Magnetic Interfaces and Nanostructures Division
Room: 105 - Session MI-WeM

Fundamental Problems in Magnetism
Moderator: C. Clavero, College of William and Mary

8:00am **MI-WeM1 Fundamental Problems in Magnetism**, ***W.H. Butler***, The University of Alabama **INVITED**

In this presentation, we shall attempt to describe the fundamental magnetic properties, the physics that controls and limits them and the practical implications of possible improvement. The most important fundamental properties of magnetic materials are Curie temperature, saturation magnetization, and magnetic anisotropy. The maximum Curie temperature (Co) and maximum saturation magnetization ($Fe_{65}Co_{35}$) at room temperature have not increased in a century. We shall discuss the reasons for this and speculate on the prospects that either may be increased. The magnetic anisotropy is somewhat less refractory. We shall discuss the prospects and implications of significant increases. Although higher room temperature saturation magnetization would be very useful, there would also be interesting applications for a magnetic material with very low magnetization, but very strong spin dependence of its transport properties. There are also interesting potential applications for insulating ferromagnets.

8:40am **MI-WeM3 Progress toward Understanding the Sign of Spin-Polarization at Interfaces in Organic Spin-Valves**, ***G.J. Szulczewski***, University of Alabama

In this talk I will present results from a systematic study to understand the role of LiF, Al_2O_3, and MgO tunnel barriers in organic spin-valves. The overall aim of this work is to better quantify the degree of spin-polarized electron injection and extraction at ferromagnetic metal/organic semiconductor interfaces. In general we find that spin-valves made with two ferromagnetic transition metals has a positive magnetoresistance. However, when one of the ferromagnetic metals is exchanged with $La_{0.67}Sr_{0.33}MnO_3$, the sign of the magnetoresistance is inverted. In addition the spin-polarized tunneling measurements the structural, electronic, and magnetic properties of these interfaces have been thoroughly investigated by cross-sectional transmission microscopy, photoelectron spectroscopy, and polarized neutron reflectometry. These results will be compared to other findings in the literature in order to summarize the current status of spin-polarized electron transport across organic semiconductor/insulator/ferromagnetic metal interfaces.

9:00am **MI-WeM4 Rational Design of New Spintronics Materials: From Topological Insulators and Spin Torque Applications**, ***C. Felser***, Johannes Gutenberg University Mainz, Germany **INVITED**

Heusler compounds are a remarkable class of intermetallic materials with 1:1:1 (often called Half-

Heusler) or 2:1:1 composition comprising more than 1500 members [1]. Today, more than a century after their discovery by Fritz Heusler, they are still a field of active research. New properties and potential fields of applications emerge constantly; the prediction of topological insulators is the most recent example [2]. Surprisingly, the properties of many Heusler compounds can easily be predicted by the valence electron count or within a rigid band approach. Their extremely flexible electronic structure offers a toolbox which allows the realization of demanded but apparently contradictory functionalities based on a virtual lab approach. The subgroup of more than 250 semiconductors is of high relevance for the development of novel materials for energy technologies. Their band gaps can readily be tuned from zero to 4 eV by changing the chemical composition. Thus, great interest has been attracted in the fields of thermoelectrics and topological insulator research. Ternary materials based on multifunctional properties, i.e. the combination of two or more functions such as superconductivity and topological edge states will revolutionize technological applications. The design scheme for topological insulstors from the view point of bands and bond will be presented.

The wide range of the multifunctional properties of Heusler compounds is reflected in extraordinary magneto-optical, magneto-electronic, and magneto-caloric properties. Tetragonal Heusler compounds Mn_2YZ as potential materials for STT applications can be easily designed by positioning the Fermi energy at the van Hove singularity in one of the spin channels [3]. A high calculated magnetic anisotropy energy (MAE) is the sufficient condition for a material with perpendicular magnetocrystalline anisotropy (PMA). Materials with saturation magnetizations of 0.2 – 4.0 μ_B, high Curie temperatures of 380 – 800 K, high spin polarizations, PMA, and required lattice constant matching with MgO can be realized with ferri- or ferromagnetic Heusler-related compounds. Such materials are strongly recommended for the spin transfer torque magnetic random access memory (STT-MRAM) data storage and the spin torque oscillators (STO) for telecommunication. Additionally the first spin gapless semiconductor is realized in Mn_2CoZ.

9:40am **MI-WeM6 Interfacial Effect on the Magnetic Properties of Core-Shell Co/Pt Supported Nanodots**, *P. Campigilo, N. Moreau, V. Repain*, ***C. Chacon***, Lab. Mat. et Phénomènes Quantiques, France, *H. Bulou, F. Scheurer*, Inst. de Phys. et Chimie des Mat. de Strasbourg, France, *P. Ohresser*, Synchrotron SOLEIL, France, *H. Magnan*, Service de Phy. et Chimie des Surfaces et Interfaces, France, *E. Fonda*, Synchrotron SOLEIL, France, *J. Lagoute, Y. Girard*, Lab. Mat. et Phénomènes Quantiques, France, *C. Goyhenex*, Inst. de Phys. et Chimie des Matériaux de Strasbourg, France, *S. Rousset*, Lab. Mat. et Phénomènes Quantiques, France

Core-shell nanoparticles have been receiving an increasing attention in order to practically employ magnetic clusters in devices [1]. The shell permits to protect the magnetism of the core, which readily oxidize in environmental conditions. Moreover, the shell can donate to the particle new chemico-physical functionalities which, combined with magnetism, permit to obtain multifunctional systems. Cobalt self-organized supported nanodots are promising candidates for applications as very high density magnetic recording media. However, it is necessary to improve the magnetic stability of such small nanostructures against thermal excitations. The capping with a non-magnetic metal of magnetic nanostructures induces different interfacial phenomena which together lead to a modification of the magnetic behavior of the system.

In the present work, the growth and the magnetism of Co/Pt core-shell have been studied. Pt has been deposited as over layer on Co self-organized on Au(111) template. The structural properties have been addressed by combining Scanning Tunneling Microscopy (*STM*) and Surface Extended X-ray Absorption Fine Structure (*SEXAFS*) measurements with molecular dynamics calculations. Magneto-Optic Kerr Effect (*MOKE*) and X-ray Magnetic Circular Dichroism (*XMCD*) have been coupled in order to identify the main magnetic phenomena acting at the Co/Pt interface. In the submonolayer regime, Pt forms metal rims around Co nanodots, and the Co magnetic anisotropy decreases. On the other hand, if more than one monolayer of Pt is deposited, the Co dots are completely covered and their magnetic anisotropy is enhanced. Furthermore, the Pt capping is found to have a minor effect of the cobalt magnetic moments. By changing the deposition conditions and by comparing the effect of Pt and Au capping [2], we identified three principal phenomena at the Co/Pt interface: inter-mixing, magnetoelasticity and band hybridization. Our results indicate that the principal one is band hybridization, which is responsible for the observed increasing of magnetic anisotropy. Intermixing and magnetoelasticity have rather the opposite effect and tend to decrease the magnetic anisotropy energy. The knowledge of the interplay between these different phenomena is fundamental in order to tune the magnetic properties of nanoparticles for precise applications, from data storage to biomedical research.

[1]A. Lu, E. Salabas, and F. Schüth, Angew. Chem. Int. Ed. 46, (2007) 1222.

[2] Y. Nahas, V. Repain, C. Chacon, Y. Girard, J. Lagoute, G. Rodary, J. Klein, S. Rousset, H. Bulou, and C. Goyhenex, Phys. Rev. Lett., 103 (2009) 067202.

10:40am **MI-WeM9 Spin-Split Bands in Non-Magnetic Systems**, ***E. Vescovo***, Brookhaven National Laboratory **INVITED**

For fundamental and technological reasons materials with a spin-split electronic band structure in proximity of the Fermi level are highly attractive. The possibility of separately manipulating the two spin channels introduces novel functional behaviors without counterpart in the corresponding spin-degenerate systems. A promising approach in this field consists in the exploitation of the spin-orbit interaction, which couples spin and orbital degrees of freedom. The Rashba interaction offers particularly interesting perspectives: at the surface of a crystalline material the breaking of the full translational symmetry gives rise to an effective (Rashba) electric field which splits in k-space the valence electrons with opposite spin orientations. For heavy elements, such as Bi, the Rashba interaction results in spin-polarized surface bands, detectable in angle-resolved photoemission experiments [1]. In this talk various cases of such systems will be presented. Bi-Ag(110) surface alloy allows to study the anisotropy of splitting induced by the anisotropic electric fields of the (110) – surface. The system Bi-Ag(111)/ Fe(110) provides direct evidence of the interplay between the

Rashba splitting of the Bi-Ag alloy and the ferromagnetic splitting of the Fe bands.

[1] Yu. M. Koroteev, G. Bihlmayer, J. E. Gayone, E. V. Chulkov, S. Blügel, P. M. Echenique, and Ph. Hofmann, Phys. Rev. Lett. 93, 046403 (2004); T. Hirahara, T. Nagao, I. Matsuda, G. Bihlmayer, E. V. Chulkov, Yu. M. Koroteev, P. M. Echenique, M. Saito, and S. Hasegawa, Phys. Rev. Lett. 97, 146803 (2006).

11:20am **MI-WeM11 Unoccupied Electron States in Rashba Systems Studied by Spin-Resolved Inverse Photoemission**, ***M. Donath***, *S.N.P. Wissing, A. Zumbülte, C. Eibl, A.B. Schmidt*, Muenster University, Germany

We present the first spin-resolved inverse-photoemission measurements of the unoccupied part of the Rashba-split surface state on Au(111). This Shockley-type state is considered as the prototype of a Rashba-split electron state on a metallic surface. The spin splitting of the occupied part of this state was first indicated by spin-integrated photoemission data [1]. This pioneering work was followed by a spin-resolved study, which directly proved the spin structure of the state [2].

Our study complements the information on the spin character by following the surface state into the unoccupied energy region. The state crosses the Fermi energy as a function of the wave vector parallel to the surface and finally leaves the bulk-band energy gap. Our spin-resolved inverse-photoemission experiment stands out from conventional systems thanks to an improved energy and **k** resolution [3]. Our data confirm the spin character of the surface state, as far as it does not overlap with bulk states. In addition, we show how the spin character is altered when the surface state becomes degenerate with bulk states.

Further Rashba systems with even larger spin splittings as well as topological insulators are currently investigated with our spin-resolved inverse-photoemission apparatus. We will provide a status report on our latest results.

[1] LaShell *et al.*, Phys. Rev. Lett. **77**, 3419 (1996)

[2] Hoesch *et al.*, Phys. Rev. B **69**, 241401(R) (2004)

[3] Budke *et al.*, Rev. Sci. Instrum. **78**, 083903 (2007)

11:40am **MI-WeM12 MBE Growth of Topological Insulator Bi_2Se_3 on Epitaxial Graphene on 6H-SiC(0001)**, ***Y. Liu****, *M. Weinert*, *L. Li*, University of Wisconsin-Milwaukee

In this work, we report results on the MBE growth of Bi2Se3, a prototypical topological insulator, on epitaxial graphene on 6H-SiC(0001). In situ scanning tunneling microscopy indicates spiral growth, characterized by atomically smooth terraces 10 to 50 nm in width, separated by steps of 1-2 quintuple-layers in height. X-ray diffraction shows only the (003) family of diffraction peaks with a full width at half maximum of 0.1 degree. Raman spectroscopy reveals two characteristic peaks at 130.21 and 171.48 cm-1, corresponding to the in-plane Eg2 and out-of-plane A1g2 vibrational modes, respectively. The close resemblance of the positions and line shapes of both these peaks to those of bulk Bi2Se3 attest to the very high quality of the film. These results and their impact on the properties of the topologically protected surface states of the Bi2Se3/graphene heterostructure will be presented at the meeting.

*Ying Liu applied for postdoctoral fellow award

***** Postdoc Award Finalist

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