MA 14 Magnetic Thin Films II

Time: Tuesday 10:15–13:00 Room: HSZ 03

MA 14.1 Tue 10:15 HSZ 03

Thin epitaxial films of the Heusler compound Co_2FeSi — •Horst Schneider[1], Sabine Wurmehl[2], Gerhard Jakob[1], Claudia Felser[2], and Hermann Adrian[1] — [1]Institut für Physik, Universität Mainz, Staudinger Weg 7, 55128 Mainz, Germany — [2]Institut für Anorganische Chemie und Analytische Chemie, Universität Mainz, Staudinger Weg 9, 55128 Mainz, Germany

Bulk samples of the Heusler compound Co_2FeSi (CFS) possess a high Curie temperature of 1100 K. An integer magnetic moment of $6\,\mu_B$/fu suggests halfmetalicity. By using pulsed laser deposition in UHV as well as RF sputtering we prepared thin CFS films on $Al_2O_3(11\bar{2}0)$ and MgO (100). X-ray analysis reveals that these films grow (110)-oriented on sapphire or (100)-oriented on MgO. They exhibit the fully ordered $L2_1$ structure. Magnetic properties were investigated by VSM- and SQUID-measurements, electronic properties by transport measurements. AFM and SEM allowed the analysis of the films' surfaces.

MA 14.2 Tue 10:30 HSZ 03

Covalent bonding and the nature of band gaps in some half-Heusler compounds — •Claudia Felser — Johannes Gutenberg - Universität, 55099 Mainz, Germany

Half-Heusler compounds XYZ, also called semi-Heusler compounds, crystallize in the MgAgAs structure belonging to the space group $F\bar{4}3m$. A systematic examination of band gaps and the nature (covalent or ionic) of bonding in semiconducting 8- and 18- electron half-Heusler compounds through first-principles density functional calculations is reported. The most appropriate description of these compounds - from the viewpoint of electronic structures - is found from a YZ zincblende lattice stuffed by an X ion. Simple valence rules are obeyed for bonding in the 8-electron compound. For example, LiMgN may be written Li^+ + $(MgN)^-$, and (MgN)*, which is isoelectronic with (SiSi), forms a zinc blende lattice. The 18-electron compounds may similarly be considered as obeying valence rules. A semiconductor such as TiCoSb can be written Ti^{4+} + $(CoSb)^{4-}$; the latter unit is isoelectronic and isostructural with zincblende GaSb. For both the 8- and 18-electron compounds, when X is fixed as some electropositive cation, the computed band gap varies approximately as the difference in Pauling electronegativities of Y and Z. What is particularly exciting is that this simple idea of a covalently bonded YZ lattice can also be extended to the very important magnetic half-Heusler phases; these are described as valence compounds, but only in one spin direction. The local moment in these magnetic compounds resides on the X site.

MA 14.3 Tue 10:45 HSZ 03

Magnetism and Phonons at Fe/InAs(001) Interfaces — •R. Peters[1], W. Keune[1], E. Schuster[1], K. Westerholt[2], W. Sturhahn[3], T. S. Toellner[3], J. Zhao[3], E. E. Alp[3], S. Kashiwada[4], and K. Yoh[4] — [1]Applied Physics, University of Duisburg-Essen, 47048 Duisburg, Germany — [2]Experimentalphysik, Ruhr-Universität-Bochum, 44780 Bochum, Germany — [3]APS, Argonne National Laboratory, Argonne, IL 60439 , USA — [4]RCIQE, Hokkaido University, Sapporo 060-8628, Japan

Fe/InAs(001) is a potential candidate for electron spin injection [1]. The properties of the interface play a decisive role. By MBE growth of an isotopically enriched ^{57}Fe(4 ML) probe layer in the Fe layer at different distances from the Fe/InAs interface and by employing Mössbauer spectroscopy (CEMS) and nuclear resonant inelastic X-ray scattering (NRIXS) we have probed the magnetic hyperfine field, B_{hf}, and the phonon density of states, g(E), respectively. Although substantial structural disorder is reflected in g(E) near the interface, the magnitude of the average B_{hf} (and the corresponding local moment $\mu_{Fe} \propto B_{hf}$) remains high. For optical detection of spin injection at magnetic remanence in the Faraday geometry we have grown $[Fe/Tb]_n$ multilayers on p-InAs(001) with perpendicular remanent magnetization at low T, as evidenced by CEMS and SQUID magnetometry. After processing a lateral line-and-space pattern of the multilayer by Ar^+ ion etching a typical Schottky-contact diode I-V characteristics was observed at 1.5 K, which is promising for spin injection. *Supported by DFG (SFB 491 and GRK 277).* [1] H. Ohno et al., Jpn. J. Appl. Phys. **42** (2003) L87.

MA 14.4 Tue 11:00 HSZ 03

Soft magnetic vapor phase co-deposited polymer-metal nanocomposites for high frequency applications — •Henry Greve[1], Vladimir Zaporojtchenko[1], Michael Frommberger[2], Eckhard Quandt[2], and Franz Faupel[1] — [1]Chair for Multicomponent Materials, CAU Kiel, Kaiserstr. 2, 24143 Kiel, Germany — [2]Smart Materials Group, caesar, Ludwig-Erhard-Allee 2, 53175 Bonn, Germany

Recent growing markets for mobile communication handsets and portable information tools require further miniaturization and lower insertion losses for inductive components installed in Monolithic Micowave Integrated Circuits (MMIC). The possible carrier frequency range is from 800 MHz to 3 GHz. Due to potential size reduction, improved quality factor and reduced magnetic stray fields, thin-film inductors will be better than air-core spirals if loss generation in the magnetic film is low at the frequency of interest. Two main loss mechanisms, eddy currents and ferromagnetic resonance (FMR), limit the applicability of soft magnetic films at frequencies $\geq$ 1 GHz. Two component nanocomposites with either a particulate or a multilayer nanostructure could play important roles in such high frequency applications. Here, we present a vapor phase co-deposition method in which we prepare such particulate or multilayer structured, softmagnetic nanocomposite films. These films are several hundred nanometers thick and consist of $Fe_{54}Ni_{27}Co_{19}$ as ferromagnetic and a fluoropolymer as the insulating material component. Up to now we obtained cut-off frequencies above 2 GHz and hf-permeabilities above 100 for the multilayer films.

MA 14.5 Tue 11:15 HSZ 03

Properties of sputtered softmagnetic trilayer sensors and their influence of the GMI-Effect — •Christian Schiefer, Henadzi Yakabchuk, and Erhard Kisker — Institut für Angewandte Physik, Heinrich-Heine Universität Düsseldorf, 40225 Düsseldorf

The GMI-effect gains more and more interest in research due to its characteristics in the detection of small magnetic fields. Compared to amorphous wires, sputtered trilayer structures have the advantage that they can be easily integrated in microchip structures. Annealed soft magnetic thin films based on FeSiBNbCu alloys show a GMI-Effect of about 100% with a sensitivity of 20%/Oe. The Influence of annealing, as well as the occurrence of an aging effect on the GMI effect are presented. The aging effect lead to an improvement in the GMI effect. This is a rarely discussed phenomenon in literature. Its occurrence is determined by various factors. Besides GMI-Mesurements, also other methods like STM or MOKE were applied to characterize the thin films.

MA 14.6 Tue 11:30 HSZ 03

Investigating pinning dominated domain reversal in epitaxial SmCo thin films — •Aarti Singh[1], Volker Neu[1], Roland Tamm[2], Karavati Subbarao[2], Sebastian Fähler[1], Werner Skrotzki[2], Ruben Hühne[1], Ludwig Schultz[1], and Bernhard Holzapfel[1] — [1]IFW Dresden, Institute of Metallic Materials, P.O. Box 270116, D-01171 Dresden, Germany — [2]Institute of Structural Physics, Dresden University of Technology, 01062 Dresden, Germany

Epitaxially grown $SmCo_5$ thin films with strong magnetic anisotropy serve as suitable candidates for understanding the basic mechanisms governing coercivity development in these films. The films were epitaxially prepared by pulsed laser deposition on Cr buffered MgO(110) substrates. The epitaxial relation : $MgO(110)[001] \| Cr(211)[011] \| SmCo(100)[001]$ is confirmed by pole figure measurements and magnetic measurements. The remanence ratio for the two in-plane directions ($\|MgO[110]$ and $\|MgO[001]$) is as low as 0.05, and the estimated in-plane anisotropy is 28 T. Along the easy axis, the maximum energy product, $(BH)_{max}$ is $160 kJ/m^3$, remanence is 0.96 T and coercivity more than 3 T. For evaluating the cause of high coercivities, a temperature dependent coercivity analysis and angle dependent coercivity analysis were done. In both the analyses the results contradict the simple nucleation dominated coercivity mechanism and are better explained by a pinning dominated magnetisation reversal. The large number of grain boundaries due to small grain sizes and stacking faults within the $SmCo_5$ crystallites are discussed as possible pinning centres.

MA 14.7 Tue 11:45 HSZ 03

Extrinsic and intrinsic properties of epitaxial Pr-Co films — •Ajit Patra, Volker Neu, Sebastian Fähler, and Ludwig Schultz — IFW Dresden, Institute for Metallic Materials, P.O. Box 01171, Dresden, Germany

Detailed investigations of the effect of deposition temperature for Cr buffer (TB) and Pr-Co layer (TD) on the phase formation, textured growth and magnetic properties of epitaxial Pr-Co films are performed by X-ray diffraction (XRD), pole figure measurements and vibrating sample magnetometry (VSM), respectively. Films have been prepared by pulsed laser deposition (PLD) on Cr buffered MgO (100) substrate. Unlike the buffer deposition temperature, the Pr-Co deposition temperature has a large influence on the structure and magnetic properties of the Pr-Co films. For the extreme temperatures, i.e. 300 °C and 700 °C, no Pr-Co phase formation is observed. However films prepared between 300 °C and 700 °C develop a hexagonal Pr-Co phase and grow epitaxially on MgO substrate. Due to the four fold symmetry of the MgO(100) substrate, the c axis is found to be along both, the MgO[010] and MgO[001] direction, which is also confirmed by magnetic measurements. Optimum magnetic properties, $\mu_0 H_c \approx 2.24$ T, $J_R \approx 1.01$ T, $(J_R/J_S) \approx 0.84$ and magnetic texture ($J_R^{hard\ axis}/J_R^{easy\ axis} \approx 0.04$) have been obtained for films deposited at 600 °C.

MA 14.8 Tue 12:00 HSZ 03

Layer-resolved magnetization of a Heisenberg film from magnetic Laue profiles — •Enrico Schierle[1], Eugen Weschke[1], Alexander Gottberg[1], Günter Kaindl[1], Walter Söllinger[2], and Gunther Springholz[2] — [1]Institut für Experimentalphysik, Freie Universität Berlin, D-14195 Berlin, Germany — [2]Institut für Halbleiterphysik, Johannes Kepler University, A-4040 Linz, Austria

Layer-dependent properties of magnetic films have been the subject of extensive theoretical studies since the work of Binder and Hohenberg [1]. Using resonant magnetic soft x-ray scattering, we studied the temperature-dependent magnetization of the individual layers in thin (111) films of the prototypical Heisenberg antiferromagnet EuTe [2]. The high magnetic sensitivity at the lanthanide M_5 resonance [3] can be exploited and for the x-ray wavelength of the resonance, the magnetic signal appears exactly at the Brewster angle, which allows to measure magnetic scattering virtually free of charge background. Thus, the magnetic Laue profile of a 20-layer thick film can be measured with unprecedented quality over a large range of momentum transfer. The real-space magnetization profile across the film is obtained from the corresponding Patterson function, yielding the temperature-dependent magnetization of each individual layer. The results are in agreement with Monte-Carlo calculations that show reduced magnetization and enhanced critical exponents for the temperature dependence in the surface region.

[1] K. Binder and P.C. Hohenberg, Phys. Rev. B 9, 2194 (2004).
[2] H. Kepa et al., Phys. Rev. B 68, 24419 (2003).
[3] E. Weschke et al., Phys. Rev. Lett., 93 (157204), 2004.

MA 14.9 Tue 12:15 HSZ 03

TEM investigations of epitaxially grown Sm-Co/Cr films on MgO single crystal substrates — •K. Subba Rao[1], R. Tamm[1], C.-G. Oertel[1], W. Skrotzki[1], A. Singh[2], V. Neu[2], S. Faehler[2], and B. Holzapfel[2] — [1]Institute of Structural Physics, TU Dresden, D-01062 Dresden, Germany — [2]IFW Dresden, Helmholtzstr. 20, D-01069 Dresden, Germany

Hard magnetic Sm-Co/Cr films were epitaxially grown on MgO(100) and (110) substrates. They were characterized by X-ray pole figure measurements and transmission electron microscopy. For films deposited on MgO(100) at 700 °C, orientations are found with the c-axis aligned in-plane and out-of-plane. By lowering the deposition temperature to 370 °C, the out-of-plane orientations disappeared. Further lowering to 350 °C leads to the formation of amorphous regions in the Sm-Co film. For films grown on MgO(110) the Cr buffer deposition temperature plays an important role. When deposited at 700 °C Cr(211) and (100) orientations are observed leading to two different types of Sm-Co in-plane orientations. By lowering the Cr-buffer deposition temperature to 300 °C only one buffer and one Sm-Co orientation exists: Cr(211) and Sm-Co(10-10). The exact orientation relationships between substrate, buffer and films will be explained and its correlation with magnetic properties will be discussed.

MA 14.10 Tue 12:30 HSZ 03

Effect of composition on Nd-Fe-B hard magnetic thin films — •Ah-Ram Kwon, Sebastian Fähler, Volker Neu, and Ludwig Schultz — IFW Dresden, , Institute for Metallic Materials, P.O. Box 270116, D-01171 Dresden, Germany

While for bulk $Nd_2Fe_{14}B$ the influence of composition on microstructure, phase formation and texture is understand quite well, only little work exists on thin films. The $Nd_2Fe_{14}B$ phase has only a very narrow existing range, thus in bulk materials a derivation from stoichometry (2:14:1) results in the formation of additional phases. Nd-Fe-B hard magnetic thin films were deposited on a combinded Cr/Ta buffer layer on heated MgO(100)substrates by pulsed laser deposition. On this buffer system $Nd_2Fe_{14}B$ grows epitaxial in one single orientation. This allows a detailed examination of the intrinsic properties and results in an almost perfect magnetic texture. The effect of composition on phase formation, morphology and magnetic properties was investigated. Optimum phase formation is obtained at a Nd/Fe ratio around 0.3. For this Nd content an excellent magnetic texture and a coercivity up to 1 T can be obtained; however, films have a granular microstructure with high roughness. Also a certain B surplus is of benefit; though with a too high B or Nd surplus phase formation is more difficult.

MA 14.11 Tue 12:45 HSZ 03

Perpendicular magnetic anisotropy induced by tetragonal distortion of FeCo alloy films grown on Pd(001) — •Aimo Winkelmann, Marek Przybylski, Feng Luo, Yisheng Shi, Jochen Barthel, and Jürgen Kirschner — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany

We grew tetragonally distorted Fe_xCo_{1-x} alloy films on Pd(001). The films were grown at 295 K by molecular beam epitaxy using thermal evaporation from two effusion cells. Theoretical first-principles calculations for such films predict a high saturation magnetization and a high uniaxial magnetic anisotropy energy for specific values of the lattice distortion c/a and the alloy composition x. The magnetic anisotropy was investigated using the magneto-optical Kerr effect. For films of varying composition, we observed a spin-reorientation transition from in-plane to out-of-plane and back to in-plane with increasing cobalt content. Out-of-plane anisotropy was observed for $Fe_{0.5}Co_{0.5}$ films in the thickness range of 4 to 14 ML. Using low energy electron diffraction Kikuchi patterns, the c/a value of about 1.13±0.02 obtained for the tetragonal distortion is consistent with the results formerly obtained for pure Fe (1.11) and Co (1.15) films on Pd(001). The magnetic anisotropy energy induced by the tetragonal distortion is estimated to be almost two orders of magnitude larger than the value for bulk FeCo alloys. A decrease of the tetragonal distortion with thickness can be related to a decrease of the out-of-plane anisotropy energy which is overturned by the in-plane magnetostatic energy above the thickness of 14 ML.