

## DS 4: Thin Film Characterisation II: Structure Analysis and Composition

Time: Monday 15:00–18:30

Location: H 0111

DS 4.1 Mon 15:00 H 0111

**Ferromagnetic InMnAs with perpendicular magnetic anisotropy synthesized by ion implantation** — •YE YUAN<sup>1,3</sup>, MUHAMMAD KHALID<sup>1</sup>, YUTIAN WANG<sup>1,3</sup>, EUGEN WESCHKE<sup>2</sup>, CARSTEN BAEHTZ<sup>1</sup>, WOLFGANG SKORUPA<sup>1</sup>, MANFRED HELM<sup>1,3</sup>, and SHENGQIANG ZHOU<sup>1</sup> — <sup>1</sup>Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — <sup>2</sup>Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany — <sup>3</sup>Technische Universität Dresden, Dresden, Germany

Dilute magnetic semiconductors (DMS) have attracted much attention both from the application and fundamental physics points of view due to potential materials for spintronic device [1]. From application view, the perpendicular magnetic anisotropy (PMA) meets the need, of which the current-induced magnetization reversal originating from a spin transfer torque (STT). For InMnAs, which could only be obtained by low temperature molecule beam epitaxy (LT-MBE) before, achieving high Curie temperature (TC) layer with PMA is relatively difficult. The reason is that, although much lattice mismatch between the DMS layer and the substrate brings inner strain and further PMA, the dislocations also come and suppress TC. However, low inner strain from mismatch make layer lose PMA.

We prepare high TC InMnAs layers with strong PMA by ion implantation and pulsed layer melting. The TC appears the highest one of InMnAs with PMA up to 77 K so far.

[1]. T. Dietl, et al., Rev. Mod. Phys. 86, 187-251 (2014)

DS 4.2 Mon 15:15 H 0111

**Crystallinity of the Fe/GaAs interface for spintronics** — •RAJKIRAN THOLAPI, LENNART LIEFEITH, MICHAEL WACHTEL, GERDA EKINDORF, TARAS SLOBODSKYY, and WOLFGANG HANSEN — Institute of Nanostructure and Solid State Physics, Jungiusstr. 11, D-20355 Hamburg, Germany.

Epitaxial Fe thin film on GaAs metal-semiconductor heterojunction system is a prospective hybrid structure for spin injection. The presence of either tunneling or Schottky barrier, crystalline quality, interface states and intermixing at the interface influence the overall efficiency of the spin injection process [1]. We will discuss results of X-ray and electron diffraction studies performed on epitaxial Fe films deposited with and without MgO tunneling barriers on GaAs (001) substrate. Moreover, the morphological, crystalline and electrical properties of the Fe films will be presented. We will also discuss the in situ strain evolution of the Fe films during deposition. We observed a high degree of crystallinity in epitaxial thin Fe films which is considered to be favorable for electrical spin injection.

[1] L. R. Fleet et. al., \*Correlating the interface structure to spin injection in abrupt Fe/GaAs (001) films\*, Phys. Rev. B 87, 024401 (2013)

DS 4.3 Mon 15:30 H 0111

**Twisted twin domains in epitaxial thin MnSi layers on Si(111)** — •MIRKO TRABEL, BENEDIKT HALBIG, NADEZDA V. TARAKINA, CHRISTOPH POHL, UTZ BASS, CHARLES GOULD, JEAN GEURTS, KARL BRUNNER, and LAURENS W. MOLENKAMP — Experimentelle Physik 3, Physikalisches Institut, Universität Würzburg, Am Hubland, D-97074, Würzburg, Germany

Thin layers of MnSi are grown by molecular beam epitaxy on Si(111) substrates and their crystal properties are investigated by X-ray diffraction (XRD), Raman spectroscopy and transmission electron microscopy (TEM) measurements. Both XRD analysis and the observed Raman phonon modes prove that the layers of 5 - 32 nm thickness are single phase MnSi. The B20 crystal structure of MnSi lacks inversion symmetry and allows right- and left-handed crystals. We demonstrate by azimuthal  $\phi$ -scans of several asymmetric X-ray reflections that certain reflections reveal the formation of twin domains in the layer as well as their corresponding azimuthal twists of  $\Delta\phi = \pm 30^\circ$  with respect to the Si substrate. The observed intensities of corresponding reflexes are equal, indicating the same volume fractions for both domains. Cross-sectional TEM confirms the formation of the twisted twin domains and reveals a typical domain size of about 200 nm. The sheet resistivity shows the same temperature dependence as bulk MnSi with helical magnetic order, but the critical temperature is increased from the bulk value of 29.5 K to about 40 - 45 K.

DS 4.4 Mon 15:45 H 0111

**Diffusion controlled solid state reactions in Fe/Pt thin-film systems with additional Ag layer** — •NATALIYA SAFONOVA<sup>1</sup>, GABOR KATONA<sup>2</sup>, FABIAN GANSS<sup>3</sup>, DMITRIY MITIN<sup>1</sup>, IURIY MAKOGON<sup>4</sup>, GUNTER BEDDIES<sup>1,3</sup>, DEZSO BEKE<sup>2</sup>, and MANFRED ALBRECHT<sup>1</sup> — <sup>1</sup>Institute of Physics, University of Augsburg, Germany — <sup>2</sup>University of Debrecen, Hungary — <sup>3</sup>Chemnitz University of Technology, Germany — <sup>4</sup>National Technical University of Ukraine "KPI", Kyiv, Ukraine

Fe(15 nm)/Ag(10 nm)/Pt(15 nm)/Si<sub>2</sub>(100 nm)/Si(100) and FePt(15 nm)/Ag(7.5 nm)/SiO<sub>2</sub>(100 nm)/Si(100) thin film systems were prepared by magnetron deposition at room temperature. Rapid thermal annealing (RTA) for 30s was performed between 600°C and 900°C. In addition samples also were isothermally annealed between 245°C and 390°C (from 0.5 to 52 hours). Composition profiles of trilayer samples (obtained by secondary neutral mass spectrometry) after the low and high temperature heat treatments show a strong intermixing between Ag and Pt, resulting in the formation of Ag<sub>x</sub>Pt<sub>1-x</sub>. Afterwards Pt diffuses through the remaining Ag layer and penetrates into the Fe grain boundaries (GBs) reducing the amount of Pt in the Ag<sub>x</sub>Pt<sub>1-x</sub> layer. This process leads to the formation of a FePt reaction product and Ag appears to "move" towards the substrate. High temperature RTA on the same samples give similar composition distributions and eventually the formation of a homogeneous L1<sub>0</sub> ordered FePt alloy (observed by X-ray diffraction). Furthermore, corresponding magnetic properties will be discussed.

DS 4.5 Mon 16:00 H 0111

**Observing the Morphology of Single Layered Embedded Silicon Nanocrystals by Using Temperature-stable TEM Membranes** — •SEBASTIAN GUTSCH<sup>1</sup>, JAN LAUBE<sup>1</sup>, DANIEL HILLER<sup>1</sup>, MARGIT ZACHARIAS<sup>1</sup>, and CHRISTIAN KÜBEL<sup>2</sup> — <sup>1</sup>Laboratory for Nanotechnology, University of Freiburg, Freiburg, Germany — <sup>2</sup>Karlsruhe Institute of Technology (KIT), Eggenstein-Leopoldshafen, Germany

Standard structural analysis of Si nanocrystal/SiO<sub>2</sub> superlattices is carried in TEM by using cross-sectional sample preparation revealing clearly the presence of the multilayer stack [1]. In this work, we use TEM compatible high temperature stable SiN membranes to investigate single layers of Si nanocrystal ensembles prepared from precipitation of a silicon-rich oxide layer sandwiched between two SiO<sub>2</sub> diffusion barriers [2]. In this way size distribution, shape and areal density of the Si nanocrystals can be easily accessed by energy-filtered TEM without the need of further specimen preparation. Using this unique approach, we demonstrate, how the nanocrystal size distribution develops from a broad to a narrow log-normal distribution, when the precipitation layer thickness and stoichiometry are below a critical value. The results are crucial to understand doping [3] and transport properties [4] of Si nanocrystals embedded in dielectrics.

[1] Hartel et al., Thin Solid Films, 520, 121-125 (2011)

[2] Gutsch et al., Beilstein J. Nanotechnology, submitted

[3] Gnaser et al., J. Appl. Phys. 115, 034304 (2014)

[4] Gutsch et al., J. Appl. Phys. 113, 133703 (2013)

DS 4.6 Mon 16:15 H 0111

**Silicon nanocrystals in silicon nitride: the absence of quantum-confinement photoluminescence** — •ANASTASIYA ZELENINA<sup>1</sup>, SERGEY DYAKOV<sup>2</sup>, DANIEL HILLER<sup>1</sup>, and MARGIT ZACHARIAS<sup>1</sup> — <sup>1</sup>IMTEK University of Freiburg, Freiburg, Germany — <sup>2</sup>Royal Institute of Technology (KTH), Kista, Sweden

Amorphous superlattices containing SiN<sub>x</sub> sublayers of different thicknesses altered with Si<sub>3</sub>N<sub>4</sub> barriers were deposited by PECVD and further annealed at high temperatures in order to form silicon nanocrystals (Si NCs). TEM images combined with XRD spectra confirmed the formation of well separated Si NCs of controllable sizes in the range of 2 - 5 nm. The expected photoluminescence (PL) peak shift is observed at 550 - 600 nm for the films with Si NCs of 3, 4 and 5 nm in size. However, the origin of the PL peak shift induced some doubts. Firstly, the PL peaks have a very low intensity and rather broad FWHM in comparison to literature results. Secondly, the sample with Si NCs of 2 nm in size did not follow the trend and had a peak position at 580 nm. Finally, spectral position of all peaks was similar to the PL of

reference Si<sub>3</sub>N<sub>4</sub> bulk film. Our research also revealed that PL decay time is in the range of nanoseconds for all the samples, which confirm a defect-related luminescence. Thereby, we concluded that all the samples demonstrate Si<sub>3</sub>N<sub>4</sub> defect-related PL, which originates from Si<sub>3</sub>N<sub>4</sub> barriers. We assumed that the PL peak shift is an optical artifact. Our well-developed simulations based on the use of the method of transfer matrix confirmed the presence of optical interference in the films, which caused the PL peak shift.

DS 4.7 Mon 16:30 H 0111

**k-resolved electronic structure by soft-X-ray ARPES: From 3D systems to heterostructures and impurities** — ●V.N. STROCOV, M. KOBAYASHI, L.L. LEV, J. KREMPASKY, V.A. ROGALEV, U. STAUB, H. VOLFOVÁ, J. MINÁR, X. WANG, T. SCHMITT, and C. CANCELLIERI — Swiss Light Source, Paul Scherrer Institute, Switzerland

The spectroscopic power of soft-X-ray ARPES in the energy range around 1 keV arises from enhanced photoelectron escape depth, sharp definition of 3D electron momentum **k**, and resonant photoexcitation delivering elemental and chemical state specificity. We demonstrate that the advanced instrumentation at the Swiss Light Source has enabled stretching this technique from 3D materials to the most photon-hungry cases of buried heterostructures and impurities [1].

One of the applications to 3D materials is the magnetoresistive 3D perovskite La<sub>1-x</sub>Sr<sub>x</sub>MnO<sub>3</sub>. Its experimental Fermi surface shows shadow contours manifesting the rhombohedral lattice distortion affecting the CMR. The heterostructures are illustrated with the LaAlO<sub>3</sub>/SrTiO<sub>3</sub> buried interface. Exploiting resonant photoexcitation of the interface Ti3<sup>+</sup> ions, we resolve different subbands of the interface quantum well states. Their spectral function reveals prominent polaronic coupling which reduces the electron mobility. An example of the impurity systems is the diluted magnetic semiconductor GaMnAs. Resonant photoexcitation at the Mn 2*p* edge enables identification of the ferromagnetic Mn impurity band as well as its energy alignment and mechanism of hybridization with the host GaAs bands.

[1] V.N. Strocov *et al.*, *Synchr. Rad. News* **27**, N2 (2014) 31

DS 4.8 Mon 16:45 H 0111

**Modification of energy band alignment and electric properties of Pt/Ba<sub>0.6</sub>Sr<sub>0.4</sub>TiO<sub>3</sub>/Pt thin-film ferroelectric varactors by Ag impurities at interfaces** — STEFAN HIRSCH, ●PHILIPP KOMISSINSKIY, STEFAN FLEGE, SHUNYI LI, KARSTEN RACHUT, ANDREAS KLEIN, and LAMBERT ALFF — Institute for Materials Science, Technische Universität Darmstadt, Alarich-Weiss-Straße 2, 64287 Darmstadt, Germany

We report on the effects of Ag impurities at interfaces of parallel-plate Pt/Ba<sub>0.6</sub>Sr<sub>0.4</sub>TiO<sub>3</sub>/Pt thin film ferroelectric varactors. Ag impurities occur at the interfaces due to diffusion of Ag from colloidal silver paint used to attach the varactor samples with their back side to the plate heated at 600-750 °C during deposition of Ba<sub>0.6</sub>Sr<sub>0.4</sub>TiO<sub>3</sub>. X-ray photoelectron spectroscopy and secondary ion mass spectrometry suggest that amount and distribution of Ag adsorbed at the interfaces depend strongly on the adsorbent surface layer. In particular, Ag preferentially accumulates on top of the Pt bottom electrode. The presence of Ag significantly reduces the barrier height between Pt and Ba<sub>0.6</sub>Sr<sub>0.4</sub>TiO<sub>3</sub> leading to an increased leakage current density and, thus, to a severe degradation of the varactor performance.

[1] S. Hirsch, P. Komissinskiy, S. Flege, S. Li, K. Rachut, A. Klein, and L. Alff, *J. Appl. Phys.* **115**, 243704 (2014).

15 min. break.

DS 4.9 Mon 17:15 H 0111

**Morphology and Optoelectronics at Metal-Polymer-Interfaces during Sputter Deposition** — ●MATTHIAS SCHWARTZKOPF<sup>1</sup>, GONZALO SANTORO<sup>1</sup>, OLEKSANDR POLONSKYI<sup>2</sup>, ALEXANDER HINZ<sup>2</sup>, EZZELDIN METWALLI<sup>3</sup>, YUAN YAO<sup>3</sup>, THOMAS STRUNSKUS<sup>2</sup>, FRANZ FAUPEL<sup>2</sup>, PETER MÜLLER-BUSCHBAUM<sup>3</sup>, and STEPHAN V. ROTH<sup>1</sup> — <sup>1</sup>DESY, Notkestr. 85, 22607 Hamburg — <sup>2</sup>CAU zu Kiel, Kaiserstr. 2, 24143 Kiel — <sup>3</sup>TU München, Physik-Department, LS Funktionelle Materialien, James-Franck-Str. 1, 85748 Garching

The reproducible low-cost fabrication of functional polymer-metal-nanocomposites with tailored optoelectronic properties remains a major issue in applied nanotechnology. In order to obtain full control over the nanostructural evolution at the metal-polymer interface and its impact on optoelectronic properties, we employed the combina-

tion of in-situ time-resolved GISAXS [1] with in-situ surface differential reflectivity spectrometry during sputter deposition of gold on thin polystyrene films. We correlate the evolution of the metallic layer morphology with changes in the key scattering. This enabled us to identify the different growth regimes with their specific thresholds and permits a better understanding of the growth kinetics of gold clusters on polymer substrates. Our study opens up the opportunity to improve nanofabrication of tailored metal-polymer nanostructures for organic electronics like photovoltaic applications and plasmonic-based technologies. [1] Schwartzkopf *et al.*, *Nanoscale* **5**, 5053-62 (2013).

DS 4.10 Mon 17:30 H 0111

**Metallic nanoparticles (Au, Al and Ag) blended into n-type organic semiconducting matrix of F4CuPc: morphology and electronic properties** — ●SERGEY BABENKOV<sup>1</sup>, OLGA MOLODTSOVA<sup>1</sup>, IRINA ARISTOVA<sup>2</sup>, OLEG VILKOV<sup>3</sup>, MAXIM TCHAPLYGUINE<sup>4</sup>, and VICTOR ARISTOV<sup>1,2,5</sup> — <sup>1</sup>DESY Hamburg, Germany — <sup>2</sup>ISSP RAS, Russia — <sup>3</sup>BESSY Berlin, Germany — <sup>4</sup>MAX-lab Lund, Sweden — <sup>5</sup>Uni Hamburg, Germany

Nowadays there is huge demand for more capacious, compact and faster memory storages. In this regard the resistive random-access memory (RRAM) with 3D cross point architecture filled out by organic based nano-composite film could become the new technological breakthrough. Such systems have two programmable high and low resistance states which can be controlled and probed by applying a voltage. Taking it into account, the morphology and electronic properties of nano-composite films based on blended aluminum, gold and silver nanoparticles into n-type organic semiconductor of fluorinated copper phthalocyanine (CuPcF<sub>4</sub>) have been investigated by means of TEM and SR-PES measurements as function of nominal amount of metal deposition. TEM measurements reveal organic film with self-assembled nanoparticles, whose size and distribution are strongly correlated with nominal amount of deposited metal. Moreover, comparative study of electronic properties self-assembled nanoparticles detects strong interaction of metal atoms with organic substrate. Acknowledgments: This work was supported by the RFBR Grant No. 13 -02-00818 and the BMBF-Project No. 05K12GU2, PSP-Element No. U4606BMB1211.

DS 4.11 Mon 17:45 H 0111

**Structure and morphology of organic semiconductor-nanoparticle hybrids prepared by soft deposition** — ●RUPAK BANERJEE<sup>1</sup>, JIŘÍ NOVÁK<sup>1</sup>, CHRISTIAN FRANK<sup>1</sup>, MARIA GIRLEANU<sup>2</sup>, MARTIN BRINKMANN<sup>2</sup>, FALK ANGER<sup>1</sup>, CHRISTOPHER LORCH<sup>1</sup>, JOHANNES DIETERLE<sup>1</sup>, ALEXANDER GERLACH<sup>1</sup>, and FRANK SCHREIBER<sup>1</sup> — <sup>1</sup>Institut für Angewandte Physik, Universität Tübingen, Auf der Morgenstelle 10, 72076 Tübingen, Germany — <sup>2</sup>Institut Charles Sadron CNRS, 23 rue du loess, 67034 Strasbourg, France

We present an extensive structural evaluation of hybrid architectures prepared by the “non-invasive” incorporation of gold nanoparticles (AuNPs) within an organic semiconductor matrix of diindenoperylene (DIP). The hybrid structures were characterized by advanced X-ray scattering techniques including grazing incidence small angle scattering (GISAXS), grazing incidence X-ray diffraction (GID), X-ray reflectivity (XRR) and complemented by atomic force microscopy (AFM) and transmission electron microscopy (TEM) measurements. We show that different strategies of incorporating the nanoparticles in the host matrix lead to drastically different structure and morphology. Particularly remarkable is the morphological change observed in the matrix of DIP as well as the AuNPs due to the influence of organic solvents. It is also demonstrated that AuNPs can be successfully used as tunable templates for the growth of the organic semiconductors with desired island sizes and distances.

DS 4.12 Mon 18:00 H 0111

**Metal/biopolymer interface for packing application** — ●SHUN YU<sup>1,2</sup>, GONZALO SANTORO<sup>2</sup>, PENG ZHANG<sup>2</sup>, HESHMAT NOEI<sup>3</sup>, MIKAEL HEDENQVIST<sup>1</sup>, and STEPHAN ROTH<sup>2</sup> — <sup>1</sup>Fibre and Polymer Technology, Royal Institute of Technology, Stockholm, Sweden — <sup>2</sup>Photon Science, Deutsch Elektron-Synchrotron (DESY), Hamburg, Germany — <sup>3</sup>Nanolab, Deutsch Elektron-Synchrotron (DESY), Hamburg, Germany

Wheat gluten (WG), one of key biopolymers, has shown great potential to substitute some of the synthetic counterparts in terms of excellent foaming ability, oxygen barrier and mechanical properties. Their availability from renewable resources, biodegradable, and less energy consumption during the manufacture are suitable for packing applications. Modern packaging industry, especially the food packag-

ing, gradually turns to a complicated material design with a multilayer structure and nanocomposite components. In this study, we investigate the interfacial structures between chemical treated WG and noble metal thin films (i.e. Au and Ag) prepared by radio frequency sputter deposition. The WG chemical structure was investigated via IR spectroscopy. Grazing incidence small angle scattering technique was used to follow the entire thin film development of Au and Ag on top of WG in real-time. Acid and base treatment renders different WG film structure. It further causes the different growth mode of noble metals on top of both. Doping effects of acid and basic additives may play as a role of the driving forces behind.

DS 4.13 Mon 18:15 H 0111

**Dynamic glass transition of ultrathin poly(2-vinyl pyridine) films** — ●SHERIF MADKOUR<sup>1</sup>, HUAJIE YIN<sup>1</sup>, MARIEKE FUELLBRANDT<sup>1,2</sup>, and ANDREAS SCHOENHALS<sup>1</sup> — <sup>1</sup>BAM Bundesanstalt für Materialforschung und -prüfung, Berlin, Germany — <sup>2</sup>Stranski-Laboratorium für Physikalische und Theoretische Chemie/ Institut für Chemie, Technische Universität Berlin, Berlin, Germany

Specific heat spectroscopy utilizing differential AC-chip calorimetry in the frequency range from 1 Hz to 2 kHz with a sensitivity of pJ/K was employed to study the dynamic glass transition behavior of ultrathin poly(2-vinyl pyridine) (P2VP) films with thicknesses from 400 down to 10 nm. The amplitude and the phase angle of the complex differential voltage as a measure of the complex heat capacity were obtained as a function of temperature at given frequencies simultaneously. Both spectra were used to determine the dynamic glass transition temperature as a function of the film thickness. As a main result, no thickness dependence of the dynamic glass transition temperature or its width was observed for P2VP thin films down to a film thickness of 10 nm, within the experimental uncertainty of \*3 K. This also indicates that the extent of the cooperativity is essentially smaller than the lowest thickness. Further, contact angle measurement was employed to measure the polymer/substrate interfacial interaction, which was found to be strong (4.09mJ/m<sup>2</sup>). Consequently, an adsorbed layer at the interface and an increase in T<sub>g</sub> should be detected. Therefore, further analyses are in progress as an endeavor to quantify the contributions of the interfacial and the free surface layers.