# MA 2 Magnetic Thin Films I

Time: Monday 10:15–12:45 Room: HSZ 03

MA 2.1 Mon 10:15 HSZ 03

**Measuring the kernel of time-dependent density functional theory with X-ray absorption spectroscopy of 3*d* transition metals** — •H. Wende[1], A. Scherz[2], E.K.U. Gross[1], H. Appel[1], C. Sorg[1], K. Baberschke[1], and K. Burke[3] — [1]Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, D-14195 Berlin-Dahlem, Germany. — [2]SSRL, 2575 Sand Hill Road, Menlo Park, California 94025, USA — [3]Department of Chemistry and Chemical Biology, Rutgers University, 610 Taylor Rd, Piscataway, NJ 08854, USA

We showed that the induced magnetic moments in ultrathin films of the light 3d elements Ti, V and Cr at the interface to Fe cannot be determined by the XMCD sum rule analysis at the $L_{2,3}$ edges. The reasons are correlation effects which result in the deviation of the intensity ratio (branching ratio) from its statistical value. Therefore, we established a double-pole approximation within time-dependent density functional theory to investigate these effects in detail. A (2×2) matrix of the matrix elements of the unknown exchange correlation kernel is used to describe the shift of the two transitions (diagonal) and the change of the branching ratio (off-diagonal elements). We experimentally measure the branching ratios and level splittings for these films, and *deduce* these matrix elements. It turns out that off-diagonal matrix elements are much smaller (factor 5) than the diagonal ones which demonstrates that the change of the branching ratio for the light 3d elements is simply due to transition repulsion, as the two transitions near one another (reduced spin-orbit splitting). Supported by BMBF (05 KS4 KEB 5).

[1] A. Scherz *et al.*, Phys. Rev. Lett. in print

MA 2.2 Mon 10:30 HSZ 03

**Acquisition of optic and magneto-optic constants of Co/Pt films** — •S. Fiedler[1], H. Stillrich[1], G. Neuber[1], M. Linkerhand[2], P. Pahl[2], and H.P. Oepen[1] — [1]Institut für Angewandte Physik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg, Germany — [2]Universität Hamburg, 20355 Hamburg, Germany

Ultrathin Co layers on fcc Pt buffers showing (111) texture exhibit a strong perpendicular magnetic anisotropy. We have created Pt-Co-Pt layers on silicon substrates utilizing ECR-sputtering. For experimental investigation of the magnetic properties we use an ex situ MOKE experiment with He-Ne laser. We measure Kerr ellipticity and rotation quantitatively in longitudinal and polar geometry at an angle of incidence of 45 degrees as well as in polar geometry at 0 degree. We have investigated the magneto-optic properties of sandwiched single Co layers with fixed thickness and varying buffer or cap layer thickness. A strong dependence of the Kerr signals on cap as well as buffer layer thickness is found. The experimental results are simulated numerically [1] taking into account the intermixing Co/Pt. The dependence on cap layer thickness will be described in the framework of a simplified analytical expression for ultrathin films [2].

[1] J. Zak, E. R. Moog, C. Liu, and S.D. Bader, J. Magn. Magn. Mat. 89, 107 (1990)
[2] C.-Y. You and S.-C. Shin, phys. stat. sol. (b) 241, No. 7, 1406-1410 (2004)

MA 2.3 Mon 10:45 HSZ 03

**XPS investigation of the Mn valence in lanthanum manganite thin films under variation of the oxygen content** — •Elke Beyreuther[1], Stefan Grafström[1], Christian Thiele[2], Kathrin Dörr[2], and Lukas M. Eng[1] — [1]Institut für Angewandte Photophysik, Technische Universität Dresden, D-01062 Dresden — [2]Institut für Metallische Werkstoffe, IFW Dresden, Postfach 270116, D-01171 Dresden

The question whether $LaMnO_3$ accepts doping with tetravalent cations such as cerium and thus allows the preparation of electron-doped mixed-valent lanthanum manganites has been discussed controversially so far. Against the background of this problem, we present a comparative X-ray photoemission (XPS) study of epitaxial $La_{0.7}Ce_{0.3}MnO_3$ (LCeMO) and $La_{0.7}Ca_{0.3}MnO_3$ (LCMO) thin films. We focus on the exchange splitting of the Mn 3*s* core level peak, which is a direct indicator of the Mn valence [1] and allows us to quantify the Mn valence in the outermost 3 nm of the films. We demonstrate that, depending on the oxygen content, the Mn valence can be tuned between a mixed $Mn^{3+/4+}$ state and a mixed $Mn^{2+/3+}$ state in *both* the LCeMO *and* the LCMO film. The oxygen content was varied by heating in ultrahigh vacuum for deoxygenation and in an oxygen atmosphere for reoxidation. In the LCeMO film, the deoxygenation not only changes the Mn valence, but also the Ce valence is driven from the 4+ towards the 3+ state.

[1] V. R. Galakhov *et al.*, Phys. Rev. B **65**, 113102 (2002).

MA 2.4 Mon 11:00 HSZ 03

**Spin-Polarized Scanning Tunneling Spectroscopy of Dislocation Lines in Fe Films on W(110)** — •Oswald Pietzsch, Matthias Bode, Kirsten von Bergmann, André Kubetzka, and Roland Wiesendanger — Institute of Applied Physics, University of Hamburg, Jungiusstrasse 11, 20355 Hamburg

The magnetic properties of 1 - 2 atomic layers Fe on W(110) have recently been studied in many aspects by spin-polarized scanning tunneling microscopy (SP-STM) and spectroscopy (SP-STS). Here we use the high lateral and energy resolution of this method to address the structural, electronic, and magnetic properties of dislocation lines which occur before completion of the second layer, thereby releasing tensile strain arising from a 9.4 % lattice mismatch. The lines are found to be ferromagnetically ordered. The magnetic contrasts are related to the film's perpendicular domain configuration, but the electronic features are quite unique. In particular, from the well-known two-peak structure of the Fe film, the occupied LDOS-peak is recovered in the dislocation line while the unoccupied peak is strongly shifted towards the Fermi level. As a consequence, the bias-voltage dependent magnetic asymmetry as determined from tunneling spectra is significantly altered in these lines.

MA 2.5 Mon 11:15 HSZ 03

**Second-order magnetoelastic coupling of strained Fe** — •Z. Tian, C.S. Tian, D. Sander, and J. Kirschner — Max-Planck-Institut für Mikrostrukturphysik,

Lattice strain is often the decisive factor which determines the magnetic anisotropy of ferromagnetic monolayers (ML). We performed combined cantilever bending beam and magneto-optical Kerr-effect measurements to determine the correlation between film stress, strain and the magnetic anisotropy of Fe ML deposited on Ir(001). The Fe ML are under compressive stress, as expected from the mismatch of 4.9% between bcc Fe and Ir. We use in-situ stress measurements to determine the lattice strain. The magnetoelastic coupling coefficient $B_2$ is determined from the change of crystal curvature upon switching the magnetization along the length and width of the sample. The value of $B_2$ deviates from the bulk value and depends on the film strain $\epsilon$. The experimental data suggest a linear dependence of $B_2$ on lattice strain as given by $B_2^{eff}=B_2^{bulk}+D_2\,\epsilon$, with the bulk value $B_2^{bulk}$=7.83 MJ/m$^3$, $D_2$=-350 MJ/m$^3$. Our results extend the experimental data base[1] to compressive strain. This result indicates the decisive role of second-order magnetoelastic effects for the magnetic anisotropy of strained Fe ML, where reliable theoretical values have not been obtained yet[2].

[1] G.Wedler, J. Waly, A. Greuer and R. Koch: Phys. Rev. B **60**, R11313 (1999).
[2] M. Fähnle, M. Komelj: Z. Metallkd. **93**, 970 (2002).

MA 2.6 Mon 11:30 HSZ 03

**Interface formation and its influence on magnetic anisotropy in ultrathin Fe films grown by TD and PLD on GaAs(001)** — •Marek Przybylski[1], Jan Zukrowski[2], Bartlomiej Kardasz[3], Oleksandr Mosendz[3], Bretislav Heinrich[3], and Jürgen Kirschner[1] — [1]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany — [2]Solid State Physics Department, Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, Mickiewicza 30, 30-059 Krakow, Poland — [3]Simon Fraser University, Department of Physics, 8888 University Drive, Burnaby, B.C., V5A 1S6 Canada

The role of the Fe/GaAs(001) interface atomic structure on the magnetic properties of ultrathin film of Fe was investigated by using a 2 ML of $^{57}$Fe probe layer grown on a GaAs(001) substrates by thermal deposition (TD) or by pulsed laser deposition (PLD) techniques. To assure film continuity and a Curie temperature well above room temperature (RT), the probe layer was covered with an additional 8 ML of natural Fe. Conversion electron Mössbauer spectra (CEMS) were measured ex situ at RT. A broad low-magnetic field component was clearly present in the measured Mössbauer spectrum for the PLD probe layer. Most likely this component can be attributed to a high degree of atomic intermixing at the Fe/GaAs interface. A low-field component was not detected in the case of the TD-grown $^{57}$Fe probe layer. Ferromagnetic resonance (FMR) was used to measure the magnetic anisotropies of the studied films. It will be shown that all anisotropies were strongly affected by TD and PLD deposition techniques.

MA 2.7 Mon 11:45 HSZ 03

**Magnetic anisotropy of $Ga_{1-x}Mn_xAs$ on GaAs (311)A** — •Christoph Bihler[1], Hans Huebl[1], Dieter Schlosser[1], Martin S. Brandt[1], Sebastian T. B. Goennenwein[2], Matthias Reinwald[3], Ursula Wurstbauer[3], Matthias Döppe[3], Dieter Weiss[3], and Werner Wegscheider[3] — [1]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany — [2]Walther-Meissner-Institut, Bayerische Akademie der Wissenschaften, Walther-Meissner-Str. 8, 85748 Garching, Germany — [3]Universität Regensburg, 93040 Regensburg, Germany

One approach to further improve the magnetic properties of $Ga_{1-x}Mn_xAs$ epilayers via optimized dopant incorporation is growth on higher index GaAs substrates. In this contribution we investigate the magnetic anisotropy of $Ga_{1-x}Mn_xAs$ grown by low-temperature molecular beam epitaxy (LT-MBE) on GaAs (311)A substrates by means of ferromagnetic resonance (FMR) spectroscopy. The angular dependence of the resonance fields observed can be explained by two main contributions to the magnetic anisotropy: a cubic magnetic anisotropy field $2K_{C1}/M = 240$ mT oriented along the crystallographic $\langle 001\rangle$ axes caused by the symmetry of the GaAs host lattice, and an effective uniaxial magnetic anisotropy field $2K_{eff}^{311}/M = 90$ mT along [311] presumably caused by the homoepitaxial growth of the layer. Even better agreement between simulation and experiment is obtained if additional uniaxial anisotropies along [100] and [$\bar{2}$33] are taken into account.

MA 2.8 Mon 12:00 HSZ 03

**The temperature dependent magnetization process in small CoPt stripes observed by low temperature MFM** — •Ulrike Wolff[1], Christoph Hassel[2], Mario Brands[2], Günther Dumpich[2], Ludwig Schultz[1], and Volker Neu[1] — [1]IFW Dresden, Institute for Metallic Materials, P.O. Box 270116, D-01171 Dresden, Germany — [2]Universität Duisburg-Essen, Standort Duisburg, Institut für Physik, AG Farle, Lotharstr. 1, 47048 Duisburg, Germany

In small structured CoPt stripes the magnetoresistive behaviour is governed by a combination of anisotropic magnetoresistance and domain wall resistance. In order to support the interpretation of magnetoresistive measurements, in this work the magnetization process in CoPt stripes with perpendicular magnetic anisotropy and varying stripe width of 300 to 2200 nm was investigated by low temperature magnetic force microscopy. At various temperatures the CoPt stripes were magnetized in a field of 1 T and MFM measurements were subsequently performed during demagnetizing field sweeps. The locally determined coercive field increases from 0.07 T at 238 K to 0.23 T at 10 K. Whereas the coercivity does not depend strongly on the stripe width, the magnetization process is strongly different for narrow and wide CoPt stripes. At 10 K the 300 nm narrow stripes switch via the nucleation of a reversed domain over the whole width of the stripe. The wider stripes form a more complicated, two dimensional domain pattern during magnetization reversal.

MA 2.9 Mon 12:15 HSZ 03

**Combined magneto-optical and magnetic force microscopy study on patterned $SmCo_5$ and $PrCo_5$ thin films** — •V. Neu[1], A. Singh[1], A. Patra[1], S. Dreyer[2], U. Wolff[1], S. Sievers[3], Ch. Jooss[2], U. Siegner[3], and L. Schultz[1] — [1]IFW Dresden, P.O. Box 270116, Dresden, Germany — [2]Institute for Materials Physics, University of Goettingen, Germany — [3]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

The direct microscopic observation of magnetization processes is the most meaningful way to understand macroscopic magnetic behavior. Whereas magnetic force microscopy (MFM) offers high spatial resolution for domain imaging — an essential feature for studying modern permanent magnet materials with domain sizes in the sub 100 nm regime — magneto-optical methods allow large overview images, and with the use of calibrated indicator films, also quantitative stray field measurements. We present a magnetization study of highly coercive epitaxial $SmCo_5$ and $PrCo_5$ films. The films are laser deposited on heated MgO single crystal substrates and possess a well defined easy axis orientation in the film plane with coercivities of 2 to 3 T [1]. Arrays of micron sized square elements are structured by electron beam lithography and ion beam etching. Stray field measurements of individual elements are performed in subsequent higher remanent states throughout the magnetizing process by magneto-optical indicator film (MOIF) technique. This study is combined with an analysis of the domain structure imaged by MFM.

[1] A. Singh, et al., Appl. Phys. Lett. 87, 072505 (2005).

MA 2.10 Mon 12:30 HSZ 03

**Study of domain patterns: A discussion of coherent and incoherent averaging in PNR and MOKE.** — •Katharina Theis-Bröhl[1], Boris Toperverg[1], Jeffrey McCord[2], and Hartmut Zabel[1] — [1]Department of Experimental and Solid State Physics, Ruhr-University Bochum, 44780 Bochum — [2]Material Research Institute, Helmholtzstr. 20, 01169 Dresden

Specular Polarized Neutron Reflectivity (PNR) provides information similar but not identical to vector-MOKE. MOKE coherently averages magnetic fluctuations over the laser spot illuminating the surface, while the coherency range of the neutron beam is determined by its collimation and monochromatization. The neutron beam is well collimated in the reflection plane $(x - z)$, while the collimation is usually relaxed along the $y-$axis. Due to the strong asymmetry in the coherency properties polarized neutron reflectivity is the result of an incoherent average over the $y-$ direction of the coherent reflection from the optical potential. The incoherent averaging over a coherent signal has a big advantage for the study of domain patterns. While coherent averaging over fluctuations from domains may lead to a vanishing signal, incoherent averaging, on the contrary, does not.

In the talk we will discuss the averaging procedure for PNR using model simulations for different domain patterns. Furthermore we will compare experimental results from PNR and vector-MOKE measurements concerning the different averaging performed on patterned magnetic structures.

We acknowledge funding by DFG, SFB 491 and BMBF 032AE8BO.