MA 53: Magnetic Heuslers, half-metals and oxides

Time: Friday 9:30–12:45 Location: H33

MA 53.1 Fri 9:30 H33

In-situ imaging of martensitic phase transitions in thin films of NiMnGa — •Bruno Weise[1], Sebastian Fähler[1], Kornelius Nielsch[1,2], and Anja Waske[1,3] — [1]Leibniz Institute of Solid State and Materials Research (IFW), Dresden — [2]Technische Universität Dresden — [3]Federal Institute for Materials Research and Testing (BAM), Berlin

In magnetocaloric material, extrinsic sample properties affect the phase transition remarkable. In recent studies it was found that e.g. the surface morphology [1] as well as defects on the surface [2] have a significant influence on nucleation and growth of the magnetocaloric phase. With this work, studying NiMnGa thin films, we show the temperature dependent growth of martensite.

The microstructure of NiMnGa thin films is monitored by scanning electron microscopy equipped with a custom-built temperature stage. This set-up allows in-situ imaging of the temperature-induced phase transition. Advanced image analysis is used to determine the phase fractions and is compared to magnetic measurements. With in-situ investigation of the transformation of both, type X and Y martensite, the impact of external influences on the martensite growth is assessed.

[1] A. Waske, et al., APL Mater. 4, 106101 (2016)
[2] R. Niemann, et al., APL Mater. 4, 064101 (2016)

MA 53.2 Fri 9:45 H33

Designing rare-earth free permanent magnets with tetragonally distorted Heusler compounds by light interstitials — •Qiang Gao, Ingo Opahle, and HongBin Zhang — Institute of Materials Science, TU Darmstadt, 64287 Darmstadt, Germany

Permanent magnets are crucial materials for energy harvesting and conversion.[1] Rare-earth (RE) based magnets with good properties are subjected to criticality and environmental issues, resulting in great need for RE free magnets. To this goal, we explore the possibility of engineering permanent magnets based on Heusler compounds with transition metals. Starting from the known stoichiometric $L2_1$ Heusler compounds, we investigated the effect of light interstitial H, B, C, and N atoms. It is observed that the interstitials will occupy the octahedral holes, leading to effective tetragonal distortion and hence enhanced magnetocrystalline anisotropy. The uniaxial magnetic anisotropy energy can be as large as 1.43 MJ/m^3 for Ni_2FeGa with N interstitial, of which the value is three times larger than that of the same tetragonal distortion for Ni_2FeGa without interstitials. Detailed analysis based on the Bruno's model[2] reveals that the local distortions around the interstitials play an important role. [1] O. Gutfleisch, M.A. Willard, E. Brück, C.H. Chen, S.G. Sankar, J.P. Liu, Adv. Mater. **23**, 821 (2011). [2] P. Bruno, Phys. Rev. B **39**, 865 (1989).

MA 53.3 Fri 10:00 H33

In-situ spin polarized time-of-flight momentum microscopy of the Heusler alloy films $Co_2MnGa(001)$, $Co_2MnSi(001)$, and $Co_2Fe_{0.4}Mn_{0.6}Si(001)$ — •Sergey Chernov[1], Christian Lidig[1], Olena Fedchenko[1], Katerina Medjanik[1], Dmitry Vasilyev[1], Sergey Babenkov[1], Martin Jourdan[1], Jürgen Braun[2], Hubert Ebert[2], Gerd Schönhense[1], and Hans-Joachim Elmers[1] — [1]Institut für Physik, Johannes Gutenberg-Universität, Staudingerweg 7, 55128 Mainz, Germany — [2]Department Chemie, Ludwig-Maximilians-Universität München, Butenandtstrasse 11, 81377 München, Germany

Half-metallic ferromagnets are an important class of materials as they provide fully spin polarized conduction electrons that may be exploited by spintronic devices. Although first-principles calculations predict many half-metallic Heusler alloys, only a few have been experimentally proven[1]. Theoretical studies indicate that local electron correlations in Heusler compounds are often significant and surface states play a dominant role. We have measured spin polarized electronic dispersions in the valence band region up to 1.5 eV binding energy using spin polarized time-of-flight k-microscopy and photoexcitation by the 4^{th} harmonic of a Ti-sapphire laser (6 eV). The comparison of spin-integrated photoemission spectra obtained with exitation at 6 eV and in the hard X-ray regime allows one to discriminate surface related from bulk states. This allows for a thorough test of theoretical models, indicating the need to extend the single particle approach to include many-body effects. [1] M. Jourdan et al., Nat. Commun. 5, 3974 (2014)

MA 53.4 Fri 10:15 H33

First principles prediction of new quaternary half-metallic ferromagnets with large Curie temperatures — Biplab Sanyal[1], •Ashis Kundu[2], Srikrishna Ghosh[2], Rudra Banerjee[1], and Subhradip Ghosh[2] — [1]Department of Physics and Astronomy, Uppsala University, Box 516, 75120 Uppsala, Sweden — [2]Department of Physics, Indian Institute of Technology Guwahati, Guwahati-781039, Assam, India

For spintronic applications, new magnetic materials with high Curie temperatures are perpetually sought for. Here, we present first principles calculations of structural, electronic and magnetic properties of quaternary Heusler compounds CoX′Y′Si where X′ is a transition metal with 4*d* electrons and Y′ is either Fe or Mn. Our study finds five new half-metallic ferromagnets with spin polarisation nearly 100% with very high Curie temperatures. The variation of Curie temperatures as a function of valence electrons can be understood from the calculated inter-atomic exchange interaction parameters. A few other compounds have been identified, which could be potential half-metals with suitable application of pressure or with controlled doping. Our analysis shows that the half-metallicity in these compounds is intricately related to the arrangements of the magnetic atoms in the Heusler lattice and hence, the interatomic exchange interactions between the moments.

MA 53.5 Fri 10:30 H33

IrMnGa - a disordered Half-Heusler compound with spin glass ground state — •Johannes Kroder[1], Kaustuv Manna[1], Dominik Krieger[1], Alexandr S. Sukhanov[1,2], Enke Liu[1], Horst Borrmann[1], Walter Schnelle[1], Johannes Gooth[1], Dmytro S. Inosov[1,2], Gerhard H. Fecher[1], and Claudia Felser[1] — [1]Max Planck Institut für chemische Physik fester Stoffe, Dresden, Germany — [2]Institut für Festkörper- und Materialphysik, Technische Universität Dresden, Dresden, Germany

Heusler compounds with heavy atoms often have interesting non-collinear magnetic structures. We therefore studied the magnetic, structural and transport properties of IrMnGa, which crystallizes within the ordinary Half-Heusler space group 216 but with some disorder. The comparison of neutron and X-ray diffraction experiments indicate that the compounds forms a Y structure (prototype LiMgPdSn). Manganese atoms distribute on two non-equivalent sites, which causes competing exchange interactions and prevents the establishment of long-range magnetic order. Instead, magnetization and AC susceptibility measurements reveal typical spin glass behavior at low temperatures. This involves for example the formation of uniaxial anisotropy during field cooling and the observation of the memory effect. Furthermore, the AC susceptibility shows a sharp cusp at the freezing temperature, whose shift as function of AC frequency can be described by the Vogel-Fulcher law and a critical scaling approach. Our work demonstrates that IrMnGa is the first canonical spin glass within the group of Half-Heusler compounds.

MA 53.6 Fri 10:45 H33

Magnetic Compensation in Mn_3Ge-based Heusler Alloys with Addition of Ni, Pt and Pd — •Johannes Seyd, Nataliia Yurievna Safonova, and Manfred Albrecht — Institute of Physics, University of Augsburg, D-86159 Augsburg, Germany

Mn_3Ge is a ferrimagnetic Heusler alloy with promising properties for spintronic applications, for example a high coercive field and low saturation magnetization[1]. We investigated substitution effects of Ni, Pt and Pd on phase formation and magnetic properties of $D0_{22}$-Mn_3Ge thin films with the intent of further lowering the saturation magnetization[2]. We prepared $(Mn_{1-x}M_x)_3Ge$ (with M=Ni, Pt, Pd) thin films by magnetron sputtering with x varying from 0.03 to 0.6 and analysed the composition and film thicknesses by Rutherford backscattering spectroscopy.

XRD analysis showed that the $D0_{22}$-structure formed only at the lowest concentrations for Ni and Pt, but it was still observed until 20% of Pd content. This was confirmed by SQUID-VSM investigation, but nevertheless the Ni and Pt samples still showed perpendicular magnetic anisotropy at 10% dopant concentration. Magnetizations and coercive fields generally decreased with increasing dopant concentration, as did

the perpendicular magnetic anisotropy. At the highest concentration of Ni, a soft ferromagnetic phase formed. For the Pt samples, the $L1_0$ phase of MnPt formed for higher Pt content.

[1] Kurt et al., Appl. Phys. Lett. 101, 132410 (2012) ;
[2] Balluff et al., Phys. Rev. B 97, 014403 (2018) .

MA 53.7 Fri 11:00 H33

Observation of topological Hall effect in antiskyrmion hosting compound Mn1.4PtSn — •Praveen Vir[1], Jacob Gayles[1], Alexandr Sukhanov[1], Nitesh Kumar[1], Yan Sun[1], Jürgen Kübler[2], Chandra Shekhar[1], and Claudia Felser[1] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]Nöthnitzer Str. 40

Skyrmions are topologically stable vortex-like spin structure which are considered as a potential candidate for future high-density memory devices. They have been detected in many chiral and polar compounds. Recently, antiskyrmions, the antiparticle of skyrmions[1], have been discovered in Mn1.4PtSn and Mn1.4Pt0.9Pd0.1Sn[2]. Due to topological charge, it can give rise to nonzero topological Hall Effect (THE). We have synthesized the single crystals of Mn1.4PtSn and measured its directional dependent magnetic and transport properties. By means of powder neutron diffraction measurement, a noncoplanar spin structure was found at low temperature. In the noncoplanar magnetic region, we found a large anisotropic THE, which has possibly a topological origin. We show for the first time that THE has contributions both from real and momentum-space Berry phase.

15 min. break

MA 53.8 Fri 11:30 H33

Microscopic understanding of the magnetic phase diagram of $Gd_{1-x}Ca_xMnO_3$ — •Hichem Ben Hamed[1], Martin Hoffmann[2], Waheed A. Adeagbo[1], Arthur Ernst[2,3], Wolfram Hergert[1], Teemu Hynninen[4], Kalevi Kokko[4], and Petriina Paturi[4] — [1]Institute of Physics, Martin Luther University Halle-Wittenberg, Germany — [2]Institute for Theoretical Physics, Johannes Kepler University Linz, Austria — [3]Max Planck Institute of Microstructure Physics, Halle, Germany — [4]Department of Physics and Astronomy, University of Turku, Finland

Rare-earth doped manganites ($RMnO_3$) exhibit a rich variety of promising properties like colossal magnetoresistance, metal-insulator transition and multiferroicity for small rare-earth cations. These properties are primary controlled by the coupling between various types of structural, magnetic, charge and orbital degrees of freedom. The magnetic phase diagram of one prominent member of the $RMnO_3$ series, $GdMnO_3$ with Calcium (Ca) doping, is investigated by methods based on density functional theory and Monte Carlo simulations. A quasi-random distribution of Gd and Ca ions is adopted for each doping concentration.

A robust ferromagnetic (FM) ground state was obtained for the hole doped region ($x < 0.5$). On the other hand, a strong competition between FM and many different anti-ferromagnetic orders was found in the ($x > 0.5$) region. These competitions are discussed in terms of the Heisenberg exchange interactions. Theoretical results are compared with experimental findings.

MA 53.9 Fri 11:45 H33

Tunable magnetic phases at $Fe_3O_4/SrTiO_3$ oxide interfaces — •Mai Hussein Hamed[1], Ronja Anika Hinz[1], Marek Wilhelm[1], Andrei Gloskovskii[2], Peter Bencok[3], Claus M. Schneider[1,4], and Martina Müller[1,5] — [1]Peter-Grünberg-Institut (PGI-6), Forschungszentrum Julich GmbH, Germany — [2]Photon Science, DESY, Hamburg, Germany — [3]Diamond Light Source, Didcot, UK — [4]Fakultät für Physik, Duisburg-Essen Universität , Germany — [5]Experimentelle Physik I, Technische Universität Dortmund, Germany

Oxide heterointerfaces can reveal exciting physical phenomena and pave the ground for novel applications. The prospect of designing and controlling the magnetic properties at the atomic scale of oxide heterointerfaces is one of the major challenges, as this would pave the route towards spintronic applications with novel quantum phases. In this context, merging transition-metal oxides into heterostructures is very promising, owing to their many remarkable properties, such as emerging conductivities, magnetism or ferroelectricity. My research demonstrates the emergence and control of magnetic phases between magnetite (Fe_3O_4), a half-metallic ferrimagnetic, and $SrTiO_3$, a transparent non-magnetic insulator. Using the bulk and interface elemental X-ray techniques, the depth-dependent electronic and magnetic properties of the films and interfaces are studied. This provides an analytical proof for the formation of a magnetically active $\gamma-Fe_2O_3$ intralayer. By taking control of the redox chemical processes at the oxide interface, the efficient reduction into a fully stoichiometric and ferrimagnetic $Fe_3O_4/SrTiO_3(001)$ system can be realized.

MA 53.10 Fri 12:00 H33

Spin-pumping in STO/LSMO/LNO/SRO heterostructures — •Christoph Hauser[1], Camillo Ballani[1], Frank Heyroth[2], and Georg Schmidt[1,2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Von-Danckelmann-Platz 3, 06120 Halle, Germany — [2]Interdisziplinäres Zentrum für Materialwissenschaften, Heinrich-Damerow-Str. 4, 06120 Halle(Saale), Germany

We have investigated spin pumping and the inverse spin-Hall effect in heterostructures based on La0.7Sr0.3MnO3(LSMO), LaNiO3(LNO), and SrRuO3 (SRO). The layers are deposited by pulsed laser deposition. Structural characterization is done by X-ray diffraction and transmission electron microscopy (TEM). The magnetic properties are determined by SQUID magnetometry, and ferromagnetic resonance at a temperature of 190 K. Spin pumping and inverse spin-Hall effect are measured below the Curie temperature of the LSMO but above the one of SRO. For LSMO/LNO/Pt multilayers increased damping in FMR is detected [1], however no ISHE can be measured. For LSMO/LNO a weak ISHE is visible, however the signal cannot be unambiguously identified because of thermo voltages. In the LSMO/LNO/SRO heterostructure a clear ISHE can be measured, which can be separated from side effects stemming from anisotropic magnetoresistance (AMR) and spin rectification [2].

[1] Y. Tserkovnyak *et al.*, Phys. Rev. B, **66**, 224403 (2002)
[2] A. Azevedo *et al.*, Phys. Rev. B, **83**, 144402 (2011)

MA 53.11 Fri 12:15 H33

Magnetic properties of layered $(Cr_{0.5}Mn_{0.5})_2AuC$ films — •Ruslan Salikhov[1], Chung-Chuan Lai[2], Quanzheng Tao[2], Johanna Rosen[2], Ulf Wiedwald[1], and Michael Farle[1] — [1]University of Duisburg-Essen, Duisburg, Germany — [2]Linköping University, Linköping, Sweden

The $M_{n+1}AX_n$ (n =1,2,3) phases are family of nanolaminated ceramics with more than 170 members discovered so far. Mn-based ternary and quaternary compounds led to a new class of magnetic materials, for example $(Cr_{0.5}Mn_{0.5})_2GaC$ [1] and Mn_2GaC [2]. Most recently the synthesis of A = Au MAX phases has been reported [3]. The Au-containing MAX phases were formed by thermally induced substitutional reaction in ternary and quaternary compounds [3]. Following this post-synthesis modification applied to the $(Cr_{0.5}Mn_{0.5})_2GaC$ films the new magnetic $(Cr_{0.5}Mn_{0.5})_2AuC$ system has been stabilized [4]. The substitution of Au for resulted in a expansion of c-axis by about 3.3% perpendicular to the basal plane. Here we present a direct comparative study of magnetic properties of $(Cr_{0.5}Mn_{0.5})_2GaC$ and $(Cr_{0.5}Mn_{0.5})_2AuC$ films and suggest a pathway for tuning magnetic properties in inherently nanolaminated hexagonal MAX phase carbides. This work is supported by DFG, Grant No. SA 3095/2-1 [1] A. Petruhins, et al., J. Mater. Sci. 50, 4495 (2015). [2] A. S. Ingason, et al., Mater. Res. Lett. 2, 89 (2014). [3] H. Fashandi, et al., Nature Mat. 16, 814 (2017). [4] C.-C. Lai, et al., APL Mat. 6, 026104 (2018).

MA 53.12 Fri 12:30 H33

Stabilization of metallic phase in epitaxial NdNiO3 films by Nd excess — Henrike Probst[1], •Marius Keunecke[1], Sebastian Merten[1], Vladimir Roddatis[2], Daniel Steil[1], Sabine Steil[1], Stefan Mathias[1], and Vasily Moshnyaga[1] — [1]Erstes Physikalisches Institut, Georg-August-Universität Göttingen — [2]Institut für Materialphysik, Georg-August-Universität Göttingen

Rare earth nickelates (RENiO3, RE=Sm, Nd, Pr, etc.) are well known for their rich phase diagram, controlled by strong electron-lattice electronic interactions, the mechanism of which is still not well understood. We report the growth of epitaxial NdNiO3 (NNO) thin films by metalorganic aerosol deposition (MAD) technique on (100)- and (111)-oriented LaAlO3 and SrTiO3 substrates. The stoichiometric films demonstrate a metal-insulator (MI) transition, coupled to a structural (orthorhombic/monoclinic) phase transition at Tmi=120-160 K, depending on the epitaxy stress and film thickness. Over stoichiometric films with Nd/Ni ratio>1.5 show overall metallic behavior, remaining in the orthorhombic structure even at low temperatures. We believe the suppression of MI transition is related to a unique nanostructure of the NNO, induced by Nd-rich Ruddlesden-Popper Nd2NiO4 phase

observed by high resolution TEM. Financial support from DFG (SFB 1073 TPA02, B07, Z02, and MO2255-4) is acknowledged.