HL 20: Focus Session: Magnetic Semiconductors (jointly with MA)

Time: Monday 16:30–18:15 Location: EW 202

HL 20.1 Mon 16:30 EW 202

Cu-doped GaN: A ferromagnetic semiconductor — •Philipp R. Ganz[1], Christoph Sürgers[2,3], Gerda Fischer[3], and Daniel M. Schaadt[1,2,4] — [1]Karlsruhe Institute of Technology, Center for Functional Nanostructures, 76049 Karlsruhe, Germany — [2]Karlsruhe Institute of Technology, Institut für Angewandte Physik, 76049 Karlsruhe, Germany — [3]Karlsruhe Institute of Technology, Physikalisches Institut, 76049 Karlsruhe, Germany — [4]Institut für Energieforschung und Physikalische Technologien,TU Clausthal, 38640 Goslar, Germany

Nitride based spintronics has caused wide interest device applications due to the long and temperature-independent spin lifetime in InN quantum dots. For spin-injection in these quantum dots a ferromagnetic spin-aligner which yields high spin-polarization at room-temperature is necessary. Nitride based magnetic semiconductors are promising candidates. Because of possible clustering of magnetic dopands, non-magnetic dopands such as copper have raised interest over the last years. Theoretical predictions show the possibility of ferromagnetism and a high spinpolarization for Cu-doped GaN. We carried out a detailed study on the structural and magnetic properties for Cu-doped GaN, grown by plasma assisted molecular beam epitaxy, for various growth conditions. These films exhibit ferromagnetic behavior with a Curie temperature higher than 400 K in a small range of doping levels.

HL 20.2 Mon 16:45 EW 202

Magnetism and bound states of Fe in GaN : a hybrid DFT study — •Paola Alippi[1], Francesco Filippone[1], Giuseppe Mattioli[1], Aldo Amore Bonapasta[1], and Vincenzo Fiorentini[2] — [1]CNR-ISM, Rome, Italy — [2]CNR-IOM and U of Cagliari, Italy

Transition- metal (TM) impurities in GaN hold promise for room-temperature ferromagnetism. They are also under investigation because of suspected effects of electron correlation in the localized impurity d shell as well as in host p valence states. We studied therefore neutral and charged Ga-substitutional Fe impurities in GaN via spin-polarized density-functional-theory calculations using the hybrid GGA+Hartree-Fock HSE functional.

For the neutral state, Fe induces localized states in the lower valence band, and dispersed N-Fe hybrids in the majority upper valence band, and empty minority states resonant with the Ga-like conduction band. The –1 charge state occupies and shift the latter into the gap, resulting in a (0/–1) transition level near the observed value. The +1 state has a hyper-deep (+1/0) donor level associated to a bound hole on ligand N's, i.e. a Fe(III)+$\underline{L}$ state. This is the first theoretical evidence of such a state, supported by some as-yet-inconclusive experiments. A Bader analysis shows that Fe:GaN follows a "charge self-regulation" rule. In the –1 state, the Fe-like gap state is counterbalanced by depleted Fe valence states, and conversely the bound hole is an empty gap state appearing only in the +1 state. The population of resonant plus gap states, however, remains constant, and the charge residing on Fe hardly changes upon charging the impurity+host system.

HL 20.3 Mon 17:00 EW 202

Ferromagnetic Semiconductor-Metal Transition in Heterostructures of Europium Monoxide — •Tobias Stollenwerk and Johann Kroha — Physikalisches Institut der Universität Bonn, Deutschland

Experiments on thin films of electron doped europium monoxide show a simultaneous ferromagnetic semiconductor-metal transition which goes along with a huge drop in resistivity over several orders of magnitude. Therefore, this material is a very promising candidate for spintronics applications. We have developed a theory which correctly predicts the simultaneous phase transition in thin films of electron doped EuO and the increase of the Curie temperature T_C with doping concentration. The origin of the increased T_C lies in the enhanced RKKY interaction between the localized 4f moments of the Eu atoms. Therefore, the phase transition is controlled by the population of the conduction band. We investigate the influence of film thickness and interface effects on the population of the conduction band and on the magnetic and electronic properties of the EuO film.

HL 20.4 Mon 17:15 EW 202

Effects of disorder and hole tunneling transport on the ferromagnetism in GaMnAs quantum wells — •Christian Ertler and Walter Pötz — Institute of Physics, Karl-Franzens University Graz, Universitätsplatz 5, 8010 Graz, Austria

Recent experiments on heterostructures comprising GaMnAs quantum wells [1] evoke strong debates about the nearly absence of ferromagnetic order observed in these structures. Based on a tight-binding approach and the non-equilibrium Green's function formalism we investigate self-consistently the interplay between ferromagnetic order, structural defects, and hole tunnel current [2]. We find that disorder has a strong influence on the IV characteristic in efficiently washing out negative differential conductance as found in experiment [1]. The hole density in the well is established by tunneling from the p-doped GaAs leads, resulting in small exchange splittings in the well on the order of 10 meV for reasonable lead doping. We predict that for cleaner samples the ferromagnetic order in the well tends to be destroyed under resonance condition. This effect leads to a characteristic signature in the spin-polarization of the tunnel current available to experimental detection.

[1] S. Ohya, K. Takata and M. Tanaka, "Nearly non-magnetic valence band of the ferromagnetic semiconductor GaMnAs", Nature Physics, 7, 342 (2011).

[2] C. Ertler and W. Pötz, "Electrical control of ferromagnetism and bias anomaly in Mn-doped semiconductor heterostructures", Phys. Rev. B 84, 165309 (2011).

HL 20.5 Mon 17:30 EW 202

Influence of the interface structure on the magnetic proximity polarization in Fe/(Ga,Mn)As bilayers — •S. Polesya[1], S. Mankovsky[1], J. Minar[1], H. Ebert[1], M. Sperl[2], and C. Back[2] — [1]Universität München, Department Chemie, Butenandtstr. 5-13, D-81377 München, Germany — [2]Institut für Experimentelle Physik, Univ. Regensburg, Germany

We present the results of detailed investigations on the influence of various conditions at the interface on the magnetic proximity polarization effect for the Fe/($Ga_{0.95}Mn_{0.05}$)As system. The ab initio electronic structure calculations were performed using the TB-KKR Green's function method. These allow the calculation of the exchange coupling parameters between magnetic atoms in the system. The finite temperature magnetic properties were determined then by means of Monte Carlo simulations. The exchange coupling between Fe and Mn atoms in the vicinity of the Fe/(Ga,Mn)As interface is found to be strongly dependent on the Mn atom position in the lattice. In particular, the substitutional Mn is coupled antiferromagnetically to Fe for Ga- as well as As-terminated interfaces while the Mn at the interstitial positions is coupled ferromagnetically to Fe. As a result, the total magnetization of the (Ga,Mn)As film can be aligned ferromagnetically with Fe. This effect is larger for As-termination. In addition, presence of the Mn interstitials influences the interaction between substitutional Mn. It is shown that a complicated competition of FM and AFM interactions between Mn atoms results in a disordered magnetic structure close to the interface with Fe.

HL 20.6 Mon 17:45 EW 202

Anomalous Hall effect in Mn doped, p-type InAs quantum wells — •Dieter Vogel, Christina Wensauer, Ursula Wurstbauer, Dieter Schuh, Werner Wegscheider, and Dieter Weiss — Institute for Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany

We measured the Hall resistivity in InAs:Mn quantum wells (QWs), containing a two-dimensional hole gas, as a function of temperature, carrier density and manganese concentration. Earlier experiments on these Mn doped InAs QWs indicated the important role of p-d exchange coupling between holes and Mn magnetic moments, giving rise to hysteretic magnetoresistance and thermal bistability of the longitudinal resistance [1]. In the present work we find that this paramagnetic two-dimensional system features a considerable anomalous Hall effect (AHE) whose size increases with decreasing temperature and increasing Mn concentration. Surprisingly, the sign of the anomalous Hall coefficient is negative. A first analysis of the data shows that the skew scattering contribution is rapidly suppressed as temperature increases. Furthermore, the empirical scaling between Hall and longitudinal conductivity in the bad-metal-hopping regime [2], $\sigma_{xy} \sim \sigma_{xx}^{\gamma}$,

with $\gamma = 1.6$, seems to be valid also in our system. Finally, we discuss the possibility to separate the intrinsic and the extrinsic scattering contribution following recent work by [3].

[1] U. Wurstbauer et al., Nature Physics **6**, 955 (2010)
[2] N. Nagaosa et al., Rev. Mod Phys. **82**, 1539 (2010)
[3] A. Shitade and N. Nagaosa, ArXiv ID 1109.5463 (2011).

HL 20.7 Mon 18:00 EW 202

Magnetotransport in (Ga,Mn)As/GaAs core-shell nanowires — •Christian Butschkow[1], Elisabeth Reiger[1], Stefan Geissler[1], Alexander Eckrot[1], Andreas Rudolph[1], Marcello Soda[1], Dieter Schuh[1], Georg Woltersdorf[1], Werner Wegscheider[2], and Dieter Weiss[1] — [1]Universität Regensburg, Germany — [2]ETH Zürich, Switzerland

We investigate angle dependent the transport properties of individual ferromagnetic (Ga,Mn)As/GaAs core-shell nanowires in a magnetic field at cryogenic temperatures. The nanowires are grown self-assembled in a bottom up process using the vapor-liquid-solid (VLS) mechanism and molecular beam epitaxy (MBE). We observe a very pronounced response of the magnetoresistance on an applied magnetic field, which we attribute to the negative magnetoresistance effect (NMR) in combination with an effective magnetic field. This effective magnetic field, which is typically used to describe ferromagnetic resonance phenomena, is composed of the anisotropy field H_a and the external magnetic field. The shape of the resulting MR-traces can be used to derive the magnetic properties of single nanowires. This way we determine a Curie-Temperature of $T_C \approx 20$K and a strong uniaxial magnetic anisotropy with a magnetic easy axis pointing along the nanowire axis. We assume that this uniaxial magnetic anisotropy is related to strain relaxation similar to the observations on lithographically defined (Ga,Mn)As stripes. However we determine a uniaxial anisotropy constant K_U which is up to 5 times larger than K_U of the etched (Ga,Mn)As stripes.