HL 96: Magnetic Semiconductors

Time: Friday 9:30–11:30 Location: H13

HL 96.1 Fri 9:30 H13

A systematic investigation of the magnetic anisotropy of III-Mn-V ferromagnetic semiconductors — •Chi Xu[1,3], Ye Yuan[1,3], Maciek Sawicki[2], Manfred Helm[1,3], and Shengqiang Zhou[1] — [1]Helmholtz-Zentrum Dresden Rossendorf, Institute of Ion Beam Physics and Materials Research, Bautzner Landstrasse 400, D-01328 Dresden, Germany — [2]Institute of Physics, Polish Academy of Sciences, Warszawa, Poland — [3]Technische Universität Dresden, D-01062 Dresden, Germany

As one of the most important physical properties of dilute ferromagnetic semiconductors (DFS), the magnetic anisotropy exhibits a complicated character and its origin is under continuous discussion [1]. Due to different physical parameters (e.g. band gap, lattice constant) in various Mn doped III-V DMSs, various magnetic anisotropies are expected and could be tailored by Mn or hole concentrations [2,3]. To investigate this in greater detail, we prepare three typical III-Mn-V DFSs, InMnAs, GaMnAs, and GaMnP by ion implantation and pulsed laser annealing, which is a complementary approach to low-temperature molecular beam epitaxy. We report a systematic investigation on the magnetic anisotropy with the aim to understand its physical origin.

[1]. T. Dietl et al., Rev. Mod. Phys. 86, 187-251 (2014) [2]. M. Sawicki et al., Phys. Rev. B 70, 245325 (2004) [3]. C. Bihler et al., Phys. Rev. B 78, 045203 (2008)

HL 96.2 Fri 9:45 H13

Application of ion beams to fabricate and tune ferromagnetic semiconductors — •Shengqiang Zhou — Helmholtz-Zentrum Dresden Rossendorf, Institute of Ion Beam Physics and Materials Research, Bautzner Landstrasse 400, D-01328 Dresden, Germany

In this talk, I will show how ion beams can be used in fabricating and understanding ferromagnetic semiconductors. First, ion implantation followed by pulsed laser melting (II-PLM) provides an alternative to the widely used low-temperature molecular beam epitaxy (LTMBE) approach [1-7]. Going beyond LT-MBE, II-PLM is successful to bring two new members, GaMnP and InMnP, into the family of III-V:Mn. Both GaMnP and InMnP films show the signature of ferromagnetic semiconductors and an insulating behavior. Second, we use helium ion irradiation to precisely compensate holes in ferromagnetic semiconductors while keeping the Mn concentration constant [8-10]. By this approach, one can tune the magnetic properties of ferromagnetic semiconductor as well as pattern a lateral structure. It also provides a route to understand how carrier-mediated ferromagnetism is influenced by localization.

[1] M. Scarpula, et al. PRL 95, 207204 (2005); [2] D. Bürger, S. Zhou, et al., PRB 81, 115202 (2010); [3] S. Zhou, et al., Appl. Phys. Express 5, 093007 (2012); [4] M. Khalid et al., PRB 89, 121301(R) (2014); [5] Y. Yuan, et al, IEEE Trans. Magn. 50, 2401304 (2014); [6] Y. Yuan, et al. JPD 48, 235002 (2015); [7] S. Zhou, JPD 48, 263001 (2015); [8] Lin Li, et al., JPD 44 099501 (2011); [9] Lin Li, et al., NIMB, 269, 2469 (2011); [10] S. Zhou, et al. PRB, in revision (2015).

HL 96.3 Fri 10:00 H13

Effective Spin Models and Critical Temperatures for Diluted Magnetic Semiconductors. — Richard Bouzerar[1], •Daniel May[2], Ute Löw[2], Denis Machon[1], Patrice Melinon[1], and Georges Bouzerar[1] — [1]Institut Lumière Matière, CNRS et Université Lyon 1, 69622 Villeurbanne Cedex, France — [2]Technische Universität Dortmund, Lehrstuhl für Theoretische Physik II, 44221 Dortmund, Germany

Diluted magnetic semiconductors (DMS) are materials where magnetic ions substitute a small percentage of the host's cations. We use a one-band VJ model with three adjustable parameters to describe DMS and extract long-range spin-spin couplings. These couplings are subsequently used as input to a classical Heisenberg model which is studied by Monte Carlo simulation (MC) and a self-consistent approach based on Green's functions (L-RPA). Both methods treat random lattice configurations beyond the standard Mean Field Approximation and without resorting to an effective medium. Our focus lies mainly on (In,Mn)P for small concentrations $x < 0.1$ of manganese where critical temperatures of 20-40 K are expected. The L-RPA provides us with a self-consistent expression for T_c whereas we use finite size scaling for the MC results to calculate a reliable critical temperature. Our goal is to provide a consistent description of recent experimental results for the magnetic properties of the Mn-doped InP diluted magnetic semiconductor.

30 min. Coffee Break

HL 96.4 Fri 10:45 H13

Long-range p-d exchange interaction in a ferromagnet-semiconductor hybrid structure — •Matthias Salewski[1], Vladimir L. Korenev[1,2], Ilya A. Akimov[1,2], Victor V. Sapega[2,3], Lukas Langer[1], Ina V. Kalitukha[2], Jörg Debus[1], Roslan I. Dzhioev[2], Dmitri R. Yakovlev[1,2], David Müller[1], Chrstoph Schröder[4], Heinz Hövel[4], Grzegorz Karczewski[5], Maciej Wiater[5], Tomasz Wojtowicz[5], Yuri G. Kusrayev[2], and Manfred Bayer[1,2] — [1]Experimentelle Physik 2, Technische Universität Dortmund, D-44221 Dortmund, Germany — [2]Ioffe Physical-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia — [3]Physical Faculty of St. Petersburg State University, 198504 St. Petersburg, Russia — [4]Experimentelle Physik 1, Technische Universität Dortmund, D-44221 Dortmund, Germany — [5]Institute of Physics, Polish Academy of Sciences, PL-02668 Warsaw, Poland

The magnetic coupling in hybrid structures composed of semiconductor (SC) nanostructures and ferromagnetic layers (FM) typically depends on the wave function overlap of SC charge carriers (p-system) and FM ions (d-system) and is therefore short-ranged. Here we report on a hybrid system with surprisingly long-ranged, robust coupling that does not vary with spacer width up to more than 30 nm. We suggest that the resulting spin polarization of acceptor-bound holes is induced by an effective p-d exchange that is mediated by elliptically polarized phonons.

HL 96.5 Fri 11:00 H13

Site resolved band structure of a diluted magnetic semiconductor — •Slavomir Nemsak[1], Mathias Gehlmann[1], Cheng-Tai Kuo[2], Tien-Lin Lee[3], Lukasz Plucinski[1], Claus M. Schneider[1], and Charles S. Fadley[2] — [1]Forschungszentrum Juelich, Germany — [2]UC Davis, CA, USA — [3]Diamond Light Source, Didcot, GB

Standing wave (SW) photoemission of core-levels and valence electrons at the density-of-states limit has proven to be a very potent and powerful method, especially for investigating electronic properties of the buried interfaces, either solid/solid [Gray et al., EPL 104, 17004 (2013)], but also solid/liquid and liquid/gas [Nemsak et al., Nat. Comm. 5, 5441 (2014)]. The exceptional depth selectivity provides a key to the depth-resolved information, which is very difficult to extract by other, less direct, methods.

The combination of the SW approach and hard X-ray angle resolved photoelectron spectroscopy (HARPES) [Gray et al., Nature Mat. 11, 957 (2012)] takes these efforts one step further. The strengths of the SW-HARPES method are demonstrated on the example of diluted magnetic semiconductor Ga(Mn)As. A strong SW is generated using hard X-ray excitation of ca. 3 keV using the (111) reflection of the undoped GaAs substrate and the 5% Mn-doped thin film with. Due to the uneven occupancy of (111) planes by either Ga(Mn) or As atoms, the element specific band structure can be obtained with a help of the SW modulation in core levels. Apart from the site specific decomposition of the electronic structure, the SW measurement confirmed a substitutional presence of Mn atoms at the Ga sites.

HL 96.6 Fri 11:15 H13

Modeling Magnetism of Diluted Magnetic Systems using the Gutzwiller Method — •Thorben Linneweber[1], Ute Löw[1], Florian Gebhard[2], and Jörg Bünemann[2] — [1]Technische Universität Dortmund, Lehrstuhl für Theoretische Physik II, 44221 Dortmund — [2]Philipps-Universität Marburg, AG Vielteilchenphysik, 35032 Marburg

Diluted magnetic semiconductors are materials in which magnetic ions substitutionally or interstitially replace a fraction of the cations of the semiconductor host material. We aim to describe the magnetic properties of the prototype substance $Cd_{1-x}Mn_xTe$. We derive a multiband Hubbard model from DFT calculations using the Wannier90 code. Large unit cells (≈ 200 atoms) account for the randomized substitution

of cations by magnetic ions. We analyze the ground state of this model within the framework of the Gutzwiller variational method. We find that the d-shell of the Mn ions resembles an atomic Hund's rule S=5/2 ground state. Due to the superexchange mechanism, there is an effective short-range Heisenberg exchange between the magnetic ions. We estimate the exchange parameters using energy calculations of different magnetic configurations and finally compare them to experimental results.