MA 38: Magnetic Materials II

Time: Thursday 9:30–12:15 Location: HSZ 403

MA 38.1 Thu 9:30 HSZ 403

Synthesis and properties of ultrathin B2 ordered FeRh films — •Ralf Witte, Richard Brand, Robert Kruk, and Horst Hahn — Karlsruhe Institute of Technology KIT, Institute for Nanotechnology, 76344 Eggenstein, Germany

The B2 ordered phase (CsCl structure) of the Fe50Rh50 alloys possess interesting magnetic properties. They are antiferromagnetically (AFM) coupled at room temperature and show a transition to a ferromagnetic phase (FM) at about 400K. This behavior has been shown in bulk material and as well in thin films. Generally, stabilization of the FM phase is associated with the Rh spin state; in the AFM phase the magnetic moment on the Rh atom is zero, while it gets polarized in the FM state. It has been calculated [1] that the FM state can be stabilized at room temperature in (freestanding, single crystalline) films with a thickness below a critically value of 9 atomic layers. This effect is attributed to the increased polarizability of the Rh atoms at the surface, which in turn stabilizes the FM state in the entire film. So far there has been no clear experimental confirmation of the theoretical results, mainly because of the difficulties in growing B2-ordered FeRh alloys in the form of an epitaxial, ultra-thin film. We present research on the synthesis and properties of FeRh thin films on different single crystalline substrates prepared by electron beam evaporation. The samples are characterized using e.g. high-resolution X-ray diffraction, atomic force microscopy, SQUID magnetometry, X-ray photo electron spectroscopy and 57Fe Mössbauer spectroscopy.

[1] S. Lounis, Phys. Rev. B 67, 094432 (2003)

MA 38.2 Thu 9:45 HSZ 403

Ferromagnetic resonance in FeRh thin films through the magnetic phase transition — •Alireza Heidarian[1,2], Jürgen Lindner[1], Rantej Bali[1], and Kay Potzger[1] — [1]HZDR Institute of Ion-Beam Physics and Materials Research P.O. Box 510119, 01314 Dresden, Germany — [2]TU Dresden Helmholtzstr. 10, 01069 Dresden, Germany

The temperature-induced antiferromagnetic (AF) to ferromagnetic (FM) phase transition of epitaxial FeRh/MgO (001) thin films is studies by means of ferromagnetic resonance (FMR). The FM as well as the AFM phase can be separated via temperature- and field dependent FMR. Our measurements show that temperature dependent FMR can be used to determine the relative volumes of AFM and FM regions across phase transition. Moreover, the temperature dependent magnetic coupling strength could be investigated. While decreasing the film thickness, the phase transition temperature shifts towards lower temperatures, which could result from the strain between substrate and the thin film.

MA 38.3 Thu 10:00 HSZ 403

Atomic Structure, Magnetic Anisotropy and Magnetization Reversal in Fe films on Pt(997) — Rafael Fradczyk, Hauke Bardenhagen, Kim-Mario Wolf, Stephan Rutsch, Matthias Nuss, and •Kai Fauth — Physikalisches Institut, Universität Würzburg, Am Hubland, D-97074 Würzburg

Vicinal surfaces may serve as templates for the growth of films with nanoscale structural and strain modulation. In magnetic materials this gives rise to various contributions to the magnetic anisotropy energy density.

In the present contribution we revisit [1] the growth of Fe on Pt(997) and the resulting magnetic properties. Under optimized growth conditions, we observe notable structural differences to previous reports from electron diffraction (LEED, LEED-IV). The magnetic easy axis, while still in the surface plane, appears rotated by 90° as a result. Our results suggest that the atomic structure established at the step edges provides the dominant contribution to the magnetocrystalline anisotropy energy density, even above the spin reorientation thickness.

We present and analyze in detail ambient and low temperature saturation magnetization, anisotropy field(s) and magnetization reversal at a Fe film thickness of five atomic layers.

[1] D. Repetto et al., *Phys. Rev. B* **74**, 054408 (2006)

MA 38.4 Thu 10:15 HSZ 403

Perpendicular magnetic anisotropy in epitaxial $DyCo_5$ thin films — •Benjamin Schleicher[1,2], Marietta Seifert[1], Ludwig Schultz[1,2], and Volker Neu[1] — [1]IFW Dresden, Institute for Metallic Materials, P.O. Box 270116, 01171 Dresden — [2]Technische Universität Dresden, Institute for Solid State Physics, 01062 Dresden

The ferrimagnetic $DyCo_5$ phase was prepared as epitaxial thin films with a thickness of 50 nm by pulsed laser deposition from elementary targets in an UHV environment. The use of Cr-buffered MgO(110) substrates results in an in-plane growth of the unit cells' crystallographic *c*-axis. Structural properties were investigated with XRD and texture measurements and the (1:5)-phase was confirmed through the successful verification of the appropriate XRD-peaks and pole figures. The remanent magnetization has been measured in a temperature range from 20 K to 400 K along distinct crystallographic directions as well as hysteresis loops at discrete temperatures to probe the anisotropic behavior of the samples. Furthermore, MFM measurements were carried out in a temperature range from 300 K to 400 K. The ferrimagnetic coupling between the heavy rare earth Dy and the transition metal Co was confirmed by identifying a minimum of the magnetization of the sample at the so called spin compensation temperature. The value of roughly 110 K is in qualitative agreement with literature data of single crystals and varies with the amount of Dy in the film. A spin reorientation transition from easy *c*-axis via easy cone to easy plane was observed between 400 K and 325 K, and leads to a perpendicular anisotropy of the film below 325 K with an out-of-plane easy axis.

15 min. break

MA 38.5 Thu 10:45 HSZ 403

Epitaxial Ni-Mn-Ga-Co films for magnetocaloric application — •Anett Diestel[1,2], Robert Niemann[1], Sebastian Fähler[1,3], and Ludwig Schultz[1,2] — [1]IFW Dresden, Institute for Metallic Materials, P.O. Box 270116, 01171 Dresden, Germany — [2]Technische Universität Dresden, Institute of Materials Science, 01062 Dresden, Germany — [3]Technische Universität Chemnitz, Institute of Physics, 09126 Chemnitz, Germany

The Heusler alloys Ni-Mn-X-Co (X = Ga, In, Sn, Sb) exhibit an inverse magnetocaloric effect (MCE) due to a field-induced martensitic transformation between austenite and modulated martensite which is accompanied by a large change of magnetization. The transformation temperatures sensitively depend on composition and chemical order so room temperature solid state refrigeration becomes feasible. For Ni-Mn-Ga-Co bulk an inverse MCE is known in comparison to the direct MCE of Ni-Mn-Ga. We prepared epitaxial Ni-Mn-Ga-Co films by magnetron sputter deposition on single crystalline MgO(100) substrates. Due to the high surface-to-volume fraction of thin films a fast heat exchange is possible and a higher cooling power can be achieved using less material. We proved epitaxial growth and the reversible field induced transformation from austenite to modulated martensite with a high change of magnetization. We also show the strong influence of deposition parameter and chemical composition on film growth, transformation temperatures and chemical order which influence the shape of magnetic hysteresis. This work is supported by DFG through SPP 1599 www.FerroicCooling.de.

MA 38.6 Thu 11:00 HSZ 403

Martensitic Transformation in Freestanding Magnetocaloric Thin Films — •Lars Helmich[1], Niclas Teichert[1], Walid Hetaba[2], Anna Behler[3], Anja Waske[3], and Andreas Hütten[1] — [1]Bielefeld University, Department of Physics, Thin Films and Physics of Nanostructures, 33615 Bielefeld, Germany — [2]Vienna University of Technology, USTEM, A-1040 Vienna, Austria — [3]TU Dresden, Institut für Festkörperphysik, 01062 Dresden, Germany

Ni-Mn-Sn is a well-known ferromagnetic shape memory alloy that shows both a martensitic transformation and the magnetocaloric effect for a suitable choice of stoichiometry. However a direct observation of the temperature change due to the magnetocaloric effect is a challenging task for thin films since the substrate provides a large heat sink.

We prepared Ni-Mn-Sn films on heated MgO(001) substrates with a sacrificial layer in between by magnetron sputtering. In a subsequent preparation step the substrate was removed by wet-chemical treatment. Thus we prepared freestanding films with a thickness in the range of 100 nm and therefore we got rid of the heat sink. This offers

the possibility for direct ΔT-measurements.

Moreover the removal of the substrate leads to a reduction of strain effects in the film. We showed that this again results in a lowering of the martensite transition temperature. Furthermore changes in electronic and magnetic properties were analysed.

MA 38.7 Thu 11:15 HSZ 403

Influence of the film thickness on the martensitic transition in free-standing Ni-Mn-Sn thin films — •Svetlana Klimova[1,2], Niclas Teichert[2], Lars Helmich[2], Andreas Hütten[2], Anna Behler[3], Anja Waske[3,4], and Walid Hetaba[2,5] — [1]Saratov State University, Department of Nano- and biomedical Technology, 410012 Saratov, Russia — [2]Bielefeld University, Department of Physics, Thin Films and Physics of Nanostructures, 33615 Bielefeld, Germany — [3]IFW Dresden, Institute for Complex Materials, 01069 Dresden, Germany — [4]TU Dresden, Institut für Festkörperphysik, 01062 Dresden, Germany — [5]TU Wien, Universitäre Service-Einrichtung für Transmissionselektronenmikroskopie (USTEM), 1040 Wien, Austria

Magnetic materials based on Ni-Mn-Sn are Heusler alloys, in which a structural transition carries out from the low temperature martensitic to the high temperature austenitic phase. In this study we have synthesized the free-standing Ni-Mn-Sn thin films between 20 nm and 200 nm and transferred onto different substrates (Si or GaAs wafers, cupper grids or glass) to investigate the influence of the film thickness on the martensitic transition. The films were epitaxially grown on MgO (001) substrates with a sacrificial V layer by DC magnetron co-sputtering at a substrate temperature of 500°C. This allows to study the substrate influence on the martensitic transition. The applied methods to study the martensitic transition include temperature dependent resistivity and magnetization measurements, X-Ray Diffraction, and Transmission Electron Microscopy.

MA 38.8 Thu 11:30 HSZ 403

Magnetocaloric and hysteretic properties of Ni-Mn based Heusler alloys — •Tino Gottschall, Konstantin Skokov, Bianca Frincu, and Oliver Gutfleisch — TU Darmstadt, Germany

The origin for the inverse magnetocaloric effect in Ni-Mn based Heusler alloys is a first-order magnetostructural transition between a low temperature paramagnetic/antiferromagnetic martensite and a high temperature ferromagnetic austenite phase. Performing direct measurements, we report a large adiabatic temperature change ΔTad exceeding -8 K at a field change of 2 T in the Ni-Mn-In-(Co) Heusler system. The thermal hysteresis of more than 8 K reduces the magnetocaloric effect drastically when the magnetic field is applied a second time. Nevertheless, we observe a cyclic adiabatic temperature change in the same field change of -3 K when moving in minor loops of magnetization, where only a certain part of the material transforms. The hysteretic behavior of the transition was in situ studied by optical microscopy.

MA 38.9 Thu 11:45 HSZ 403

Low temperature scanning tunneling microscopy of the $Ni_2MnGa(001)$ surface. — •Niklaus Blenk[1], Aleksej Laptev[1], Mikhail Fonin[1], S. W. D'Souza[2], and Sudipta Roy Barman[2] — [1]Fachbereich Physik, Universität Konstanz, 78457 Konstanz — [2]UGC-DAE Consortium for Scientific Research, 452001 Indore, India

Due to their possible applications as actuators and sensors ferromagnetic shape memory alloys (FSMA) have attracted strong scientific interest. Ni-Mn-Ga is the most prominent and the most studied FMSA due to demonstrated magnetic field induced strains of up to 12% [1].

Here we report on low temperature STM-measurements on the $Ni_2MnGa(001)$ surface performed at 10 K. At this temperature the Ni_2MnGa single crystal is in the ferromagnetic state and shows a 5M modulated martensitic structure. We observe charge-density modulations with a wavelength of 1.4 nm and wavefronts aligned along the [010] direction associated with a bulk charge-density wave (CDW). The modulation period is shown to be independent on the tunneling voltage U_T. On the other hand the resulting corrugation amplitude depends on U_T. A phase shift in the modulation appears at around 100 mV.

The observed co-existence of ferromagnetism and a CDW in Ni_2MnGa is in agreement with the observation of a pseudogap, which hallmarks the CDW, by photoemission techniques [2,3].

[1] A. Sozinov et al., Appl. Phys. Lett. 102, 021902 (2013).
[2] D'Souza et al., Phy. Rev. B 85, 085123 (2012).
[3] C. P. Opeil et al., Phys. Rev. Lett. 100, 165703 (2008).

MA 38.10 Thu 12:00 HSZ 403

Unraveling nanotwinned martensites in Ni_2MnGa from first-principles — •Markus Ernst Gruner[1,2], Ulrich K. Rössler[1], and Sebastian Fähler[1,3] — [1]IFW Dresden — [2]Universität Duisburg-Essen — [3]TU Chemnitz

The unique magnetic shape memory properties of the Heusler compound Ni_2MnGa are intimately connected with the presence of modulated structures. These were recently interpreted in terms of an adaptive arrangement of [110] aligned nanotwins consisting of nonmodulated tetragonal $L1_0$ building blocks, which is considered as the ground state of this compound. This implies, that the energy of the nanotwinned microstructure can be decomposed into the contribution from the $L1_0$ volume fraction, the twin interface energy and the interaction between two neighboring interfaces at a given separation. Based on comprehensive total energy calculations in the framework of density functional theory calculations we verify this building principle through a systematic evaluation of twinned microstructures constructed from strained $L1_0$ martensite with different c/a. For the equilibrium distortion of martensite, $c/a = 1.26$, we observe indeed nearly perfect additivity of the corresponding contributions. Furthermore, we find that for intermediate distortions specific nanotwinned configurations can be significantly lower in energy than the respective nonmodulated building blocks. In particular, the so-called 4O orthorhombic structure consisting of two double-layer twins becomes energetically comparable to the nonmodulated $L1_0$ ground state martensite.