic surface reflects parasitical infrared radiation from the environment. This reflection needs to be suppressed in order to measure the real sample temperature.

We report on a new, versatile setup for the measurement of the adiabatic surface temperature change in magnetocaloric samples. The measurement are performed in vacuum, thus heat losses due to convection can be neglected. Furthermore the sample temperature can be varied. Therefore magnetocaloric properties can be observed as a function of the initial temperature.

A special, custom-developed thin film absorption layer is applied to prevent reflections. Heat losses to this absorption layer can be corrected based a numerical heat-transfer model.

MA 51.2 Fri 9:45 H 0112

Spin polarized Fermi surface and conduction electron polarization in the Heusler Cu_2MnAl meausred with 2D ACAR — •Josef Andreas Weber[1], Andreas Bauer[1], Peter Böni[1], Hubert Ceeh[1], Stephen Dugdale[2], Michael Leitner[3], Christian Pfleiderer[1], and Christoph Hugenschmidt[1,3] — [1]Technische Universität München, Physik Department, Lehrstuhl E21/E51, James-Franck-Straße, D-85748 Garching, Germany — [2]H.H. Wills Physics Laboratory, University of Bristol, Tyndall Avenue, Bristol BS8 1TL, UK — [3]Technische Universität München, Forschungs-Neutronenquelle Heinz Maier-Leibnitz, Lichtenbergstraße 1, D-85748 Garching, Germany

Although a conceptual understanding for the so-called Heusler systems exists, the nature of the electronic interactions is known to be rather delicate. Especially if it is required to tailor special features, a deep insight into these interactions is necessary. We want to contribute to the knowledge about this class of materials by the investigation of the prototypical Heusler alloy Cu_2MnAl with the two Dimensional Angular Correlation of positron electron Annihilation Radiation (2D-ACAR) technique. In order to extract the spin polarized Fermi surface, a refined reconstruction method is introduced. Furthermore, a comparison of the measurements with ab-initio calculations additionally to a procedure to extract the sign of the conduction electron polarization is presented.

MA 51.3 Fri 10:00 H 0112

Angular-resolved photoemission spectra of Heusler alloys: Ni_2MnGa as a case study — •Václav Drchal[1], Vitalyi Feyer[2], Claus Michael Schneider[2], Yaroslav Polyak[1], Josef Kudrnovský[1], Oleg Heczko[1], Jan Honolka[1], Vladimír Cháb[1], Jaromír Kopeček[1], and Ján Lančok[1] — [1]Institute of Physics, Acad. Sci. Czech Republic, Praha, Czech Republic — [2]Peter-Grünberg-Institut, Forschungszentrum Jülich, 52425 Jülich, Germany

We have calculated the electronic structure and angular-resolved photoemission spectra of Heusler alloys from first principles using the TB-LMTO method. The disorder, caused either by non-stoichiometry, or by swapping of atoms between sublattices is treated within the CPA. Matrix elements are included within the dipole approximation. Theoretical results are compared with experimental data of a weakly off-stoichiometric $Ni_{49.7}Mn_{29.1}Ga_{21.2}$ alloy that were measured by a photoelectron microscope at the NanoESCA beamline of the Elettra synchrotron. We will discuss the dependence of spectra on the structure (austenitic/martensitic) and the role played by disorder.

MA 51.4 Fri 10:15 H 0112

Effects of annealing on the martensitic transformation of Ni-based ferromagnetic shape memory Heusler alloys and nanoparticles — •Tina Fichtner, Changhai Wang, and Claudia Felser — Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

We report on the effects of annealing on the martensitic phase transition in the Ni-based Heusler system: bulk Ni-Mn-Sn and Co-Ni-Ga nanoparticles. For the powdered Ni-Mn-Sn, structural and magnetic measurements reveal that re-annealing reduces the martensitic phase transformation. This might be associated with a release of internal stress in Ni-Mn-Sn compound during the annealing process. Whereas in the case of Co-Ni-Ga nanoparticles, a *vice versa* phenomenon is observed. The as-prepared Co-Ni-Ga nanoparticles do not show the martensitic phase transition, as revealed by temperature-dependent x-ray diffraction measurements. However, post-annealing followed by ice quenching is found to trigger the formation of the martensitic phase in Co-Ni-Ga nanoparticles. The occurrence of the martensitic transition is attributed to the modified phase structure and the introduced stress due to annealing.

MA 51.5 Fri 10:30 H 0112

Ordering kinetics in Ni-Mn based ferromagnetic shape memory alloys — •Pascal Neibecker[1], Michael Leitner[1], Georg Benka[2], and Winfried Petry[1] — [1]Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München, Lichtenbergstr. 1, 85748 Garching, Germany — [2]Physics Department, Technische Universität München, James-Franck-Str. 1, 85748 Garching, Germany

Ni-Mn based Heusler alloys of the type Ni_2MnX have gained significant interest in recent years due to their magnetic shape memory properties. These alloys usually crystallize in the high temperature B2 phase and undergo at lower temperatures first a transition to the higher ordered $L2_1$ phase and later to a variant-rich martensitic phase.

Yet, the existence and characteristics of the martensitic transition as well as the temperature of the magnetic transition are heavily dependent on the degree of $L2_1$-type order adjusted in the alloy. While in Ni_2MnGa, the degree of $L2_1$ order is inherently high, other promising alloys such as Ni_2MnAl are lacking thereof.

In this respect, we report on the kinetics of $L2_1$ order adjustment in Ni_2MnAl, both in the case of thermodynamic equilibrium vacancy concentrations and in the case of quenched-in vacancy excess. We demonstrate the acceleration of ordering kinetics under vacancy excess, which permits the adjustment of hitherto unreachable states of order in the Ni_2MnAl system. Our results were obtained employing Differential Scanning Calorimetry (DSC), magnetic measurements using a Physical Property Measurement System (PPMS) as well as X-ray Powder Diffractometry (XRD).

MA 51.6 Fri 10:45 H 0112

Coupling of Structural and Micromagnetic Properties in Twinned Epitaxial Ni-Mn-Ga films — •Aleksej Laptev[1], Mikhail Fonin[1], Yuansu Luo[2], Konrad Samwer[2], Gesa Welker[3], and Kristof Lebecki[4] — [1]Fachbereich Physik, Universität Konstanz, 78457 Konstanz — [2]I. Physikalisches Institut, Georg-August-Universität Göttingen, 37077 Göttingen — [3]Leiden University, Leiden Instute of Physics, 2333 CA Leiden, Netherlands — [4]Nanotechnology Centre, VSB-TU Ostrava, 70833 Ostrava-Poruba, Czech Republic

Isothermal and temperature-dependent magnetization properties for (010)-oriented Ni-Mn-Ga epitaxial films deposited on MgO(001) substrates have been studied. In particular, the pronounced abrupt changes in slope of the magnetization loop near ± 0.06 T found in these films have been addressed. The mechanism of this characteristic hysteretic behavior could be understood with the help of micromagnetic simulations, which have been compared to experimental data. The results suggest that the abrupt changes in slope, which could be observed down to 10 K, can be attributed to the movement of 180° magnetic domain walls within one of four existing twin variant orientations. The occurrence of such specific hysteresis loops is facilitated by the specific twinned microstructure, which leads to a periodic orientation change of the magnetic easy axis on micrometer scale.

MA 51.7 Fri 11:00 H 0112

Study of magneto-elastic properties in shape-memory Heusler alloys by resonant ultrasound spectroscopy — •Catalina Salazar Mejia[1], Ajaya K. Nayak[1], Claudia

Felser[1], Michael Nicklas[1], Jason Schiemer[2], and Michael A. Carpenter[2] — [1]Max Planck Institute for Chemical Physics of Solids, Nöthnitzer Str. 40, 01187 Dresden, Germany — [2]Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge CB2 3EQ, UK

Resonant ultrasound spectroscopy (RUS) is a versatile technique in materials science for measuring elastic constants. We have applied RUS to study the magneto-elastic properties in Heusler alloys. Heusler alloys that undergo a martensitic transformation (MT) have been shown to exhibit diverse functional properties such as the shape memory effect, magnetic-driven superelasticity and giant magnetocaloric and barocaloric effects, which derive from magnetoelastic couplings. The study of the magneto-elastic properties in these materials is important both from fundamental and the application points of view. We have studied polycrystalline Heusler alloys from the Ni-Mn-Ga and Ni-Mn-In families, in a temperature range that include the ferromagnetic and the martensitic transitions. We have observed fundamental differences in the behavior of the crystal lattice at the martensitic transition, i.e., stiffening versus softening, determined by the presence or absence of a pre-martensitic transition and the relation between the Curie temperature and the MT temperature. We will discuss these results in connection with magnetization and calorimetric data.

MA 51.8 Fri 11:15 H 0112

The effect of stoichiometry on the magnetic interactions in NiMn-based martensitic Heusler alloys. — •Ivan S. Titov[1,2], Mehmet Acet[1], Ralf Meckenstock[1], Yixi Su[3], and Michael Farle[1] — [1]Universität Duisburg-Essen, Duisburg, Germany — [2]M.V. Lomonosov Moscow State University, Moscow, Russia — [3]Heinz Maier-Leibnitz Zentrum, Garching, Germany

NiMn-based Heusler alloys doped with Ga, In and Sn exhibit in the martensitic state a thermally broad, coupled antiferromagnetic-ferromagnetic (AF-FM) magnetic transition below the Curie temperature T_C^M giving rise to a splitting between ZFC and FC magnetization curves and exchange bias effects. We explain this by Mn atoms, coupling together both AF and FM depending on the Mn-Mn distance. These are evidenced from FMR and polarized neutron scattering experiments on NiMnZ Heusler alloys with Z as In, Sb and Sn. To study the conditions giving rise to mixed magnetism, we consider the magnetic interactions in over and under Mn-stoichiometry with respect to Ni_2MnZ with Z as Ga and Sn. In such stoichiometries, the system can be adjusted so that Mn-Mn neighbors can either only be next nearest or both nearest and next nearest. FMR and polarized neutron studies on Ni-Mn-Ga and Ni-Mn-Sn alloys with varying concentrations of Sn and Ga provide complementary information on the nature of the coupling in such alloys. The results show that for understoichiometry predominantly FM interactions are observed, whereas for overstoichiometry additional AF coupling is observed.

Work supported by the DFG (SPP 1239).

MA 51.9 Fri 11:30 H 0112

Structural and magnetic phase transition in epitaxial Ni-Mn-Ga-Co films on ferroelectric substrates — •Benjamin Schleicher[1,2], Robert Niemann[1,2], Anett Diestel[1], Ludwig Schultz[1,2], and Sebastian Fähler[1,2] — [1]IFW Dresden, Institute for Metallic Materials, P.O. Box 270116, D-01171 Dresden, Germany — [2]TU Dresden, Institute for Solid State Physics, D-01062 Dresden, Germany

To reduce today's demand of energy for cooling applications solid-state cooling cycles relying on magnetic field induced phase transitions have been proposed. Promising materials are Heusler alloys such as Ni-Co-Mn-Ga which show an inverse magnetocaloric effect with a structural and magnetic phase transition between a ferromagnetic austenite at high T and a weak magnetic martensite at low T. Additionally to high external magnetic fields, the transformation can also be induced by the application of mechanical stress. This can be achieved by the deposition of a magnetocaloric thin film on a ferroelectric substrate. We present first results on sputter deposited epitaxial Ni-Mn-Ga-Co thin films on ferroelectric $Pb(Mg_{1/3}Nb_{2/3})_{0.72}Ti_{0.28}O_3$ (PMN-PT) substrates. Temperature dependent texture and magnetic measurements show the magnetic and structural phase transition in the material. By applying an electric field at the ferroelectric PMN-PT substrate we can induce the martensitic transformation in Ni-Mn-Ga-Co electrically which changes the magnetization significantly. This work is supported by DFG through SPP 1599 www.FerroicCooling.de.

MA 51.10 Fri 11:45 H 0112

Structure and Giant Inverse Magnetocaloric Effect of Epitaxial Ni-Co-Mn-Al Films — •Niclas Teichert[1], Daniel Kucza[1], Oguz Yildirim[2,3], Ilker Dincer[4], Anna Behler[5], Lars Helmich[1], Alexander Boehnke[1], Anja Waske[5], Yalcin Elerman[4], and Andreas Hütten[1] — [1]Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany — [2]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf e.V., Germany — [3]Dresden University of Technology, Germany — [4]Ankara University, Department of Engineering Physics, Faculty of Engineering, Turkey — [5]IFW Dresden, Institute for Complex Materials, Germany

The structural, magnetic, and magnetocaloric properties of epitaxial Ni-Co-Mn-Al thin films with different compositions have been studied. The films were deposited on MgO(001) substrates by co-sputtering on heated substrates. All films show a martensitic transition where the transition temperatures are strongly dependent on the composition. The structure of the martensite phase is shown to be 14M. The metamagnetic martensitic transition occurs from a strong ferromagnetic austenite to a weak magnetic martensite. The structural properties of the films were investigated by atomic force microscopy and temperature dependent X-ray diffraction. Magnetic and magnetocaloric properties were analyzed using temperature dependent and isothermal magnetization measurements. We find that $Ni_{41}Co_{10.4}Mn_{34.8}Al_{13.8}$ films show giant inverse magnetocaloric effects with magnetic entropy change of $5.8\,J\,kg^{-1}K^{-1}$ for $\mu_0\Delta H = 1\,T$.

MA 51.11 Fri 12:00 H 0112

Density functional and tight-binding analysis of energy balance between $L1_0$ and $L2_1$ structures in Ni-Mn-X (X=Ga, Sn, In) Heusler alloys — •Ingo Opahle, Georg K. H. Madsen, and Ralf Drautz — ICAMS, Ruhr-Universität Bochum, Germany

The energy balance between the cubic $L2_1$ austenite structure and the tetragonal $L1_0$ martensite structure of Ni-Mn-X (X=Ga, Sn, In) Heusler alloys is analyzed using density functional theory and tight-binding (TB) models. Without spin-polarization the $L1_0$ structure with $c/a > 1$ is favoured over the cubic $L2_1$ structure. In contrast, magnetic contributions are found to stabilize the cubic austenite structure. The presence or absence of a martensitic ground state is determined by a subtle energy balance between the magnetic contributions and the nonmagnetic energy gain by a tetragonal distortion. The role of the electron per atom (e/a)-ratio, the size of the p-element X and the Jahn-Teller distortion for the martensitic transition temperature in the Ni-Mn-X Heusler alloys is discussed. The absence of a martensitic ground state in stoichiometric Ni_2MnIn can be understood from the different contributions of the p-element to the bond energy in the TB model compared to Ni_2MnGa.

MA 51.12 Fri 12:15 H 0112

Direct measurement of the magnetocaloric effect in $Ni_{50}Mn_{35}In_{15}$ in pulsed magnetic fields — •M. Ghorbani Zavareh[1,2], C. Salazar Mejia[3], A. K. Nayak[3], Y. Skourski[1], J. Wosnitza[1,2], C. Felser[3], and M. Nicklas[3] — [1]Hochfeld-Magnetlabor Dresden (HLD), Helmholtz-Zentrum Dresden-Rossendorf, D-01314 Dresden — [2]Institut für Festkörperphysik, TU Dresden, 01069 Dresden, Germany — [3]Max Plank Institute for Chemical Physics of Solids, 01187 Dresden, Germany

Ferromagnetic shape-memory Heusler alloys undergo a martensitic transformation, i.e, a first-order structural transition from a cubic high-temperature phase to a low-temperature monoclinic phase. Due to a pronounced magneto-structural interaction in these compounds, a strong magnetic field can induce a metamagnetic transition and drive the system from a martensite to an austenite phase. In this case, both lattice and magnetic entropy contribute to the net magnetocaloric effect (MCE). We have measured the MCE of the shape memory Heusler alloy $Ni_{50}Mn_{35}In_{15}$ using a set-up for direct magnetocaloric measurements in pulsed magnetic fields. The martensitic transition occurs at about 246 K in zero field and the material has a Curie temperature of 315 K. We find a saturation of the inverse MCE, related to the first-order martensitic transition, with a maximum value of -7 K. The MCE associated with the Curie temperature evolves as typical for a second-order magnetic transition. The effect is positive, nearly temperature independent and yields a value of 11 K.