MA 20: Magnetic Thin Films II

Time: Wednesday 15:15–18:45 Location: H5

MA 20.1 Wed 15:15 H5

Electronic transport in Co_2FeSi thin films — •Horst Schneider and Gerhard Jakob — Johannes Gutenberg-Universität, Institut für Physik, Mainz, Germany

Recently it has been discussed whether the Heusler compound Co_2FeSi is a half-metallic system. The comparison of band structure calculations with experimental results indicate that electron correlations play an inportant role in this question. In order to gain further insight into the electronic structure of this material, we have prepared thin epitaxial as well as disordered films of Co_2FeSi. Subsequent patterning of these samples allowed the precise investigation of their anisotropic transport properties. Measurements of magnetoresistance and Hall effect will be presented and compared to the structural and magnetic properties of the films. Possible explanations for the observed behaviour will be given.

MA 20.2 Wed 15:30 H5

Epitaxial Heusler alloy cobalt iron silicide films on GaAs — •Jens Herfort, Masahiko Hashimoto, Hans-Peter Schönherr, Achim Trampert, and Klaus Ploog — Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin

Heusler alloys are promising candidates for spintronic and magnetotunneling applications due to their high Curie temperatures, compatibility with compound and elemental semiconductors and their possibly half-metallic behavior. However, atomic ordering and interface quality have a significant influence on their structural, electrical and magnetic properties. Here, we present our results on the fabrication as well as the structural, electrical and magnetic properties of single-crystal Co_2FeSi/GaAs(001) heterostructures grown by molecular-beam epitaxy at various growth temperature T_G. As evidenced by double crystal X-ray diffraction (DCXRD) and transmission electron microscopy (TEM) measurements, ferromagnetic layers with high crystal and interface perfection can be obtained. The exact stoichiometry of the Heusler alloy films can be achieved for almost lattice matched films. From DCXRD, TEM and resistivity measurements we find an optimum T_G, near 200°C, to obtain layers with high crystal and interface perfection as well as high a degree of atomic ordering. It is important to note that this optimum T_G is considerably higher than that for Fe and Co on GaAs(001). The layers are ferromagnetic at room temperature with the easy axis of magnetization within the film plane. The dependence of the magnetic in-plane anisotropy on the stoichiometry as well as on the atomic ordering will be addressed.

MA 20.3 Wed 15:45 H5

Magnetism and magnetoelectric properties of multiferroic $HoMnO_3$ thin films — •Jong-Woo Kim[1], Kathrin Dörr[1], Konstantin Nenkov[1], Ludwig Schultz[1], Bas B. van Aken[2], and Manfred Fiebig[2] — [1]Institute for Metallic Materials, IFW Dresden, Postfach 270116, 01171 Dresden, Germany — [2]HISKP, Universität Bonn, Nussallee 14-16, 53115 Bonn, Germany

Hexagonal $HoMnO_3$, one of the most promising single-phase multiferroics, has received much interest because of its strong magnetoelectric effect [1,2]. We have grown twin-free epitaxial $HoMnO_3$ films of thicknesses from 25 nm to 240 nm on (111) Y:ZrO_2 (YSZ) substrates by pulsed laser deposition. Ferroelectric polar order and Mn antiferromagnetism of the films has been observed by optical second harmonic generation [3]. Magnetization measurements reveal magnetic Ho ordering which is, with subtle deviations, similar to that of bulk crystals.

For the investigation of magnetoelectric properties, trilayer capacitor structures using an epitaxial Pt bottom electrode have been prepared. Measurements of the electric polarization at such trilayers demonstrate ferroelectric switching at 300 K, inspite a certain degree of leakage. Measurements of the magnetoelectric response in both ways, i. e. of the electric polarization vs. magnetic field and of the magnetization vs. electric field are in progress.

[1] F. Yen, et al., Phys. Rev. B 71, 180407 (2005)
[2] T. Lottermoser, et al., Nature 430, 541 (2004)
[3] J.-W. Kim et al., Appl. Phys. Lett. (in press)

MA 20.4 Wed 16:00 H5

Morphology and electronic structure of Cobalt islands grown on Pd(111) — •Marta Waśniowska[1], Wulf Wulfhekel[1,2], Marek Przybylski[1], and Jürgen Kirschner[1] — [1]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120, Halle, Germany — [2]Physikalisches Institut, Universität Karlsruhe, 76128 Karlsruhe, Germany

We have investigated Co islands grown on Pd(111) at three different temperatures, i.e. 180 K, 300 K, 550 K. The island shapes and electronic structure of these Co islands were studied with scanning tunneling microscopy and scanning tunneling spectroscopy. Depending on the growth temperatures, monolayer or double layer islands are formed in the early stages of growth. On the hexagonal double layer islands formed at 300 K a Moiré pattern appears. The unit cell of the Moiré pattern contains Co in fcc and hcp stacking, as well as Co in the bridge or on top position. Both fcc and hcp regions show similar features in dI/dU spectra. However, the surface state peak positions are slightly shifted. Triangular monolayer high islands formed at 550 K either continuous in fcc or hcp stacking. The position of the surface state peak depends on stacking of the island, as well. The magnetic structure of the islands was investigated by means of spin polarized scanning tunneling spectroscopy. The measurements reveal a spin contrast reflecting the out-of-plane magnetization of the islands.

MA 20.5 Wed 16:15 H5

Ripple Induced Modifications of Magnetic Properties. — Maciej Oskar Liedke, Adrian Keller, Stefan Facsko, and •Jürgen Fassbender — Forschungszentrum Dresden-Rossendorf, Institute of Ion Beam Physics and Materials Research, D-01314 Dresden

Self-organized ripple formation during ion erosion of a Si wafer is used to create a template system with a well defined roughness of uniaxial symmetry. By using special buffer layers subsequent thin magnetic film deposition by molecular beam epitaxy leads to a periodically modulated magnetic thin film with drastically modified magnetic properties with respect to a nominally flat film of the same thickness. In the case of Permalloy thin films, an enhancement of the uniaxial in-plane anisotropy by approximately a factor of 20 is observed. The enhancement can be explained by a combination of step induced dipolar and magnetocrystalline surface anisotropy contributions. If a ferromagnet/antiferromagnet-bilayer is deposited a superposition of ripple-induced uniaxial anisotropy and exchange coupling induced unidirectional anisotropy is observed. Since the direction of the unidirectional anisotropy depends only on the magnetic field direction during a field cooling procedure any angle between both anisotropy contributions can be set.

MA 20.6 Wed 16:30 H5

Investigation of the crystallographic structure of hydrogenated (Ga,Mn)As — •Christoph Bihler[1], Hans Huebl[1], Bastian Galler[1], Martin Brandt[1], Gema Martinez-Criado[2], Gianluca Ciatto[2], Aldo Amore Bonapasta[3], Francesco Filippone[3], Wladimir Schoch[4], and Wolfgang Limmer[4] — [1]Walter Schottky Institut, TU München, Am Coulombwall 3, 85748 Garching — [2]ESRF, 6 rue J. Horowitz, Boite Postale 220, 38043 Grenoble, France — [3]ISM, Via Salaria, CP 10, 00016 Monterotondo Stazione, Italy — [4]Institut für Halbleiterphysik, Universität Ulm, 89069 Ulm

The lattice expansion of (Ga,Mn)As samples after deuteration $\Delta V_D/V_{\mathrm{Mn-As}} \approx 0.14$ obtained from x-ray diffraction (XRD) agrees best with that expected for a complex with the D atom bond-centered (BC) between the Mn and a neighboring As atom, but the difference to the volume expansion expected for the antibonding (AB) configuration is too small to draw unambiguous conclusions. However, the absence of a second peak or shoulder in the Fourier transform of the Mn K-edge extended x-ray absorption fine structure (EXAFS) χ function corresponding to the first coordination shell of deuterated samples, as well as the comparison of the corresponding x-ray absorption near-edge structure (XANES) with simulations of the different complexes strongly suggests that the BC complex predicted by theoretical calculations can be excluded in the deuterated samples. Rather, both EXAFS and XANES spectra can be explained by the formation of AB complexes or complexes in which the D atom is not bound to a nearest As neighbor, but a more distant As atom.

MA 20.7 Wed 16:45 H5

Magneto-optics in the vicinity of the $M_{2,3}$ and $L_{2,3}$ edges

of iron — •Armin Kleibert[1], Joachim Bansmann[2], Ponpandian Nagamony[1], and Karl-Heinz Meiwes-Broer[1] — [1]Institut für Physik, Universität Rostock, Universitätsplatz 3, D-18051 Rostock — [2]Institut für Oberflächenkatalyse, Universität Ulm, D-89069 Ulm

Soft x-ray and EUV based experimental techniques are powerful and very sensitive methods in order to investigate the properties of systems with low dimensions such as ultrathin films or clusters. In particular magnetic linear and circular dichroism effects in the vicinity of element-specific resonances have attracted much attention. While respective absorption experiments are frequently applied in order to study the properties of magnetic nanostructures reflectivity-based techniques are still comparably rare to find. However, the reflectivity as well as the absorption properties of a material are determined by one dielectric tensor and thus yield the same information. In this contribution, we present the full dielectric tensor of iron in the vicinity of the $M_{2,3}$ as well as the $L_{2,3}$ edges obtained from absorption experiments as well as from reflectivity data. The data are then used in order to simulate magneto-optical effects occuring in absorption, transmission as well as in reflection of polarized radiation in both energy ranges. Characteristic properties are discussed for some practically relevant situations in respective experiments.

MA 20.8 Wed 17:00 H5

Magnetic orbital moment and uniaxial anisotropy in tetragonally distorted $Fe_{1-x}Co_x$ films — Fikret Yildiz, •Marek Przybylski, Feng Luo, Carsten Tieg, Radu Abrudan, and Jurgen Kirschner — Max-Planck-Institut fur Mikrostrukturphysik, Halle, Germany

The quenching of the orbital moment, which occurs in high lattice symmetries, can be removed by a symmetry reduction. The unquenched orbital magnetization is accompanied by a significant anisotropy of the orbital moment itself, which in turn induces a strong magnetic anisotropy owing to spin-orbit coupling. Previously we have shown that the $Fe_{1-x}Co_x$ alloy films of the composition around $x = 0.5 - 0.6$ show a clear out-of-plane easy axis of magnetization when their fcc lattice is tetragonally distorted. Rectangular polar magneto-optical Kerr loops were measured up to a thickness d_c, which was found to depend strongly on the film composition. Here we report on the magnetic circular dichroism in soft x-ray absorption measurements of the same $Fe_{1-x}Co_x$ tetragonally distorted films, which were carried out at the UE56/2-PGM2 beamline at BESSY in Berlin. In contrast to fcc-crystals of cubic symmetry where the orbital moment is almost completely quenched, a strong enhancement of the Co orbital moment is found - depending on composition - with a maximum value at $x = 0.6$. This dependence of the orbital moment coincides well with the composition dependence of the d_c, which is a measure of the volume magnetocrystalline anisotropy.

MA 20.9 Wed 17:15 H5

Electronic structure of chemically disordered FePt films — •Hans-Gerd Boyen[1], Sven Bornemann[2], Ulf Wiedwald[1], Anitha Ethirajan[1], Gerd Kästle[1], Paul Ziemann[1], Jan-Ulrich Thiele[3], David Bachelor[4], Kai Fauth[5], Jan Minar[2], Hubert Ebert[2], Andriy Romanyuk[6], and Peter oelhafen[6] — [1]Institut für Festkörperphysik, Univ. Ulm — [2]Abteilung Physikalische Chemie, LMU München — [3]Hitachi Global Storage Technologies, San Jose Research Center, San Jose — [4]BESSY GmbH, Berlin — [5]MPI für Metallforschung, Stuttgart — [6]Institut für Physik, Univ. Basel

FePt nanoparticles deposited as two-dimensional arrays on top of suitable substrates are currently in the focus of interest because they offer the potential to be used as ultra-high density data storage media in magnetic recording applications. In order to better understand the electronic properties and, finally, the resulting complex magnetic behaviour of such nanoscaled systems, corresponding bulk alloys have been prepared as reference systems in the chemically disordered state allowing to systematically analyze their electronic structure over a wide range of compositions. Synchrotron radiation induced photoemission (photon energy 180-900eV) is used as a tool to access the element-specific densities of states within the different alloys. Experimental valence-band spectra will be compared to theoretical spectra predicted for the various photon energies and alloy compositions on the basis of band structure calculations performed within the framework of a scalar-relativistic Korringa-Kohn-Rostocker approach using the Coherent Phase Approximation.

MA 20.10 Wed 17:30 H5

fcc and fct FePt: magnetic moments, magnetic moment anisotropy and their relation to magnetocrystalline anisotropy — •Kai Fauth[1], Carolin Antoniak[2], Sven Bornemann[3], Jan-Ulrich Thiele[4], Ulf Wiedwald[5], Marina Spasova[2], Fabrice Wilhelm[6], Andrei Rogalev[6], Hans-Gerd Boyen[5], Jan Minar[3], Hubert Ebert[3], Paul Ziemann[5], Michael Farle[2], and Gisela Schütz[1] — [1]MPI für Metallforschung, D-70569 Stuttgart — [2]Universität Duisburg-Essen, Fachbereich Physik, D-47048 Duisburg — [3]LMU München, Department Chemie und Biochemie, D-81377 München — [4]Hitachi Global Storage Technologies, San Jose Research Center, San Jose, CA 95135, USA — [5]Universität Ulm, Abteilung Festkörperphysik, D-89069 Ulm — [6]ESRF, Polygone Scientifique Louis Néel, F-38000 Grenoble

The transition from the disordered fcc FePt alloy to the the chemically ordered fct $L1_0$ phase is accompanied by the occurrence of very large magnetocrystalline anisotropy. $L_{3,2}$ edge X-ray magnetic circular dichroism was used to investigate Fe and Pt magnetic moments as well as their anisotropy for both, disordered and ordered FePt, respectively. The orbital magnetic moments at both, Fe and Pt sites are maximized along the easy magnetization axis in the $L1_0$ phase. Calculated magnetic moments were determined from fully relativistic band structure calculations and display the same anisotropy behaviour. In addition, the calculations indicate that chemical ordering is the dominant contribution to magnetocrystalline anisotropy as compared to tetragonal lattice distortion.

MA 20.11 Wed 17:45 H5

Non-collinear magnetism of magnetic 3d-monolayers on Cu and Ag (111) surfaces — •Robert Wieser, Elena Vedmedenko, and Roland Wiesendanger — Institut für Angewandte Physik, Jungiusstr. 11, 20355 Hamburg

It has been recently shown that in low-dimensional, 3d transition metal films on noble metal substrates or at the metal-metal interface complex non-collinear spin structures are possible (P. Kurz et al., PRL **86**, 1106, (2001)). Understanding of the magnetic ordering in 3d metals on non-magnetic substrates is important as non-collinear structures have been proposed to play a key role for the exchange bias. The magnetic non-collinearity arises due to the delocalized nature of the electrons responsible for magnetic properties of itinerant magnets and super-exchange interactions via the substrate. These phenomena cannot be described in the framework of the simple Heisenberg Hamiltonian. To describe the non-collinear magnetism we generalize the classical Heisenberg spin model by addition of the contributions coming form exchange interaction up to 3rd nearest neighbor, biquadratic exchange and four-spin interactions. In this presentation the results of classical Monte Carlo calculations for monolayers of Mn on Cu(111) and V on Ag(111) will be shown. All interaction parameters come from the first principles calculations. Magnetic ordering of both systems is found to be non-collinear. The low-temperature, stable configuration of Mn/Cu(111) is a 3Q magnetic state. For V/Ag(111) we find a magnetic phase transition between two different stable configurations at $T \sim 20K$. Interestingly both structures are uncompensated.

MA 20.12 Wed 18:00 H5

Spin-dependence of the Ni *d*-band transition in inverse photoemission on ultrathin Ni films on Cu(001) — •Volker Renken and Markus Donath — Physikalisches Institut, Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany

Ultrathin Ni films on Cu(001) represent one of the most studied magnetic thin-film systems. The spin-dependent bulk band structure of Ni(001) shows that only minority *d*-bands exist above the Fermi level, while the majority *d*-bands are completely occupied. This makes Ni a strong ferromagnet. Consequently, spin- and angle-resolved inverse photoemission measurements of Ni(001) and of thick Ni films on Cu(001) show a spectral feature just above the Fermi level, which results from transitions into the unoccupied *d*-bands and appears for minority spin only. In contrast, for ultrathin Ni films on Cu(001) the corresponding spectral feature appears for both minority spin and majority spin. At this, the spectral feature resulting from the *d*-bands is affected by several factors, which are discussed within this talk: the influence of the Cu(001) substrate, additional quantum-well states, a reduced magnetization in thin films and at room temperature, a change of the magnetic anisotropy, and a two-dimensional band structure which is different from the bulk one.

MA 20.13 Wed 18:15 H5

Real time optical monitoring of ultrathin magnetic film

growth on Cu(110) — •Richard Denk, Michael Hohage, L.D. Sun, and Peter Zeppenfeld — Institut für Experimentalphysik, Johannes Kepler Universtät Linz, A-4040 Linz, Austria

Reflectance Difference Spectroscopy (RDS) has been used to monitor the growth of thin Ni films on Cu(110)(2x1)O and to characterise them. Whereas the regular optical anisotropy signal originates from the morphology of the film, the RD-spectrometer may sense additionally the out of plane magnetisation of the film via polar Magneto-Optical Kerr Effect (MOKE) [1]. The RD-spectrometer allows conducting spectroscopic measurements of the films at photon energies between 1.5 eV and 5.5 eV. To perform the magnetic measurements the UHV chamber is equipped with an in-situ electromagnet. As the magnetic signal is superimposed onto the regular anisotropy signal, applying the RD-technique at opposite magnetisation (M^+,M^-) of the film, the pure RDS signal ($\Delta r/r(M^+) + \Delta r/r(M^-)$)/2 can be separated from the MOKE signal ($\Delta r/r(M^+) - \Delta r/r(M^-)$)/2. Using RD- transients at a fixed wavelength hysteresis curves at any desired photon energy between 1.5 eV and 5.5 eV can be recorded. For film characterization, in addition to RDS, the chamber is equipped with a STM and a LEED/AES system. A major focus of the study has been the effect of adsorption on the magnetic properties of ultrathin Ni films, as well as the way how the remanent polar magnetisation develops within the ultrathin Ni films. References [1] M. Wahl, Th. Herrmann, N. Esser, and W. Richter, phys. stat. sol. c, 3002 (2003)

MA 20.14 Wed 18:30 H5

Das Einsetzen von Ferromagnetismus in ultradünnen epitaktischen ^{57}Fe-Filmen auf GaAs(001)-(4x6) — •Ellen Schuster[1], Robert Peters[1], Werner Keune[1], Heiko Wende[1], Andreas Westphalen[2] und Hartmut Zabel[2] — [1]Fachbereich Physik, Universität Duisburg-Essen, D-47048 Duisburg — [2]Experimentalphysik/Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum

Ultradünne ^{57}Fe(001)-Filme wurden bei Raumtemperatur (RT) auf GaAs(001)-(4x6) epitaktisch aufgewachsen und ihre Struktur mittels RHEED untersucht. Unterhalb einer Dicke von $t_{Fe} \sim 3$ ML (Monolagen) wurde Inselwachstum beobachtet. Die magnetischen Eigenschaften wurden in-situ im UHV (unbedeckte Filme) und ex-situ nach Pt-Bedeckung mittels Mössbauerspektroskopie (CEMS) ermittelt. Unbedeckte Fe-Filme mit $t_{Fe} \sim 2$ ML und ~ 3 ML besitzen magnetische Übergangstemperaturen weit unterhab RT und zeigen einen steilen linearen Abfall des magnetischen Hyperfeinfeldes B_{hf} mit T, was auf superparamagnetisches Verhalten von Fe-Clustern hinweist. Nach Pt-Bedeckung steigen die magnetischen Übergangstemperaturen drastisch an, bei RT wird das Einsetzten von langreichweitigem Ferromagnetismus bei $t_{Fe} = 2.5 \sim 3$ ML beobachtet, und B_{hf}(T) weist auf 2D-Verhalten hin. Dies ist eine Folge der magnetischen Kopplung der Fe-Cluster über die Pt-Schicht. Gefördert durch die DFG (SFB 491)