MA 25 Spin-Electronics I

Time: Thursday 10:15–13:00 Room: HSZ 103

MA 25.1 Thu 10:15 HSZ 103

Magnetism of ultrathin GaMnAs films on GaAs — •Michal Kosuth, Svetlana Polesya, Voicu Popescu, and Hubert Ebert — Department Chemie und Biochemie / Physikalische Chemie, Universität München, Butenandstr. 5-13, D-81377 München, Germany

The electronic and magnetic properties of ultrathin GaMnAs layers on GaAs have been studied using the fully-relativistic TB-KKR band structure method. We will present results of our theoretical investigations on the dependence of the magnetic anisotropy energy on the thickness of GaMnAs film, as well as on the concentration and on the position of Mn atoms in the GaMnAs film. It is shown that, in line with previous experimental findings, the occupation of interstitial positions by Mn leads to a reduction of magnetisation and influences also the magnetic anisotropy.

In addition, we will show results on the temperature dependence of magnetic properties of these systems, that have been obtained by Monte Carlo simulations within a classical Heisenberg spin model on the basis of exchange coupling parameters, calculated using the TB-KKR Green function method.

MA 25.2 Thu 10:30 HSZ 103

Magnetic properties and disorder effects in diluted magnetic semiconductors — •Lars Bergqvist[1,2], Olle Eriksson[2], Josef Kudrnovsky[3], Vaclav Drchal[3], Anders Bergman[2], Lars Nordström[2], and Ilja Turek[4] — [1]Institut für Festkörperforschung, Forschungszentrum Jülich,Forschungszentrum Jülich, D-52428 Jülich, Germany — [2]Department of Physics, Uppsala University, Box 530, S-75121 Uppsala, Sweden — [3]Institute of Physics, Academy of Sciences of the Czech Republic,Na Slovance 2, CZ-182 21 Prague 8, Czech Republic — [4]Institute of Physics of Materials, Academy of Sciences of the Czech Republic, Žižkova 22, CZ-616 62 Brno, Czech Republic

We present calculations of the exchange interactions and critical temperatures for several diluted magnetic semiconductor systems with an impurity band. It is shown that the exchange interactions are dominated by short ranged interactions that have a strong directional dependence. Using a combination of first principles calculations of the exchange interactions together with Monte Carlo simulations of the classical Heisenberg model, in which the positional disorder and spin fluctuations are properly included, the calculated critical temperatures are in good agreement with experimantal observations. It is showed that agreement between theory and experiment, as regards ordering temperatures, is obtained only when the magnetic atoms are randomly positioned in a simulation cell which proves that disorder effects play a very important role. The effect of strong electron-electron interaction has been studied by means of the LSDA+U scheme. We investigate in detail the nature of the anisotropic exchange interactions by means of a Fermi surface analysis.

MA 25.3 Thu 10:45 HSZ 103

Ferromagnetism in (GaV)As and (Zn,Co)O — •Brahim Belhadji[1], Peter H. Dederichs[1], Kasunori Sato[2], Voicu Popescu[3], and Hubert Ebert[3] — [1]Institut fuer Festkoerperforschung, Forschungszentrum juelich — [2]The institute of Scientific and Industrial Research, Osaka University, Osaka 567-0047, Japan — [3]Department Chemie/Physikalishe Chemie, University of Muenich, Butenandtstr. 5-13, D-81377 Muenich

The exchange interactions in dilute magnetic semiconductors can take very different forms. While in the model system (Ga,Mn)A s ferromagnetism is favored by Zener's p-d exchange, in systems with impurity bands in the bandgap the situation is more complicated. If the Fermi level lies in the impurity band, ferromagnetism is favored by Zener's double exchange. However if the F ermi level is outside the impurity band, the interaction is determined by super-exchange, and is usually antiferromagnetic, l ike e.g. in (Ga,Fe)As or (Cd,Mn)Te. However, in constrast to this we find that in (Ga,V)As and (Zn,Co)O, where the Fermi leve l lies between the eg and t2g states, that the interaction is ferromagnetic. Our calculations are based on the local density approximation the Korringa-Kohn-Rostoker method in connection with the Coherent-Potential-Approximation (KKR-CPA). For (Ga,V)As the calculated coupling constants Jij between two V atoms are ferromagnetic, short ranged and nearly independant of the V concentration. Due to the short range the Curie temperature is strongly suppressed for small V concentrations. We discuss th e reason for the occurrance of ferromagnetic super-exchange on these systems.

MA 25.4 Thu 11:00 HSZ 103

Low temperature ferromagnetism in Co-doped ZnO due to hopping — •Karl-Wilhelm Nielsen[1], Maike Luebbe[1], Sebastian Bauer[1], Juergen Simon[2], Werner Mader[2], Sebastian T. B. Goennenwein[1], Matthias Opel[1], and Rudolf Gross[1] — [1]Walther-Meissner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching — [2]Institut fuer Anorganische Chemie, Universitaet Bonn, 53177 Bonn

Transition-metal doped ZnO is a promising candidate for the realization of a diluted magnetic semiconductor. According to a model by Coey *et al.* [1], the ferromagnetism is mediated through an impurity band and Curie temperatures above room temperature can be expected. We have fabricated homoepitaxial Co-doped ZnO thin films on ZnO substrates by pulsed laser deposition. The samples were grown in Ar atmosphere at different substrate temperatures to obtain various concentrations of oxygen vacancies. SQUID magnetometry and magnetotransport measurements showed clear ferromagnetic behavior below 50 K. Clusters as the source of ferromagnetism can be excluded by transmission electron microscopy.
Our detailed magneto-transport measurements show that correlated hopping in the oxygen vacancy band is essential for the ferromagnetic coupling. We critically compare these findings with the model of Coey *et al.* [1] and discuss the possibility of room temperature ferromagnetism.
This work is supported by the DFG via SPP 1157.

[1] J. M. D. Coey *et al.* Nature Materials **4** 173 (2005).

MA 25.5 Thu 11:15 HSZ 103

Ferromagnetic Gd-implanted ZnO single crystals — •Shengqiang Zhou[1], K. Potzger[1], F. Eichhorn[1], F. Herrmann[1], D. Grambole[1], M. Helm[1], W. Skorupa[1], J. Fassbender[1], T. Herrmannsdörfer[2], and A. Bianchi[2] — [1]Institute of Ion Beam Physics and Materials Research, Forschungszentrum Rossendorf, P.O. Box 510119, 01314 Dresden, Germany — [2]Dresden High Magnetic Field Laboratory, Forschungszentrum Rossendorf, P.O. Box 510119, 01314 Dresden, Germany

In order to introduce ferromagnetic properties, ZnO single crystals have been implanted with Gd ions at 180 keV ion energy and two different fluences. Magnetization reversal hysteresis loops have been recorded using a superconducting quantum interference device. The virgin ZnO shows a pure diamagnetic behaviour. Besides the diamagnetic background, weak ferromagnetism has been observed for the as-implanted films. Post-implantation annealing greatly improved the magnetism. For a fluence of 5x10^15 Gd/cm2, post implantation annealing at 820K in vacuum leads to an increase of the saturation moment up to 1.8 Bohr magneton per Gd at exactly 300 K thus excluding Gd, ZnGd or Gd2O3 secondary phases to be formed. The increase of the saturation moment can be explained along with changes in resistivity due to the annealing reported elsewhere. Moreover magnetic domains were observed up to 2 microns by atomic/magnetic force microscope, which again evidenced the formation of diluted magnetic semiconductor. [1]K. Potzger et al, submitted to J. Appl. Phys. (2005). [2]S. O. Kucheyev et al. J. Appl. Phys. 93, 2972 (2003).

MA 25.6 Thu 11:30 HSZ 103

Magnetic, structural and electronic properties of Fe implanted GaN — •Georg Talut, Helfried Reuther, Frank Eichhorn, Arndt Mücklich, and Kay Potzger — Institute of Ion Beam Physics and Material Research, Forschungszentrum Rossendorf e.V., Bautzner Landstraße 128, 01314 Dresden

The request for room-temperature diluted magnetic semiconductors resulted in a large interest in GaN containing transition metals. In contrast to the (Ga,Mn)N-system, the origin of the ferromagnetism in Fe implanted GaN is still not sufficiently investigated. The formation of secondary phases and valence states of Fe play an important role in the discussion of the source of the ferromagnetism.

In this study, the electronic, structural and magnetic properties of p-GaN implanted with Fe^+ ($1 - 16 \cdot 10^{16}$ cm^{-2}) at 350° C and subsequently annealed at 650° - 1000° C were examined by conversion electron Möss-

bauer spectroscopy, x-ray diffraction, transmission electron microscopy and magnetometry.

First experiments show ferromagnetic behaviour above room temperature in samples implanted with the highest amount of Fe. First x-ray diffraction and conversion electron Mössbauer spectroscopy measurements reveal the creation of α-Fe-clusters which are most likely responsible for the ferromagnetism.

MA 25.7 Thu 11:45 HSZ 103

Migration of Mn atoms by thermal treatment of ferromagnetic Mn-implanted TiO_2 single crystals — •D. Menzel[1], F. Iacomi[2], D. Cacaina[3], I. Jursic[1], and J. Schoenes[1] — [1]Institut für Physik der Kondensierten Materie, TU Braunschweig, Germany — [2]Al. I. Cuza University, Faculty of Physics, Iasi, Romania — [3]Babes-Bolyai University, Faculty of Physics, Cluj-Napoca, Romania

Single crystalline rutile-type TiO_2 was doped with Mn using ion implantation in order to prevent Mn clustering. The Mn doped TiO_2-layer orders ferromagnetically at room temperature. The magnetic moment of the as implanted samples (0.3 μ_B per Mn) is reduced after an annealing process at 400°C but recovers after annealing at higher temperatures reaching 0.4 μ_B per Mn which indicates an incorporation of Mn atoms on substitutional sites. This interpretation is corroborated by shifts of XRD peaks and changes in the peak intensities. ESR investigations show two types of signals which do not depend on the orientation of the magnetic field and correspond to isolated Mn^{2+} ($g = 1.98$) and to Mn^{2+}–O–Mn^{2+} ($g = 2.00$). In addition, four lines are strongly dependent on the orientation of the magnetic field and can be attributed to Mn^{4+}. The well-resolved structure of Mn^{4+} may be interpreted in terms of the hyperfine interaction of the ^{47}Ti and ^{49}Ti ions which occupy the nearest sites along the crystalline c-axis.

MA 25.8 Thu 12:00 HSZ 103

Loss-Free Spin Injection From Co Into Organic Semiconductor CuPc — •Oleksiy Andreyev[1], Yongli Gao[2], Marina Sánchez-Albaneda[1], Mirko Cinchetti[1], Huanjun Ding[2], Jan-Peter Wüstenberg[1], Michael Bauer[1], and Martin Aeschlimann[1] — [1]Department of Physics, University of Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Department of Physics and Astronomy, University of Rochester, Rochester, NY 14627-0171, USA

We present experimental evidence for loss-free spin injection of hot electrons from ferromagnetic Co(001) surface into organic semiconductor copper phthalocyanine (CuPc). We used spin-resolved two-photon photoemission (SR-2PPE) spectroscopy, which allows us to study the dynamics of both electron and spin relaxation in solids and interfaces with femtosecond time resolution. With SR-2PPE, we investigated the energy distribution and spin polarization of hot electrons originally excited in Co and injected in CuPc, and observed an almost unchanged spin polarization in comparison to that of the initial Co surface. This demonstrates that interface spin scattering is insignificant. The loss-free spin injection into CuPc suggests that it can be a promising material for spin-based electronic devices. Moreover, we observed a surprising enhanced spin polarization induced by a submonolayer CuPc coverage on the Co surface. This phenomenon is attributed to spin-dependent charge transfer responsible for the bonding between CuPc admolecule and the Co surface. We further investigated CuPc/Co junctions with intentionally enhanced interface roughness, and we found that the junction quality did not affect the efficiency of the spin injection.

MA 25.9 Thu 12:15 HSZ 103

Magnetism and spin-polarization of half-metallic ferromagnets at finite temperatures — •Marjana Ležaić, Phivos Mavropoulos, Jussi Enkovaara, Gustav Bihlmayer, and Stefan Blügel — IFF, Forschungszentrum Jülich, D-52425 Jülich

Half-metallic ferromagnets (HMF) present a spin-polarization P of 100% at the Fermi level. At elevated temperatures, however, the spin-polarization is reduced. We investigate the effect of temperature on the band gap of HMF which contain more than one magnetic atom in the unit cell, and describe the mechanisms which lead to the drop of polarization.

We use the full-potential linearized augmented plane-wave method [1] to calculate the exchange constants of the Heisenberg model and apply a Monte Carlo method to find the magnetization $M(T)$ and the Curie temperature. Additionally, a mean-field like description of the system at $T > 0$ is obtained with the coherent-potential approximation to the disordered local moment state calculated within the Korringa-Kohn-Rostoker Green function method [2].

For multicomponent HMF we cannot confirm the proposed model which assumes that $P(T) \sim M(T)$ [3]. The presence of different magnetic components can lead to a drop of P at $T > 0$ which is much faster than the drop of $M(T)$. This effect can be drastic and depends largely on the strength of the hybridization among the components. We describe the effects of temperature in more detail for NiMnSb and Co_2MnSi.

[1] `http://www.flapw.de`
[2] H. Akai and P. H. Dederichs, Phys. Rev. B **47**, 8739 (1993)
[3] R. Skomski and P. A. Dowben, Europhys. Lett. **58**, 544 (2002)

MA 25.10 Thu 12:30 HSZ 103

Spin-filtering through multiferroic $BiMnO_3$ tunnel barriers — •Manuel Bibes[1], Martin Gajek[2], Martin Sirena[2], Gervasi Herranz[2], Karim Bouzehouane[2], Stéphane Fusil[3], Manuel Varela[4], Josep Fontcuberta[5], Agnès Barthélémy[2], and Albert Fert[2] — [1]Institut d'Electronique Fondamentale, Université Paris-Sud, 91405 Orsay, France — [2]Unité Mixte de Physique CNRS-Thales, Route départementale 128, 91767 Palaiseau, France — [3]Université d'Evry, rue du Père Jarlan, 91025 Evry, France — [4]Dept. de Fisica Aplicada i Optica, Universitat de Barcelona, Diagonal 647, 08028 Barcelona, Spain — [5]Institut de Ciència de Materials de Barcelona, CSIC, Campus de la UAB, 08193 Bellaterra, Spain

We will present the properties of $BiMnO_3$ (BMO) and $La_{0.1}Bi_{0.9}MnO_3$ (LBMO) epitaxial thin films grown onto conductive buffers like $La_{2/3}Sr_{1/3}MnO_3$ (LSMO). Both BMO and LBMO films are ferromagnetic and piezoresponse atomic-force microscopy also evidences their ferroelectric character, thereby confirming their multiferroic nature. Remarkably, these properties are preserved even for films a few nm thick that can thus be used as multiferroic tunnel barriers. We will show that tunneling from a Au electrode, through these ferromagnetic tunnel barriers, into a collecting ferromagnetic counter-electrode of LSMO, results in large tunnel magnetoresistance (TMR), observed upon switching the magnetic configuration of the barrier and LSMO magnetizations from parallel or antiparallel. This demonstrates a spin-filtering effect by the BMO and LBMO barriers. The possible influence of ferroelectricity on the tunnel process will also be discussed.

MA 25.11 Thu 12:45 HSZ 103

Spin-dependent transport in hybrid ferromagnetic and nonmagnetic nanowires — •O. Posth, M. Brands, and G. Dumpich — Experimentalphysik, Universität Duisburg-Essen (Campus Duisburg), Lotharstr. 1, 47048 Duisburg

In this work the spinaccumulation effect and the spin relaxation length in different nonmagnetic materials are determined. For this, polycrystalline nanowires are fabricated by means of high-resolution electron beam lithography (HR-EBL) in combination with electron beam evaporation and lift-off-technique. The measurements of the spinaccumulation effect are performed in a nonlocal geometry at T = 4,2 K using cobalt as ferromagnetic material and copper and aluminium as nonmagnetic materials.

To improve the quality of the interface between the cobalt-wire and the nonmagnetic wire *oblique evaporation* is used. Thus, both the cobalt- and the nonmagnetic wires are fabricated in one deposition-step. The spinaccumulation effect is detected in copper and aluminium and, assuming known values for the polarization of the interface between the ferromagnetic and the nonmagnetic material, an upper and a lower bound for the spin relaxation length can be calculated. In copper a spin relaxation length of 0,75 μm $\leq l_S^{Cu} \leq$ 1,1 μm is found and the spin relaxation length in aluminium is 1,0 μm $\leq l_S^{Al} \leq$ 1,4 μm.

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