INNOVATIVE ECONOMY
NATIONAL COHESION STRATEGY

Grants for innovation

FNP
Foundation for Polish Science

EUROPEAN UNION
EUROPEAN REGIONAL
DEVELOPMENT FUND

Workshop on

ATOMIC & MOLECULAR LEVEL DEVISING of FUNCTIONAL NANOSTRUCTURES for MAGNETIC & CATALYTIC APPLICATIONS (TEAM project "AMON")

Organized by: Faculty of Physics and Applied Computer Science
AGH University of Science and Technology
in co-operation with: Jerzy Haber Institute of Catalysis and Surface Chemistry
Polish Academy of Sciences

AGH

BOOK of ABSTRACTS

ZAKOPANE, 12-16 April 2011

Project operated within the Foundation for Polish Science
TEAM Program, co-financed by the EU Regional Development Fund

PROGRAM

Tuesday, April 12	Wednesday, April 13	Thursday, April 14	Friday, April 15	Saturday, April 16
	08:00 breakfast	08:00 breakfast	08:00 breakfast	08:00 breakfast
	09:00 Opening	09:00 excursion	09:00 Hajo Elmers	09:00 Departure: Bus to Krakow
	09:20 Roland Wiesendanger		09:50 Lech Tomasz Baczewski	
	10:10 Tomasz Slezak		10:20 Coffe	
	10:40 Coffe		10:50 Ryszard Zdyb	
	11:10 Kristiaan Temst		11:40 Anna Kozioł-Rachwał	
	12:00 Ewa Młyńczak			
			13:00 LUNCH	
	13:00 LUNCH	14:00 LUNCH		
			14:10 Jacek Goniakowski	
	14:20 Andrea Locatelli			
15:00 Bus to Zakopane: AGH at Library			15:00 Józef Korecki	
	15:10 Alex Zakharov	15:30 Christoph Quitmann	15:30 Marcin Zając	
	16:00 Iwona Kowalik		16:00 Coffe	
	16:30 Coffe	16:20 Ron Saris	16:30 Paola Luches	
	17:00 Bogdan Sepiol	16:50 Witold Skowroński		
			17:20 Ewa Madej	
	17:50 Jacek Szade	17:30 poster session		
19:00 welcome party	19:00 workshop dinner	19:00 dinner	19:00 dinner	
		19:50 poster session, continued		

ORAL CONTRIBUTIONS

Roland Wiesendanger	Atomic Spin Logic Devices	O-1
Tomasz Ślęzak	Non-collinear magnetization structure at the thickness and temperature driven spin reorientation transition in ultrathin epitaxial Fe films on W(110)	O-2
Kristiaan Temst	Exchange bias in Co/CoO bilayers and oxygen-implanted Co thin films	O-3
Ewa Młyńczak	Structure and magnetic properties of Fe-CoO bilayers	O-4
Andrea Locatelli	XPEEM and LEEM at Elettra	O-5
Alex A. Zakharov	Surface dynamics studied by Spectroscopic PhotoEmission and Low Energy Electron Microscopy	O-6
Iwona A. Kowalik	Nano magnetism in functional dilute magnetic semiconductors: (Ga, Fe)N films	O-7
Bogdan Sepiol	Atomic motion studied by coherent X-rays	O-8
Jacek Szade	Resistive switching and its relation to electronic structure in epitaxial Fe doped $SrTiO_3$ films	O-9
Christoph Quitmann	Dynamics of mesoscopic magnetic structures	O-10
Ron Saris	$Co_{40}Fe_{40}B_{20}/MgO/Co_{40}Fe_{40}B_{20}$ double wedge magnetic tunnel junctions with perpendicular anisotropy	O-11
Witold Skowroński	Preparation and characterization of magnetic tunnel junctions for the STT-RAM and ST-oscillators application	O-12
Hans-Joachim Elmers	Circular dichroism elucidates spin-orbit interaction in magnets	O-13
Lech Tomasz Baczewski	Spin configuration in Co/Mo epitaxial multilayers studied by polarized neutron reflectivity PNR	O-14
Ryszard Zdyb	Magnetization of ultrathin films studied with Spin Polarized Low Energy Electron Microscopy	O-15
Anna Kozioł-Rachwał	IEC in epitaxial Fe/MgO/Fe multilayers	O-16
Jacek Goniakowski	Polarity at the nanoscale	O-17
Józef Korecki	Polar iron oxide films on Pt(111)	O-18
Marcin Zając	Dynamic properties of ultrathin FeO on Pt(111) studied with nuclear resonance scattering of synchrotron radiation	O-19
Paola Luches	Morphology, structure and interface properties in metal/oxide systems	O-20
Ewa Madej	Bimetallic Au-Fe clusters on TiO_2(110)	O-21

POSTERS

K. Balin	Growth and Characterization of Eu-Fe Films.	P-1
B. Figarska	STM studies of Gold Nanostructures on Vicinal FeO/Pt(997) Surface	P-2
K. Freindl	Comparison of oxygen adsorption on Fe(110) surface and Fe(110)/W(110) monolayer	P-3
T. Giela	Au films on W(110): reconstruction and dislocations	P-4
J. Gurgul	Exchange-bias in epitaxial CoO/Fe bilayer grown on MgO(001)	P-5
J. Gurgul	Layer- by- layer epitaxial growth of polar FeO(111) thin film on MgO(111)	P-6
W. Karaś	Surface electronic properties of Fe(001) probed via hyperfine interactions	P-7
J. Kubacki	Surface and electronic structure KTaO3 crystal modified by Ar+ ion beam	P-8
K. Matlak	Room temperature perpendicular magnetic anisotropy in epitaxial $[Fe/MgO]_N$ multilayers.	P-9
P. Mazalski	Domain structures studies in NiFe/Au/Co/Au multilayers	P-10
B. Olbromska	Magneotoptic Kerr Effect Imaging of the Magnetization Reversal in Fe/MgO/Fe trilayers	P-11
M.Pashkevich	Magnetization statics and light-induced ultrafast dynamics in Co/garnet heterostructures	P-12
M. Pilch	Resistive switching behaviour in STO doped by La	P-13
R. P. Socha	Synthesis of epitaxial layers of mixed Fe_xMn_yO oxides on MgO(001)	P-14
N. Spiridis	The Magnetic Anisotropy of Fe/Au(001) Ultrathin Films in a Function of Fe Thickness and Thickness Driven Polar Spin Reorientation Transition.	P-15
T. Stobiecki	Spin-transfer-torque dependence on MgO tunnel barrier thickness in MTJs	P-16
B. Strzelczyk	Ultrathin FeO and Fe_3O_4 oxides on Pt(111)	P-17
M. Ślęzak	Growth and Spin Structure of Ultrathin Fe Films on W(110)	P-18
D. Wilgocka-Ślęzak	Nanoscale Spectro-Microscopy For Krakow Synchrotron	P-19
M. Wojtyniak	Influence of Fe and Mn dopants on the resistive switching of $SrTiO_3$ thin films.	P-20

Atomic Spin Logic Devices

Roland Wiesendanger

Institute of Applied Physics and Interdisciplinary Nanoscience Center Hamburg, University of Hamburg, D-20355 Hamburg, Germany

Spin-Polarized Scanning Tunneling Microscopy (SP-STM) provides new insight into spin structures at a length scale and a sensitivity level which are inaccessible by other magnetic-sensitive measurement techniques [1]. The combination of atomic resolution in direct space, single spin sensitivity, and high energy resolution nowadays offers unique possibilities for probing spin-dependent states and interactions in natural or artificially created nanostructures. Moreover, spin-state manipulation based on spin-current induced switching and spin-state read-out by SP-STM methods offers another novel exciting research direction [2,3]. Ultimately, a new type of magnetic recording technology might be developed based on spin-state writing and read-out rather than using magnetic stray fields. While the detection of magnetic stray fields becomes more and more difficult as the magnetic bit size is further reduced, the concept of spin manipulation and spin-state determination has already been demonstrated down to the atomic level using SP-STM based techniques.

Besides spin-resolved studies of nanometer-scale structures, the magnetism of individual atoms on surfaces has become a focus of research in recent years. The ultimate goal has been the combination of spin-resolved imaging with atomic resolution and magnetometry at the single-atom level in order to probe spin states and magnetic interactions of individual adatoms and nanostructures at solid surfaces in a most direct way. This challenging goal has recently been achieved by operating a SP-STM system at temperatures below 1 Kelvin and in external magnetic fields up to several Tesla [4,5]. The new method of single-atom magnetometry with an unprecedented degree of magnetization measurement sensitivity is applicable to metallic [4,5] as well as to semiconducting [6] and molecular systems [7]. The combination of single-atom manipulation techniques and single-atom magnetometry allows unprecedented insight into the magnetic properties of artificially created nanostructures [8]. Moreover, the recent demonstration of atomic-scale spin logic devices based on the combination of atomic manipulation and spin-sensitive read-out by SP-STM offers great potential for future information technologies using spins rather than charges for computation and information transmission at the atomic level.

[1] R. Wiesendanger, “Spin mapping at the nanoscale and atomic scale”, Rev. Mod. Phys. 81, 1495 (2009).
[2] S. Krause, L. Berbil-Bautista, G. Herzog, M. Bode, R. Wiesendanger, “Current-induced magnetization switching with a spin-polarized scanning tunneling microscope”, Science 317, 1537 (2007).
[3] G. Herzog, S. Krause, R. Wiesendanger, “Heat assisted spin torque switching of quasistable nanomagnets across a vacuum gap”, Appl. Phys. Lett. 96, 102505 (2010).
[4] F. Meier, L. Zhou, J. Wiebe, R. Wiesendanger, „Revealing magnetic interactions from single-atom magnetization curves”, Science 320, 82 (2008).
[5] L. Zhou, J. Wiebe, S. Lounis, E. Vedmedenko, F. Meier, S. Blügel, P.H. Dederichs, R. Wiesendanger , “Strength and directionality of surface Ruderman-Kittel-Kasuya-Yosida interaction mapped on the atomic scale”, Nature Physics 6, 187 (2010).
[6] A. A. Khajetoorians, B. Chilian, J. Wiebe, S. Schuwalow, F.Lechermann, and R. Wiesendanger, "Detecting excitation and magnetization of individual dopants in a semiconductor", Nature (October 28, 2010), in press.
[7] J. Brede, N. Atodiresei, S. Kuck, P. Lazic, V. Caciuc, Y. Morikawa, G. Hoffmann, S. Blügel, and R. Wiesendanger, "Spin- and energy-dependent tunneling through a single molecule with intramolecular spatial resolution", Phys. Rev. Lett. 105, 047204 (2010).
[8] D. Serrate, P. Ferriani, Y. Yoshida, S.-W. Hla, M. Menzel, K. von Bergmann, S. Heinze, A. Kubetzka, R. Wiesendanger, “Imaging and manipulating the spin direction of individual atoms”, Nature Nanotechnology 5, 350 (2010).

Non-collinear magnetization structure at the thickness and temperature driven spin reorientation transition in ultrathin epitaxial Fe films on W(110)

T. Ślęzak[1], M. Ślęzak[1], A. Kozioł-Rachwał[1], K. Matlak[1], K. Freindl[3], N. Spiridis[3], E. Partyka-Jankowska[4], D. Wilgocka-Ślęzak[3], M. Zając[1, 2], R. Rüffer[2], J. Korecki[1,3]

[1]*Faculty of Physics and Applied Computer Science, AGH, Kraków, Poland*
[2]*European Synchrotron Radiation Facility, BP 220, 38043 Grenoble Cedex, France*
[3]*Jerzy Haber Institute of Catalysis and Surface Chemistry, PAS, ul. Niezapominajek 8, Kraków, Poland*
[4]*Faculty of Physics, University of Vienna, A-1090 Wien, Austria*

Thickness and temperature induced in-plane spin reorientation transition (SRT) in epitaxial Fe films on W(110) [1] was studied in situ using the nuclear resonant scattering of synchrotron radiation. NRS is a synchrotron analogue of Mössbauer spectroscopy (MS), in the sense that recoilless excitation (induced by the resonant x-rays with energy 14.4 keV for ^{57}Fe) of the nuclear energy levels, split due to the hyperfine interactions, is involved [2]. In this method, the hyperfine parameters can be obtained from a characteristic beat pattern seen in the time evolution of the intensity of nuclear resonant scattering (the so called time spectrum). The well defined polarization of the synchrotron x-rays provides high sensitivity to the orientation of the hyperfine magnetic field and electric field gradient.
The numerical analysis of the NRS time spectra measured during Fe evaporation, indicates that transition from the uniform [1-10] oriented magnetization state observed at lower thickness to the [001] magnetization orientation at higher thickness undergoes via formation of non-collinear spin structure. It is clear that with increasing film thickness the bottom Fe(110) atomic layers initiate SRT while the surface magnetization reverses at the end. This thickness induced SRT originates at the Fe/W(110) interface and proceeds via a non-collinear spin structure resembling a planar domain wall that propagates towards the surface with increasing film thickness. The nature of the temperature induced transition is also non-collinear and with increasing temperature surface magnetization switches first from [1-10] to [001] direction.

This work was supported by the Team Program of the Foundation for Polish Science co-financed by the EU European Regional Development Fund.

[1] U. Gradmann, J. Korecki, C. Waller, Appl. Phys. A 39 101 (1986)
[2] W. Sturhahn, Hyperfine Interact. 125, 149 (2000)

Exchange bias in Co/CoO bilayers and oxygen-implanted Co thin films

J. Demeter[1], J. Meersschaut[1], F. Almeida[1], S. Brems[2], C. Van Haesendonck[2], A. Teichert[3,1,2], R. Steitz[3], A. Vantomme[1], and K. Temst[1]

[1]*Instituut voor Kern- en Stralingsfysica and INPAC, K.U.Leuven, Celestijnenlaan 200D, B-3001 Leuven, Belgium*
[2]*Laboratorium voor Vaste-Stoffysica en Magnetisme and INPAC, K.U.Leuven, Celestijnenlaan 200D, B-3001 Leuven, Belgium*
[3]*Helmholtz Zentrum Berlin für Materialien und Energie, Glienicker Strasse 100, D-14109 Berlin, Germany*

Exchange bias (EB), the interfacial coupling between a ferromagnet (FM) and an antiferromagnet (AFM) has been a widely studied phenomenon since its discovery. It has been studied in bilayers, core-shell clusters, and nano-structured materials. In the first part of the lecture we will review the properties of exchange bias in surface-oxidized Co thin films, with the emphasis on the asymmetry of the magnetization reversal mechanism and the training effect. We will also discuss how the training effect can be (partially) restired by applying a magnetic field perpendicular to the initial cooling field direction.
In the second part we will discuss the use of ion implantation and irradiation, which has been limited so far to the modification of pre-existing exchange bias systems. We present the application of ion implantation to generate an EB system [1], rather than to modify it. We implanted O ions in thin Co films (100 nm) in order to form CoO, embedded in the film. The coupling between the formed CoO and the Co matrix gives rise to EB. We show the feasibility of this approach and prove that the observed EB is a consequence of the formation of CoO and not of implantation related damage, by comparison to Ne implanted Co films. Furthermore, this system exhibits a clear training effect, i.e. the EB effect depends on the number of times the hysteresis loop is measured. In the more conventional EB bilayers, this effect is understood by a change in magnetization reversal mechanism. Due to the clear morphological differences of the FM-AFM interface between this implanted system and bilayers, a strong influence on the reversal mechanism is anticipated. Therefore it was studied with anisotropic magnetoresistance and polarized neutron reflectometry. Both measurements reveal a different behavior from bilayers: all reversals are governed by domain wall nucleation and motion, where in bilayers a change from domain wall nucleation and motion to coherent rotation is observed.

[1] J. Demeter, J. Meersschaut, F. Almeida, S. Brems, C. Van Haesendonck, A. Teichert, R. Steitz, K. Temst, and A. Vantomme, Appl. Phys. Lett. 96 (2010) 132503

Structure and magnetic properties of Fe-CoO bilayers

E. Młyńczak[1], J. Gurgul[1], K. Freindl[1,2], A. Kozioł-Rachwał[2], K. Matlak[2], J. Przewoźnik[2], N. Spiridis[1], T. Ślęzak[2], D. Wilgocka-Ślęzak[1] and J. Korecki[1,2]

[1]Jerzy Haber Institute of Catalysis and Surface Chemistry, Polish Academy of Sciences, Niezapominajek 8, 30-239 Krakow, Poland
[2]Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, al.Mickiewicza 30, 30-059 Krakow, Poland

In bilayers consisting of a ferromagnet (FM) and an antiferromagnet (AFM) the exchange bias (EB) phenomenon may occur. It manifests itself in the shift of the hysteresis loops after samples are field cooled through the Néel temperature of the AFM. Since the discovery in 1956 by Meiklejohn and Bean a lot of theoretical models explaining EB have been created but a satisfactory quantitative explanation of this phenomenon is still lacking. The reason of the discrepancy between the theoretically predicted and experimentally found magnitudes of EB is believed to be the lack of thorough description of the FM/AFM interface structure.
In this contribution we present the analysis of the structural and magnetic properties of Fe-CoO bilayers grown on MgO(001) exhibiting exchange bias, with the special attention paid to the characterization of the interface structure. The layers were prepared using molecular beam epitaxy (MBE) and characterized using low energy electron diffraction (LEED) after each deposition step. The iron used as a FM layer gave the possibility of applying ^{57}Fe conversion electron Mössbauer spectroscopy (CEMS) to study chemical composition at the interfaces with CoO. We used vibrating sample magnetometry (VSM) to determine coercive field (H_C) and exchange bias field (H_{EB}) as a function of the temperature. The two sets of samples, one with CoO deposited onto Fe and the other with Fe deposited onto CoO are described. Because of the differences in the growth modes, CoO/Fe and Fe/CoO samples show significant differences in the structural and magnetic characteristics. Strong enhancement of H_C close to the blocking temperature in CoO/Fe samples and the sign change of H_{EB} will be discussed in terms of interfacial structural properties.

This work was supported in part by the Polish Ministry of Science and Higher Education and by the Team and MPD Programs of the Foundation for Polish Science co- financed by the EU Regional Development Fund.

XPEEM and LEEM at Elettra

A. Locatelli

Elettra - Sincrotrone Trieste S.C.p.A. Strada Statale 14 - km 163,5 in AREA Science Park
34149 Basovizza, Trieste, Italy
andrea.locatelli@elettra.trieste.it

Driven by the strong interest in surface processes occurring at sub-micron length scales, the use of x-ray photo-emission electron microscopy (XPEEM) has become widespread at 3rd generation synchrotron radiation facilities. Most instruments are now equipped with energy filter and reach a lateral resolution of less than few tens of nanometer. They enable us to characterize surfaces, interfaces and thin films with both chemical, magnetic and electronic-structure sensitivity. The combination of energy filtered XPEEM with low-energy electron microscopy (LEEM) into a single instrument then adds structure sensitivity to spectroscopy, enabling thus a unique multi-technique approach to the study of surfaces.
In this talk, I will report recent work exploiting the capabilities of the LEEM-XPEEM microscope in operation at the Nanospectroscopy beamline of the Elettra Synchrotron Laboratory, illustrating selected application examples in Surface and Materials sciences. The research topics will range surface magnetism [1] to self assembly [2,3] and e-beam assisted chemical patterning in thin films [4,5]. The characterization of short-range corrugations in SiO_2-supported and suspended exfoliated graphene will serve to illustrate the potential of microprobe diffraction with a LEEM instrument [6]. Besides imaging at high lateral resolution, I will show advantages and limitations of microprobe-ARPES, a XPEEM operation mode that is still rarely employed. I will conclude by illustrating the challenges of XPEEM measurements at high photon flux under micro-focus illumination, using both synchrotron radiation and seeded harmonic generation [7,8]. The implications of space charge effects will be thoroughly discussed.

References

[1] E. Vescovo, T.O. Menteş, J.T. Sadowski, J.M. Ablett, M.Á. Niño, and A. Locatelli, Phys. Rev. B, 82, 184405 (2010).
[2] T. O. Menteş, A. Locatelli, L. Aballe, E. Bauer, Phys. Rev. Lett. 101, p. 085701 (2008).
[3] T. O. Menteş, N. Stojic, A. Locatelli, L. Aballe, N. Binggeli, M. Á. Niño, M. Kiskinova, E. Bauer, EPL, accepted.
[4] T. O. Menteş, A. Locatelli, L. Aballe, A. Pavlovska, E. Bauer, T. Pabisiak and A. Kiejna, Phys. Rev. B 76, 155413 (2007).
[5] S. Günther, S. Bocklein, R. Reichelt, J. Wintterlin, A. Barinov, T. O. Menteş, M. Á. Niño, A. Locatelli, Chem. Phys. Chem., 11, 1525-1532 (2010).
[6] A. Locatelli, K. R. Knox, D. Cvetko, T.O. Menteş, M.Á. Niño, S. Wang, M. B. Yilmaz, P. Kim, R. M. Osgood Jr., and A. Morgante, ACS Nano, 4, 4879-4889 (2010).
[7] G. De Ninno, E. Allaria, M. Coreno, F. Curbis, M. B. Danailov, E. Karantzoulis, A. Locatelli, O. Menteş, M.Á. Niño, C. Spezzani, and M. Trovò, Phys. Rev. Lett. 101, 053902 (2008).
[8] A. Locatelli, T.O. Menteş, M.Á. Niño, and E. Bauer; Ultramicroscopy, in press. DOI: 10.1016/j.ultramic.2010.12.020

Surface dynamics studied by Spectroscopic PhotoEmission and Low Energy Electron Microscopy

A. A. Zakharov

Max-lab, Lund University, Sweden

In this talk the latest results from the Elmitec SPELEEM microscope installed at MAX-lab synchrotron facility will be presented with a special emphasis on surface dynamics. Parallel imaging of SPELEEM at around video frequency allows real time studies of dynamic processes at temperatures up to 1700K, and during deposition of a wide variety of materials. One of the fast developing research areas is droplet dynamics on solid surfaces and by studying Ga droplets on GaP(111)B surface we established a new mechanism for self-propelled motion of Ga droplets. Another application example to be presented is the real time microscopic studies of intercalation process in graphene and doping (both n- and p-type) process for the quasi-free standing graphene. A coexistence regime of the two phases (n- and p-) for one monolayer free standing graphene is demonstrated, so that the engineering of lateral p-n junctions can be envisioned.

Nano magnetism in functional dilute magnetic semiconductors: (Ga, Fe)N films

I. A. Kowalik[1], M. A. Niño[2], A. Locatelli[3], T. Onur Mentes[3], A. Bonanni[4], T. Dietl[1,5] and D. Arvanitis[6]

[1]*Institute of Physics, Polish Academy of Sciences, Warsaw, Poland*
[2]*IMDEA, Facultad de Ciencias Módulo C-IX, Madrid, Spain*
[3]*Sincrotrone Trieste, Basovizza, Trieste, Italy*
[4]*Institut für Halbleiter-und-Festkörperphysik, J. Kepler University, Linz, Austria*
[5]*Institute of Theoretical Physics, University of Warsaw, Warsaw, Poland*
[6]*Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden*

We present results of magnetic investigations at room temperature on (Ga,Fe)N films by means of soft x-ray based element specific and spin sensitive spectroscopy [1]. The studied samples were grown by MOVPE and studied previously by SQUID magnetometry, transmission electron microscopy, synchrotron radiation based x-ray diffraction techniques, [2,3] as well as by EXAFS and XANES [4]. In order to establish a relationship between the nanocrystal structure and their magnetic properties we carried out measurements of XMCD, XLMD and XMCD-PEEM on the Fe L-edge and XMCD on the N-K edge.

Here we complement these results by means element specific dichroic spectro-miscroscopy using synchrotron radiation soft x-rays as the excitation source. XAS micrographs taken by X-PEEM at the Fe L-edges indicate that Fe is incorporated both on Ga substitutional sites in the GaN lattice as well as self-assembled Fe_xN nanocrystals with sizes up to 80 nm. The XAS micrographs confirm that the Fe atoms are embedded in different local environments. By means of XMCD-PEEM we identify magnetic Fe-rich nanocrystals and study their magnetic domain structure. XMCD contrast from nanocrystals with a lateral size of 40 nm is clearly visualized. The obtained set of findings allows to identify both ferromagnetic and antiferromagnetic nanocrystals. The present set of data illustrates the complementarity of X-PEEM and XMCD-PEEM with low noise XAS and XMCD measurements without spatial resolution.

[1] I. Kowalik et al., Phys. Rev. B, in press [arXiv: 1011.0847].
[2] A. Bonanni et al., Phys. Rev. B 75, 125210 (2007); Phys. Rev. Lett. 101, 135502 (2008).
[3] A. Navarro-Quezada et al., Phys. Rev. B 81, 205206 (2010).
[4] M. Rovezzi et al., Phys. Rev. B 79, 195209 (2009).

Atomic motion studied by coherent X-rays

Bogdan Sepiol, Michael Leitner, Friedrich Gröstlinger and Markus Stana

Dynamics of Condensed Systems, Universität Wien, Fakultät für Physik
Strudlhofgasse 4, A-1090 Wien, Austria
e-mail: bogdan.sepiol@univie.ac.a

It is widely accepted that determining temperature-driven motion of single atoms in solids is more complex than figuring out their structure. Nevertheless, gaining knowledge how atoms move and measuring their hopping rate is the aim of many experiments and theoretical studies. One shall also keep in mind that ab initio methods which are so booming in the studies of structural properties are still uncertain in dynamical properties predictions. The only confident way is in this situation are comparisons with dedicated experiments. Worth mentioning is that the topic of the AMON Science Team Programme encloses devising of functional nanostructures for magnetic and catalytic applications. It seems evident that dynamical properties and especially atomic motion can play a crucial role in nanostructures operation.
Tracer methods have been applied to study diffusion in various crystalline [1] and amorphous systems [2], being, however, limited to their purely macroscopic nature. The highly desirable feat of probing the dynamics with spatial and temporal resolution turns out to be extremely challenging due to many serious limitations such as a limited number of suitable isotopes or low resolution in energy necessitating very high temperatures of measurements. This prohibits measuring systems such as metallic glasses which are unstable above a certain temperature.
The availability of coherent X-rays enabled in the last decade photon correlation spectroscopy studies of diffusion. This method, commonly termed X-ray photon correlation spectroscopy (XPCS) [3], is very promising for studying dynamics with atomic resolution. The fundamental characteristics of the XPCS method resemble that of coherent quasi-elastic neutron scattering, but differ from resonant methods like Mössbauer spectroscopy [4]. The potential of XPCS has been demonstrated for the first time with the intermetallic alloy $Cu_{90}Au_{10}$ [5]. These and subsequent experiments were carried out at beamline ID10A at the European Synchrotron Radiation Facility in Grenoble, France.
The presentation is intended as a short introduction into the underlying principles of diffusion studies with coherent synchrotron radiation and will report our most recent, unpublished experimental results.

This work was supported by the Austrian FWF grant P22402.

[1] H. Mehrer, Diffusion in Solids: Fundamentals, Methods, Materials, Diffusion-Controlled Processes (Springer, Berlin /Heidelberg 2007).
[2] F. Faupel et al., Rev. Mod. Phys. 73, 237 (2003).
[3] M. Sutton et al., Nature 352, 608 (1991).
[4] G. Vogl and B. Sepiol in Diffusion in Condensed Matter (eds P. Heitjans, and J. Kärger) p. 65 (Springer, 2005).
[5] M. Leitner et al., Nature Mat. 8, 717 (2009).

Resistive switching and its relation to electronic structure in epitaxial Fe doped $SrTiO_3$ films

J. Szade[1], K. Szot[1,2], J. Kubacki[1], D. Kajewski[1], R. Wrzalik[1], M. Wojtyniak[1], M. Pilch[1], Ch. Lenser[2], R. Dittmann[2], R. Waser[2]

[1]*A Chełkowski Institute of Physics, University of Silesia, Katowice, Poland,*
[2]*Institute of Solid State Research, Forschungszentrum Juelich, 52425 Juelich, Germany*

Doped SrTiO3 films shows a resistive switching behaviour which is very promising for applications in new non-volatile memories. The model of switching is based on well conducting filaments where the conductivity can be reversibly switched between high and low resistance states.

$SrTiO_3$ thin films with a Fe nominal concentration of 0%, 1 % and 2 % were grown by PLD method on the single crystalline $SrTi_{0.99}Nb_{0.01}O_3$ substrate. The films had the thickness of 15-50 nm. LEED examination showed they are single crystalline.

Resistive switching behaviour was studied with the use of local conductivity atomic force microscopy (LC-AFM) and was present in all samples. Fe doping was found to influence the character of switching. The regions treated with the conducting AFM tip (applied dc voltage up to 6 V) showed high electrical inhomogeneities. The studies of electronic structure were performed with the use of standard photoelectron spectroscopy (XPS and UPS) and resonant photoemission (RESPES). They indicated to significant Fe contribution to the in-gap states which can be related to switching ability.

The effect of electroformation with the use of AFM tip was observed in microscopic studies - SEM, AES and LEEM. These observations indicate to modification of the chemical reactivity within the treated regions.

Dynamics of mesoscopic magnetic structures

C. Quitmann

Swiss Light Source, Paul Scherrer Institut, 5232 Villigen-PSI, Switzerland

Synchrotrons are ideally suited to study the dynamics of mesoscopic magnetic objects because they provide tunable energy, circular polarization and short pulses.
We use these properties to study the dynamics of small magnetic structures on a 100ps temporal and 100nm spatial scale. I will report on the PolLux beamline where a Fresnel zone plate is used to focus the x-rays to a small spot through which the sample is raster scanned. The transmitted intensity is recorded by an APD detector. When exciting magnetic samples with resonant RF-fields and recording the transmitted x-ray intensity synchronous with the RF-excitation and the x-ray arrival time we can measure the dynamics of the magnetization in small objects. At present we are studying the dynamics of permalloy/Cobalt double layers. These show a multitude of static groundstates depending on the interlayer coupling.
In the second part of the talk I will report on a possible collaboration between SOLARIS and SLS providing possibilities for research of Polish scientists in the field of magnetism and surface science at SLS.

$Co_{40}Fe_{40}B_{20}/MgO/Co_{40}Fe_{40}B_{20}$ double wedge magnetic tunnel junctions with perpendicular anisotropy

R. Saris[1], M. Czapkiewicz[2], W. Skowroński[2], J. Wrona[2], T. Stobiecki[2] , H.J.M. Swagten[1]

[1]*Eindhoven University of Technology, Den Dolech 2, Eindhoven, the Netherlands*
[2]*Department of Electronics, AGH University of Science and Technology, al. Mickiewicza 30, Krakow, Poland*

We have investigated a $Co_{40}Fe_{40}B_{20}(t_{bottom})/MgO(0.89)/Co_{40}Fe_{40}B_{20}(t_{top})$, crossed double wedge ($t_{bottom}$: 0.66-1.08, t_{top}: 0.99-1.62, thickness in nm), by VSM and MOKE measurements. Therefrom we determined the perpendicular anisotropy, saturation magnetization, coercive field, remanent magnetization and saturation field as a function of the, perpendicularly crossed, thicknesses of the bottom and top CoFeB layers. The wafer areas most suitable for pseudo-spin valve magnetic tunnel junctions (PSV MTJs) were used to fabricate circular nanopillars with diameters of 150, 200, 280, 350 and 400 nm. Preliminary tunnel magnetoresistance (TMR) measurements show an MR ratio of 20% and a very low Resistance-Area (RA) product of 2 $\Omega\mu m^2$. A switching phase diagram for both major and minor loops are measured.

Acknowledgements
Project supported by the Polish Ministry of Science and Higher Education grants (IP 2010037970 and NN 515544538), and the Foundation for Polish Science MPD Programme cofinanced by the EU European Regional Development Fund. We thank Singulus Technologies AG for sample deposition. Research conducted at the Dept. of Electronics, AGH in the frame the Erasmus-Socrates program.

Preparation and characterization of magnetic tunnel junctions for the STT-RAM and ST-oscillators application

W. Skowroński[*1], T. Stobiecki[1], J. Wrona[1], Z. Szklarski[1], G. Reiss[2], and S. van Dijken[3]

[1]*AGH University of Science and Technology, Al. Mickiewicza 30, 30-059 Kraków, Poland*
[2]*Thin Films and Physics of Nanostructures, Bielefeld University, 33615 Bielefeld, Germany*
[3]*Department of Applied Physics, Aalto University, P.O.Box 15100, FI-02015 Aalto, Finland*

Novel magnetic random access memories (MRAM) are implemented based on magnetic tunnel junctions (MTJs) working as a memory cell, that takes advantage of so called current induced magnetization switching (CIMS) effect originating from the interaction between spin polarized current and local magnetization called spin transfer torque (STT) [1]. The active part of the MTJ consist of the trilayer: CoFeB(2.3) / MgO(0.85) / CoFeB(2.3) (thicknesses in nm). Due to an extremely low resistance area (RA) product (about 3 Ohm × μm2) and possibly uniform magnetization of the ferromagnetic layers, the MTJ is formed as a nanopillar with the elliptical cross-section using e-beam lithography. In this paper, the MTJ preparation and characterization techniques for the spin electronics devices will be presented.

W.S. and T.S would like to thank the Foundation for Polish Science MPD Programme co-financed by the EU European Regional Development Fund and the Polish Ministry of Science and Higher Education grants (IP 2010037970 and NN 515544538)

[1] W. Skowronski et al. JAP 107, 093917, 2010

* e-mail: skowron@agh.edu.pl

Circular dichroism elucidates spin-orbit interaction in magnets

Hans-Joachim Elmers

Institut für Physik, Johannes Gutenberg-Universität, Staudingerweg 7, D-55128 Mainz, Germany

Magnetic anisotropies essentially determine the hysteresis behavior of ferromagnets. Therefore the understanding of magnetic anisotropies in thin films is of crucial importance for the development of magnetic devices based on new materials. While a huge amount of phenomenological data has been gathered, measurements of the electronic origin of magnetic anisotropy have been neglected in the past. Due to the interplay between spin-orbit coupling and exchange interaction in ferromagnets, photoemission excited by circularly polarized light leads to an asymmetry in the photocurrent upon reversal of the magnetization direction. This magnetic circular dichroism (MCD) opens a direct insight into the spin-orbit coupling despite its little effect on the electronic structure compared to the exchange splitting. We report on MCD studies of epitaxial Co/Pt films with perpendicular magnetization and epitaxial Ni2MnGa films showing a magnetic shape memory effect.

Spin configuration in Co/Mo epitaxial multilayers studied by polarized neutron reflectivity PNR

L.T. Baczewski[1], K. Mergia[2], A. Petroutchik[1], A.Wawro[1],J. Kisielewski[3], A. Maziewski[3], F. Ott[4]

[1]*Institute of Physics, Polish Academy of Sciences, Warsaw, Poland*
[2]*Institute of Nuclear Technology, NCSR Demokritos, Athens, Greece*
[3]*Institute of Experimental Physics, University of Bialystok, Poland*
[4]*Laboratoire Leon Brillouin, CEA, Saclay, France*
bacze@ifpan.edu.pl

The interface magnetic structure was studied in Mo/Co epitaxial multilayers. In order to ascertain whether there is a surface magnetization state of Mo, a set of samples with different Mo thickness was grown by MBE technique. The crystallographic structure of the layers was monitored in-situ by RHEED, which showed that the in-plane directions relation Mo(110)/Co(0001) was satisfied for every sample. Sapphire wafers with orientation (11-20) were used as substrates, on which a Mo buffer layer was deposited at 1000 deg C. Au buffer was annealed at 200 deg C for 15 min. All subsequent layers were deposited at room temperature. The multilayer samples were deposited with varying Mo layer thickness and constant Co layer thickness: Al203 / Mo/Au/ (Co 25/ Mo d)x 20 /Pt where d = 0.5, 1.0, 1.5 and 2.0 nm. Cobalt film thickness d = 2.5 nm was chosen in the range where in-plane anisotropy is present in such structures. Detailed structural analysis regarding constituent layers thickness, density and interface roughness was performed by X-ray reflectivity. Multilayers magnetic structure was studied by polarized neutron reflectivity (PNR) and magnetization measurements. Hysteresis loops and magnetization temperature dependence M(T) were measured using SQUID magnetometer. The PNR measurements were carried out at Laboratoire Léon-Brillouin, CEA-Saclay, at 10 K and with an in-plane external magnetic field of 1.0 T in order to magnetically saturate the samples. The spin-up and spin-down reflectivities (R+,R-) of the all samples were measured. The least squares fitting of all the reflectivity data (X-rays and neutrons) was made using the SimulReflec software [1]. For the scattering lengths of X-rays and neutrons and absorption cross sections the tabulated values were employed.

From the PNR data of four Mo/Co samples the Mo and Co magnetic moments have been determined. In all the Mo/Co multilayers it was found that a magnetic moment has been induced in the Mo and that the Mo layer is antiferromagnetically coupled to the Co layer. The product of the molybdenum layer thickness by its moment is almost constant for all studied Mo/Co samples, which demonstrates that only a top slab of molybdenum layer close to the interface with Co is magnetically active. The thickness of this slab is less or equal to 4 ML and the induced molybdenum magnetic moment higher or equal to 0.8 μB/at (thinner magnetically active slabs imply larger Mo moments). It seems that the roughness is further reducing the number of Mo next neighbours, distorts the bond lengths and angles and between 3 to 5 monolayers of Mo acquire a magnetic moment. Also, the lattice strain occurring at the interfaces during epitaxial growth of hcp Co on Mo bcc metal can influence the ordering at the interface Large magnetic moments for V have been already reported for the thin films of Fe/V [2], Gd/V [3] and Co/V [4] but this is the first experimental evidence of an induced magnetic moment in Mo.

[1] http://www-llb.cea.fr/prism/programs/simulreflec/simulreflec.html, version 1.9
[2] A.C. Jenkins, W.M. Temmerman, J. Magn. Magn. Mater. 198-199 (1999) 584
[3] L. T. Baczewski, P. Pankowski, A. Wawro, K. Mergia, S. Messoloras, F. Ott, Phys. Rev. B 74 (2006) 75417-75427
[4] Y. Huttel, G. van der Laan, T.K. Johal, N.D. Telling, P. Bencok, Phys Rev B 68 (2003) 17440

Magnetization of ultrathin films studied with Spin Polarized Low Energy Electron Microscopy

Ryszard Zdyb[1,2] and Ernst Bauer[2]

[1]*Institute of Physics, Maria Curie-Sklodowska University, 20-031 Lublin, Poland*
[2]*Department of Physics, Arizona State University, Tempe, Arizona 85287-1504, USA*

Spin Polarized Low Energy Electron Microscopy is a microscopy technique that allows investigation of magnetism in low dimensional systems. Particularly, it is well suited for the in situ study of magnetization direction in ultrathin ferromagnetic films. It also allows measurements of exchange asymmetry A which to a first approximation is proportional to the scalar product of magnitude of domain magnetization M and the beam polarization P vectors, $A \sim P \cdot M$. Although this dependence works well close to the critical temperature [1], simple assumption that asymmetry is proportional to the magnitude of magnetization is in general not true. Among the most important reasons are: multiple scattering, limited sampling depth and quantum size effect.
In this talk influence of these limitations on experimentally derived asymmetry parameter will be discussed with the emphasis put on the quantum size effect. As example the results for well known system of Fe grown on W(110) will be given.

This work was supported in part by the Polish Ministry of Science and Higher Education under Grant No. N N202 174539.

[1] R. Zdyb and E. Bauer, Phys. Rev. Lett. 100, 155704 (2008).

IEC in epitaxial Fe/MgO/Fe multilayers

A. Kozioł-Rachwał[1], K. Freindl[1,2], K. Matlak[1], E. Młyńczak[2],
N. Spiridis[2], M. Ślęzak[1], T. Ślęzak[1], D. Wilgocka-Ślęzak[2], P. Korecki[3], J. Korecki[1,2]

[1]*Faculty of Physics and Applied Computer Science, AGH, Kraków, Poland;*
[2]*Jerzy Haber Institute of Catalysis and Surface Chemistry, PAS, Kraków, Poland;*
[3]*Faculty of Physics, Astronomy and Applied Computer Science, Jagiellonian University, Kraków, Poland*

We investigated magnetic properties of Fe/MgO/Fe trilayers as a function of the MgO spacer thickness. Room temperature magnetooptical Kerr effect measurements proved the existence of a strong antiferromagnetic coupling (AFC) between the Fe layers mediated by the insulating MgO barrier. A bilinear interlayer exchange coupling constant J1 was determined from the measured magnetic hysteresis loops. AFC extends in the range of the 2.0Å- 6Å MgO thickness with its maximum strength of -1.2 erg/cm2 at dMgO=2.5Å.

This work was supported in part by the Polish Ministry of Science and Higher Education and by the Team Program of the Foundation for Polish Science co-financed by the EU Regional Development Fund.

Polarity at the nanoscale

J. Goniakowski

Institut des Nanosciences de Paris, UMR 7588, CNRS & Université Paris 06,
4 place Jussieu, 75252 Paris cedex 05, France

Extended polar objects present an electrostatic instability and require substantial modifications of their surface characteristics in order to become stable. Microscopic surface processes related to polarity compensation have been extensively studied in the last years, also as a potential tool for tuning surface electronic and structural properties [1].

More recently it has become clear that polarity does also concern nano-objects, but that the relevant electrostatic forces and the response they induce differ from the known ones [2]. Indeed, below a critical size nano-objects may sustain finite dipole moments which drive strongly size- and dimensionality- dependent properties. Moreover, at small sizes, polarity effects may extend beyond the surface region and drive structural transformations of the entire object, resulting in novel structures, with no bulk counterparts.

Since oxide nano-objects, such as ultra-thin films, are often synthesized on metal substrates, their polarity characteristics are additionally modified by the electrostatic coupling between their structure and the interface charge transfer [3]. On the one hand, electron exchange due to interfacial interactions (function of the metal electronegativity) induces a structural distortion and yields a non-vanishing polarization in both non-polar and uncompensated polar films. On the other hand, metal substrate provides the charges necessary for polarity compensation, inducing a strong stabilization of polar films.

[1] J. Goniakowski, F. Finocchi, C. Noguera, L. Giordano, Rep. Prog. Phys. 2008 71, 016501
[2] J. Goniakowski, C. Noguera, L. Giordano, Phys. Rev. Lett 2004 93, 215702; 2007 98 205701; J. Goniakowski, J. Noguera, Phys. Rev. B 2011 83, 115413
[3] J. Goniakowski, C. Noguera, Phys. Rev. B 2009 79, 155433; J. Goniakowski, L. Giordano, J. Noguera, Phys. Rev. B 2010 81, 205404

Polar iron oxide films on Pt(111)

J. Korecki[1,2], D. Wilgocka-Ślęzak[2], N. Spiridis[2], K. Freindl[1,2], A. Kozioł-Rachwał[1], K. Matlak[1], M. Ślęzak[1], T. Ślęzak[1], M. Zajac[2,3]

[1]*Faculty of Physics and Applied Computer Science, AGH, Kraków, Poland*
[2]*Jerzy Haber Institute of Catalysis and Surface Chemistry, PAS, Kraków, Poland*
[3]*European Synchrotron Radiation Facility, BP 220, 38043 Grenoble Cedex, France*

Ultra-thin (2ML) FeO(111) films can be grown on the Pt(111) surface with no signs of the polarity compensation mechanisms known for semi-infinite surfaces [1]. Going with the film thickness beyond the limit of 2 ML is important for understanding the polar surface issue. In this contribution, among others, we report on stabilization of FeO-like (111)-oriented films such thick as 4 nm that show some features, which can be explained as consequences of polarity compensation.

This work was supported in part by the Polish Ministry of Science and Higher Education and by the Team Program of the Foundation for Polish Science co-financed by the EU Regional Development Fund.

[1] J. Goniakowski, C. Noguera PRB 83 (2011) 115413

Dynamic properties of ultrathin FeO on Pt(111) studied with nuclear resonance scattering of synchrotron radiation

M. Zając [1,2], N. Spiridis [3], D. Wilgocka-Ślęzak [3], K. Freindl [2,3], A. Kozioł-Rachwał [2], M. Ślęzak [2], T. Ślęzak [2], J. Korecki [2,3]

[1] *European Synchrotron Radiation Facility, Grenoble, France*
[2] *Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, Kraków, Poland*
[3] *Jerzy Haber Institute of Catalysis and Surface Chemistry PAS, Kraków, Poland*

In bulk FeO (wüstite), oxygen and iron form the (111) planes of ideal two-dimensional hexagonal lattices. In the bulk iron planes are ferromagnetic and additionally antiferromagnetically coupled between each other. The FeO(111) layers are polar, which may strongly influence properties of epitaxial films with this orientation [1]. FeO(111) ultrathin films can be stabilized on the single crystal Pt(111) substrate up to 2 – 2.5 ML showing complex structure and magnetism [2], however so far magnetic properties were not verified experimentally. Recently in the Krakow group we applied a growth protocol that allowed to stabilize several nanometer thick FeO-like films on Pt(111) [3]. The conversion electron Mössbauer spectroscopy measurements showed a drastic change of the magnetic properties as a function of the film thickness. To account for this we have performed nuclear resonance scattering (NRS) of synchrotron radiation experiment in the UHV system [4] at the ID18 NRS-beamline at ESRF Grenoble [5]. The new instrument allowed systematic investigation of the thermo-elastic properties of the ^{57}Fe containing nano-systems by measuring the density of phonon states (DOS) *in situ* under ultrahigh vacuum conditions [6,7].

The LEED-characterized FeO films with thickness between 1 and 16 ML were UHV transferred to the NRS chamber, where grazing incidence NRS time spectra and the energy dependence of the nuclear inelastic scattering (NIS) was measured. The preliminary analysis of NIS data shows a structural transition between 4th and 11th monolayer (increasing of the lattice stiffness), which correlates with a magnetic transition. Remarkably, for the thickest investigated film the phonon-DOS deviates strongly from that of bulk FeO [8], similarly as the Mössbauer hyperfine parameters do.

This work was supported in part by the Polish Ministry of Science and Higher Education and by the Team Program of the Foundation for Polish Science co-financed by the EU Regional Development Fund.

[1] W. Weiss and W. Ranke, Progress in Surface Science 70 (2002) 1
[2] L. Giordano et al., Phys. Rev. B 76 (2007) 075416
[3] TEAM AMON group, this workshop
[4] S. Stankov et al., Rev. Sci. Instrum. 79 (2008) 045108
[5] R. Rüffer, A. I. Chumakov, Hyperfine Interact. 97/98 (1996) 589
[6] S. Stankov et al., Phys. Rev. Lett. 99 (2007) 185501
[7] T. Ślęzak et al., Phys. Rev. Lett. 99 (2007) 066103
[8] V.V. Struzhkin et al., Phys. Rev. Lett. 87 (2001) 255501

Morphology, structure and interface properties in metal/oxide systems

Paola Luches

Centro S3, CNR-Istituto di Nanoscienze, Modena, Italy

Coupled metal/oxide systems represent the active part of different catalytic or magnetic devices. The physical and chemical properties of these systems are determined by the atomic scale structure of the constituents in reduced dimensionality and by the details of the interfaces between the oxide and the metal.
In this talk I will show the results of our recent studies of two different metal/oxide systems.
The first part will deal with cerium oxide ultrathin films on Pt(111). Ultrathin films with a good morphological and structural quality have been obtained by reactive evaporation. The oxide stoichiometry could be reversibly changed by heating treatments in UHV and O_2. The ceria films have been used for subsequent growth of Ag nanoparticles. The morphology and electronic properties of the obtained system will be discussed.
In the second part I will talk about Fe ultrathin films on NiO(001), a model ferromagnetic / antiferromagnetic system, which we have characterized in structure, morphology and magnetic properties [1,2]. In particular I will present the results of our recent depth-resolved magnetic characterization of the interface, which showed the presence of an antiferromagnetic oxidized Fe phase at the interface and of a bulk-like Fe phase a few layers above it [3].

[1] P. Luches et al., Phys. Rev. Lett. 96, 106106 (2006).
[2] P. Luches et al., Phys. Rev. B, 81, 054431 (2010).
[3] P. Luches et al., Phys. Rev. B, in press.

Bimetallic Au-Fe clusters on TiO_2(110)

Ewa Madej[1]*, Robert P. Socha[1], Nika Spiridis[1], Józef Korecki[1, 2]

[1]*Jerzy Haber Institute of Catalysis and Surface Chemistry, Polish Academy of Sciences, Poland*
[2]*Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, Poland*

Gold nanoparticles on metal oxide surfaces demonstrate outstanding catalytic activity in low temperature CO to CO_2 oxidation [1, 2]. Such properties have been reported for Au islands supported on many substrates like TiO_2, Fe_2O_3 or MgO. The best for the catalytic applications are clusters with the diameter of 2-4 nm, regardless of the selected substrate [3]. In the catalytic processes, sintering of the active nanoparticles results in a loss of activity due to increase in clusters size.
The morphology of Au clusters and their electronic properties can be modified by adding a second metal, e.g. iron. Bi-metallic Au-Fe nanoclusters were deposited under ultrahigh vacuum conditions (UHV) on a rutile-TiO_2 (110) substrate. The influence of the iron amount on the clusters morphology, surface composition and thermal stability of Au-Fe bimetallic nanoparticles was studied in situ by scanning tunneling microscopy (STM) and X-ray photoelectron spectroscopy (XPS) as a function of annealing temperature (between 25ºC and 600ºC).
In the contribution studies of Au clusters formed on TiO_2 (110) surface with preadsorbed wedge of Fe in amount from 0Å to 0.65Å will be presented.

This work was supported in part by the Polish Ministry of Science and Higher Education and by the Team Program of the Foundation for Polish Science co-financed by the EU Regional Development Fund.

[1] M. Haruta, T. Kobayashi, H. Sano, M. Yamada: Chemistry Letters 405 1987.
[2] G. Ertl, H. Knozinger, F. Schuth, J. Weitkamp, Handbook of Heterogeneous Catalysis, J. Wiley&Sons, 2008.
[3] M. Valden, X. Lai and D.W. Goodman, Science, 1998, 281, 1647

* Presenting author: nczackie@cyf-kr.edu.pl

Growth and Characterization of Eu-Fe Films.

K. Balin[1,2], J. Szade[1], A. Nowak[1,3] A. Gibaud[3], and Z. Celinski[2],

[1]*A. Chełkowski Institute of Physics, University of Silesia, Katowice, 40-007, Poland*
[2]*Center for Magnetism and Magnetic Nanostructures, University of Colorado at Colorado Springs, Colorado Springs, CO 80918*
[3]*Laboratoire de Physique de l'Etat Condensé, Université du Maine, Le Mans Cedex,72085, France*

According to the literature, Eu and Fe do not form bulk compounds [1] with the exception of $EuFe_2$ [2]. We examine this assertion by studying Eu-Fe alloys in the form of thin films using Molecular Beam Epitaxy. The electronic and crystallographic structures of prepared films have been investigated as well as magnetic and transport properties.
A molecular beam epitaxy system, equipped with XPS and RHEED, was used to prepare Eu-Fe films. A series of Eu-Fe layers, with the thicknesses of ~15nm, were grown at room temperature by co-deposition or in multilayers form on GaAs or Si substrates with a 50 nm thick Mo buffer layer. To allow the formation of Eu-Fe alloy the films were annealed (up to 480K) and XPS measurements were performed before, during and after annealing. Relative changes in Eu4d/Fe2p area ratio as well as chemical shifts of core levels (Eu3d up to 8.9eV, Eu4d and Fe2p up to 0.1eV) monitored by the XPS indicate mixing between europium and iron. The valance transitions of europium from Eu2+ to Eu3+ were observed.
Small changes in a polycrystalline structure of the films, monitored by RHEED, as well as calculations based on the x-ray reflectivity measurements indicate intermixing of the layers and possible formation of Eu-Fe based alloys.
The SQUID magnetometry measurements show a significant difference in the temperature dependence of magnetic moment, measured in field cooled (FC) and zero field cooled (ZFC) modes, with the maximum observed in ZFC measurements close to 300K for applied field 100 Oe. Additionally an increasing value of blocking temperature (maximum in ZFC curves) was observed with decreasing value of applied external field. The hysteresis loops show a decreasing value of coercive field with increasing temperature. For selected films, some anomalies were also observed in temperature dependence measurements of electrical resistivity.

This work was supported by the NSF grants (DMR0907053)

[1] Landolt-Bornstein; Group IV Physical Chemistry - Phase Equilibria, Crystallographic and Thermodynamic Data of Binary Alloys, Volume 5
[2] Ning Yuan-Tao, Zhou Xin-Ming, Zhen Yun, Chen Nian-Yi, Xu Hua and Zhu Jian-Zhong; Journal of the Less-Common Metals, 147 (1989) 167-173

STM studies of Gold Nanostructures on Vicinal FeO/Pt(997) Surface

N. Spiridis[1], D. Wilgocka-Ślęzak[1], K. Freindl[1], B. Figarska[1], J. Korecki[1,2]

[1]Jerzy Haber Institute of Catalysis and Surface Chemistry, Polish Academy of Sciences, ul. Niezapominajek 8, 30-239 Kraków, Poland
[2]Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, Al. Mickiewicza 30, 30-059 Kraków, Poland

Vicinal surfaces of polar oxides seem to be very good candidate for nanostructure growth. Steps, creating a set of regular defects, together with periodic modulations of electrostatic field, should act as well organized centers for absorption.
Our STM studies indicate that FeO monolayer grown on vicinal single crystalline platinum (997) prepared by iron film oxidation reflects morphology of the stepped substrate very well, revealing at the same time Moire pattern on its (111) oriented terraces. In this contribution we investigate influence of the steps and the Moire superstructure of the oxide on gold adsorption. We demonstrate that there exists correlation between distribution of gold nanoclusters (0.1ML) and the oxide ‘defects’. Studies for thicker Au layers (5ML) show that the oxide steps play a key role in geometry of adsorbed gold islands but their morphology strictly depends on preparation procedure.

This work was supported in part by the Polish Ministry of Science and Higher Education and by the Team Program of the Foundation for Polish Science co-financed by the EU Regional Development Fund.

Comparison of oxygen adsorption on Fe(110) surface and Fe(110)/W(110) monolayer

K. Freindl[1, 2], M. Zając[1,3], T. Ślęzak[1], M. Ślęzak[1], N. Spiridis[2], K. Matlak[1], E. Madej, E. Partyka-Jankowska[4] and J. Korecki[1,2]

[1]*Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, Al. Mickiewicza 30, 30-059 Kraków, Poland*
[2]*Jerzy Haber Institute of Catalysis and Surface Chemistry, Polish Academy of Sciences, ul. Niezapominajek 8, 30-239 Kraków, Poland*
[3]*European Synchrotron Radiation Facility, 6 rue Jules Horowitz, BP 220, 38043 Grenoble Cedex, France*
[4]*Faculty of Physics, University of Vienna, Strudlhofgasse 4, A-1090 Vienna, Austria*

Oxygen adsorption on iron surfaces attracted a lot of interest because of its importance in such processes as oxidation, passivation, corrosion and catalysis. In literature it is well established that on Fe(110) molecular oxygen is adsorbed dissociatively from a precursor diffusing on the iron substrate [1]. However, despite quite a number of papers [2 and references herein], the data are fragmentary and often contradictory. Here, we report on concern room temperature adsorption of oxygen on the Fe(110) surface of epitaxial Fe films grown on W(110). The low energy electron diffraction (LEED) was used to identify the symmetry of the adsorbate structure. We found three well defined structures of oxygen adsorbate: the well known (2x2) (at oxygen exposure 3 L), the so called split 3x1 (at oxygen exposure 17 L) and a new one (3x2), to our knowledge not reported before. We studied also modification the Fe electronic structure induced by oxygen the nuclear resonance scattering (NRS) of synchrotron radiation at the beamline ID 18, ESRF Grenoble.
Oxygen adsorption on the bulk Fe(110) surface was compared with that on a pseudomorphic Fe monolayer on W(110). In complementary LEED, AES and STM experiments different surface structures could be identified, covering the whole range of oxygen coverages, Additionally, NRS and conversion electron Mössbauer spectroscopy results revealed a distinct transition in electronic structure interpreted as the onset of oxide formation at oxygen doses of about 100 L.
Differences in the oxygen adsorption on Fe(110) surface and Fe/W(110) monolayer were interpreted in terms of Fe lattice expansion and influence of the tungsten substrate.

This work was supported in part by the Polish Ministry of Science and Higher Education and by the Team Program of the Foundation for Polish Science co-financed by the EU Regional Development Fund.

[1] G. Pirug et al., Surf. Sci. 94 (1980) 323,
[2] A. Hodgson et al. Surf. Sci. 319 (1994) 119

Au films on W(110): reconstruction and dislocations

Tomasz Giela[1], Kinga Freindl[1,2], Nika Spiridis[1], Józef Korecki[1,2]

[1]*Jerzy Haber Institute of Catalysis and Surface Chemistry, Polish Academy of Sciences, Krakow, Poland*
[2]*Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, Krakow, Poland*

The poster contains the complex description of the studies related to the mechanism of formation of the “herringbone” reconstruction on Au(111) surface. As a substrate for epitaxial experiments (110) surface of tungsten monocrystal was used. The content incorporates the theoretical base concerning anticipated growth modes of gold as well as STM data on stress induced deformations of the reconstructed surface layer. During the investigation of a given system preferred preparation conditions were defined. Influence of the amount of deposited material on morphology of thin gold films is discussed in relation to the present interfacial stress components. The key element of this part of the work was an explanation of the process of creating group dislocation arrangements on the anisotropically reconstructed Au surface. Pairing and bunching of screw dislocations limited by strict geometrical constrains is supposed to be responsible for the occurrence of the observed specific defects.

This work was supported by the Team Programs of the Foundation for Polish Science co-financed by the EU European Regional Development Fund.

Exchange-bias in epitaxial CoO/Fe bilayer grown on MgO(001)

J. Gurgul[1], K. Freindl[1,2], A. Kozioł-Rachwał[2], K. Matlak[2], J. Przewoźnik[2], N. Spiridis[1], T. Ślęzak[2], D. Wilgocka-Ślęzak[1], J. Korecki[1,2]

[1]Jerzy Haber Institute of Catalysis and Surface Chemistry, Polish Academy of Sciences, ul. Niezapominajek 8, 30-239 Kraków, Poland
[2]Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, al. Mickiewicza 30, 30-059 Kraków, Poland

The exchange-bias (EB) has been recently extensively studied because of its crucial importance in the design of novel magnetic devices. Details of the EB effects essentially depend on the chosen combination of antiferromagnetic (AF)/ferromagnetic (FM) films. In this contribution we focus on the properties of epitaxial bilayer films grown on MgO(001). The main advantages of choosing CoO as the AF layer are the Néel temperature close to room temperature, the strong magnetic anisotropy and the simple rock salt crystal structure. Additionally, the use of iron as the FM layer gives us possibility of applying CEMS.
Two samples with different sequences of sublayers: (A) - CoO(21Å)/Fe(200Å)/MgO(100) and (B) - Fe(50Å)/CoO(50Å)/MgO(100) were prepared under UHV condition. Both bilayers were prepared by MBE on pre-heated MgO(001) substrate. The CoO films were produced by the reactive deposition of cobalt in the molecular oxygen atmosphere. The oxygen partial pressure (in 10^{-6} mbar pressure range), the substrate temperature and the deposition rate were optimized in the deposition process. LEED and AES were used to control the quality of the epitaxial growth.
Room temperature CEMS measurements showed that the reactive deposition of CoO leads to oxidation of the interfacial Fe layer, which results in a complex structure (a mixture of metallic and oxide phases) for the sample A. On the contrary, in the sample B there is a sharp CoO-metallic Fe interface. The differences in the interface structures correlate with different magnetic properties, as measured using VSM and MOKE.

This work was supported in part by the Polish Ministry of Science and Higher Education and by the Team Program of the Foundation for Polish Science co-financed by the EU European Regional Development Fund.

Layer- by- layer epitaxial growth of polar FeO(111) thin film on MgO(111)

J. Gurgul[1], E. Młyńczak[1], N. Spiridis[1], J. Korecki[1,2]

[1]Jerzy Haber Institute of Catalysis and Surface Chemistry, Polish Academy of Sciences, ul. Niezapominajek 8, 30-239 Kraków, Poland
[2]Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, al. Mickiewicza 30, 30-059 Kraków, Poland

Polar surfaces have attracted wide attention due to their potentially interesting applications, such as novel catalysts and two-dimensional electronic devices. However, theoretical predictions and experimental results show that bulk terminated polar surfaces are not stable. In contrast to the surface of single crystals, non- reconstructed polar surfaces of thin films could be produced below the critical thickness [1].
We demonstrate a method of layer-by-layer epitaxial growth of FeO(111) onto MgO(111) substrate. FeO film as thick as 16 ML was prepared by deposition of ^{57}Fe and subsequent oxidation using molecular oxygen. The film quality was checked after each preparation step using LEED and AES. Room temperature ^{57}Fe-CEMS measurements performed for 2 ML, 4 ML, 8 ML and 16 ML of FeO confirmed that a single phase of wustite was formed. In addition, a CEMS measurement for 16 ML of FeO was performed at 80 K. The obtained spectrum reveal a complex magnetic structure characteristic for wustite in the antiferromagnetic state.

This work was supported in part by the Polish Ministry of Science and Higher Education and by the Team Program of the Foundation for Polish Science co-financed by the EU European Regional Development Fund.

[1] C. Noguera, J. Phys.: Condens. Matter 12 (2000) R367 and references therein.

Surface electronic properties of Fe(001) probed via hyperfine interactions

N. Spiridis[1], K. Freindl[1,2], W. Karaś[2], K. Matlak[2], M. Ślęzak[2], T. Ślęzak[2], D. Wilgocka-Ślęzak[1], M. Zając[2,3], and J. Korecki[1,2]

[1]*Jerzy Haber Institute of Catalysis and Surface Chemistry, PAS, Kraków, Poland*
[2]*Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, Kraków, Poland*
[3]*European Synchrotron Radiation Facility, 6 rue Jules Horowitz, BP 220, 38043 Grenoble Cedex, France*

Measurements of surface magnetic moments are challenging. Details of surface magnetism come in principle only from theoretical studies [1]. For the Fe(001) surface they predict a strong enhancement of the ground state magnetic moment of the surface atoms to about 2.9 μ_B (as compared to 2.2 μ_B in the bulk). While local measurements of magnetic moments with depth resolution are challenging, hyperfine magnetic fields were measured near the Fe(110) surface using Mössbauer spectroscopy [2] or its synchrotron counterpart, the nuclear resonant scattering of synchrotron radiation [3]. The measured hyperfine magnetic field (B_{hf}) for the Fe(110) surface at room temperature is slightly reduced compared to the bulk (31 T and 33 T, respectively), which is in fair agreement with *ab initio* calculations [4]. It should be noted that the slight reduction of B_{hf} corresponds to the 20% enhancement of the theoretical magnetic moment, from 2.2 μ_B to 2.65 μ_B.

We present the experimental analysis of the hyperfine interactions at the Fe(001) surface. It is more open than Fe(110), and the contrast between the calculated surface behaviour of the hyperfine magnetic field and the magnetic moment is much stronger. We studied the surface of an epitaxial Fe(001) film on MgO(001). The 500 nm thick film was deposited using the non-Mössbauer ^{56}Fe isotope and treated as an iron single crystal to produce a clean and well-ordered surface, as confirmed with LEED, AES and STM.

In such a film, ^{57}Fe probe monolayers were deposited at room temperature at and below the surface. The conversion electron Mössbauer spectroscopy (CEMS) measurements were performed in situ. In an ideal case of a flat surface, the 2 ML ^{57}Fe probe would produce a two-component spectrum, with a surface and sub-surface hyperfine magnetic field of B_{hf1}= 25.2 T and B_{hf2}= 39.5 T, respectively (according to 0 K theory [3]). Instead, we observed a complex spectrum fitted with six components split in two groups. We assigned these components to different surface and sub-surface ^{57}Fe atoms, respectively, in correlation with the STM images that clearly showed small terraces, for which a significant number of atoms were located at steps and corners. The low-coordinated sites could be identified by a high quadrupole interactions and broader distribution of the hyperfine magnetic field around the theoretically predicted value.

The experimental results were compared with *ab initio* calculations using the Wien2k code, showing that the surface magnetic hyperfine field of 25 T corresponds to a 30% enhancement of the surface magnetic moments.

This work was supported in part by the Polish Ministry of Science and Higher Education and by the Team Program of the Foundation for Polish Science co-financed by the EU Regional Development Fund.

[1] S. Ohnishi, A. J. Freeman, and M. Weinert, Phys. Rev. B 28 (1983) 6741.
[2] J. Korecki, and U. Gradmann, Phys. Rev. Lett. 55 (1985) 2491.
[3] T. Slezak et al. Phys. Rev. Lett. 99 (2007) 066103.
[4] C. L. Fu, and A. J. Freeman, J. Magn. Magn. Mat. 69 (1987) L1.

Surface and electronic structure KTaO3 crystal modified by Ar+ ion beam

Jerzy Kubacki, Krzysztof Szot

A. Chełkowski Institute of Physics, University of Silesia, Katowice, 40-007, Poland

The surface of oxide materials as a complex system played the important role in contact phenomena, especially in catalysis. $KTaO_3$ is the model material with perovskite structure, which can be used to dissociation of water and production of hydrogen. It is known that the dissociation of molecules takes place mainly on the active centres of the surface like steps, kink and another atomic defect.
We used the Ar+ ion beam to produce different defect on the polished (100) KTaO3 surface. The electronic structure and changes in topography were studied by XPS and AFM method. The activation energy related to averaged temperature dependence of local conductivity was estimated from Arrhenius plot. The structural and chemical reconstruction of the $KTaO_3$ surface modified by Ar+ ion beam was deduced.

Room temperature perpendicular magnetic anisotropy in epitaxial $[Fe/MgO]_N$ multilayers.

K. Matlak[1], A. Kozioł-Rachwał[1], M. Ślęzak[1], T. Ślęzak[1], K. Freindl[1,2], N. Spiridis[2], D. Wilgocka-Ślęzak[2], J. Korecki[1,2]

[1]Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, Kraków, Poland
[2]Jerzy Haber Institute of Catalysis and Surface Chemistry, PAS, Kraków, Poland

$[Fe/(MgO)]_N$ multilayers were grown by molecular beam epitaxy on MgO(001) single crystal substrate for the different Fe and MgO thicknesses. Analysis of RT CEMS spectra measured for $(Fe_2MgO_2)_{10}$ and $(Fe_4MgO_2)_{10}$ indicates transition from paramagnetic to ordered magnetic state as a function of Fe thickness. Moreover CEMS spectra accumulated for multilayers with varying MgO thickness indicate clearly SRT between in plane magnetization direction for Fe_4MgO_2 to out of plane for Fe_4MgO_3. In addition with increasing repetition number N the enhancement of PMA occurs. CEMS data were complemented with MOKE measurements.

This work was supported in part by the Polish Ministry of Science and Higher Education and by the Team Program of the Foundation for Polish Science co-financed by the EU Regional Development Fund.

Domain structures studies in NiFe/Au/Co/Au multilayers

P. Mazalski[1], M.Tekielak[1], A. Maziewski[1], B. Szymański[2], F. Stobiecki[2], S. Pizzini[3], F. Maccherozzi[4], A. Bendounan[4,5]

[1]*Laboratory of Magnetism, University of Bialystok, Lipowa Str. 41, 15-424 Bialystok, Poland*
[2]*Institute of Molecular Physics, Polish Academy of Sciences, M. Smoluchowskiego 17, 60-179 Poznan, Poland*
[3]*Laboratoire Louis Néel, CNRS, BP 166, 38042 Grenoble Cedex 9, France*
[4]*Elettra-Sincrotrone Trieste, Strada Statale 14, 34012 Basovizza-Trieste, Italy*
[5]*Synchrotron Soleil, L'Orme des Merisiers Saint-Aubin - BP 48F-91192 Gif-sur-Yvette cedex, France*

$(Ni_{80}Fe_{20}/Au/Co/Au)_{10}$ multilayers (MLs) are examples of layered films consisting of layers with alternating out-of-plane (Co) and in-plane anisotropy ($Ni_{80}Fe_{20}$ - Permalloy). Cobalt thickness d_{Co} was changed for tuning magnetic anisotropy. Previously, we have demonstrated on the basis of complementary studies (magnetoresistance, conventional magnetometry, and element specific soft X-ray resonant magnetic scattering hysteresis measurements) that the magnetization reversal of the $Ni_{80}Fe_{20}$ layers is strongly influenced by a magnetostatic coupling originating from the out-of-plane stripe domain stray fields of the Co layers [1, 2]. Magnetization processes were studied using magnetooptical magnetometry and VSM technique. For investigated MLs with repetition number N=10 and with d_{Co}= 0.4, 0.8, 1.2 nm the presence of submicrometer stripe domains was revealed by magnetic force microscopy (MFM); similar results were reported in [2, 3]. Photoemission electron microscopy combined with X-ray magnetic circular dichroism (PEEM-XMCD) technique [4] was used to study of magnetization distribution separately in Co and $Ni_{80}Fe_{20}$ layers. This study indicate on the replication of the domain structure from Co to $Ni_{80}Fe_{20}$ layers [5]. The process is stimulated by a magnetostatic interactions (coupling caused by domains in Co layers). The magnetic structure of the investigated system and particularly the replication of domains is also observed in micromagnetic simulations performed using OOOMF technique [6].

[1] M. Urbaniak, F. Stobiecki, B. Szymański, A. Ehresmann, A. Maziewski, M. Tekielak, J. Appl. Phys., vol. 101, 013905 (2007)
[2] F. Stobiecki et al., Appl. Phys. Lett., vol. 92, 012511 (2008)
[3] M. Urbaniak, F. Stobiecki, D. Engel, B. Szymański, A. Ehremann, J. Kim, Phys. Stat. Sol. C, vol. 3, 57 (2006)
[4] W. Kuch et al., J. Elec. Spec. Rel. Phenom., vol. 109, 249 (2000)
[5] B. Szymanski, P. Mazalski, M. Urbaniak, F. Stobiecki, A. Maziewski, S. Pizzini and F. Maccherozzi, IEEE Trans. on Mag., vol.46, 231 (2010)
[6] M. Donahue and D. Porter, Object Oriented Micromagnetic Framework (OOMF), http://math.nist.gov/oommf.

Magneotoptic Kerr Effect Imaging of the Magnetization Reversal in Fe/MgO/Fe trilayers

B. Olbromska[1], A. Kozioł-Rachwał[1], K. Freindl[1,2], K. Matlak[1], E. Młyńczak[2], N. Spiridis[2], M. Ślęzak[1], T. Ślęzak[1], D. Wilgocka-Ślęzak[2], P. Korecki[3], J. Korecki[1,2]

[1]Faculty of Physics and Applied Computer Science, AGH, Kraków, Poland;
[2]Jerzy Haber Institute of Catalysis and Surface Chemistry, PAN, Kraków, Poland;
[3]Faculty of Physics, Astronomy and Applied Computer Science, Jagiellonian University, Kraków, Poland

We used magnetooptical Kerr effect microscope for the investigations of the interlayer coupling in Fe/MgO/Fe epitaxial trilayers with the wedge-shaped MgO spacer. The trilayer was grown on the MgO(001) polished single crystal that in part was covered by the epitaxial 100Å thick MgO buffer layer. The orientation of the MgO wedge spacer allowed to compare the dependence of the interlayer exchange coupling on the spacer thickness for the Fe/MgO/Fe system deposited directly on the polished MgO(001) and buffered with MgO layer. A sequence of magnetic images was recorded as a function of external magnetic field. Subsequently dedicated software enabled determination of local magnetization curves. The existence of the strong antiferromagnetic coupling was proved in the broad 1.5 – 6.5Å MgO thickness range. The antiferromagnetic coupling is much stronger for the case of buffered trilayer.

This work was supported in part by the Polish Ministry of Science and Higher Education and by the Team Program of the Foundation for Polish Science co-financed by the EU Regional Development Fund.

Magnetization statics and light-induced ultrafast dynamics in Co/garnet heterostructures

M.Pashkevich[1,3], A.Stupakiewicz[1], A. Maziewski[1], A.Kimel[2], A.Kirilyuk[2], F.Atoneche[2], A.Stognij[3], N.Novitskii[3], and T.Rasing[2]

[1]Laboratory of Magnetism, University of Bialystok, Lipowa 41, Bialystok, Poland
[2]Institute for Molecules and Materials, Radboud University Nijmegen, Heyendaalseweg 135, Nijmegen, The Netherlands
[3]Scientific-Practical Materials Research Centre of the NASB, P. Brovki 19, Minsk, Belarus

Many interesting magnetic properties were observed in Co substituted YIG films (YIG:Co) films, eg. photomagnetic effect [1]. Large ultrafast light-induced magnetic anisotropy has been recently observed in YIG:Co [2]. In such garnet films the phase of magnetization precession depends on polarization of the light. It is well known that coupling between in-plane anisotropy of ferromagnetic layer and perpendicular anisotropy of garnet film appears at the interface [3]. Consequently, after deposition of ultrathin ferromagnetic layers on the garnet films one can expect new effects of magnetization statics and ultrafast dynamics in garnet films due to influence of effective magnetic field of ferromagnetic layer and/or coupling between ferromagnetic layer and garnet.
The initial 5.8 μm thick garnet films grown liquid phase epitaxy was thinned up to 1.8 μm by oxygen ion beam etching in low energy regime. Au(4nm)/Co(2nm)/garnet(1.8 and 5.8 μm) heterostructures were then obtained by ion-beam sputter deposition method.
Domain structure and static magnetization processes were investigated by both magneto-optical Faraday and Kerr effects as a function of magnetic field applied to perpendicular and in-plane of the sample. A strong influence of 2 nm Co layer on the domain structure geometry, magnetization processes and coercive field has been found for 1.8 μm garnet films. The observed magnetization reversal process in the heterostructure could be explained by both (i) thickness-driven magnetic anisotropy of garnet films and (ii) strong modification of garnet domain structure for both thicknesses by virtue of magnetostatic coupling between Co and garnet films.
Ultrafast magnetization dynamics of both garnet films and Co/garnet heterostructures were observed by time-resolved measurements using an optical pump-probe technique. The amplitude and frequency of precession was measured as a function of external magnetic field and linear polarization of the pump light. The polarization dependence of light-induced effect by pump was observed for both thickness of garnet films. However change of the phase of oscillation process was not observed for the Co/garnet heterostructures. These experimental results were discussed taking into account the following contributions to the total magnetic anisotropy energy in heterostructures system of: (i) in-plane anisotropy of ultrathin Co layer and (ii) cubic, growth and stress induced uniaxial as well as light-induced uniaxial anisotropies of garnet films.

This work was supported the EU Seventh Framework, Programme FP7/2007-2013 under grant N214810 FANTOMAS and Polish network SPINLAB.

[1] A. Stupakiewicz, A. Maziewski, I. Davidenko, and V. Zablotskii, Phys. Rev. B 64, 064405 (2001)
[2] F Anatoche, A.M. Kalashnikova, A.V. Kimel, A. Stupakiewicz, A. Maziewski, A.Kirilyuk, and Th. Rasing, Phys. Rev. B 81 214440 (2010)
[3] N.Vukadinovic et. al, Phys. Rev. B 79,184405 (2009)

Resistive switching behaviour in STO doped by La

M. Pilch[1], J. Szade[1], W. Speier[2], R. Waser[2], K. Szot[1,2]

[1]*University of Silesia, Institute of Physics, Katowice, Poland*
[2]*Forschungszentrum Juelich, IFF-6: Electronic Materials*

The analysis of the electronic structure of La-doped $SrTiO_3$ single crystals, $Sr_{1-x}La_xTiO_3$ with x=5 at % (SLTO), shows that additional electrons in the host matrix are accommodated by a change of the valence of Ti ions from Ti^{+4} to Ti^{+3} and Ti^{+2}. We found also a metallic peak near the Fermi level by electron spectroscopy. Similarly, electrical characterisation of the material revealed semiconducting and mettalic behaviour. This stands in accordance to the general idea of a macroscopic insulator-to-metal transition in SLTO at a doping level of a few percent of La. By means of conducting AFM we found evidence of an inhomogeneity of the in-plane conductivity at the nano-scale and the possibility of locally manipulating the electric resistivity by means of an electrical stimuli, i.e. resistive switching. The observed inhomogeneity is attributed to a non-uniform distribution of La doping and a high density of extended defects in SLTO crystal.
The understanding of the nature of the resistive switching phenomena in SLTO at room temperature should go beyond the standard models of the electric transport in this kind of material, which have been developed on the basis of homogeneous of dopants in matrix, and should instead focus on the local electronic structure, the effect of electro-migration and kinetic demixing at the nano-scale and take into consideration the percolative character of the transport at the macro-scale.
The switching mechanism between the low resistance state (LRS) and the high resistance state (HRS) is due to the formation of a conductive filament (especially via extended defects). These inverse operations are electrochemically induced (charge iniection/transport). SLTO pretends to be a new class of resistance memories (RRAM) emerging as serious candidate for future high-density memory application replacement.

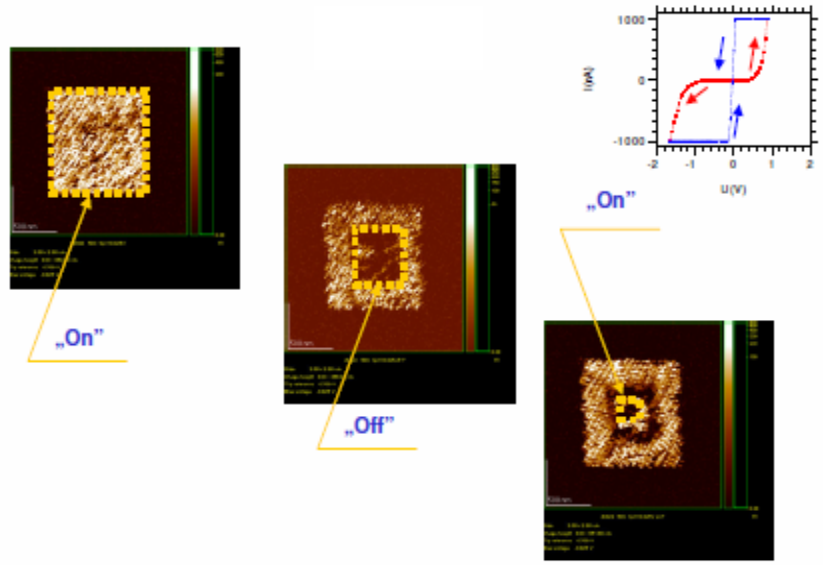


Fig.1. Changes of the conductivity and shape well conductive filaments/islands on the SLTO-5%La surface (Local Conductivity AFM)

References:
[1] S. Hirose et al., Journal of Applied Physics 104, 053712 (2008)
[2] S. Hashimoto et al., Journal of Alloys and Compounds 397, 245 (2005)
[3] K.Szot et al., Nature Materials No.5 (2006) 312.

Corresponding author: michal.pilch@us.edu.pl

Synthesis of epitaxial layers of mixed Fe_xMn_yO oxides on MgO(001)

R. P. Socha[1], M. Szczepanik[2], E. Madej[1], B. Figarska[1], N. Spiridis[1], J. Korecki[1,2]

[1]*Jerzy Haber Institute of Catalysis and Surface Chemistry PAS, ul. Niezapominajek 8, 30-239 Kraków, Poland*
[2]*Department of Physics and Applied Informatics AGH University of Technology, 30-059 Kraków, Poland*

Synthesis of mixed iron manganese oxides was performed by two different methods i.e. oxidation of intermetallic Fe_xMn_y alloy or annealing of metallic layer deposited on manganese oxide (II). MgO(001) annealed at 820 K was used as a substrate. Deposition of manganese and iron was performed from the effusion cells. The composition and electronic states of elements in the studied systems were analyzed by AES, XPS and Mossbauer Spectroscopy. Every step of synthesis was structurally characterized by LEED. In first synthesis, the manganese layer of 20 nm in thickness was covered by 2 nm of ^{57}Fe and then the bimetallic layer was annealed in the temperature range of 373-673 K and finally oxidized in oxygen. Annealing of bimetallic layer resulted in iron dissolution in manganese bulk. When the system was oxidized, the mixed Fe_xMn_yO oxide isostructural with MnO(001) was obtained. In second synthesis route, a layer of MnO(001) was prepared by oxidation of manganese layer (20 nm). Then metallic ^{57}Fe (2 nm) was deposited at the MnO surface at 295 K resulting in sharp (1 monolayer of FeO) Fe/MnO interface.

Acknowledgments: The studies were financed partly by Polish MNiSW from scientific funds in 2010-2013 within the grant No. 2692/B/H03/2010/38 and partly within the project Team Program of the Foundation for Polish Science co-financed by the EU Regional Development Fund and ISD co-financed by the EU Social Fund.

The Magnetic Anisotropy of Fe/Au(001) Ultrathin Films in a Function of Fe Thickness and Thickness Driven Polar Spin Reorientation Transition.

D. Wilgocka-Ślęzak[1], T. Ślęzak[2], N. Spiridis[1], K. Freindl[1, 2], M. Zając[2,3], M. Ślęzak[2], K. Matlak[2], and J. Korecki[1,2]

[1]*Jerzy Haber Institute of Catalysis and Surface Chemistry, Polish Academy of Sciences, ul. Niezapominajek 8, 30-239 Kraków, Poland*
[2]*Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, Al. Mickiewicza 30, 30-059 Kraków, Poland*
[3]*European Synchrotron Radiation Facility, 6 rue Jules Horowitz, BP 220, 38043 Grenoble Cedex, France*

Polar spin-reorientation transition (pSRT) and magnetic anisotropy near transition have been under extensive studies for the last two decades for many ferromagnetic ultrathin layers [1]. The exception is Fe/Au(001) system for which pSRT is expected for extremely low iron thickness (well bellow 3ML) difficult for experimental research. There is only one early work dedicated to SRT in iron on gold (001) [2]. In present work we intended to complete this experimental gap and performed systematic investigations of magnetic anisotropy for Fe/Au(001) system as a function of Fe layer thickness around polar SRT in the range between 1 ML and 3 ML of Fe at room temperature.

Ultrathin Fe/Au(001) films were grown by molecular beam epitaxy (MBE) under UHV conditions (base pressure below $1x10^{-10}$ mbar) at room temperature on polished MgO substrates. The (001) gold orientation was forced by 40Å Cr seed layer deposited at 100°C directly on thermally cleaned MgO substrate. The Au(001) buffer layer was evaporated using special multilevel procedure [3]. The quality of samples was controlled by Auger electron spectroscopy (AES), low energy electron diffraction (LEED) and scanning tunneling microscopy (STM). To investigate SRT and avoid the problem of deposition conditions instability a step-shaped sample with Fe thickness changing from 1 to 3 ML was prepared. Moreover reference sample with 3ML of Fe was also prepared. As deposited samples were covered with Au protective layer (30Å) to allow *ex situ* measurements.

Magnetic properties of ultrathin Fe/Au(001) films were investigated by *ex situ* magnetooptical Kerr effect at room temperature in polar and longitudinal geometry. To determine the saturation magnetization value of Fe films SQUID measurements were carried with magnetic field in- and out-of-plane configurations for the reference sample.

MOKE measurements indicate that spin reorientation from in-plane direction to out-of-plane of the system when reducing the iron thickness takes place between 2.3 and 2.0 ML Fe in the presence of an intermediate state. Values of effective magnetic anisotropy constants were determined from MOKE and SQUID measurements. Effective anisotropy constants flow analysis in the anisotropy space [4,5] points out that in the intermediate state the magnetic easy axis is canted. Gradual thickness reduction of Fe layer below 2.0 ML resulted in gradual diminution of MOKE signal with its total disappearance at around 1ML indicating paramagnetic state.

[1] P.J. Jensen_, K.H. Bennemann Surface Science Reports 61 (2006) 129–199
[2] C.Liu, D.Bader, J.Vac.Sci.Technol A 8 (1990) 2727
[3] N.Spiridis, J.Korecki, Applied Surface Science, 141 (1999) 313
[4] Y.Milev, J.Kirschner PRB 54 (1996) 4137
[5] H.P.Oepen, M. Speckmann, Y.Millev, J.Kirchner PRB 55 (1997) 2752

Spin-transfer-torque dependence on MgO tunnel barrier thickness in MTJs

W. Skowroński [*,1], T. Stobiecki [1], J. Wrona [1], G. Reiss [2], and S. van Dijken [3]

[1] *AGH University of Science and Technology, Al. Mickiewicza 30, 30-059 Kraków, Poland*
[2] *Thin Films and Physics of Nanostructures, Bielefeld University, 33615 Bielefeld, Germany*
[3] *Department of Applied Physics, Aalto University, P.O.Box 15100, FI-02015 Aalto, Finland*

Spin transfer torque (STT) effect is used in spin electronics devices such as magnetic tunnel junctions (MTJs) or giant magnetoresistance (GMR) spin valves to change the local magnetization of the ferromagnetic layer using a spin polarized current. In contrast to GMR systems, where only in-plane torque component is observed [1], the existence of the both in-plane and perpendicular components of STT in MTJs were reported [2]. Using the spin-torque diode effect [3], we extract the information about both perpendicular and parallel components of STT in MTJs with different MgO tunnel barrier thickness. We found that in entire measured barrier thickness range, the parallel torque is linear function of the applied bias voltage, whereas the perpendicular torque is approximately quadrant. Moreover, the absolute value of the parallel torque increases with decreasing MgO tunnel barrier thickness. The possible influence of measured torques on practical application will be discussed.

W.S. and T.S would like to thank the Foundation for Polish Science MPD Programme co-financed by the EU European Regional Development Fund and the Polish Ministry of Science and Higher Education grants (IP 2010037970 and NN 515544538)

[1] – J. Sankey et al. Nature Physics 4, 67, 2008
[2] – Se-Chung Oh et al. Nature Physics 5, 898, 2009
[3] – A. Tulapurkar et al. Nature 35, 339, 2005

* e-mail: skowron@agh.edu.pl

Ultrathin FeO and Fe_3O_4 oxides on Pt(111)

D. Wilgocka-Ślęzak[1], N. Spiridis[1], K. Freindl[1, 2], T. Ślęzak[1], K. Matlak[1], B. Strzelczyk[2], B. Figarska[1], J. Korecki[1,2]

[1]Jerzy Haber Institute of Catalysis and Surface Chemistry, Polish Academy of Sciences, ul. Niezapominajek 8, 30-239 Kraków, Poland
[2]Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, Al. Mickiewicza 30, 30-059 Kraków, Poland

Ultrathin FeO(111) and Fe_3O_4(111) oxides were grown on a Pt(111) single crystal. The best FeO structures were obtained by oxidizing of single Fe monolayers at 2 L oxygen exposition at $5x10^{-8}$mbar O_2 and 280°C substrate temperature, followed by UHV annealing at 600°C. FeO could be stabilized for many monolayer cycles, contrary to previous papers reporting that FeO on Pt(111) is stable only up to 2.5ML [1]. In the case of Fe_3O_4, the optimal method of preparation was reactive deposition of iron at $8x10^{-6}$ mbar oxygen pressure and 250°C substrate temperature followed by UHV annealing at 500°C. Using this method Fe_3O_4 layers of thickness from 8 Å to 100 Å were obtained.
LEED and STM investigations of the oxides surfaces indicated a high degree of the structural order. A characteristic feature of the FeO surface was a Moire superstructure being a consequence of a large lattice misfit (11%) between FeO(111) and Pt(111). We found that FeO grows layer-by-layer. For Fe_3O_4(111), STM images indicated Stranski-Krastanov growth. The surface of Fe_3O_4 islands was atomically flat and well ordered. Generally the showed (1x1) structure of the (111) surface with 6Å periodicity of the hexagonal unit cell. Only occasionally small islands with a superstructure (35÷40Å) and atomic periodicity of 3Å could be found.
CEMS studies performed in a wide range of thickness and temperature exhibited a long range magnetic order in FeO films of several angstrom thickness. This unusual property of the FeO film contrasts with the bulk-like behavior of the Fe_3O_4 films, displaying characteristic electronic properties (including the Verwey transition) down to the smallest thickness.

This work was supported in part by the Polish Ministry of Science and Higher Education and by the Team Program of the Foundation for Polish Science co-financed by the EU Regional Development Fund.

[1] W. Weiss, W. Ranke, *Prog. in Surf. Sci.*, 70 (2002) 1-151.

Growth and Spin Structure of Ultrathin Fe Films on W(110)

M. Ślęzak[1], A. Kozioł-Rachwał[1], K. Matlak[1], T. Ślęzak[1], M. Zając[1,2], R. Rüffer[2], J, Korecki[1,3]

[1]*Faculty of Physics and Applied Computer Science, AGH, Kraków, Poland*
[2]*European Synchrotron Radiation Facility, BP 220, 38043 Grenoble Cedex, France*
[3]*Jerzy Haber Institute of Catalysis and Surface Chemistry, PAS, ul. Niezapominajek 8, Kraków, Poland*

Using *in-situ* Grazing Incidence Nuclear Resonant Scattering of X-rays [1], we investigated structure and magnetism of ultrathin epitaxial Fe films grown on W(110). The experiment was performed in a multi-chamber ultra high vacuum system at ID 18 at ESRF in Grenoble [2]. On the atomically clean W(110) single crystal, ^{57}Fe films were grown at a rate of about 0.12 Å/min. First, 1.8 Å of ^{57}Fe, corresponding to 1.1 pseudomorphic monolayer was deposited at 500 K. Next, a series of room temperature deposition steps was performed, each one corresponding to evaporation of 0.4 Å, till 10 Å (~ 5ML) of the total Fe thickness was reached. After each deposition step, a time-spectrum was collected at room temperature. The whole process of deposition and time-spectra accumulation took only 1.5 h, and therefore the residual gas adsorption effects were negligible. The GI-NRS data were fitted using the program CONUSS [3]. For coverage between 3 and 6.0 Å, analysis of the time spectra indicated a gradual transition from nearly perpendicular magnetization for 3Å film to the in plane collinear magnetic order above 6.0 Å. For intermediate coverage a complex magnetic structure was derived from the numerical analysis. The magnetic structure is related to the film morphology characterized by a deviation from a layer-by-layer growth mode. Competition of out-of-plane and in-plane magnetic anisotropy for double layer Fe patches and for thicker Fe areas, respectively, leads to coexistence of non-collinear spin structures at buried layers.

This work was supported in part by the Polish Ministry of Science and Higher Education and by the Team Program of the Foundation for Polish Science co-financed by the EU European Regional Development Fund

[1] R. Röhlsberger, Nuclear Condensed Matter Physics with Synchrotron Radiation
STMP 208, (Springer-Verlag Berlin Heidelberg 2004).
[2] S. Stankov et al, Review of Scientific Instruments, 79 (2008) 045108
[3] W. Sturhan, Hyp. Interact. 87, 149, (2000)

Nanoscale Spectro-Microscopy For Krakow Synchrotron

D. Wilgocka-Ślęzak [1*], M. Ślęzak [2], N. Spiridis[1] and J. Korecki [1,2]

[1] *Jerzy Haber Institute of Catalysis and Surface Chemistry PAS, ul. Niezapominajek 8, 30-239 Kraków, Poland*
[2] *AGH University of Science and Technology, Al.Mickiewicza 30, 30-153 Kraków, Poland*

The idea of implementing a spectro-microscopic facility at the Kraków Synchrotron has good chances to come into being as a result of interaction between two Polish projects: "National Centre of Electromagnetic Radiation for research aims" [1] that realizes construction of a synchrotron in Kraków and a smaller one: "National Centre of Magnetic Nanostructures for Applications in Spin Electronics – SPINLAB" [2]. SPINLAB is an infrastructural project co-financed by European Regional *Development* Fund, in the frame of the Operational Programme - *Innovative Economy 2007-2013*. Institute of Catalysis and Surface Chemistry of the Polish Academy of Sciences, as a SPINLAB's partner, purchases Photoelectron Emission Microscope (PEEM) with band-pass filtering and offers to install it at the synchrotron as a permanent equipment.

Synchrotron-based PEEM (called XPEEM), including laterally resolved versions of X-ray absorption and photoelectron spectroscopies (XAS and XPS), as well as X-ray magnetic circular and linear dichroisms (XMCD and XMLD) became a powerful tool in surface and material sciences. It enables true chemical, electronic and magnetic micro-characterization of surface and sub-surface regions with 10 nanometers spatial resolution [3]. By virtue of the time structure of the synchrotron radiation, the method is also suitable for investigation dynamic processes. Applications of XPEEM are not limited to surface and material sciences but are expanding to novel fields like geology, medicine and biology.
In this contribution the perspectives of the XPEEM with respect to the characteristics of the soft x-ray beamline of the Polish synchrotron will be discussed.

[1] "National Centre of Electromagnetic Radiation for research aims": http://synchrotron.pl/
[2] "National Centre of Magnetic Nanostructures for Applications in Spin Electronics – SPINLAB": http://www.ifmpan.poznan.pl/poig.php
[3] A. Locatelli, E. Bauer, "Recent advances in chemical and magnetic imaging of surfaces and interfaces by XPEEM", J.Phys.: Condens. Matter. **20** (2008) 093002

Influence of Fe and Mn dopants on the resistive switching of $SrTiO_3$ thin films.

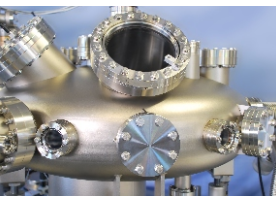
Marcin Wojtyniak, Roman Wrzalik

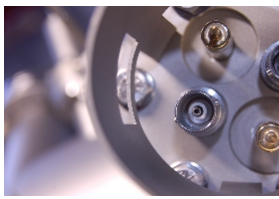
University of Silesia, Institute of Physics, Katowice, Poland

The resistive switching phenomenon was investigated in epitaxial Fe-doped and Mn-doped thin layers of $SrTiO_3$ with 1 and 2% dopant concentration. Thin layers were obtained by Pulsed Laser Deposition on single crystalline Nb-doped $SrTiO_3$ substrates. The crystalline character of the films was confirmed by Low Energy Diffraction experiments. The Atomic Force Microscopy in local-conductivity mode showed inhomogeneities in electric conductivity, observed already in $SrTiO_3$ single crystals. The well conducting spots in the nanometer size were correlated with the extended defects and red-ox processes in the nano-scale. The size and the distribution of such conducting spots are frequently correlated with surface topography and strongly depend on the type and the concentration of dopants. For all samples, the switching behavior has been clearly observed. The Scanning Tunneling Microscopy was additionally implemented in order to receive better resolution and insight into surface properties.

PREVAC

Precision and Vacuum Technology





PREVAC sp. z o.o. was founded in Rogów (Upper Silesia) in 1996.

Since its foundation PREVAC has been the world's leading manufacturer of research equipment for analysis of high and ultra high vacuum applications.

The company is focused on setting the standards in precision UHV technology and PREVAC`s logo is recognizable throughout the world as a mark of quality in this field.

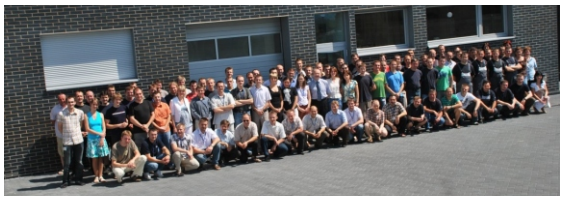
PREVAC`s greatest assets are many years of experience in vacuum technology and a highly skilled, dynamic and ambitious workforce comprising the best specialists, who are characterized by openness to innovation, initiative and creativity.

With many years market presence, PREVAC can be proud of some impressive achievements. Products, created from beginning to end in Poland, are currently helping some of the world's leading researchers achieve their goals in Poland, Germany, France, England, Sweden, Norway, Italy, Spain, Czech Republic, USA, Canada, Japan, China, Russia, India, Australia, South Africa, etc.

The Company's success is the result of the highest quality goods and services. The crowning achievement of quality care and continuous improvement of business processes was the award of the Certificate of TÜV Rheinland InterCert Kft compliance with quality management system ISO 9001:2000.

A confirmation of the high level of innovation and high quality products and services are many prizes and awards contained in the company's collection. Among these, awards from Polish Vacuum Society, Quality International Forum, Gazelle. Particularly important for the company is the main prize received in the category "Product of the Future" in the 11th edition of the "Polish Product of the Future" of the honorary patronage of the Prime Minister.

PREVAC, as a member of the Polish Society of Vacuum assist from 13 May 1999, is an activist to promote science, technology and uses of vacuum.


PREVAC sp. z o.o., Raciborska Str. 61, 44-362 Rogów, Poland
Ph.: +48 32 459 20 00, Fax +48 32 459 20 01
www.prevac.eu prevac@prevac.eu