Poster Session B

Poster B

SP5 (1/3), SP7, SP9, SP11, SP12, SP13, SP17
Poster B

P-B.001

Interface perpendicular magnetic anisotropy at a lattice-matched $Co_2FeAl/MgAl_2O_4$ interface

H. Sukegawa, J. P. Hadorn, Z. Wen, T. Ohkubo, S. Mitani, K. Hono

Text Perpendicular magnetic anisotropy (PMA) observed at ultra-thin ferromagnetic layer/oxide interfaces has been attracting attention due to its potential applications such as spin-transfer-torque magnetoresistive random access memories (STT-MRAMs). Here, we report strong PMA at Heusler alloy based $Co_2FeAl/MgAl_2O_4$ epitaxial interfaces prepared by magnetron sputtering and post-oxidation of MgAl. A PMA energy density (K_{eff}) up to 4 Merg/cm^3 for a 1-nm-thick Co_2FeAl layer was demonstrated by controlling the interfacial oxidation states [1]. This large K_{eff} was mainly attributed to achievement of a lattice-matched $Co_2FeAl/MgAl_2O_4$ interface. Interestingly, Al atomic diffusion from Co_2FeAl to $MgAl_2O_4$ was confirmed and this diffusion plays assisting role in enhancing PMA [2]. This study shows that the use of a crystalline $MgAl_2O_4$ layer can induce strong interface PMA suitable for STT-MRAM applications. This study was supported by the ImPACT Program, and JSPS KAKENHI Grant Nos. 16H06332, 16H03852, and 17H06152.
[1] H. Sukegawa *et al.*, Appl. Phys. Lett. **110**, 112403 (2017). [2] J. P. Hadorn *et al.*, Acta Mater. **145**, 306 (2018).

Poster Session B

Poster B

P-B.002

Interfacial perpendicular magnetic anisotropy in magnetic thin film multilayers

S. Jaiswal, K. Lee, M. Vafaee Khanjani, J. Zazvorka, J. Langer, B. Ocker, G. Jakob, M. Kläui

Text We investigate the perpendicular magnetic anisotropy (PMA) arising at the interface for materials with different sign of spin-Hall angles as heavy metal (HM) seed layers in HM/CoFeB/MgO (HM=W, Pt, Pd, W_xTa_{1-x}) as a function of FM thickness and composition for as-deposited and annealed samples. The coercivities and anisotropy fields of annealed material stacks are higher than for as-deposited stacks due to crystallisation of the ferromagnetic layer. We find a critical thickness of MgO > 1 nm providing adequate oxide formation at the top interface as a requirement for PMA. The PMA in Pt seeded stacks depends not on the buffer layer of Ta but on the FM alloy composition requiring a Co rich FM. We find stripe domain formation in Pd/CoFeB/MgO layers and investigate the stripe and bubble domain structure and skyrmion formation as a function of HM selection. Three different means of selective tuning of the PMA are discussed apart from the conventional FM thickness variation. Delta doping of W_xTa_{1-x} yielded a new seed layer with extremely low coercive field (< 1 mT) and strong PMA with the ability to tune the anisotropy as a function of Ta doping. Strong anisotropy fields of up to 1 T and low pinning of domain structures were measured in W/CoFeB/MgO stacks. In narrow thickness ranges of the low pinning materials skyrmion formation is found and the DMI values are extracted from asymmetric bubble expansion experiments [1].

[1] S. Jaiswal et al., Appl. Phys. Lett. 111, 022409 (2017)

Poster Session B

Poster B

P-B.003

Internal stress influence on the domain wall dynamics and on the magnetic properties of Fe77.5Si7.5B15 microwires

I. Baraban, A. Litvinova, V. Rodionova

Text In this work, we investigated an effect of the stressed state of metal core before and after partial removal of the mechanical stresses of the metallic core by removing the glass coating on the magnetic properties and parameters of the domain wall propagation in amorphous ferromagnetic Fe-based microwires. Microwires have parameters: d (diameter of metal core) from 9 to 13 μm and D (total diameter of microwire) from 16 to 35 μm. Coercive force decreases from 486 A/m to 178 A/m after glass removing, initially rectangular hysteresis loops become S-shaped. This indicates a change in a preferential mechanism of the magnetization reversal from the rapid propagation of the domain wall to the rotation of the vector of the magnetic moment as a result of the partial removal of the stresses of the microwire's core. Velocity of the domain wall propagation increases and mobility's value changes from 5.4 m2/(s*A) to 29.1 m2/(s*A). Based on magnetic data we can conclude that micromagnetic structure changes due to the stress components redistribution along the radius of the metallic core of the microwire: the volume of the region with the axial direction of magnetization decreases and the volume of the periphery with easy magnetisation axis directed along the radius of the microwire increases.

Poster Session B

Poster B

P-B.004

Investigation of $BiFeO_3/CoFe_2O_4$ bilayered multiferroic nano-hollowspheres

M. Alam, K. Mandal

Text Here, we reported the synthesis of bilayered $BiFeO_3/CoFe_2O_4$ nano-hollow spheres (NHSs) by depositing a $BiFeO_3$ (BFO) layer of thickness ~20 nm on $CoFe_2O_4$ (CFO) nano-hollow spheres surface of diameter ~ 250 nm and investigated their electric, magnetic, dielectric and magnetoelectric properties in view of their applications in electronic and magnetic devices. The nano-composites display better properties compared to their bulk counterpart. The maximum polarization in CFO/BFO NHSs is found to be 2.1 $\mu C/cm^2$ at a frequency 50 Hz. Magnetic measurements show the saturation magnetization to be 30.1 emu/g with high value of remnant magnetization (17.9 emu/g), and coercivity (1320 Oe). Its magnetoelectric coefficient, α_{ME} at 1 kHz is estimated to be ~ 8.6 mV/cm Oe. The dielectric behaviour and conductivity of CFO/BFO NHSs are investigated as a function of temperature (in the range 30-300 ^0C) and frequency (in the range of 10^{-1} – 10^6 Hz).

Reference:
M. Alam, S. Talukdar, K. Mandal, Multiferroic properties of bilayered $BiFeO_3/CoFe_2O_4$ nano-hollowspheres, Materials Letters, 210 (2018) 80–83.

Poster Session B

Poster B

P-B.005

Is it really possible to control the magnetic properties of nanoparticles by chemical composition?

R. Cabreira-Gomes, R. Aquino, V. Pilati, F. H. Martins, F. L. O de Paula, V. Pilati, F. L. O. de Paula, P. Coppola, J. Depeyrot, R. Perzynski

Text It has been known that mixed ferrites are promising materials for heat exchange applications and theranostic ones. Recently we have studied the magnetic fluids based on this materials composed by Zn and Mn with different stoichiometric proportions and we have paid attention basically to the magnetically induced properties [1]. Furthermore, we have seen a coherently behavior of both magnetic properties and optical ones dependent to Mn-proportion and we have put ourselves the title question. However, to answer that and other questions it is imperative to understand the materials from a fundamental point of view, i.e. how it is formed and structured. To perform this study, two classes of core@shell nanoparticles and their ferrofluids were synthesized. They are leading made of “pure ferrites” ($MnFe_2O_4$@γ-Fe_2O_3 and $ZnFe_2O_4$@γ-Fe_2O_3) and “mixed” ones nominally composed by $Zn_XMn_{(1-X)}Fe_2O_4$@γ-Fe_2O_3, where X = 0.3, 0.6 and 0.9 [1]. Magnetic and magneto-optical properties of these two classes of nanomaterials are compared. The answer to the title question is found into the material’s crystalline structure [2], [3]. Rietveld refinement of neutron diffraction measurements shows that the ionic distribution within the crystalline structure is the key source of magnetic properties of the materials.

[1] V. Pilati et al., J. Phys. Chem. C, vol. 122, p. 3028, 2018.
[2] F. H. Martins et al., J. Phys. Chem. C, vol. 121, p. 8982, 2017.
[3] J. A. Gomes et al., J. Phys. Chem. C, vol. 116, p. 24281, 2012.

Poster Session B

Poster B

P-B.006

Low-temperature magnetic transitions in Fe_2MnSi and Fe_2MnAl Heusler alloys prepared in bulk and ribbon form

O. Zivotsky, A. Titov, J. Bursik, D. Janickovic, Y. Jiraskova

Text Microstructural and magnetic properties of the Fe_2MnSi and Fe_2MnAl Heusler alloys in the bulk and ribbon form have been investigated from a viewpoint of technology of their production. X-ray diffraction has confirmed the $L2_1$ cubic phase in both polished 500 μm thick discs cut from a button type ingot and 20 μm thick and 2 mm wide ribbons prepared by planar flow casting. Lattice parameters, 0.567(1) nm for Fe_2MnSi and 0.582(1) nm for Fe_2MnAl, were independent on production technology which, on the other hand, has markedly influenced the microstructure clearly pointing to larger size of grains and grain boundaries in the disc samples. From the magnetic viewpoint both alloys are paramagnetic at room temperature without visible influence of their production. Contrary, the low temperature magnetic behaviours are affected by both chemical composition and microstructure.
For both Fe_2MnSi samples the peak value of magnetization is reached at temperature T_p = 70 K. Its decrease and a splitting of FC-ZFC curves below 70 K can be connected with the antiferromagnetic pinning of Mn atoms inside the ferromagnetically-coupled Fe atoms. A sharp transition into a paramagnetic state at the Curie temperature T_c = 220 K is observed in the disc sample, whereas a gradual transition at about 270 K is detected for the ribbon sample.
For the Fe_2MnAl system, both characteristic temperatures T_p and T_c are different; 38 K and 105 K for the disc sample and 58 K and 185 K for the ribbon sample.

Poster Session B

Poster B

P-B.007

MBE growth and magnetic properties of self-assembled GeMn/Si quantum dots

L. Michez, S. T. Pham, S. Bertaina, V. Le Thanh

Text The development of active spintronic devices requires an efficient spin injection into semiconductors, particularly into silicon (Si). However compounds exhibiting both natural impedance match to group-IV semiconductors and high Curie temperature (TC) are noticeably lacking. Mn-doped Ge quantum dots (QDs) grown by self-assembly via Stranski-Krastanov growth mode on Si(001) would be an ideal candidate. Although ferromagnetism has already been observed above room temperature in such a structure, these results could not be reproduced probably due to Ge/Si inter-diffusion and Mn diffusion into the Si substrate during growth. We have therefore carried out an exhaustive study of their magnetic, morphological, structural properties by varying both growth temperature and Mn concentration. We were able to demonstrate that inter-diffusion is quasi-suppressed in GeMn QDs grown at a substrate temperature below 430 °C. Magnetic characterizations (SQUID and XMCD) reveal the presence of two different ferromagnetic contributions with a Tc of 220K and another above 300K. Interestingly, a Mn concentration of about 2% leads to the largest magnetization value, probably indicating the maximum content that can be incorporated into substitutional sites of the Ge lattice. A detailed TEM analysis coupled to EDX measurements clarifies the origin of the ferromagnetism. This comprehensive work constitutes the first step toward reproducible room-temperature ferromagnetism.

Poster Session B

Poster B

P-B.008

Magnetic Properties of Supersaturated Solid Solutions processed by Severe Plastic Deformation

M. Stückler, S. Wurster, A. Bachmaier

Text Severe plastic deformation can be used to mix binary alloys which exhibit large miscibility gaps in their thermodynamical equilibrium. With high-pressure torsion, a method of severe plastic deformation, supersaturated solid solutions at high homogeneity over a wide compositional range can be processed. After deformation, these materials are already available in bulk form for further investigations. For systems consisting of ferromagnetic and diamagnetic elements, the intrinsic magnetic properties can be continuously tuned. Furthermore, supersaturated solid solutions processed by high-pressure torsion exhibit grain sizes in the ultrafine or nanocrystalline regime, which causes a significant change in the coercivity according to G. Herzer.[1] Therefore, the preparation of supersaturated solid solutions with high-pressure torsion delivers a technique to tune the whole shape of the magnetic hysteresis.

In this study, binary systems are studied using iron or cobalt as ferromagnetic and copper or silver as diamagnetic component. After severe deformation, magnetic properties are investigated and correlated to the microstructure, which is studied by scanning and transmission electron microscopy.

This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 757333).

[1]G. Herzer, *Soft-magnetic nanocrystalline materials*, Scripta Metall. Mater. **33** (1995) 1741

Poster Session B

Poster B

P-B.009

Magnetic Properties of Ultrathin Cobalt films on Si substrates

L. Rios E., E. J. Patino

Text Magnetism in ultra-thin films has attracted many research efforts because of its practical applications in solid state devices. One of the most interesting properties of this area is that, contrary to the magnetism in bulk materials, it is possible to manipulate the magnetism by controlling the thickness of the sample. In this experimental work, we studied the variation of remanent and saturation magnetizations as well as the coercive fields for Cobalt films grown by Sputter deposition. The films were fabricated with thicknesses between 1 to 10nm and were characterized via AFM and VSM measurements. At 1.6nm results showed a deviation in both, the surface roughness and the saturation magnetization. Also a significant change in coercive fields was found for thicknesses below 1.6nm.

Poster Session B

Poster B

P-B.010

Magnetic and Structural Properties of FeCrNiCd Thin Films Produced with Different Deposition Rates by a DC Sputtering Technique

O. Senturk, A. Karpuz, N. Kaplan, O. Karaagac, H. Kockar

Text FeCrNiCd thin films were produced on a flexible substrate by a DC sputtering technique. The thickness of films was 50 nm. The film content analysed by energy dispersive X-ray Spectroscopy displayed that the diamagnetic content increased and the paramagnetic content decreased when the deposition rate increased. However, the ferromagnetic content remained almost constant. The composition of the films is in accordance with the X-ray diffraction peak intensities. The crystalline structure of films is a mixture of the hexagonal close packed and the body centered cubic phase. Surface morphological investigation which was performed by a scanning electron microscope revealed that the size and number of grains decreased as the deposition increased. The magnetic measurements were achieved by a vibrating sample magnetometer. The saturation magnetization decreased from 1030 emu/cm^3 to 217 emu/cm^3 when the deposition rate increased from 0.02 nm/s to 0.08 nm/s. Similarly, coercivity, H_c values decreased from 10.5 to 1.95 Oe when the deposition rate increased with the same manner. It was shown that FeCrNiCd films have soft magnetic properties because of their low H_c values. According to results, the change in magnetic properties arises from the change in structural properties caused by the variation of deposition rates.

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Poster Session B

Poster B

P-B.011

Magnetic and optical properties of metal filled luminescent porous silicon

P. Granitzer, K. Rumpf, P. Poelt, M. Reissner

Text In today's research activities Magneto-optics is intensely investigated and thus the purpose of this work is to influence the photoluminescence of microporous silicon (PSi) by filling with a magnetic metal (e.g. Ni). This happens in two ways. On the one hand the surface plasmon of the metal deposits is exploited to modify the luminescence and on the other hand it is influenced by an external magnetic field. Due to the metal filling of the PSi the photoluminescence is blue-shifted and furthermore an increase of the intensity is observed. The influence of the magnetic metal filling on the optical properties is discussed and the magnetic characterization of the nanocomposits is presented. Photoluminescence spectra of bare PSi show a maximum around 620 nm whereas in the case of Ni filled samples the peak is blue-shifted to around 580 nm and the luminescence intensity is increased.
Field dependent magnetization measurements performed with the magnetic field applied perpendicular and parallel to the sample surface show a high magnetic anisotropy. It can be clearly seen that the samples offer a film-like behavior due to the interconnected Ni structures which is represented by the easy axis parallel to the surface. Furthermore the influence of an external magnetic field on the optical properties is elucidated. The presented systems are promising candidates for applications in optoelectronics and also for magneto optical integrated devices.

Poster Session B

Poster B

P-B.012

Magnetic and transport properties of heterostructures of calcium-doped lanthanum manganites

P. B. Patil, P. K. Siwach, H. K. Singh

Text Perovskite manganites having general formula $RE_{1-x}AE_xMnO_3$ (where RE = Rare-Earth and AE = Alkaline-Earth elements) are widely studied as they combines both the tremendous technological potential and deep fundamental physics. Recently research on magnetic oxide superlattices has been focused towards the technological goals of obtaining fruitful properties in lower applied magnetic fields and more useful temperature ranges for various applications. Heterostructures of calcium-doped lanthanum manganites are interesting candidates for investigations of exchange bias. Their rich phase diagram allows for the possibility of both ferromagnetic and antiferromagnetic compounds, which have similar and well-matched crystal structures. We have investigated the magnetic and transport properties of epitaxial [(F) $La_{0.58}Ca_{0.42}MnO_3$/(AF) $Pr_{0.58}Ca_{0.42}MnO_3]_N$ bilayers. Stoichiometric targets of $La_{0.58}Ca_{0.42}MnO_3$ and $Pr_{0.58}Ca_{0.42}MnO_3$ have been prepared by solid state route and phase formations have been confirmed by X-ray diffraction. These targets were used to grow exchange-biased multilayers on $SrTiO_3$ single crystal substrates by rf sputtering. The number of bilayers, N, was adjusted so that the total thickness was kept close to 3000 Å. Single layer LCMO and PCMO films, also 3000 Å thick, were prepared for comparison. Dependence of the exchange bias effect on the thickness of the antiferromagnetic as well as the ferromagnetic layer was studied.

Poster Session B

Poster B

P.-B.013

Optical and magneto-optical interactions in Tm, Eu and Tb IG thin films on GGG substrates

L. Beran, J. Šetina, E. Rosenberg, A. Quindeau, C. A. Ross, M. Veis

Text Ferrimagnetic garnets have recently received considerable attention due to the novel spintronic effects such as spin Seebeck effect [1] or spin Hall magnetoresistence [2]. Among them thulium, terbium and europium iron garnets (Tm, Tb, Eu IGs) represent very important group due to their robust perpendicular magnetic anisotropy (PMA) induced by strain in thin films. Although the dynamic control of their magnetism via spin-orbit torque was demonstrated [3], systematic study of their optical and magneto-optical (MO) properties has not been reported yet.
In this work, we present a systematic study of optical and MO properties of PLD deposited thin films of Tm, Tb and Eu IGs on GGG substrates using MO spectroscopy and spectroscopic ellipsometry. Faraday and Kerr MO spectra measured in the photon energy range from 1 to 5 eV showed behavior typical for ferrimagnetic garnets. Notable differences in positions of spectral bands originating from transitions at tetrahedral Fe sites pointed on different amount of strain in Tm, Tb and Eu IGs as tetrahedral sites are more are more susceptible to deformations. Using the MO and ellipsometric experimental data a spectral dependence of complete permittivity tensor of investigated garnets was deduced in wide spectral range.

[1] A. Kirahara et al., Nat. Mat. 11, 686 (2012)
[2] H. Nakayama et al., Phys. Rev. Lett. 110, 206601 (2013)
[3] C. O. Avci et al., Nat. Mat. 16, 309 (2017)

Poster Session B

Poster B

P-B.014

Magnetic behaviour of Mn12-stearate single-molecule magnets anchored inside SBA-15 mesoporous silica matrix

M. Laskowska, M. Bałanda, M. Fitta, M. Dulski, M. Zubko, P. Pawlik, L. Laskowski

Text The present work is devoted to the magnetic behaviour of Mn12-stearate single-molecule magnets ([Mn12O12(CH3(CH2)16CO2)11(CH3CO2)5(H2O)4]·2CH3COOH) immobilized inside the SBA-15 mesoporous silica. The Mn12-stearate used in the synthesis of SBA-Mn12 hybrid material were prepared in accordance to the procedure described in the literature [1]. This derivative of Mn12, in contrast to the Mn12-ac which was used previously by the authors [2], is soluble in most organic solvents and resistant against water catalyzed reduction. The silica matrix in this case provides controlled separation of magnetic molecules. In order to check the impact of silica matrix on final material properties, samples containing three different concentration of M12-st molecules were prepared and compared with the bulk Mn12-st. All materials have been examined by means of infrared spectroscopy, transmission electron microscopy and squid magnetometry. The obtained results confirmed the successful deposition of magnetic molecules inside the silica matrices. Additionally, due to different concentrations of magnetic molecules in the samples, relevant properties were observed. The results of magnetic tests show a correlation between the number of Mn12-st molecules inside the mesopores and the magnetic parameters of the obtained hybrid materials.
[1] C.-D. Park, D.-Y. Jung, Bull. Korean Chem. Soc. 2001, 22, 611
[2] M. Bałanda, R. Pełka, M. Fitta, Ł. Laskowski, M. Laskowska, RSC Adv., 2016, 6, 49179

Poster Session B

Poster B

P-B.015

Magnetic coupling effects in curvilinear nanomagnets

D. Makarov, O. Volkov, A. Kakay, J. Fassbender

Text While conventionally magnetic films and structures are fabricated on flat surfaces, the topology of curved surfaces has only recently started to be explored and leads to new fundamental physics as well as applied device ideas [1]. In particular, novel effects occur when the magnetization is modulated by curvature providing a new degree of freedom that leads to new magnetization configurations and is predicted to have major implications on the spin dynamics due to topological constraints [2].
Advances in this novel field solely rely on the understanding of the fundamentals behind the modifications of magnetic responses of 3D-curved magnetic thin films. The lack of an inversion symmetry and the emergence of a curvature induced effective anisotropy and Dzyaloshinskii-Moriya interaction are characteristic of curved surfaces, leading to curvature-driven magnetochiral effects and topologically induced magnetization patterning. In addition to these rich physics, the application potential of 3D-shaped objects is currently being explored as mechanically reshapeable magnetic field sensorics [3], spin-wave filters and high-speed racetrack memory devices. The fundamentals as well as application relevant aspects of curvilinear nanomagnets will be covered in this presentation.

[1] R. Streubel, D. Makarov et al., J. Phys. D: Appl. Phys. 49, 363001 (2016).
[2] D. Sander, D. Makarov et al., J. Phys. D: Appl. Phys. 50, 363001 (2017).
[3] D. Makarov et al., Appl. Phys. Rev. 3, 011101 (2016).

Poster Session B

Poster B

P-B.016

Magnetic field distribution in a magnetic liquid spike

M. Trbušić, A. Hamler

Text The Rosensweig, or normal field instability, is a well known phenomenon where formation of a spike like shape appears on a magnetic liquid surface when it is exposed to a sufficiently large external magnetic field. While the surface shape of magnetic liquid has an impact on the magnetic field distribution and vice versa, it is somehow essential to know the magnetic field distribution within the magnetic liquid. The aim of the magnetic field calculation is to determine the spatial distribution of magnetic energy density within the fluid, which is crucial data when surface shape is calculated through minimization of the energy functional. The calculation is placed in the 3D space and performed at the equilibrium state of magnetic liquid using the Finite Element Method based software Opera Field. Only a single spike of the magnetic liquid is included in the computational model, while the pattern of the surface deformation is assumed to be hexagonal and distributed periodically over the surface.

Poster Session B

Poster B

P.-B.017

Optical and magneto-optical spectroscopy of Co doped Ni-Mn-Ga films

L. Nowak, D. Král, S. Schwabe, A. Diestel, K. Nielsch, O. Heczko, L. Beran, S. Fähler, M. Veis

Text Heusler compounds that undergo martensitic transformation are of scientific interest due to their potential for future applications [1]. The most known alloy of this class is Ni-Mn-Ga, which has been intensively studied during the last decade as it exhibits magnetically induced reorientation [2]. The martensitic transformation to low symmetry phase, which is the key to this behavior, can be tailored by proper doping. Deep understanding of changes in electronic structure induced by doping is therefore necessary for future applications of these compounds.
Here we present optical and magneto-optical (MO) investigations of Co doped Ni-Mn-Ga films on MgO substrates grown by dc sputtering. The amount of Co doping was kept from 3 to 12 atomic percent. MO experiments were done in polar configuration using rotating analyzer technique in the spectral energy range from 1.2 to 5 eV. The MO spectra clearly exhibited two prominent spectral bands around 1.4 and 3.8 eV. The first band originates from the crystal field transition of Ni, while the second one originates from the charge transfer transition between Ni and Mn 3d states [3]. Changes in the low energy spectral band with different Co doping were observed. This indicates changes in the electronic structure of Co doped Ni-Mn-Ga due to the replacement of Ni by Co.

[1] O. Söderberg et al., Mater. Sci. Eng. A 481–A482, 80 (2008)
[2] O. Heczko, Mater. Sci. Tech. 30, 1559 (2014)
[3] M. Veis et al., J. Appl. Phys. 115, 17A936 (2014)

Poster Session B

Poster B

P-B.018

Magnetic properties of CoFe2O4/Fe2O3 and NiFe2O4/Fe2O3 core/shell particles

F. Gomes da Silva, P. Coppola, D. Fiorani, J. Depeyrot, R. Aquino, N. Yaacoub, R. Mathieu, R. Perzynski, D. Peddis

Text We prepare core shell (CS) Nanoparticles (NPs) of different sizes consisting of Cobalt and Nickel ferrites cores surrounded by a maghemite shell. The mean size diameters are determined by XRD measuments. Our previous investigations demonstrated that the inner region has a well-ordered ferrimagnetic structure, surrounded by a surface layer of spins randomly frozen at low temperatures [1]. This disordered surface contribution is evidenced by in-field Mössbauer spectroscopy [2] showing a progressive spin alignment along the ferrite core.
Here we investigated the influence of the size diameter on the exchange bias (EB) effect. Mössbauer spectra recorded 12K under a field of 8T shown the presence of the surface spin disorder, as observed previously. This disorder is clearly more evident for NPs of smallest size. The EB field Hex, measured at 5K after FC measurement of 3 kOe, is present for all the samples and it increases as the size particle of the NPs decreases (11 nm; Hex=15 Oe, 5,4 nm; Hex=105 Oe ; 2,2 nm; Hex= 155 Oe). For the smallest particle size (2 nm) we investigated the effect of changing the composition of the core, comparing the Hex value with that Nickel ferrite particles of same size. The Hex is higher for cobalt ferrite (Hex 155 Oe; for NiFe2O4/-Fe2O3, Hex 95 Oe), indicating the role of the core anisotropy, which is larger for CoFe2O4.

1. R. Aquino et al, Phys. Rev. B 72, 1 (2005).
2. E. C. Sousa et al, J. Appl. Phys. 106, 093901 (2009)

Poster Session B

Poster B

P-B.019

Magnetic properties of iron borate film on gallium borate substrate

K. Seleznyova, S. Yagupov, M. Strugatsky, Y. Mogilenec, A. Drovosekov, N. Kreines, J. Kliava

Text A new magnetic material, iron borate FeBO3 thin film — promising for studying surface magnetism as well as for practical applications as a memory element — has been synthesized for the first time, and its magnetic characteristics have been studied by Electron magnetic resonance (EMR).
We have developed a synthesis technique and prepared FeBO3 films on GaBO3 substrates by liquid phase epitaxy. This technique allows obtaining films appropriate for magneto-optical and magneto-acoustical studies.
The EMR studies have been carried out with laboratory-developed spectrometer in the range of 15.0 to 35.7 GHz and 293 to 350 K, and the magnetizing field B up to 1 T applied in the basal plane of the crystal.
The EMR studies show that the Néel temperature and the effective Dzyaloshinskii-Moriya field for the film are in good accordance with those for FeBO3 single crystal. Besides, these studies suggest that magnetic nanoclusters are formed in the transition layer between the film and the substrate. Moreover, the isotropic energy gap at 300 K in the film is several times larger than in single crystal, probably because the mechanical stresses caused by a mismatch between the lattice parameters in the film and in the substrate.
This work was supported by the RFBR and the Ministry of Education, Science and Youth of Crimea (17-42-92015 ‘‘р_а”, 18-32-00210 “мол_а”) and the V.I. Vernadsky CFU Development Program 2015 – 2024.

Poster Session B

Poster B

P-B.020

Magnetic properties of magnetic field annealed nanostructured bulk materials

S. Wurster, M. Stückler, A. Bachmaier

Text To study the influence of magnetic field annealing below the Curie temperature on magnetic properties, nanostructured materials were subjected to thermal treatments with and without magnetic fields at different temperatures.
Specimens were compacted from powder mixtures of diamagnetic (e.g. Cu, Ag) and ferromagnetic (e.g. Fe, Co) materials using room temperature high pressure torsion, a method of severe plastic deformation. As a result, nanocrystalline, fully dense bulk specimens are readily available for further investigations. Annealing was performed in an electromagnet's air gap. The air gap is large enough to contain a vacuum chamber, avoiding oxidation while annealing. For comparison reason, specimens were kept at elevated temperatures with and without a magnetic field. Different orientations of the magnetic field in relation to the specimen shape, their texture and the subsequently applied magnetic testing fields were taken into account. After magnetic field / non-field annealings for different times and temperatures, changes in the magnetic properties such as the hysteresis curve were determined. These findings are connected with results from microstructural examinations with scanning and transmission electron microscopy.
This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 757333).

Poster Session B

Poster B

P-B.021

Magnetic properties of nano-engineered 3D Fe-Co structures

M. Al Mamoori, L. Keller, C. Schröder, M. Huth, J. Müller

Text Driven by the quest for novel magnetic phenomena, there is an ongoing effort dedicated to expand 2D nanomagnetism to the third dimension where spin textures extend into the vertical direction of the substrate plane, thereby creating more complex ferromagnetic properties and opening the door for a fascinating new research area. In a related poster contribution by L. Keller, the fabrication of freestanding ferromagnetic 3D nano-architectures by the direct-write method focused electron beam induced deposition (FEBID) is described. Here, we present the magnetic properties of small arrays of Fe-Co nanostructures directly deposited on the surface of a home-built micro-Hall sensor.
We report systematic measurements of the magnetic stray fields of small arrays of nano-cube and tetrahedral nano-tree structures as a function of temperature and magnetic field angle. We compare the experimental findings to micromagnetic simulations in order to unveil the complex switching behaviour and mechanism of magnetization reversal. This combination of methods reveals a reversal of the edge spin textures proceeding via complex vortex configurations. In order to gain further insights in the hysteresis loops, (irreversible) magnetic interaction effects and coercivity distributions we present first-order-reversal curves (FORC) of these 3D nanomagnets. We give an outlook to the future design of such structures towards the realization of 3D artificial spin ice architectures.

Poster Session B

Poster B

P-B.022

Magnetic properties of nano-wires with ferromagnetic core and polycrystalline anti-ferromagnetic shell

A. Patsopoulos, D. Kechrakos

Text We study numerically the magnetic hysteresis of isolated cylindrical ferromagnetic nanowires with an antiferromagnetic oxide layer using a classical spin model and Monte Carlo simulations. For monocrystalline and uniaxial nanowires, we find that the coupling to the antiferromagnetic shell leads to suppression of the coercivity and emergence of a weak exchange bias effect. The magnetization reversal in the core-shell nanowire proceeds mainly by domain wall propagation and annihilation. However, the interface exchange coupling introduces a secondary reversal mechanism with characteristics of coherent rotation, which acts in synergy to wall propagation leading to enhancement of the wall mobility. This mechanism is more pronounced in nanowires with large exchange bias values and is due to uncompensated interface moments that act as nucleation centres for reversal. The effect of shell polycrystallinity is studied for crystallites with variable size and random anisotropy. As the size of the crystallites decreases we find a decrease of exchange bias field, an increase of coercivity and a concomitant decrease of the domain wall mobility. Furthermore, the angular dependence of the bias field is modified due to shell polycrystallinity, exhibiting to a non-monotonous behavior. The results of our multispin simulations are compared with a Meiklejohn-Bean macrospin model including an effective off-axis unidirectional anisotropy. Recent experiments in Co/CoO nanowires are discussed.

Poster Session B

Poster B

P.-B.023

Optical and magneto-optical properties of Bi-substituted Yttrium Iron Garnets on GGG and Si substrates for nonreciprocal photonic devices

S. Tazlárů, T. Fakhrul, L. Beran, Y. Zhang, C. A. Ross, M. Veis

Text Monolithic integration of non-reciprocal photonic devices requires high quality thin films of materials with strong magneto-optical (MO) effect. So far most research on integrated optical isolators has been based on Ce-substituted Yttrium Iron Garnet (Ce:YIG) as the MO material [1]. However, Ce:YIG has an absorption peak at 1 eV making it unsuitable for use in optical isolators operating at the lowest dispersion wavelength of 1300 nm. To overcome this limit Bi-substituted Yttrium Iron Garnet (Bi:YIG) gained a considerable attention due to its high MO response and low optical absorption.
In this work we report about spectrally dependent optical and MO properties of epitaxial and polycrystalline thin films of Bi:YIG with various Bi content on GGG and Si substrates grown by pulsed laser deposition. The effect of growth temperatures and O2 pressure on the film optical and MO properties was studied. On Si substrates, bottom-up and top-down crystallization of Bi:YIG using YIG seed layers below or above the Bi:YIG was investigated in order to enable integration of garnets on photonic substrates. In-depth optical and MO characterizations of the bilayer films were performed by MO Faraday spectroscopy along with spectroscopic ellipsometry in wide spectral range from 0.7 to 6 eV. Utilizing the absorption coefficients together with Faraday rotations we deduced spectrally dependent figure of merit for all investigated samples.

[1] M. Onbasli et al., Sci. Rep. 6, 23640 (2016)

Poster Session B

Poster B

P-B.024

Magnetic states in ordered arrays of nanostructures studied by X-ray Resonant Magnetic Scattering and XMCD-PEEM

J. Díaz, C. Quirós, J. I. Martín, M. Vélez, M. Valvidares, P. Gargiani, C. Redondo, R. Morales, A. Scholl, E. M. González, J. L. Vicent

Text Ordered arrays of lines and dots have been prepared by laser interference lithography over large areas (typically 25 mm2) of permalloy (in-plane magnetic anisotropy) and Co/Pd multilayers (out-of-plane magnetic anisotropy). Magnetic dots are arranged in a 900 nm square lattice. Each individual dot has a 600 x 600 nm2 square shape oriented at 45º relative to the square array principal directions. This geometry is chosen to enhance interdot interactions along the dot diagonals that may induce correlations in magnetic states across the array. Average magnetic properties have been characterized by VSM magnetometry, showing low remanence hysteresis loop typical of vortex states. This has been confirmed by the characterization of the local magnetization configuration at remanence by Photoemission electron microscopy in x-ray magnetic circular dichroism contrast mode (XMCD-PEEM) at BL11.0.1 of the ALS synchrotron. Global magnetization configuration at the arrays has been studied by X-ray resonant magnetic Scattering (XRMS) measured with circularly polarized soft X-rays at the Fe L3 edge under resonance conditions at BL29 of the ALBA Synchrotron. Comparison of magnetic dichroism contrast at the different XRMS peaks for in-plane magnetic saturation and remanence has been used to study magnetic vortex chirality in the square dot array.

Poster Session B

Poster B

P-B.025

Magnetism and Multiferroic properties of ATiO3 (A = Mn, Fe, Ni) surfaces

R. Ribeiro, L. H. S. Lacerda, J. Andrés, E. Longo, S. R. Lazaro

Text The manipulation of multiferroic surfaces - widespread candidates for spintronic-based technologies - becomes more intriguing owing to the coupling between magnetic and ferroelectric orders. The present study illustrates how Density Functional Theory (DFT) calculations can rationalize at atomic level the structure as magnetism ordering for the low-index (110), (101), (100), (001), (111), and (012) surfaces of ATiO3 (A = Mn, Fe, Ni) materials. For this purpose, hybrid PBE0 functional calculations were performed using CRYSTAL14 code. The surface stability was found to be controlled from octahedral [AO6] and [TiO6] clusters, i.e., their local coordination on surfaces. In addition, the crystal morphology has been predicted to determine the most likely terminations to be present as well as the intrinsic magnetization density associated with morphologies. The intriguing magnetic properties were discussed by means of the crystal-field energy scales in the cleaved surface environments associated with the presence of different local Ti and A-site cation coordinations. By combining between morphological map and singular spin densities associated with the surfaces structure, it was found that the exposure of the (001) surface plane is mandatory to increase the superficial magnetism and the magnetoelectric coupling in ATiO3 materials.

Poster Session B

Poster B

P-B.026

Magnetization dynamics of $NdCo_x$/Al/Py crossed anisotropy bilayers

L. M. Álvarez-Prado, F. Váldes-Bango, D. Markó, A. Hierro-Rodriguez, M. Vélez, C. Quirós, J. I. Martín, D. Schmool, J. M. Alameda

Text Stripe domains in thin films having weak perpendicular magnetic anisotropy (PMA) can be used to control reconfigurable magnonic devices *[1,2]*. On the other hand, X-ray transmission microscopy has recently shown that PMA favours topological defects *[3]*. Amorphous $NdCo_x$ exhibits weak PMA up to room temperature *[4,5]*. To further increase the versatility of these systems, we have sputtered trilayers containing a $NdCo_x$ film, 65nm thick, coupled to a standard in-plane magnetic anisotropy (IMA) material 10nm thick, Permalloy, through a non-magnetic spacer: Al in our case. This ultrathin Al film guides a transition through different magnetic exchange regimes between $NdCo_x$ and Permalloy: directly exchange coupled/stray-field coupled/uncoupled. We have characterized the static (Kerr Effect, Alternating Gradient Magnetometry) and dynamic (Ferromagnetic Resonance up to 40 GHz) behaviour of the PMA/IMA bilayers at room temperature for $x_{Co} \in [5,10]$. Results have been compared to 3-D micromagnetic simulations to interpret the origin of the observed dynamic signal.

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[1] C. Banerjee *et al.* , Phys. Rev. B 96, 024421 (2017).
[2] G. Csaba *et al.*, Physics Letters A 381, 1741 (2017).
[3] C. Blanco-Roldán *et al.*, Nat. Comm. 6, 8197 (2015).
[4] R. Cid *et al.*, Phys. Rev. B 95, 224402 (2017).
[5] L. M. Álvarez-Prado *et al.*, J. Mag. Mag. Mat. 456, 251 (2018).

Poster Session B

Poster B

P-B.027

Magnetization reversal in antidot lattices with perpendicular anisotropy at presence of self-organized surface ripple

N. Kulesh, Z. Grinina, A. Bolyachkin, V. Lepalovskij, V. Vas'kovskiy, M. Vázquez

Text In the past years, nanopatterning became a powerful tool for tailoring properties of magnetic materials through the nanoscale control over the local dipole and exchange interactions. Thin films with artificial nanoholes lattices (antidot) represent a class of such nanostructures with magnetization processes modified by local stray fields. In this contribution, we studied and compared magnetization reversal behavior of TbCo and GdCo films with perpendicular anisotropy (PA) having three types of patterning: flat antidot, antidot with self-organized ripple, and nanohills. For synthesizing corresponding samples, we deposited 30 nm thick films onto the polished or as-prepared surface (for flat and rippled antidot lattice) or onto the barrier layer (nanohills lattice) of anodic alumina substrates [1]. High-resolution Kerr microscopy was used for extracting vectorial information as well as for observation of the magnetic domain structure. The surface ripple in antidot films reduced PA in both TbCo and GdCo films (comparing to continuous film and flat antidot), whereas nanohills lattice reduced PA in TbCo, but increased PA in GdCo film. For interpretation of the experimental data obtained on different patterned structures and the observed discrepancy for TbCo and GdCo films, micromagnetic modeling has been employed.
This work was supported by the President of Russian Federation grant for young scientists (Contract 14.Y30.18.1891-MK)
[1] Lee W., Park S.-J. Chem Rev. (2014) 7487-7556.

Poster Session B

Poster B

P-B.028

Magnetization reversal in one-dimensional bi-component array of Py wires with periodic and Fibonacci order

K. Szulc, F. Lisiecki, A. Makarov, J. Rychły, M. Zelent, P. Kuświk, J. Dubowik, A. Maziewski, F. Stobiecki, M. Krawczyk

Text Influence of magnetostatic interaction between permalloy (Py, Ni80Fe20) nanowires on the remagnetization process were investigated experimentally and theoretically in dependence on the order and dimensions of the wires. The nanowires of two widths - 350 nm and 700 nm separated by 100 nm with length 5 µm and thickness 30 nm or 50 nm arranged in a periodic order (bi-component magnonic crystals, MCs) and according to the Fibonacci sequence (magnonic quasicrystals, MQs) into ribbons with separations 10 µm, 1.5 µm, and 0.76 µm were considered. Hysteresis loops measured with longitudinal magneto-optical Kerr effect microscope show reversal process with two main phases separated by a plateau phase. Increase of separation between ribbons stretches magnetization reversal process, same as increase of the wire thickness which also influence plateau phase length, also an order of stripes has influence on plateau phase position. Monte Carlo simulations of magnetic dipoles confirm shape of hysteresis loops and suggested need for implementation of scaling factor of demagnetizing field value. Calculated volume average demagnetizing fields and shape anisotropy in MCs and MQs under consideration explain main characteristics of the hysteresis in MCs and MQs, influence of stripe thickness and separation between ribbons.

Poster Session B

Poster B

P-B.029

Magnetization reversal in radially distributed nanowire arrays

C. Garcia Garcia, W. O. Rosa, J. Garcia, P. Vargas, J. A. Lopez, B. Hernando, V. M. Prida, C. A. Ross

Text The magnetic properties of radially-oriented Co, Ni, and CoNi alloy nanowires synthesized by pulsed electrodeposition into porous alumina structures are measured and compared with those of similar nanowires grown in a planar geometry. The alloy composition affects the anisotropy axis direction, which is determined by the balance between the magnetocrystalline and shape anisotropies, lying transverse to the nanowires for Co samples and along the nanowire axis for Ni. Monte Carlo simulations were performed to model the magnetic hysteresis of the radially-oriented and planar geometry nanowires using an approach based on a conical distribution of
anisotropies. The model provides an excellent fit compared with experimental hysteresis loops.

Poster Session B

Poster B

P-B.030

Magneto-Optical Probe Magnetic Field Sensor Based on Magnetoplasmonic Crystal

V. Belyaev, A. Grunin, V. Rodionova, A. Fedyanin

Text Development of magnetic field sensors are valuable, important and rapidly development part of modern science. Using magnetic sensors for magnetic cardiography and tomography applications requires precision measurements of magnetic field with magnitude of 10 nT for characterizing the stray fields of biological objects. The sensitivity of sensors based on magneto-optical (MO) effects in reflection geometry is not enough for measuring low magnitudes but it can be increased by excitation of surface plasmon-polaritons (SPPs) on metal-dielectric interface which leads to appearance of resonant MO effects which increase the polarization plane rotation or changing the intensity of reflected light due to maximization of adsorption of light in media. Thereby MO effects can be enhanced by excitation of SPPs in magnetoplasmonic crystals (MPlCs) – multilayer structures fabricated of noble and ferromagnetic layers on substrate with 1D diffraction grating which allow designing local and high sensitive AC and DC magnetic field sensors.
Developed sensor based on MPlC utilized transverse MO Kerr effect enhanced by excitation of SPPs. The sensor unites the principles of magnetomodulation technique with a possibility of using optical radiation spot as a probe. This approach provides high sensitivity at very small volume of media defined by diffraction limit and penetration depth of optical radiation into MPlC. Experimentally measured sensitivity equals to 10^-5 Oe at a spot size of 1 mm^2.

Poster Session B

Poster B

P-B.031

Magneto-dynamic properties of La0.7Sr0.3MnO3/SrTiO3 (111) probed by Ferromagnetic Resonance

S. Singh, T. Bolstad, I. Hallsteinsen, T. Tybell, E. Wahlström

Text We have studied the magneto-dynamic properties of pulsed laser deposited epitaxial La0.7Sr0.3 MnO3/SrTiO3 (111) ultrathin thin films by rotationally dependent X-band field swept Ferromagnetic Resonance (FMR) spectroscopy. Apart from the main mode, we also observe a number of substantially weaker modes with higher magnetic anisotropy attributed to interface and surface regions of the sample. The main (bulk) mode is found to have a weak crystalline magnetic anisotropy (effective field variation of < 1 Oe), with six-fold symmetry along in-plane easy crystallographic directions [1-10], and [11-2]. We do also observe a stronger uniaxial anisotropy of this mode with a symmetry that coincides with the step direction of the sample. The weaker interface / surface modes are found to have much stronger in-plane anisotropy that coincide with the symmetry of the main mode. Temperature dependent measurements indicate a higher Curie temperature for the mode assigned as interface than for the bulk mode and the surface mode. We will also discuss the case of a surface mode with uniaxial anisotropy found in some samples.

Poster Session B

Poster B

P-B.032

Magneto-optical investigation of FeRh nanostructure arrays

J. A. Arregi, L. Vojáček, J. Líška, O. Wojewoda, M. Horký, L. Flajšman, M. Urbánek, V. Uhlíř

Text The FeRh alloy undergoes a first-order metamagnetic phase transition from antiferromagnetic (AF) to ferromagnetic (FM) order at 360 K, representing an interesting material platform where magnetic order can be controlled via several driving mechanisms. While FeRh has been intensely investigated in the form of a thin film, its behavior when confined to the nanoscale has been studied only scarcely [1]. Here, we have patterned FeRh films into arrays of sub-micron structures and investigated their phase transition characteristics via vectorial magneto-optical Kerr effect. By focusing the laser spot to a region ranging from 500 nm to several tens of microns, we determine the temperature-dependent magnetization behavior of single nanostructures as well as arrays. For structure sizes below one micron, we observe the suppression of the phase-separated state and a pronounced supercooling effect in the FM-to-AF transition, in line with our previous findings in FeRh wires [1]. The thermal behavior associated with supercooling is studied by performing statistics on arrays. We also study the spin reorientation of magnetic moments at the transition, which is dependent on the strain state of FeRh [2]. In particular, we investigate the emergence of perpendicular magnetic anisotropy, largely suppressed in films due to magnetostatic effects.

[1] V. Uhlíř, J. A. Arregi, and E. E. Fullerton, Nat. Commun. 7, 13113 (2016)
[2] C. Bordel et al., Phys. Rev. Lett. 109, 117201 (2012)

Poster Session B

Poster B

P-B.033

Magnetocaloric effect in Gd_2O_3 electrospun nanofibers

P. D. H. Yen, A. M. Grishin, N. P. Markova, T. D. Thanh, S. C. Yu

Text In this work we evaluated highly crystalline Gd2O3 nanofibers with a large length-to-diameter aspect ratio synthesized by electrospinning method.[1] Gadolinium oxide precursors solution was prepared by dissolving gadolinium nitrate in deionized water mixed with ethanol with the ratio of ethanol:water=2:1. Polyvinyl pyrrolidone was added to the mixture to increase its viscosity to level appropriate for electrospinning. Viscous solution was ejected from a plastic syringe with a metallic needle at a constant rate of 0.5 ml/h in electric field of 1.2 kV/cm applied between the needle and aluminum foil collector. After 1 hour of electrospinning, bead-free mat of fibers was collected, dried at 100^{o}C/24h in air then calcined in air at 800 ^{o}C for 1 hour. Structure of Gd_2O_3 nanofibers appeared to be a single phase C-type cubic. Gd_2O_3 fibers show superparamagnetic behavior and high $1/T_1$ and $1/T_2$ proton NMR relaxivities were observed in Gd_2O_3 fibers capped with diethyleneglycol (DEG). Magnetocaloric properties of Gd_2O_3 nanofibers were evaluated from indirect measurements of isothermal magnetization data. At 5 K pure Gd_2O3 nanofibers fabric exhibits entropy change of 28 J/kgK at Δ H=7 T. Strong MCE exhibits crystalline Gd_2O_3 nanofibers as a prospective refrigerating agent for micro- and nano-electromechanical systems.

Poster Session B

Poster B

P-B.034

Magnetostriction Behaviors of Ni-Fe(110) and Ni-Co(110) Single-Crystal Thin Films Under Rotating Magnetic Fields

K. Serizawa, M. Ohtake, T. Kawai, M. Futamoto, F. Kirino, N. Inaba

Text Soft magnetic films have been studied for applications like magnetic sensors. Magnetostriction gives an influence on the device performances. To investigate the relationship between magnetic anisotropy and magnetostriction behavior, it is useful to employ single-crystal magnetic alloy films with different compositions. In the present study, fcc(110) single-crystal films of $Ni_{100-x}Fe_x$ and $Ni_{100-y}Co_y$ (x = 0-20, y = 0-100 at.%) are prepared on Cu/Pd/MgO(110) substrates. The magnetostriction is measured by using a cantilever method under in-plane rotating magnetic fields up to 1.2 kOe. Two-fold symmetry in in-plane magnetic anisotropy is observed for all the films. The magnetostriction waveform of $Ni_{80}Fe_{20}$ film is deformed from an ideal sinusoidal shape, when the magnetic field is lower than 0.3 kOe. The waveform approaches sinusoidal with further increasing the magnetic field. The magnetization seems to keep its direction along the in-plane easy magnetization direction when the magnetic field is lower than 0.4 kOe (saturation field of $Ni_{80}Fe_{20}$ film). The waveform deformation can be related to the angle difference between applied field and magnetization directions. Similar magnetostriction behaviors are recognized for the $Ni_{100-y}Co_y$ films. The deformation is more enhanced with increasing the strength of magnetic anisotropy (with increasing y value). The magnetostriction behavior under rotating magnetic fields is strongly influenced by the strength of magnetic anisotropy.

Poster Session B

Poster B

P-B.035

Metastable fcc Fe thin films for focused ion beam magnetic patterning

M. Urbánek, L. Flajšman, V. Křižáková, M. Horký, J. Gloss, M. Schmid, V. Peter

Text Focused ion beam (FIB) irradiation of metastable $Fe_{78}Ni_{22}$ thin films grown on Cu(100) substrates [1] is used to create ferromagnetic, body-centered-cubic patterns embedded into paramagnetic, face-centered-cubic surrounding. The structural and magnetic phase transformation can be controlled by varying parameters of the transforming gallium ion beam. The focused ion beam parameters as ion dose, number of scans, and scanning direction can be used not only to control a degree of transformation, but also to change the otherwise four-fold in-plane magnetic anisotropy into the uniaxial anisotropy along specific crystallographic direction. This change is associated with a preferred growth of specific crystallographic domains [2].
We study static and dynamic magnetic properties of the FIB transformed areas in metastable films grown on Cu(100) single crystals and also grown on hydrogen-terminated Si(100) with 130 nm thick buffer layer. We show that these films are ideal candidates for rapid prototyping of magnonic devices such as spin-wave wavegudes and magnonic crystals.

[1] J. Gloss, et al. , Appl. Phys. Lett. 103, 262405, (2013)
[2] M. Urbánek, et al. , arXiv:1803.04348, (2018)

Poster Session B

Poster B

P-B.037

Micromagnetic modeling and correlation analysis of magnetic microstructure in nanocrystalline thin films

A. Izotov, B. Belyaev, P. Solovev, N. Boev

Text Thin nanocrystalline films belong to the class of magnetically soft nanostructured materials, which properties are studied widely because of great prospects of their practical applications [1]. Among various characterizing techniques of such materials, the correlation magnetometry is an interesting method, which is now actively developing [2]. This method is based on the interpretation of microscopic properties of nanostructured ferromagnets from an analysis of the integral magnetization curve behavior. The existence of a direct link between correlation and microscopic parameters in nanostructured materials gives a principal opportunity to evaluate microstructural and magnetic parameters of the samples. The determination of this connection is a very complex and important task, to solve which experimental and theoretical studies are needed.
In this work we have studied by micromagnetic modeling the correlation between magnetic microstructure, local ordering of the magnetic moments, microstructural and magnetic properties of thin films composed of particles with randomly oriented easy axes of magnetization.
This work was supported by the Ministry of Education and Science of the Russian Federation, №RFMEFI60417X0179.

References
1. J. Petzold, *J. Magn. Magn. Mater.* **242–245** (2002), 84.
2. R.S. Iskhakov, V.A. Ignatchenko, et al., *JETP Letters*, **78** (2003), 646.

Poster Session B

Poster B

P-B.038

Microwave measurements of thin ferromagnetic films by ferromagnetic resonance and transmission-reflection techniques

A. Shiryaev, K. Rozanov, S. Bobrovskii, S. Maklakov, A. Osipov, S. Vysulin, A. Kevraletin, A. Granovsky

Text The ferromagnetic resonance (FMR) technique is frequently employed to measure the microwave magnetic characteristics of materials due to its high sensitivity. However, materials are used in a demagnetized state in most practical applications. The presentation is devoted to studying the transition to magnetized state by transmission-reflection (TR) technique under external magnetic bias and comparing the data obtained by TR and FMR techniques. The samples under study are thin cobalt films produced by magnetron sputtering onto a flexible mylar substrate. The films have magnetic in-plane anisotropy, so the microwave measurements are made in two perpendicular directions. Magnetometric measurements are also carried out. The quantitative agreement of the data obtained by the techniques is observed. In the absence of external magnetic bias, two resonances are observed in the measured by TR technique frequency dependence of permeability. Also traces of these resonances are present on FMR data. The high-frequency resonance disappears under magnetic bias of 400 Oe, when, according to magnetometric data, the film becomes saturated. From the behavior of the frequency dependence under low magnetic bias, the conclusion is made that the high-frequency resonance is due to the presence of a domain structure, and the low-frequency resonance is related to the uniform ferromagnetic resonance.

Poster Session B

Poster B

P-B.039

Mn_5Ge_3 thin film contacts for semiconductor spintronics

H. Funk, M. Kern, I. Fischer, J. Schulze, J. van Slageren

Text Electric spin-injection into semiconductors requires a suitable ferromagnetic contact-material. For successful spin-injection and -detection, contacts need to possess both, suitable magnetic and electric properties. Furthermore, integration with established technology requires materials and processes that are compatible with current semiconductor manufacturing technology. The ferromagnetic germanide Mn_5Ge_3 has been shown to fulfill the physical requirements for spin-injection and -detection. We report on the solid-phase epitaxial growth of thin (thickness d = 16 nm) layers of Mn_5Ge_3. The preparation process implements a self-aligned germanidation process similar to processes used in the nonmagnetic contact formation for state of the art semiconductor devices. Prepared samples are studied for their magnetic and electrical properties. A superconducting quantum interference device magnetometer is used to determine the magnetic properties of the Mn_5Ge_3-films. The vital interface properties between the Mn_5Ge_3 and Germanium substrate are studied electrically and using transmission electron microscopy. Results from spin-injection through Mn_5Ge_3 contacts are shown. The prepared layers show properties that allow direct use for spintronic devices. A first application for such devices may be the study of interactions between spin currents and organic quantum bits.

Poster Session B

Poster B

P-B.040

Model hard-soft magnetic nanocomposites produced by nanolithography

I. de Moraes, Y. Hong, C. Naud, S. Le Denmat, V. M. T. S. Barthem, T. Devillers, N. Dempsey, D. Givord

Text Hard-soft nanocomposites offer a potential solution for permanent magnet fabrication with reduced rare earth content. In principle a high energy product magnet can be obtained combining soft material of high magnetization with hard material with high coercivity[1]. The main challenge is the nanoscale control (size and shape) in order to optimize exchange and dipolar coupling and thus retard magnetization reversal. Here we report on an original route for the preparation of model hard-soft nanocomposites, namely nanolithography, combined with thin film deposition. The level of control afforded reduces the gap between real samples and micromagnetic simulations [2].
The systems produced consist of elongated Co and FeCo nano-rods (thickness = 5 - 10 nm, width = 20 - 30 nm, length = 400 nm and inter-rod distance of the order of twice the width), produced by e-beam lithography, embedded in a NdFeB thin film matrix (<50 nm). We present both global (VSM-SQUID) and local (MFM) magnetic measurements, the latter performed using an in-situ pulsed field ($\mu_0 H_{max} \sim 4$ T). The magnetic results are related to characteristics of the nano-structures, derived from TEM imaging.

[1] Kneller, E. F. & Hawig, R., The exchange-spring magnet: a new material principle for permanent magnets. IEEE Trans. Mag 27,3588–3560 (1991).
[2] Skomski, R., et al. ,Geometry dependence of magnetization reversal in nanocomposite alloys. JOM, 66(7), 1144-1150(2014).

Poster Session B

Poster B

P-B.041

Modification of local structure and its influence on magnetic properties of nanopatterned Co/Pd multilayers

A. Zarzycki, A. Maximenko, M. Sikora, M. Marszalek

Text We present the results of local structure analysis of nanopatterned Co/Pd multilayers with strong perpendicular magnetic anisotropy based on EXAFS spectroscopy. The patterning was performed using TiO2 nanotubular (TiNT) templates obtained by anodization process. The [Co0.3nm/Pdt]15/Pd10nm (t = 0.6 and 1.0 nm) multilayers were deposited on TiNT templates forming thin film with antidots and on flat silicon wafers. EXAFS analysis shows a strong enhancement of the atomic intermixing in nanopatterned samples with respect to that observed in flat analogues. Surprisingly, atomic intermixing does not show a significant influence on perpendicular magnetic anisotropy. However, an increase of coercivity for nanopatterned samples is clear. It is attributed to the spread of antidot pinning sites. A change of reversal magnetisation mechanism from domain wall motion for flat samples to nucleation and rotation for nanopatterned samples is observed. All these features are predominantly caused by patterning and changes in morphology, while the thickness of Pd layers seems to be a minor effect. The studies of local structure and magnetic properties were complemented with X-ray diffraction and reflectivity as well as with SEM imaging.

This work was partially supported by Polish National Science Centre grants UMO 2015/19/D/ST3/01843 and UMO-2014/13/N/ST8/00731. The EXAFS experiments were performed on the Super-XAS beamline at the Swiss Light Source, Paul Scherrer Institut, Villigen, Switzerland.

Poster Session B

Poster B

P-B.042

Modification of the perpendicular anisotropy in synthetic antiferromagnets by global and local ion beam irradiation

M. Lenz, L. Koch, F. Samad, P. Arekapudi, L. Fallarino, O. Hellwig

Text We investigate sputter deposited synthetic antiferromagnets consisting of Co/Pt multilayer-blocks with perpendicular anisotropy. Repeated multilayer-blocks are antiferromagnetically coupled to each other via Ru interlayers. This complex sample structure allows an exact tuning of the perpendicular anisotropy, interlayer exchange and magnetostatic energy contributions: In fact by varying either the number of Co/Pt bilayer repeats (X) or the number of multilayer-blocks (N), our sample system develops various magnetic phases and 3-dimensional textures [1].
Interestingly, ion beam irradiation is a powerful technique to change the balance in between the energy contributions mentioned above, by globally or locally modifying the energetic landscape mainly due to intermixing at selected interfaces [2]. By taking advantage of this technique, we successfully achieve the stabilization of a rich variety of magnetic phases in a controlled manner. More importantly, by local irradiation one can achieve a lateral coexistence of different magnetic phases within one and the same sample. Therefore we present our investigations of globally and locally irradiated synthetic antiferromagnets with a strong emphasis on the magnetization reversal process, as well as magnetic domain state evolution under the application of an external magnetic field.

[1] O. Hellwig et al., J. Magn. Magn. Mater. 319, 13 (2007)
[2] C. Chappert et al., Science 280, 1919 (1998)

Poster Session B

Poster B

P-B.043

Modulation of uniaxial anisotropy in thin Permalloy films driven by artificial local corrugation of the substrate

I. Turčan, L. Flajšman, O. Wojewoda, M. Vaňatka, M. Urbánek

Text In the field of magnonics, there is an increasing interest in the development of functional spin-wave devices with unique properties. These devices allow us to control the spin wave flow and are needed for future spin-wave based information processing. Conventionally used approaches rely on planar magnonic structures, where the magnetic properties are exclusively given by the intrinsic parameters of used materials and thus properties like uniaxial magnetic anisotropy cannot be directly controlled. In our work we exploit recently presented approach of inducing the effective magnetic interaction by the curvature to the system [1]. The corrugated structures on different substrates are prepared by focused ion beam milling and by focused electron beam induced deposition. Thin Permalloy films grown on such modified substrates show a dominant uniaxial anisotropy. By changing the depth and period of the modulation, we are able to control the uniaxial anisotropy constant. This eventually leads to the spatial modulation of uniaxial anisotropy.
Curvature induced effects allow us to tailor the static and dynamic response of the structures with high degree of freedom for optimization. Correspondingly, micromagnetic simulations reveal possible engineering of a band structure of magnonic crystals by periodic modification of a planarity of the surface [2].

[1] K Chen et al. Phys. Rev. B, 86, 064432 (2012).
[2] A V Chumak et al. J. Phys. D: Appl. Phys. 50, 244001 (2017).

Poster Session B

Poster B

P-B.044

Multiferroic and photocatalytic activity of Y-deped BiFeO3 nanoceramics prepared by mechanical activation

H. Maleki

Text In this paper, structural, thermal and magnetic properties of BiFeO3 (BFO) and Bi1-xYxFeO3 (BYFO, x=0.05, 0.1, 0.15, 0.2 and 0.25) nanoceramics were investigated. Ceramics of BYFO solid solutions have been prepared by solid-state reaction followed by sintering. X-ray diffraction (XRD), Fourier transfer infrared spectroscopy (FTIR) and microstructural analysis showed that all as-prepared samples have single phase perovskite structure with space group R3C. Differential thermal analysis (DTA) indicated that TC (ferroelectric-para-electric transition) decreases with the addition of yttrium content. Optical properties of all as-prepared samples were studied by diffuse reflectance UV-vis spectroscopy. The results indicated that with increasing yttrium content, the optical band-gap decreases.The ferroelectric properties of BNFO nanoparticles were improved compared to the undoped bismuth ferrite. The photocatalytic activity of as-synthesized nanoparticles was also evaluated by the degradation of methyl orange (MO) under visible light irradiation and indicated that substitution of yttrium into the BFO structure increased the photocatalytic activity of products.

Poster Session B

Poster B

P-B.045

Multiferroic enhancement of La-doped bismuth ferrite rod-like nanoceramics

H. Maleki, M. Taraz, N. Badvi Delfard

Text In this work, the influence of lanthanum content on the structural, thermal and multiferroic properties of Bi1-xLaxFeO3 (x=0, 0.05, 0.1, 0.15, 0.2 and 0.25) nanorods prepared by hydrothermal method was investigated. Structural characterization and phase analysis were performed using X-ray diffraction (XRD) and Fourier transform infrared (FTIR) spectroscopy. The analysis of crystal structure revealed a single phase perovskite structure with space group R3C. Transmission electron microscope (TEM) observation showed a nonhomogeneous distribution of rod-like nanoparticles with the average diameter of ~40 nm and length of ~2μm. The ferroelectric Curie temperature was determined by differential thermal analysis (DTA). UV-vis spectra showed that the absorption coefficient and energy band-gap were decreased by increasing the lanthanum content. The ferroelectric properties of BiFeO3 (BFO) nanoparticles were improved by adding lanthanum into the structure of bismuth ferrite. Moreover, leakage current density curves show that lanthanum doping can significantly decrease the leakage current of bismuth ferrite nanorods. Finally, vibrating sample magnetometer (VSM) measurements indicated the weak ferromagnetic behavior at room temperature (RT) for as-prepared samples with x≤0.15. However, for the 20% lanthanum doping, a magnetic transition from weak ferromagnetic to anti-ferromagnetic is observed.

Poster Session B

Poster B

P-B.046

Nanopatterning of the magnetic Co/Pd thin films by the perforated oxide templates

A. Maximenko, A. Zarzycki, Y. Zabila, J. Kasiuk, J. Fedotova, M. Marszałek

Text A simple way of nanopatterned magnetic films (or antidots) fabrication is to deposit magnetic films on the porous templates like Al2O3 and TiO2. We have investigated the possibility to control the magnetic properties of hard magnetic Co/Pd films by nanopatterning. The modifications were performed by varying the antidots diameter between 5-180 nm. It was found that Co/Pd nanopatterned films preserve perpendicular magnetic anisotropy with the effective anisotropy constant Keff up to 2.8 erg/cc for 18 nm antidots on TiO2 and 2.1 erg/cc for 5 nm antidots on Al2O3. We verified the role played by the crystalline structure of porous and continuous films in magnetic properties. The observed increase of the coercive field HC for the antidots (up to 3.7 kOe) in comparison to the continuous film (HC =1.7 kOe) is related to the pinning of the magnetic moments on the edges of the pores. The increase of the pore size resulted in decrease of Keff and HC to about 1.2 erg/cc and 2.0 kOe, respectively. Also we found the transition of the magnetization reversal mechanism from the domain wall motion described by the modified Kondorsky model for the continuous films, to coherent rotation mode described by the Stoner-Wolhfarth model for the nanoporous films due to corresponding engineering of the porosity and/or pore size of the templates.
The support from the Polish National Science Centre grant 2014/13/N/ST8/00731 and project 2.44 of GPNI “Nanomaterials and Nanotechnology” is acknowledged.

Poster Session B

Poster B

P-B.047

$NiFe_2O_4$ Nano-Hollow Spheres with Improved Magnetic and Dielectric Properties

D. Mandal, K. Mandal

Text $NiFe_2O_4$ (NFO) is one of the most significant spinel ferrites due to its highly specific qualities such as low coercivity (H_C), high saturation magnetization (M_S), high Curie temperature (T_C), high electrical resistivity, low eddy current loss, and remarkable thermal and chemical stability. The cavity inside and large surface area of NFO Nano Hollow spheres (NHS) enhances their capability of capturing and delivering drugs and also multiple internal reflections increase their applicability as microwave absorbers.
Herein, an interesting study on NFO nano-hollow spheres (NHS) synthesized in solvothermal method has been reported. The morphological analysis evidences the sample to be nano-hollow spheres, shown in SEM and TEM micrographs. A temperature dependent M-H study of NFO NHS along with a comparison of magnetic properties between NFO NHS, Bulk NFO and NFO nanoparticles (NPs) has been performed. Study of magnetic properties shows NFO NHs as soft ferrimagnetic materials having M_S and H_C, 63.5(emu/g) and 116 Oe respectively. A detailed study on dielectric properties of NFO NHS has been carried out in this report. The study of the dielectric properties (calculated from impedance (Z) – phase (θ) data) gives information about the polarization behavior, conduction mechanisms and dielectric relaxation. Their variation with frequency (f) and temperature influences their applications for microwave devices e.g. in isolators, circulators etc.

Poster Session B

Poster B

P-B.048

Nuclear Inelastic Scattering and Density Functional Theory Studies of Spin Crossover Compound ligand [Fe(1,2,4-triazole)2(1,2,4-triazolato)](BF4)2

J. Wolny, V. Schünemann, L. Scherthan, H. C. Wille, K. Jenni, C. Strohm

Text Since it has been synthesized 24 year ago [1], the [Fe(trzH)2(trz)](BF4) complex is one the most investigated spin crossover systems [2]. It contains the 1D polymeric chains and reveals the spin transition with the hysteresis of 40 K. In order to obtain insight into its vibrational properties we performed Nuclear Inelastic Scattering (NIS) experiments at the temperatures corresponding to its high-spin and low-spin states [3]. The DFT calculations (B3LYP*/CEP-31 theory) for linear oligonuclear (n=7,9) models of the compound yielded the normal vibrations and electronic energies for high-spin and low-spin isomers of three different models, differing in the distribution of anionic trz- ligands and BF4- anions. On the basis of the obtained energies the structure exhibiting the centrosymmetric Fe(trzH)4(trz-)2 coordination core for each but the terminal irons is proposed. The the distribution of the BF4- anions in the structure is similar to that obtained on the basis of X-ray [4]. The NIS spectra of the parent complex diluted (10%) in the matrix of the corresponding Zn(II) complex show the change of the spectral pattern of the low-spin centres. That is shown, on the basis of the DFT calculations, to be the result of the change of the structure of the neighbours.

1. J. Kröber et al., Chem. Mater., 6, 1404 (1994).
2. A. Bousseksou et al., Chem. Soc. Rev., 40, 3313 (2011).
3. K. Jenni et al. Phys.Chem.Chem.Phys., 2017
4. A. Grosjean et al. Eur. J. Inorg. Chem., 796 (2013).

Poster Session B

Poster B

P-B.049

Analysis of magnetic properties for quantum Heisenberg chain systems in molecular materials

M. Rams, M. M. Rams, S. Chorazy, C. Näther

Text Hamiltonians for infinite magnetic systems, based on Heisenberg exchange, remain not solved analytically. For this reason various approximations or numerical extrapolations are usually applied to calculate magnetic susceptibility and specific heat for such systems. However, the number of models for which such approximations are readily available in literature in an easy-to-use form is very limited. We discuss two numerical methods that can be applied for a wide range of systems.
The first method is to use quantum Monte Carlo simulations, as implemented e.g. in the ALPS package. As example we present the analysis of properties for alternative spin chains (S = 7/2, s = 3/2) in $[Gd(pyridone)_2(H_2O)_4]$ $[Cr(CN)_6]$ H_2O [1]. The practical limitations of this method are also noted.
The second method, which can be used for solving strictly one-dimensional Hamiltonians, is based on density matrix renormalization group (DMRG) approach. As example of such calculations we present the analysis of magnetic and calorimetric data for $Ni(NCS)_2(bocaminopyridine)_2MeCN$, where zero-field splitting for the Ni (S = 1) Heisenberg chain has to be taken into account [2].

References
1. S. Chorazy, M. Rams et al. CrystEngComm, 20 (2018) 1271
2. S. Suckert, M. Rams, M.M. Rams, C. Näther. Inorg. Chem. 56 (2017) 8007

Poster Session B

Poster B

P-B.050

Calculation of spin-admixture parameter in organic-semiconductors from first principles

U. Chopra, S. Pandey, J. Sinova, E. R. McNellis

Text We present a method for calculation of spin-admixture in organic semiconductors (OSC) from first-principles theory. OSCs have become interesting candidates for spintronic materials owing to their small spin-orbit coupling (SOC) and its role in spin transport. It has been shown that SOC can be characterized by mixing of up- and down-spin states and is expressed by the spin-admixture parameter, γ^2 [1]. This parameter governs the probability of a spin-flipping as it hops between different sites. As for most OSCs, transport is described by hopping mechanism the spin-dependent properties are sensitive to γ^2 therefore it's important to determine it with high accuracy. However, there lacks a systematic study on the level of Density Functional Theory (DFT) to obtain this parameter. In this work, we use a methodical procedure to obtain precise values of γ^2. We perform fully relativistic DFT calculations based on the Zeroth Order Regular Approximation (ZORA) to obtain the SOC matrix elements. We demonstrate the effect of exchange-correlation functional on the admixture parameter,γ^2. Moreover, we generalize this approach under the Unrestricted DFT formalism. We find that γ^2 has a strong dependence on the exchange correlation functional used and tends to increase as the functional becomes more localized. This suggests that it is of great importance to select the exchange-correlation functional with care while determining γ^2.

Poster Session B

Poster B

P-B.051

Computational Study of the Magnetic Properties of Metal-Doped Boron Nitrogen Carbon Nanoribbon

J. Rufinus

Text The field of spintronics has been continuously attracting researchers. Tremendous efforts have been made in the quest to find good candidates for future spintronic devices. One particular type of material called graphene is under extensive theoretical study as a feasible component for practical applications. However, pristine graphene is found to be diamagnetic. Thus, a lot of research has been performed to modify the graphene-based structure to achieve meaningful magnetic properties. Recently, a new type of graphene-based one-dimensional material called Boron Nitrogen Carbon nanoribbon (BNCNR) has been of interest, due to the theoretical predictions that this type of material shows semiconducting or metallic property. Here we present the results of systematic ab-initio computational study of Metal-doped (Metal = V, Cr, or Mn) Zigzag BNCNR, the objective of which is to determine whether the presence of these dopants will give rise to ferromagnetism. We have found that the concentration and the atomic distance among the dopants affect the magnetic ordering of this type of material. These results provide a meaningful theoretical prediction of Metal-doped Zigzag BNCNR as one of basic candidates of future spintronic devices.

Poster Session B

Poster B

P-B.052

Effect of organic radicals on magnetic anisotropy and exchange coupling in Ni(II) metal-organic complexes

S. Spachmann, C. Koo, R. Bischoff, H.-J. Krueger, R. Klingeler

Text Strong magnetic coupling of transition metal ions with organic radicals in coordination complexes opens a route towards the design of high-spin magnetic molecular complexes by employing radical bridges between paramagnetic centers. We have studied experimentally magnetic coupling and anisotropy in a series of mono- and dinuclear Ni(II) metal-organic complexes by means of static magnetization and high-frequency/high field (B = 16 T) electron paramagnetic resonance (HF-EPR) measurements. Our data confirm strong effects by organic radicals. Magnetic coupling of the radical (S = 1/2) to Ni(II) (S = 1) is found to be strongly ferromagnetic, showing up in S = 3/2 and S = 5/2 ground states in the Ni(II) monomer and dimer, respectively, with $J_{Ni\text{-}rad}$ up to -500 K. While, the non-radical azopyridine-bridged Ni(II)-dimer has a singlet ground state with a weak antiferromagnetic intradimer coupling of $J_{Ni\text{-}Ni} \approx 20$ K. $J_{Ni\text{-}Ni}$ is of very similar magnitude in the radical bridged system which hence evolves a robust S = 5/2 ground state. Anisotropy in the non-radical Ni(II) monomer (dimer) is of the easy-plane type with D_{Ni} = 4.02 K and |E| = 0.32 K (10.9 K and 0 K). The g-factor amounts to g = [2.146, 2.144, 2.110]. Noteworthy, D changes sign in the radical bridged system towards axial anisotropy with $D_{5/2}$ = -0.87 K and |E| = 0.28 K.

Poster Session B

Poster B

P-B.053

Element-specific magnetic properties of mixed 3d-4f metallacrowns

A. Alhassanat, C. Gamer, A. Athanasopoulou, J. Sutter, L. Völker, C. Luo, H. Ryll, F. Radu, A. Sapozhnik, T. Mashoff, E. Rentschler, H. J. Elmers

Text Single molecule magnets (SMMs) comprising rare earth metals are of high interest because the unquenched orbital moments of the rare earth ions result in a large energy barrier for magnetization reversal. We investigate the magnetic properties of polynuclear 3*d* - 4*f* 15-MC-5 metallacrowns using X-ray magnetic circular dichroism of powder samples at a temperature of 7 K in a magnetic field of 7 T. The aim of this study is the tailoring of the magnetic anisotropy by chemical variation of the ligand field at the 4*f* site. The sum rule analysis reveals element-specific spin and orbital moments. For the evaluation of the spin moment we consider the expectation value of the dipole operator (T_z). The magnetic moments of the 3*d* transition metal ions are coupled antiferromagnetically to each other while the 3*d* - 4*f* coupling is comparatively weak. The spin and orbital moments of the rare earth ions decreased compared to the ionic values resulting from Hund's rules although the field-dependent magnetization indicates that the external field almost saturates the molecular moment. We explain the reduction of the orbital magnetic moment by a finite magnetic anisotropy. Considering an energy functional including magnetic anisotropy and Zeeman energy the orientational average reveals a magnetic anisotropy of 28 meV (340 K) in the case of Dy and 7 meV (85 K) in the case of Tb.

Poster Session B

Poster B

P-B.054

Fine scale analysis of Fe-implanted 6H-SiC by Atom Probe Tomography: Towards a Diluted Magnetic Semiconductor (DMS)

L. Diallo, A. Fnidiki, L. Lechevallier, F. Cuvilly, I. Blum, M. Viret, M. Marteau, D. Ayidi, A. Declémy

Text Great hopes are placed on diluted magnetic semiconductors (DMS) for new components due to the possibility of integrating charge and spin degrees of freedom in a single material1. Development of new components with both semiconducting and ferromagnetic properties can have many applications including magnetic random access memory (MRAM) and quantum computing2. In this work, we perform an atomic scale investigation of the Fe-implantation in single crystalline 6H-SiC substrates as a function of Fe content, the implantation temperature and the annealing temperature by means of Atom Probe Tomography (APT). APT investigations allow us to characterize the structure of the samples, the presence of nano-clusters and their core phase. The observed nanoscale structure was then correlated to the magnetic properties studied by Mössbauer spectrometry and SQUID magnetometry in order to determine the magnetic contribution of Fe atoms diluted in the matrix and the part due to the Fe rich nano-clusters. The aim is to select the sample (without clusters) for which the magnetism is only due to Fe diluted atoms with properties that could tend towards the properties of a DMS. Our results show an absence of nanoclusters in SiC matrix for as-implanted sample. Nanoclusters of 1-4 nm size range appear after the 900 °C annealing. After the 1300 °C annealing the nanocluster size increases up to 12 nm. The Fe3Si was found to the core of some clusters.

Poster Session B

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P-B.055

Guiding Molecular Spintronics Design Using First-Principles Multi-Scale Modeling

E. R. McNellis, U. Chopra, S. Müller, S. Egorov, R. Mahani, J. Sinova

Text The vast tunability of molecular materials and components holds great potential for advances in spintronics. In real molecular materials, spin dynamics are governed by the interplay of a range of phenomena, including electronic spin-orbit coupling, local magnetic fields, electron dynamics, morphological and geometric effects etc. This complexity poses a great challenge for theoretical modeling.
We have developed a multi-scale modeling framework for microscopic spin dynamics in realistic material models. Starting from comprehensive first-principles theory for single to tens of molecules, we reach bulk material scales using state of the art tight-binding, stochastic and classical models.
These techniques uniquely allow us to describe the subtle balance of influences on spin dynamics in various regimes, and to make quantitative predictions guiding experimental efforts to improve the design of molecular spintronics.
First targets for our methodology include fully first-principles spin dynamics in bulk Alq3, spin diffusion mechanics in several high-mobility polymer materials, the origin of the CISS effect, and, more generally, the role and characteristics of molecular spin orbit coupling in molecular spintronic phenomena.

Poster Session B

Poster B

P-B.056

High TMR at Room Temperature in Magnetic Tunnel Junctions with Phenalenyl-molecule Tunnel Barriers

N. Jha, C. Denker, A. Paryar, P. K. Vardhanapu, H. Mohamad, U. Martens, C. Helm, S. Mandal, M. Münzenberg

Text Phenalenyl (PLY) based molecules, which can be regarded as Graphene fragments are promising candidates for spintronic applications. Attempts to use open shell PLY molecules have been unsuccessful due to their instability. We investigated a new closed shell molecule, PLY with a Copper complex, for its spintronics suitability. TMR in various samples of PLY-Cu MTJs was determined by measuring the resistance across the MTJ under a high magnetic field during parallel and antiparallel configurations of the ferromagnets (FMs). Preliminary results show outstanding Magnetoresistance (MR) at room temperature. Our works demonstrate convincingly that spin-polarized currents can be injected into organic materials with reasonably high efficiency, providing strong evidence of spin polarized tunneling as the dominant transport mechanism in PLY-Cu based magnetic tunnel junctions, and the use of PLY-based molecules as a viable and scalable platform for building molecular-scale quantum spin memory and processors for technological developmen

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Poster B

P-B.057

Improved spin-ground states and molecular magnetism in FLO-SIC

K. Trepte, S. Schwalbe, R. Joshi, J. Kortus, J. Peralta, K. A. Jackson

Text An efficient method based on Fermi-Löwdin orbitals to correct the self-interaction error within DFT (FLOSIC) was recently proposed by Pederson and co-workers [1,2,3]
This method yields self-consistent Fermi-Löwdin localized orbitals with chemical meaning and, for the simple case of the local spin density approximation, it delivers improved total energies, ionization energies, and level ordering.
FLOSIC also improves the description of complex spin-ground states [4,5,6].
Within this contribution we present and analyze self-interaction free DFT calculations of magnetic properties based on the FLOSIC methodology for several cases, from atoms to complex molecular systems.

[1] M. R. Pederson et al., JCP, vol. 140, 121103 (2014)
[2] T. Hahn et al., JCP, vol. 143, 224104 (2015)
[3] T. Hahn et al., JCTC, vol. 13, 5823–5828 (2017)
[4] M. R. Pederson et al., JCP, vol. 144, 164117 (2016)
[5] D. Kao, JCP, vol. 147, 164107 (2017)
[6] D. Kao, MP, vol. 115, 552–559 (2017)

Poster Session B

Poster B

P-B.058

Iron(II) spin crossover systems viewed by the 57Fe nuclear probe

V. Schünemann

Text Mössbauer spectroscopy and synchrotron based nuclear resonance scattering are ideal tools to study electronic and dynamic properties of iron centers in chemical systems. We apply nuclear inelastic scattering (NIS) to study iron based vibrational modes in spin crossover (SCO) systems [1,2]. NIS has been used to detect iron based phonon modes in powders and in single crystals of iron(II) based spin crossover (SCO) compounds. Nuclear forward scattering (NFS) of SCO microstructures [3] has been applied to monitor the spin switch between the S=0 and S=2 state. Quantum chemical calculations based on density functional theory (DFT) serve to identify spin molecular modes, which are responsible for spin marker bands. Very recently, also ns-time resolved optical pump NIS/NFS probe experiments have been performed with SCO systems and first results will be presented.

1. J. Wolny, I. Faus, J. Marx, R. Rüffer, A. Chumakov, K. Schlage, H.-C. Wille and V. Schünemann, Magnetochemistry 2, 19 (2016)
2. K. Jenni, L. Scherthan, I. Faus, J. Marx, C. Strohm, M. Herlitschke, H.-C. Wille, P. Würtz, V. Schünemann and J. A. Wolny Phys. Chem. Chem. Phys. 19, 18880 (2017)
3. S. Rackwitz, I. Faus, B. Lägel, J. Linden, J. Marx, E. Oesterschulze, K. Schlage, H.-C. Wille, S. Wolff, J. A. Wolny and V. Schünemann, Hyperfine Interact. 226, 667 (2014)

Poster Session B

Poster B

P-B.059

Kondo effect of a singly occupied molecular orbital in bis(phthalocyaninato)-dysprosium double decker molecules

T. Frauhammer, E. Inami, M. Yamaguchi, J. Chen, T. K. Yamada, M. Ruben, W. Wulfhekel

Text Double decker bis(phthalocyaninato)-dysprosium single molecule magnets adsorbed on Au(111) have been investigated using low temperature scanning tunneling microscopy. The dysprosium 3+ ion in its center has an expected total angular momentum of J = 15/2. Molecules have been sublimed in UHV onto clean Au(111) surfaces and are rather mobile such that they preferentially adsorb on step edges and ellbow sites. In agreement with previous reports for rare earth metal-organic complexes, no direct magnetic signal by the 4f electrons could be detected in scanning tunneling spectroscopy. Interestingly, all adsorbed molecules show a clear Kondo resonance on the ligands with a Kondo temperature of about 5 K. This indicates an odd number of electrons residing in the molecular orbitals of the ligands. This is similar to previous results by T. Komeda et al. for the terbium complex, where a Kondo resonance with a higher Kondo temprature of 31 K was observed on the ligands. Assuming there is a strong enough exchange coupling between the unpaired spin on the ligands and the 4-f angular momentum of the dysprosium central ion, the observed Kondo effect might be used as a means to indirectly address the 4-f magnetic moment.

Poster Session B

Poster B

P-B.060

Magnetic chains of Fe_3 clusters in $\{Fe_3YO_2\}$ butterfly molecules

J. Rubín, L. Badía-Romanos, F. Luis, V. Mereacre, D. Prodius, A. Arauzo, F. Bartolomé, J. Bartolomé

Text Clusters in molecules with transition metals M and rare earths Ln can show single molecule magnet (SMM) behaviour. While M provides most of the cluster magnetization, Ln metals generate an enhanced magnetic anisotropy via the intracluster M-Ln interactions. The use of Y as a non-magnetic substitution for Ln in isostructural compounds provides a way to explore possible interactions between the transition metals. The "butterfly" molecule $Fe_3Y(\mu_3{-}O)_2(CCl_3COO)_8(H_2O)(THF)_3$ (in brief $\{Fe_3YO_2\}$) includes three close Fe^{3+} ions which build a robust Fe_3 cluster with a strong intracluster antiferromagnetic exchange $J = -50$ K and a total spin S=5/2 [1]. We present heat capacity and *DC* susceptibility measurements below 2 K, which show the cluster anisotropy and intercluster interactions. However, no phase transition to a long-range magnetically ordered phase is observed down to 20 mK. The intercluster interaction is analysed in the framework of the one-dimensional Blume-Capel model with an antiferromagnetic chain exchange constant $J' \approx -0.04$ K, and a uniaxial anisotropy with parameter $D \approx -0.56$ K. This is proposed to be associated to chains of Fe_3 clusters oriented along the shortest intercluster distances displayed by the crystal structure of $\{Fe_3YO_2\}$. *AC* susceptibility measurements reveal magnetic relaxation below 5 K with quantum tunnelling of the magnetization below 0.2 K, and a thermally activated process for higher temperature.
[1] J. Bartolomé *et al.*, *Phys. Rev. B* **80**, 014430 (2009).

Poster Session B

Poster B

P-B.061

Magnetic coupling of cementite nanoparticles within double-wall carbon nanotubes

W. Nieto, J. Chimborazo, A. Briones-Leon, O. Domanov, H. Shiozawa, T. Pichler, P. Ayala, D. Niebieskikwiat

Text Studying the novelty of magnetism in carbon nanotubes is still intriguing and it has not been completely explored, despite a number of promising technological applications. In this study, we focus on the magnetic properties of bundles of double-walled, metallic carbon nanotubes with encapsulated cementite (Fe_3C) nanoparticles of ~ 3 nm in length inside their hollow core. These nanoparticles are not unintentional impurities, but have been deliberately introduced to fill the nanotubes with ferromagnetic material. Results of VSM magnetometry of the filled nanotubes give an anisotropy constant of ~ 3 x 10^6 erg/cm^3, much larger than the anisotropy of free cementite nanoparticles, indicating a strong magnetic coupling of the nanoparticles with the nanotubes. On the other hand, the calculated activation volume for magnetization reversal, of ~ 400 nm^3, shows that around 300 nanoparticles of cementite are mutually coupled through the conduction electrons of the nanotubes. Considering a spin diffusion length of 130 nm along the direction of the nanotubes, the activation volume suggests that magnetic coupling also occurs between neighboring nanotubes in the direction perpendicular to their axis, with a perpendicular magnetic correlation length of ~ 5-6 nm, i.e. involving four parallel nanotubes.

Poster Session B

Poster B

P-B.062

Magnetic properties of Bis-Lanthanoates

S. Felton, K. Esien, E. McCourt, P. Nockemann

Text Magnetic ionic liquids (MILs) are a class of ionic liquid incorporating one or more magnetic atoms into the anion or cation of the ionic liquid, endowing the ionic liquid with magnetic properties alongside the existing properties of ionic liquids. MILs have applications in e.g. fluid-fluid separations, electrochemistry, and polymer chemistry.

In this study three different types of bis-lanthanoates, that exist in different phases, have been synthesised and characterised (Ln = lanthanide): 1) imidazolium lanthanide acetate – $[C_4Mim]_2[Ln_2(OAc)_8]$ – forms a crystalline solid at room temperature, 2) phosphonium lanthanide acetate – $[P_{666\ 14}]2[Ln_2(OAc)_8]$ – is in a solid glassy state, and 3) phosphonium lanthanide octanoate – $[P_{666\ 14}]_2[Ln_2(Oct)_8]$ – is an ionic liquid. X-ray diffraction of the crystalline solid
1) confirm that the Ln(III) ions form dimers, bridged by carboxyl groups, but cannot yield information about samples 2) and 3) since these lack long-range order. SQUID magnetometry studies of samples where the lanthanide is dysprosium, show that all three samples have effective magnetic moments consistent with non-interacting Ln(III) ions at room temperature, but deviate from this behaviour in the same way below 50 K. The experimentally determined magnetic susceptibility has been compared to a simple model for a system with two Dy(III) ions; the implications from these fits for the magnetic interactions and the structure of the ionic liquid and glass will be discussed.

Poster Session B

Poster B

P-B.063

Magnetodyanmics in endohedral-fullerene-based molecular magnets

S. Avdoshenko, A. Popov

Text A system dynamics is a merit of the system's complexity. In the single molecular magnets research, there are many plausible contributions to the dynamics. For example, even before magnetometry beginnings, molecular dynamics will control molecular orderings in bulk or surface arrays. During magnetometry itself, the spin-polarized electronic state of magnetic centers will evolve accordingly to a quantum equation of motions. These quantum dynamics is coupled strongly to local atomic vibrations, which has a strong contribution to the magnetic stability in return.
In this contribution, we touched in briefly these dynamical processes in the application to endohedral-fullerene-based molecular magnets. We discussed how molecular dynamics research can help to understand what structural elements are to expect on the metal and dielectric surfaces in the experiments with functionalized endohedral-fullerenes. We proposed a general phenomenological model based on theories for open quantum systems to predict spin relaxation dynamics with and without explicit phonons in the model Hamiltonian.

Poster Session B

Poster B

P-B.064

Molecular Magnetic Tunnel Junctions Based On Self Assembled Monolayers

B. Quinard, S. Delprat, M. Galbiati, M. Mattera, S. Tatay, A. Forment-Aliage, F. Petroff, P. Seneor, R. Mattana

Text Molecular spintronics has opened novel and exciting opportunities in terms of functionalities for spintronics devices. Among them, it was shown that spin dependent hybridization at the metal/molecule interface could lead to a radical tailoring of spintronics properties [1].
In this direction Self-Assembled Monolayers (SAMs) appear to be a very promising candidate thanks to their impressive molecular scale crafting properties. Despite all the promising possibilities to build molecular spintronic devices, up to now less than a handful of experiments on the use of SAMs as spin-dependent tunnel barriers have been reported [2], still already highlighting promising potential at low temperatures [3].
In an effort to achieve room temperature spin signal, we have developed magnetic tunnel junctions based on alkanethiol and biphenyl dithiol as, tunnel barrier and conventional “3d” ferromagnetic electrodes (such as Co, NiFe…) for which we have developed a process to recover the oxidized ferromagnet from oxidation [4].
We will discuss the magnetoresistance effects observed at room temperature (up to 10%) and the influence of SAMs electronic structure on TMR.

[1] C. Barraud et al. Nature Physics 6, 615 (2010)
[2] W. Wang et C.A. Richter, Appl. Phys. Lett., 89, 153105 (2006) ; J.R. Petta et al., Phys. Rev. Lett., 93, 136601
[3] M. Galbiati et al., Adv. Mater. 24, 6429 (2012).
[4] M. Galbiati et al., AIP advances 5, 057131 (2015)

Poster Session B

Poster B

P-B.065

Molecular dynamics study of the vibrational properties of spin-crossover materials

R. Rauter, C. Mücksch, H. M. Urbassek

Text Spin-crossover materials exhibit the unique ability to switch between a low-spin and a high-spin state, indicating their potential as possible organic storage devices. A switch between the low and the high spin state is reflected by a frequency shift in the phonon density of states. This makes the phonon density of states an interesting tool to analyze spin-crossover materials. The calculation of crystal or molecular nanostructures built of spin-crossover materials exceeds the limit of DFT calculations, due to the large number of atoms that need be considered. We use a molecular dynamics approach to calculate the phonon density of states for both spin states. The force constants required for the simulation are provided by DFT calculations. The phonon density of states is then determined by calculating the Fourier-transform of the velocity autocorrelation function. We report on the progress of the molecular dynamics simulations of spin crossover materials, particularly focusing on the calculation of the phonon density of states. The calculated phonon density of states is compared to experimental nuclear-inelastic scattering spectra and results from DFT calculations.

Poster Session B

Poster B

P-B.068

Oxygen Impurities Link Bistability and Magnetoresistance in Organic Spin Valves

I. Bergenti, F. Borgatti, A. Riminucci, P. Graziosi, V. Dediu

Text Vertical crossbar devices based on manganite and cobalt injecting electrodes and a metal-quinoline molecular transport layer are known to manifest both magnetoresistance (MR) and electrical bistability. The two effects are strongly interwoven, inspiring new device applications such as electrical control of the MR and magnetic modulation of bistability. To explain the device functionality, we identify the mechanism responsible for electrical switching by associating the electrical conductivity and the impedance behavior with the chemical states of buried layers obtained by in operando photoelectron spectroscopy. These measurements revealed that a significant fraction of oxygen ions migrate under voltage application, resulting in a modification of the electronic properties of the organic material and of the oxidation state of the interfacial layer with the ferromagnetic contacts[1]. Variable oxygen doping of the organic molecules represents the key element for correlating bistability and MR, and our measurements provide the first experimental evidence in favor of the impurity-driven model describing the spin transport in organic semiconductors in similar devices.

[1]I. Bergenti et al, ACS Appl. Mater. Interfaces, 2018, 10 (9), pp 8132–8140

Poster Session B

Poster B

P-B.069

Photomagnetic Control of Liposomal Drug Release with Radical Pair Model

H. Nakagawa

Text Up to the present, so many liposomal nanocapsules have been developed as biocompatible carriers for drug-release technologies. It goes without saying that liposomal membrane structures must be stable enough in the blood flow for the purpose of the reduction in side effects, but are subsequently able to release encapsulated materials based on the destabilization and/or effective fusion reaction of the membranes in the target tissue. Consequently, liposomal membrane permeability is a much more beneficial tool for drug-release controlling rather than membrane fusion/destabilization. This is because free radicals can readily pass through every liposomal lipid bilayer, although pure liposomal membranes can not transport encapsulated materials and ions from the inner to the outer water phase and vice versa.
In this study, various types of liposomes equipped with possible magnetic controls were prepared for evaluating the drug-release potentials with radical pair mechanisms on the photochemical reaction developing in the model membrane. As it turned out, a close connection between magnetic field effects and the escape-radical releases was observed depending on the field strength. The liposomal drug-release technology with magnetic controls must be one of the most adaptable drug-delivery system; therefore, further detailed evaluations of the methodology are now under investigation.

Poster Session B

Poster B

P-B.070

Reliable spin states from FLO-SIC DFT

S. Schwalbe, K. Trepte, J. Richter, T. Hahn, K. A. Jackson, J. Kortus

Text Coordinated molecules (e.g. octahedral Fe^{2+} complexes) are particularly interesting as they may exhibit a spin-crossover (SCO) transition. SCO transitions describe processes where the system switches the magnetic ground state (e.g. low spin to high spin and vice versa) due to weak external changes like small temperature-, pressure- or magnetic field variations.
Therefore, these kind of system might be promising candidates for molecular switches or data storage devices.

Theoretical investigations are needed for a more precise understanding of the underlying phenomena in such molecular systems. Unfortunately, existing semilocal exchange- correlation functionals used in density functional theory (DFT) calculations are known to fail in predicting the energy differences between the different spin states of these systems.

The Fermi-Löwdin orbital self-interaction correction (FLO-SIC) [*1*,*2*,*3*] is applied to selected Fe^{2+} containing complexes and benchmarked against standard DFT and diffusion Monte Carlo (DMC) results. The correct treatment of exchange within the FLO-SIC methodology leads to improved description of spin states. Based on these results, the effect of FLO-SIC on exchange-coupling constants is discussed further.

[1] M. R. Pederson et al., JCP, vol. 140, 121103 (2014)
[2] T. Hahn et al., JCP, vol. 143, 224104 (2015)
[3] T. Hahn et al., JCTC (2017)

Poster Session B

Poster B

P-B.071

Single-ion magnets with very high magnetization reversal barrier representing DyO+ ion confined in the apatite lattice

M. Zykin, A. Eliseev, E. Gorbachev, P. Kazin

Text In this work we report a new single-ion magnet representing isolated DyO^+ ions dispersed in a stable inorganic diamagnetic matrix of alkaline-earth phosphates with apatite structure. Calcium and strontium hydroxyapatites with a partial substitution of metal cation for dysprosium were synthesized by a solid state reaction. Dysprosium is coordinated by 7 oxygen atoms in such compounds but with one substantially shorter Dy-O distance so forming nearly linear ion DyO^+. These well separated from each other paramagnetic ions dispersed in a diamagnetic phosphate matrix demonstrate a slow relaxation of magnetization as a typical single ion magnets. Hysteresis in the magnetization at 1.8 K for both calcium and strontium samples were registered and blocking temperature 11 K for the strontium and 4.5 K for the calcium samples were determined.
Relaxation time versus temperature dependencies coincide for the samples with different dysprosium concentration for the calcium as well as the strontium series but the strontium samples are characterized by a longer relaxation times and higher magnetization reversal barrier U_{eff}. The most prominent sample is characterized by a very high magnetization reversal barrier U_{eff}=1043 cm^{-1}.
Support by Russian Science Foundation (RSF) under Grant 16-13-10031 is acknowledged.

Poster Session B

Poster B

P-B.072

Spin transport in chemically doped conjugated organic polymers

S.-J. Wang, D. Venkateshvaran, R. Mahani, E. R. McNellis, R. Di Pietro, G. Schweicher, M. Cubukcu, K. Kang, A. Wittmann, T. J. Wagner, C. Jellett, J. N. M. Siebrecht, U. Chopra, M. Little, I. McCulloch, J. Wunderlich, J. Sinova, H. Sirringhaus

Text Spin transport in organic semiconductors has traditionally been studied through measurements of magnetoresistance in trilayer spin valve architectures. In these devices, an organic semiconductor is sandwiched between two ferromagnets and the resistance of the trilayer stack is monitored as a function of the relative magnetisation orientation between the two magnetic layers. Although such measurements have proven useful in probing spin transport in organic materials, many of the reported findings are now called into question due to the presence of potential artefacts such as tunnelling anisotropic magnetoresistance (TAMR) and pinholes within the organic spin valve. The current state of the field of organic spintronics thus necessitates new and novel device architectures capable of probing spin transport in organic materials unambiguously. In this work, we showcase a variety of novel nanofabricated device architectures capable probing spin transport in organic semiconductors, overcoming the limitations of trilayer organic spin valves. Based on spin pumping and on nonlocal detection of spin currents, our novel nanofabricated devices demonstrate their capability of measuring spin diffusion lengths of a few hundred nanometers in doped organic systems. Our results are validated by an existing theory that proposes an efficient mechanism for spin transport that is exchange mediated.

Poster Session B

Poster B

P-B.074

Spin-transport effects in heteromolecular bilayer films on ferromagnets

B. Arnoldi, B. Stadtmüller, M. Aeschlimann

Text The active functionalization of metal-organic hybrid interfaces is usually hindered by the interaction between the organic molecules and the transition metal surface. The strong hybridization of the molecular orbitals with metallic states results in the loss of the functional properties of the organic units. This is significantly different for the second layer of molecules which is only weakly bound to the surface and the molecular character is largely preserved.

In this work, we explore the potential of organic bilayer systems to actively tune the properties of spin-interfaces. We adsorbed a monolayer of CuPc as a spacer layer on a Co surface. As a second layer we evaporated C60 on top of the CuPc layer. In order to study the spin dependent dynamics of photo excited transported electrons, we applied spin- and time-resolved 2-photon photoemission spectroscopy.

Spin-polarized d-electron from the Co are excited by the pump-pulse and thereafter transported into the LUMO of the 2nd layer molecule C60.The probe pulse excites the electron thereafter into the vacuum. Analyzing the extracted electrons as a function of the pump probe delay gives insight into the spin-dependent carrier dynamics of the heteromolecular bilayer film.

Poster Session B

Poster B

P-B.075

Weak exchange interactions in Cu(II) coordination polymers studied via electron paramagnetic resonance

V. Santana, R. Calvo, O. Nascimento, P. Neugebauer

Text Organometallic copper compounds can comprise one (monomeric), two (dimeric) or more (polymeric) copper ions per molecule that may be connected by covalent or non-covalent paths to their neighbors. These coordination polymers are relevant to several fields such as molecular magnetism and biochemistry. In this work, we are interested in the magnetic interactions among the spins of Cu(II) ions inside and between molecular complex units. Intramolecular exchange is expected to be high while the long distances between neighbor metal ions connected by weak non-covalent chemical paths results in a weak intermolecular exchange. Weak exchange affects magnetic resonance spectra which are very sensitive to the spin dynamics. Exchange couplings smaller than 1 mK can be measured selectively by electron paramagnetic resonance (EPR) in oriented single crystals and in powder samples, even at room temperatures. So, we choose EPR as the best suited technique for the electronic and magnetic study of several copper compounds. The correlation between the structures and the electronic properties and the magnetic interactions are analyzed and discussed using EPR, allowing to progressively observe dynamical exchange effects in the line shapes of different compounds as frequency, temperature, and magnetic field orientation varies. In conclusion, we use EPR to evaluate small exchange interactions connecting molecules that form a weakly bond tridimensional structure of magnetic units.

Poster Session B

Poster B

P-B.076

Ab initio theory of the spin Hall effect in random Pt-based alloys

I. Turek, V. Drchal, J. Kudrnovsky

Text The formulation of a material-specific parameter-free theory of the spin Hall effect (SHE) in random alloys represents a long-standing problem for several reasons. First, the correct definition of the spin-current operators is not trivial in systems with spin-orbit interaction. Second, the presence of disorder calls for an efficient technique of configuration averaging. In this contribution, we present our approach to the SHE in substitutionally disordered alloys based on the concept of intersite electron transport developed within the tight-binding linear muffin-tin orbital (TB-LMTO) method [1]. This scheme leads to non-random and spin-independent effective current (velocity) operators, which enables one to define easily the corresponding effective spin-current operators that are non-random as well. The formulation of the spin Hall conductivity within the coherent potential approximation (CPA) can then be done in analogy with that developed for the usual conductivity tensor [2]. Details of the formulation will be presented and discussed along with the first numerical results obtained for selected Pt-based alloy systems.

[1] I. Turek, J. Kudrnovsky, V. Drchal, L. Szunyogh, and P. Weinberger, Phys. Rev. B 65, 125101 (2002).
[2] I. Turek, J. Kudrnovsky, and V. Drchal, Phys. Rev. B 89, 064405 (2014).

Poster Session B

Poster B

P-B.078

Calculated trends in spin-orbit coupling related transport parameters for the 5d transition metal elements

R. Sasidharan Nair, E. Bharati, K. Gupta, P. J.Kelly

Text A spin current injected into a non-magnetic material is not conserved because of spin-orbit coupling (SOC). Its spatial decay is characterized in terms of a material dependent spin-flip diffusion length (SDL) that has become an extremely important parameter in the field of spin transport. In spite of its importance, there is a great deal of controversy about the numerical values of the SDL for specific materials. A second very important SOC-related effect is the spin Hall effect characterized by the spin Hall angle (SHA). This measures the efficiency with which a transverse spin current is generated by an electric current. The numerical value of the SHA is inextricably linked to knowledge of the SDL.

In this work, we perform a systematic study of the temperature dependence of the SDL and SHA for the 5d transition metal elements. To do so, we use a TB-LMTO based scattering code to calculate the conductance as well as local charge and spin currents for a length L of target material sandwiched between leads. Electron phonon coupling is mimicked using a Gaussian distribution of atomic displacements with a mean square displacement chosen to reproduce the experimental resistivity. The SHA is extracted from the transverse spin currents normalized to the driving longitudinal charge current. We present values of the SDLs and SHAs for the 5d transition metals as a function of temperature and discuss the most important trends.

Poster Session B

Poster B

P-B.079

Characterization of field- and current-induced magnetization switching in epitaxial Au/Fe/MgO(001)

P. Gospodaric, E. Mlynczak, A. Kakay, I. Soldatov, D. E. Bürgler, R. Schäfer, L. Plucinski, J. Fassbender, C. M. Schneider

Text Presently, the spin-orbit torque (SOT) is considered as one of the most promising means of current-induced switching of ferromagnets and antiferromagnets. In heavy metal/ferromagnet bilayers, for example, the spins in the ferromagnetic layer can be manipulated via SOT with an in-plane electric current.

Here, we study an epitaxial Fe(001) ultra-thin film, sandwiched between the MgO substrate and an epitaxial Au thin film. We performed a thorough characterization of the field- and current-induced magnetization reversal in the Au/Fe bilayers using magneto-transport measurements and Kerr microscopy. The magnetic properties of the Fe film were studied in the Hall bar geometry via the planar Hall effect. The analysis shows the characteristic four-fold in-plane magneto-crystalline anisotropy of Fe(001) layers, present due to the high crystalline quality of the films. We observe changes in the hysteretic response of the magnetization to the external magnetic field when a longitudinal current of high density is applied to the Au/Fe Hall bar. Kerr microscopy of the Hall bars reveals further details on the switching mechanism in presence and absence of a high longitudinal current. By comparing field- and current-induced magnetic hystereses the information on the current-induced effective fields can be obtained. Our study points out the considerable effect of the Oersted field for the switching mechanism in Au/Fe heterostructures.

Poster Session B

Poster B

P-B.080

Comparison of magnetic and vibrational properties of Tb based manganite single crystal multiferroics

P. Sharma, R. Li, A. Kumar, B. Kang, W. Ren, S. Cao *

Text Manganite multiferroics, (such as $RMnO_3$ and RMn_2O_5) have been broadly studied due to their wide range of potential applications [1-4]. We have studied and compared the magnetic and Raman scattering properties of $TbMnO_3$ with $TbMn_2O_5$ single crystal [5]. In $TbMnO_3$, Mn ion spins ordered below T_N = 41K to form a spin density wave (SDW) with propagation vector. At lower temperatures there is an additional transition below T_N^{Tb} = 7K in which Tb spins order also incommensurately. Though $TbMn_2O_5$, revealed a Neel temperature transition at T_N = 39–45 K, however a ferroelectric transition occurs at T_N for the Mn spin sublattice. In Raman spectra, the peak intensities are function of the polarizability and the symmetry, which empowers one to probe the bonding covalence and the local structural environment. $TbMnO_3$ belongs to orthorhombic (Pbnm) structure. Room temperature Raman spectra for $TbMnO_3$ shows nine modes while in $TbMn_2O_5$ six modes have been reported. Only magnetic field parallel to *a*-axis (H∥a) shows a clear peak attributed to the Tb magnetic ordering and the results are completely different for H∥c. Furthermore, three anomalies are also observed below temperature of 50K for $TbMnO_3$ along c-axis. The corresponding temperatures agree well with the ones observed in the C_p/T measurements, so they can be assigned as to T_{N1}, T*f*, and T*N2*. Improved understanding of magnetoelectric effect in these perovskite oxides may help to fulfill the need of material for room temperature applications.

Poster Session B

Poster B

P-B.081

Current induced magnetization switching in epitaxial Fe/Au bilayers grown on MgO(001)

E. Mlynczak, P. Gospodaric, A. Kakay, D. E. Bürgler, L. Plucinski, J. Faßbender, C. M. Schneider

Text In structures based on ferromagnet/heavy metal bilayers, spin-orbit torque (SOT) is expected to occur. SOT enables manipulation of the magnetization direction using an in-plane charge current, which offers new prospects for spintronic devices. In this contribution, we will present devices based on a thin Au/Fe bilayer epitaxially grown on an MgO substrate. Magnetic properties of the structures were determined at room temperature using the planar Hall effect. We show that magnetization direction can be reproducibly switched between easy axes using an in-plane charge current of a density beyond $2x10^7$ A/cm^2. The magnetic states of the device are non-volatile and can be unambiguously detected by measuring the planar Hall voltage. We found that smaller densities of the writing current result in stable magnetization states yielding intermediate values of the transversal voltage. These multi-state characteristics will be discussed in relation to the magnetic domain structure that we studied using Kerr microscopy. Our results indicate that Au/Fe heterostructures could be used as multi-state magnetic memory element. As our devices show properties of memristors, also applications in neuromorphic architectures can be envisioned.

Poster Session B

Poster B

P-B.082

Delayed feedback in current-driven magnetisation dynamics

J. Williame, D. Rontani, M. Sciamanna, J.-V. Kim

Text Feedback in dynamical systems describes the process by which the output signal of the system is returned to the input. This instills additional memory into transient processes and allow phenomena such as chaos to appear. Despite the ubiquity of delayed feedback in natural systems and control engineering, its role in the magnetisation dynamics of spintronic devices remains largely unexplored. Here we describe how delayed feedback can induce chaotic states in two distinct geometries using simulation. The first concerns the macrospin oscillator, where chaos appears through aperiodic transitions between in-plane and out-of-plane precession. The second involves a domain wall racetrack, where a Mackey-Glass oscillator can be implemented by combining a suitable readout scheme with applied in-plane currents. These results highlight the prospect of inducing novel dynamical phases in spintronic devices. Moreover, the use of such delayed feedback in spintronics could be useful as building blocks for reservoir computing based on time-delay architectures.

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Poster Session B

Poster B

P-B.083

Dissipative coupling of precessing magnetizations in an optically excited spin valve

A. V. Scherbakov, B. A. Glavin, A. P. Danilov, A. W. Rushforth, D. P. Pattnaik, D. R. Yakovlev, A. M. Kalashnikova, M. Bayer

Text Spin transport phenomena yield dynamical coupling between magnetic nanolayers and enable designing structures with fascinating properties, e.g. spin-torque nano-oscillators. However, excitation and observation of coupled magnetic modes in magnetic multilayers may not be detectable if conventional spectroscopic microwave techniques are employed. Here we use the flexibility of optical excitation and time-domain detection of the magnetization precession in a spin valve structure to demonstrate dissipative coupling [1] of the precessing magnetizations mediated by the spin pumping [2].

The studied structure consists of 4- and 7-nm thick Galfenol ($Fe_{0.81}Ga_{0.19}$) layers separated by a 5-nm Cu spacer. The magnetization precession is launched in both ferromagnetic layers by the femtosecond laser pulse and monitored by the transient magneto-optical Kerr effect. The different magnetic anisotropies of the two layers allow controlling frequency detuning of the precessing magnetizations by external magnetic field. At resonance, the spin pumping effects are enhanced, and the precessional dynamics become a superposition of two degenerate modes with a large splitting of the decay rates. This behavior corresponds to the case of dissipatively coupled resonators [1], and is modeled by the LLG equation with additional spin-pumping-related terms [2].

[1] D. Dragoman and M. Dragoman. Quantum-Classical Analogies (Springer, 2013), p. 119.
[2] B. Heinrich et al. Phys. Rev. Lett. **90**, 187601 (2003).

Poster Session B

Poster B

P-B.084

Effect of the Higgs mode in the spin transport of a Heisenberg antiferromagnet on a square lattice

A. Pires

Text Higgs mode in magnetic systems (which corresponds to amplitude fluctuations of the magnetization) allows insights into its behavior in different symmetries and dimensionalities. One system where the Higgs mode can be conveniently studied is the two dimensional spin one antiferromagnet with single ion anisotropy. This model presents a quantum phase transition from a paramagnetic phase to a Neel phase when the anisotropy parameter is varied. For a finite easy plane anisotropy the staggered magnetization lies in the x-y plane and we have to use a generalized SU(3) spin-wave approach. In this work, I study spin transport in this model in the Neel phase. Spin currents can be generated by a magnetic-field gradient. The regular part of the spin conductivity is calculated, at zero temperature, using the Kubo formalism. Three magnon processes provide the dominant contribution to the spin conductivity. The effect of the Higgs mode is analyzed.

Poster Session B

Poster B

P-B.085

Electric-current-driven magnetization dynamics in Co/Pt bilayer thin film

Y.-C. Weng, C.-T. Liang, J. G. Lin

Text The torque effect on magnetization dynamics could be reflected from the variation of the linewidth (W) of a ferromagnetic resonance (FMR) spectrum. In this work, we use FMR to study the current driven magnetization dynamics in Cobalt (Co)/Platinum (Pt) bilayer thin film with an applied DC current (J_c) ranging from -160 to 160mA. The Co(10 nm)/Pt(10 nm) film is deposited by sputtering technique on a Si< 100 > substrate and its surface area is 3.0×1.5 mm^2. The magnetic field is applied in plane with two directions: transversal and parallel to J_c.
For transversal (parallel) case, the normalize linewidth $W^* \equiv [W(J_c)/W(J_c=0)]$ decreases from 1.000 to 0.945 (1.000 to 0.929) with a temperature increment (ΔT) of 5℃(8℃) when J_c increases from 0 to 60mA. In this range, the change of W^* is mainly related to the current-induced torque. On the other hand, the W^* increases from 0.945 to 1.228 (0.929 to 1.791) with ΔT = 47℃(66℃) when J_c increases from 60 to 160mA, which is attributed to the joule heating.
Spin torque effect occurs only in the transversal case and the direction of spin torque depends on the direction of J_c. In such a case, the spin torque induced change of damping constant (α) could be derived from the FMR linewidth. Due to the spin torque effect, α is not symmetric with respect to J_c=0. The variation of α, $\Delta\alpha \equiv [\alpha(+J_c)-\alpha(-J_c)]$, increases from 0 to 0.376×10^{-4} with $|J_c|$ changing from 0 to 60mA. Accordingly, the spin Hall angle is estimated to be 0.434 for our Co/Pt bilayer film.

Poster Session B

Poster B

P-B.086

Electrical and Optical Characterization of Fe/*n*-GaAs Non-Local Spin Valve

J. Y. Kim, M. Samiepour, J. Ryu, D. Iizasa, T. Saito, M. Kohda, J. Nitta, H. E. Beere, D. A. Ritchie, E. Jackson, A. Hirohata

Text Fe/*n*-GaAs system has been investigated as a promising candidate for spin field-effect transistor [FET] since successful injection and detection of electron spins were reported. However, manipulation of injected spins via electric or optical gates is still required to create a working spin FET.

In this study, we fabricated Fe/*n*-GaAs non-local spin valves and investigated spin transport using electrical and optical methods. The *n*-GaAs structure consisted of a 2 μm thick *n*-GaAs channel (n = 2 x 10^{16} cm^{-3}) and 30 nm of a highly-doped *n*+ (n = 2 x 10^{16} - 5 x 10^{18} cm^{-3}) Schottky barrier layer.

From three- and four-terminal Hanle measurements, Lorentzian peaks were obtained with half-width at half-maximum field values of around 440 mT, corresponding to spin dephasing times of around 60 ps. The unusually short spin dephasing times and the large (~1 T) field required to saturate the signals indicated that the injected spins were dephasing in the highly-doped *n*+ layer. The channel (*n*-GaAs) layer spin dephasing time was confirmed to be 2.9 ns by pump-probe Kerr rotation measurements. Nonetheless, an introduction of circularly-polarised light in the channel layer showed preliminary signs of optical modulation of the non-local voltage. In addition, an optimisation of the Fe/*n*-GaAs interface has been achieved using non-destructive junction imaging.

This work has been partially supported by UK-EPSRC (EP/M02458X/1).

Poster Session B

Poster B

P-B.087

Fe-Al/$MgAl_2O_4$/CoFeB perpendicular magnetic tunnel junctions with large perpendicular magnetic anisotropy

T. Scheike, H. Sukegawa, X. Xu, K. Masuda, Y. Miura, S. Mitani, K. Hono

Text Recently, large interface perpendicular magnetic anisotropy (PMA) was obtained at lattice-matched $Co_2FeAl/MgAl_2O_4$ interfaces due to the assistance of Al diffusion from Co_2FeAl into $MgAl_2O_4$ [1]. Such good lattice-matching and well-controlled atomic diffusion will provide robust interface PMA properties suitable for a perpendicularly-magnetized magnetic tunnel junction (p-MTJ) toward high-density magnetoresistive random access memory applications. In this study, we choose an Fe_3Al based material ($Fe_{100-x}Al_x$, $10 \leq x \leq 30$) instead of Co_2FeAl in order to further enhance PMA. Here, we report a large PMA energy >1 MJ/m^3 in ultrathin (0.8 nm thick) $Fe_{100-x}Al_x/MgAl_2O_4(001)$ epitaxial heterostructures fabricated by co-sputtering and plasma-oxidation. We also obtained p-MTJ structures with an $Fe_{100-x}Al_x/MgAl_2O_4$/CoFeB structure and demonstrated a tunnel magnetoresistance (TMR) ratio >40%. Based on our first principle calculations of $Fe_3Al/MgAl_2O_4(001)$, further enhancement in the PMA energy and TMR ratio can be expected if an optimized interface structure is achieved. This study was supported by the ImPACT Program, and JSPS KAKENHI Grant Nos. 16H06332, 16H03852, and 17H06152.
[1] J.P. Hadorn *et al.*, Acta Mater. **145**, 306 (2018).

Poster Session B

Poster B

P-B.088

Ferromagnetic/Nonmagnetic Nanostructures for the Electrical Measurement of the Spin Hall Effect

V. T. Pham, L. Vila, P. Noël, G. Zhand, A. Marty, W. Savero Torres, M. Jamet, J.-P. Attané

Text Spin–orbitronics is based on the ability of spin–orbit interactions to achieve the conversion between charge currents and pure spin currents. As the precise evaluation of the conversion efficiency becomes a crucial issue, the need for straightforward ways to observe this conversion has emerged as one of the main challenges in spintronics. Here, we propose a simple device, akin to the ferromagnetic/nonmagnetic bilayers used in most spin–orbit torques experiments, and consisting of a spin Hall effect wire connected to two transverse ferromagnetic electrodes. We show that this system allows probing electrically the direct and inverse conversion in a spin Hall effect system and measuring both the spin Hall angle and the spin diffusion length. By applying this method to several spin Hall effect materials (Pt, Pd, Au, Ta, W), we show that it represents a promising tool for the metrology of spin–orbit materials.

Poster Session B

Poster B

P-B.089

Field-voltage switching diagram of coupled layers perpendicularly magnetized

N. Perrissin, N. Strelkov, R. Sousa, L. Prejbeanu, B. Dieny, L. Buda-Prejbeanu

Text The magnetic proprieties of a nanopillar with multiple magnetic layers are dependent on the intrinsic parameters of each layer but also on the coupling between the layers. In this study, we analyze numerically the field-voltage diagram of a magnetic tunnel junction based nanopillar consisting of three coupled macrospin layers perpendicularly magnetized. The dipolar coupling between various layers together with the mutual spin-transfer torque increases the number of the possible stable states. Consequently, the diagrams become more complex having several new boundaries. The systematic evolution of the shape of the diagrams and their various boundaries are discussed upon changing the material parameters and the strength of the couplings. The control parameters for each boundary are identified, pointing thus out the required optimal conditions for memory application (MRAM) and less limitation on the cell writing.

Poster Session B

Poster B

P-B.090

Hanle effect in giant magnetoresistance measurement using lateral spin valves

G. Zahnd, A. Marty, V. T. Pham, F. Rortais, M. Jamet, L. Vila, J.-P. Attané

Text Lateral spin valves have been deeply studied, mostly since its geometry enables to separate the charge and spin currents. Hence, lateral spin valves are a powerful tool to study spin transport in non-magnetic materials, spincaloritronics and spin-orbitronics effects, as well as spin transfer torques due to pure spin currents. Among the possible measurements to perform on lateral spin valves, the Hanle measurement is a technique enabling an in depth spin dependent transport characterization. It consists in having the injected spin accumulation precessing due to an applied perpendicular magnetic field. This accumulation rotates and decays while diffusing toward the detecting electrode. Additionally, it is possible to measure giant magnetoresistance (GMR) in lateral spin valves by having the current flowing through both ferromagnetic electrodes via the non-magnetic channel. We will show that the Hanle effect can be detected also in GMR measurement. This effect leads to a substantial drop of resistance larger than the GMR effect observable when the applied field is colinear with the magnetization of the electrodes. We will also analyze our results with an analytical model, enabling to find characteristic parameters of our materials (CoFe, Al, Cu). In order to verify our results, we will compare the extracted parameters to what we obtained from classical Hanle measurement.

Poster Session B

Poster B

P-B.091

Heusler alloys: Spin-polarized electrical transport at finite temperatures

D. Wagenknecht, K. Carva, I. Turek

Text Realistic description of spintronics materials at finite temperatures by first-principles methods attracted great interest in recent years. For this purpose, an alloy-analogy model was implemented in our fully relativistic tight-binding linear muffin-tin orbital (TB-LMTO) numerical codes [1, 2]. Random displacements of atoms from their equilibrium positions (phonons) are treated analytically by the coherent potential approximation (CPA); therefore, this method is numerically efficient and universal. The combined effect of chemical, magnetic, and temperature-induced disorder may be described in a wide range of metalic bulk materials. Spin-resolved conductivities and other electrical transport properties are obtained with incorporated atomic displacements caused by nonzero temperatures.

In this contribution, results of the study of Heusler alloys at finite temperatures will be presented. For realistic chemical disorder in NiMnSb, i.e. Ni-rich system having up to 10 % of Ni impurities, we obtained spin polarization more than 95 % even at room temperature. This value is strongly dependent on magnetic impurities and we will discuss comparison with data of other authors as well.

[1] D. Wagenknecht et al.: IEEE Trans. Mag. 53, 11 (2017)
[2] D. Wagenknecht et al.: Proc. SPIE, Spintronics X, 10357 (2017)

Poster Session B

Poster B

P-B.092

Insights into spin and anomalous Hall effect induced charge and spin currents through ferromagnetic/nonmagnetic interfaces

A. Hönemann, C. Herschbach, D. Fedorov, M. Gradhand, I. Mertig

Text Transport phenomena caused by spin-orbit coupling such as spin Hall effect (SHE) [1] and anomalous Hall effect (AHE) [2] are highly relevant topics of current research. In ferromagnetic/nonmagnetic heterostructures the interplay of spin-orbit and exchange interaction enables new phenomena as for example spin-orbit torques [3].

We use an *ab initio* approach, a relativistic Korringa-Kohn-Rostoker method, [4] and solve the linearized Boltzmann equation to describe the electronic transport [5]. We investigate the AHE-induced charge current as well as the SHE-induced spin current perpendicular to the interface in a Co/Cu superlattice alloyed with Bi. In detail, we analyze the dependence of these currents and its corresponding conductivities on the impurity position within the Co/Cu superlattice. We are particularly interested in the spatial distribution of charge and spin current with respect to the interface. The presented results help to understand the underlying microscopic mechanism of charge and spin transport through interfaces.

[1] Sinova *et al.*, Rev. Mod. Phys. **87**, 1213 (2015); [2] Nagaosa *et al.*, Rev. Mod. Phys. **82**, 1539 (2010); [3] Gambardella *et al.*, Phil. Trans. R. Soc. A **369**, 3175-3197 (2011); [4] Gradhand *et al.*, PRB **80**, 224413 (2009); [5] Gradhand *et al.*, PRL **104**, 186403 (2010);

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P-B.093

Inverse Spin Hall Effect in Organic Semiconductor

M. Qaid, O. Zadvorna

Text The Inverse Spin Hall Effect measurements in Organic Semiconductors are strongly debated in literature, with some claiming to have measured it and some saying that the ISHE signal was no more than the Seebeck Effect signal. Control experiments are done to ensure that artefacts such as Seebeck and Nernst effects are excluded and that the signal is indeed ISHE. Measurements of ISHE dependence on charge concentration (doped and gated devices) are also carried out.

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P-B.094

Investigation of the Spin Seebeck and Spin Hall effects on $Co_{90}Fe_{10}$/Ta bilayers

M. Cababie, J. Bonaparte, M. Aguirre, M. Granada, A. Butera, J. Gomez, L. Aviles, L. Steren

Text The generation, manipulation and detection of spin currents in nanostructures are crucial challenging tasks in today spintronics. The perspective of applying spin currents instead of charge currents offers a solution to the technological limit of miniaturization due to Joule heating in conventional electronic devices. In spite of the intense activity being done today aiming to understand the mechanisms at the origin of charge-to-spin current conversion and also at the generation of spin voltages by temperature gradients, there are still open questions. In the present work we studied the Inverse Spin Hall Effect (ISHE) and Spin Seebeck onto Co90Fe10/Ta (CF-Ta) bilayers looking to get a deeper comprehension of these phenomena, regarding the influence of interfaces. With this purpose, we grew two series of CF-Ta samples onto SiO_2 and MgO substrates. We analyzed the structural quality and composition of the samples by HR-TEM and EDS. The magnetic properties of the samples were examined by ferromagnetic resonance spectroscopy and magnetometry prior to performing Spin Pumping and Spin Seebeck Effect (SSE) experiments. Finally, in the resonant condition, we succeeded in injecting a pure spin current from the Co90Fe10 into the Ta, measuring a perpendicular charge voltage by means of the ISHE. In addition, we measured the SSE on the same group of samples. In our contribution, we will present these ISHE and SSE results, and correlate them to their structural characterization.

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P-B.095

Large enhancement of the spin Hall effect in Au by side-jump scattering on Ta impurities

P. Laczkowski, Y. Fu, P. Noël, J.-C. Rojas-Sanchez, V. T. Pham, G. Zhand, C. Deranlot, H. Yang, S. Collin, C. Bouard, P. Warin, V. Maurel, M. Chsiev, A. Marty, J.-P. Attané, A. Fert, H. Jaffrès, L. Vila, J.-M. Georges

Text We present measurements of the spin Hall effect (SHE) in AuW and AuTa alloys for a large range of W or Ta concentrations by combining experiments on lateral spin valves and ferromagnetic-resonance/spin-pumping techniques. The main result is the identification of a large enhancement of the spin Hall angle (SHA) by the side-jump mechanism on Ta impurities, with a SHA as high as +0.5 (i.e., 50%) for about 10% of Ta. In contrast, the SHA in AuW does not exceed +0.15 and can be explained by intrinsic SHE of the alloy without significant extrinsic contribution from skew or side-jump scattering by W impurities. The AuTa alloys, as they combine a very large SHA with a moderate resistivity (smaller than 85μΩcm), are promising for spintronic devices exploiting the SHE.

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P-B.096

Large spin Hall effect in an amorphous binary alloy

M. Meinert, K. Fritz, S. Wimmer, H. Ebert

Text We investigated the spin Hall effect of W-Hf thin films, which exhibit a phase transition from a segregated phase mixture to an amorphous alloy below 70% W. The spin Hall angle was determined with a planar harmonic Hall voltage technique. Due to the accompanying jump in resistivity, the spin Hall angle shows a pronounced maximum at the composition of the phase transition. The spin Hall conductivity does, however, reduce from W to Hf with a weak discontinouity across the phase transition. The maximum spin Hall angle of θ_{SH} = -0.25 is obtained for amorphous $W_{0.7}Hf_{0.3}$. A detailed comparison with spin Hall conductivities calculated from first principles for hcp, fcc, and bcc solid solutions provides valuable insight into the alloying physics of this binary system.

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P-B.097

Low current modifications in anomalous Hall Effect signals in perpendicularly magnetized system

R. Guerrero, A. Anadon, A. Gudin, J. M. Diez, F. Ajejas, J. Camarero, R. Miranda, P. Perna

Text In magnetic multilayers, the interplay between the perpendicular magnetic anisotropy, the interfacial Dzyaloshinskii-Moriya interaction (DMI) and the dipolar coupling may result in the appearance of a variety of chiral magnetic textures, such as skyrmions, even at room temperature [1–3]. We have studied a Ta(5nm)/Co(0.8nm)/Pt(5nm)/Ta(5nm) trilayer deposited on SiO2 and patterned by optical lithography in 10 μm wide Hall bars. The interest of this structure lies in: i) the different spin Hall angle signs in Ta and Pt enhances the Spin-orbit torque (SOT), ii) large DMI has demonstrated in [3, 4] of the order of 1.3 mJm-2 iii) and the possibility to neglect the interlayer coupling contribution that may be play a fundamental role on the effect of SOT on the magnetic behavior. . We have investigated the anomalous Hall effect (AHE) and we have disclosed the effect of the SOT by detecting simultaneously the Hall resistance curve and the polar Kerr hysteresis curves. The results exhibit a clear discrepancy at current densities as low as 600 MAm-2 between both quantities that consist on large peaks corresponding to the annihilation and creation of magnetic domains. We have moreover investigated these features as function as the current density and in-plane magnetic fields.

1. A. Fert et al, Nat. Nanotechnol. 8, 152 (2013).
2. Legrand, W. et al. . Nano Lett. 17, 2703 (2017).
3. Woo, S. et al. . Nat. Mater. 15, 501–506 (2016).
4. Torrejon, J. et al. Nat. Commun. 5, 4655 (2014).

Poster Session B

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P-B.098

Modeling of Time and Length Scales of Spin Relaxation in Microwave-Driven Magnetic Nanostructures

F. Sahbaz, M. C. Onbasli

Text Detailed understanding of spin relaxation processes in magnetic nanostructures is crucial in order to conserve and rationally control spin information. Time and length scales of spin relaxation originates from the phononic, electronic or spin wave dispersion behavior of materials. In spin-wave dynamics, different mechanisms emerge due to spin-spin, spin-phonon, spin-photon or spin-orbit interactions at sub-nanometer to millimeter length scales and at sub-picosecond to millisecond time scales.

In this study, we computationally investigated the effect of increasing damping, width and thickness of 100 nm-long nanostructured Yttrium Iron Garnet ($Y_3Fe_5O_{12}$, YIG) on spin relaxation behavior under 1 GHz ac external magnetic field (i.e. microwave excitation) using OOMMF solver. We used rectangular YIG nanostructures (Ms=140 kA/m, A=3.65±0.38 pJ/m) and investigated the effect of its changing width (10 to 150 nm), damping values ($\alpha = 10^{-4}$ to 10) and the effect of changing thickness (10-75 nm) on time-dependent spin relaxation over ps and ns timescales.

Spin relaxation time decreases from 961.5 to 5.2 ns when the damping decreases from 10 to 1, the thickness increases from 10 to 25 nm, and the width increases from 110 to 150 nm. Based on OOMMF modeling results, the spin relaxation time can be reduced to a few-ns regime for enabling microwave read-write operations by using YIG nanorectangles with proper aspect ratios and an enhanced damping between 1 and 0.1.

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P-B.099

Nonreciprocal transmission of spin 1/2 particles trough noncoplanar magnetic systems

A. Fraerman, O. Udalov, D. Tatarskiy

Text The noncoplanarity of a magnetic structure leads to new transport phenomena for spin 1/2 particles. In this report we give a brief review of our works devoted to the experimental and theoretical study of the propagation of spin 1/2 particles through noncoplanar magnetic field. This review includes
- discussion of experiments with a nonreciprocal cell for neutrons. We will show that the change in the places of the source and the receiver of neutrons leads to a change in the transmission coefficient by a factor of ~ 7 [1,2]
- theoretical results for nonreciprocal neutron scattering by the lattice of magnetic skyrmions [3] and a conical magnetic spiral [4]
- recent theoretical results for non-reciprocal neutron scattering by systems with a random distribution of the magnetic field. The possibility of observing nonreciprocal effects in the transport properties of conducting ferromagnets with a noncoplanar magnetization distribution is discussed. This work was supported by the Russian Science Foundation (Grant No. 16-12-10340).

1. D.A. Tatarskiy et al., Physics - Uspekhi 59 (6) 583 - 587 (2016)
2. D.A. Tatarskiy et al. JETP Lett. 102, 633 (2015)
3. O. G. Udalov, A. A. Fraerman, Phys.Rev.B 90, 064202 (2014)
4. D.A. Tatarskiy, A. A. Fraerman, Physics of the Solid State, 58, No. 11, pp. 2237–2239 (2016)

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P-B.100

Origins of the unidirectional spin Hall magnetoresistance in metallic bilayers

C. O. Avci, J. Mendil, G. S. D. Beach, P. Gambardella

Text Unidirectional spin Hall magnetoresistance (USMR) has emerged as a novel tool to investigate spin accumulation at normal metal/ferromagnet interfaces, and to detect in-plane magnetization reversal[1-3]. Here, we investigate the USMR caused by the current-induced spin accumulation in Co/Pt and CoCr/Pt bilayers. We identify three competing mechanisms underpinning the resistance asymmetry, namely interface and bulk spin-dependent electron scattering and electron-magnon scattering. Our measurements provide a consistent description of the current, magnetic field, and temperature dependence of the USMR and show that both positive and negative USMR can be obtained by tuning the interface and bulk spin-dependent scattering terms relative to the magnon population. These results may invigorate the research into unidirectional magnetoresistive phenomena and provide insights into designing heterostructures with tunable USMR for magnetic memory applications.

[1]Avci et al., Nat. Phys. 11, 570 (2015)
[2]Olejnik et al., 91, 180402(R) (2015)
[3]Avci et al., Appl. Phys. Lett. 110, 203506 (2017)

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P-B.101

Parallel and anti-parallel echoes in helium spin echo experiments

I. Litvin, Y. Alkoby, O. Godsi, G. Alexandrowicz, T. Maniv

Text The refocusing of velocity-dependent spin-phase is the basic phenomenon behind helium and neutron beams spin echo experiments. In this talk we present quantum and classical descriptions of the spin echo phenomenon and show that non-adiabatic transitions, which take place during rotation of the magnetic field axis between the two propagation arms in helium spin echo setups,lead to echo conditions without reversing the magnetic field orientation between the two arms. The usual spin echo conditions, created by reversing the magnetic field orientation, do not require such non-adiabatic transitions. These two echo conditions are termed parallel and anti-parallel spin echoes, respectively. We derive the dependence of the relative intensity of the two echoes on the scattering geometry of the setup and show experimental results which verify the co-existence of the two echo conditions, the theoretically derived expressions for their relative intensity and the effect of an additional spin-rotator coil introduced within the non-adiabatic transition region.

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P-B.102

Phase shift keying in spin torque oscillators

A. Litvinenko, C. Murapaka, P. Sethi, A. Jenkins, L. Vila, V. Cros, P. Bortolotti, R. Ferreira, U. Ebels

Text Spin torque oscillators (STO) are promising for wireless communication schemes due to their nano-scale size and their frequency tunability. However, one of the main issues is their high phase noise figure which can limit the data transmission rate for STO based communication systems [1,2]. One way to reduce the STO phase noise is to injection lock the STO to an external signal [3].
Here, we exploit the phenomenon of synchronization to implement signal modulation via phase shift keying. A specific feature of the synchronization phenomenon is that the phase of the locked oscillator is shifted with respect to the source. This phase shift is determined by the frequency detuning between the free running oscillator and the rf source and can be induced by injecting an additional modulation current. This concept was validated for magnetic tunnel junction based vortex STOs whose free running parameters are f=300MHz, df=100kHz and P=1μW. We obtained a phase noise reduction of -50dBc/Hz at 10kHz offset and 4Mb/s PSK data transmission rate for the synchronization at 2f. This gives prospect for novel, robust wireless communication schemes based on STOs, at high signal to noise ratio.
Financial support from the FP7 program ICT MOSAIC 317950, the French space agency CNES and ERC MagiCal 669204 is acknowledged.
[1] H. S. Choi et al., Sci. Rep. 4, 5486 (2014)
[2] A. Ruiz-Calaforra et al, Applied Physics Letters 111, 082401 (2017).
[3] R. Lebrun et al. Phys. Rev. Lett. 115, 017201 (2015)

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P-B.103

Reducing the switching current with a Dzyaloshinskii-Moriya interaction in nanomagnet with perpendicular anisotropy

S.-i. Takamatsu, K. Yamada, Y. Nakatani

Text Reducing the switching current keeping the thermal stability in nanomagnets with perpendicular anisotropy are key factors in the development of STT-MRAM, which is expected to be a next generation nonvolatile memory[1]. In this paper, we investigated the effect of the Dzyaroshinskii-Moriya interaction (DMI) on the switching current and the thermal stability in nanomagnets[2]. It is expected that the magnetization structure and the switching mechanism will be changed by DMI, therefore not only the switching current but also the thermal stability will be changed. We investigated the conditions to reduce the switching current keeping the thermal stability by DMI using micromagnetic simulations.
In the simulation, a circular disk with 30 nm of the diameter and 2 nm of the thickness was used. The thermal stability factor (Δ) changes by the perpendicular anisotropy constant and the DMI. We investigated the condition to keep Δ=60[3] by simulations.
The effects of the Gilbert damping constant (α), pulse width, and DMI on the switching current were obtained by simulations. The switching current was decreased 60% in maximum. In the short pulse case, the reduction rate of the switching current does not change by α. However in a long pulse case, the switching current increases as α is increased.

[1] M. Hosomi et al., International Electron Devices Meeting (IEDM), 2005, pp. 459-462.
[2] I. E. Dzialoshinskii, Sov. Phys. 5, 1259 (1957).
[3] K.Yamada et al., Appl. Phys. Lett. 106, 042402 (2015).

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P-B.105

Spin Injection into Gold

K. Buehlmann, R. Gort, S. Daester, A. Vaterlaus, Y. Acremann

Text We present measurements on spin injection into a non-magnetic layer on the femtosecond time scale. The system under investigation consists of a few monolayers of gold on top of an iron film. The ultrafast demagnetization process occurring in the iron layer is used as a femtosecond spin current source. The sample is excited by a 800 nm laser pulse and then probed by spin resolved photoelectron spectroscopy. We use 21 eV UV pulses from a high harmonic source for photoemission, spin sensitivity is provided by low energy diffraction on an iridium crystal. As the escape depth of electrons with kinetic energy in the measured range (around 18 eV) is only a few angstroms we expect a very weak contribution of electrons directly emitted from the iron: Before the pump laser pulse, no spin polarization can be detected. At time zero the signal rises within the experimental time resolution (around 50 fs) to its maximal value of roughly two percent and decays again within 2 ps. Surprisingly, the sign of the observed polarization is opposite to the one of iron in the same energy window. The experiment shows, that a spin polarization can be induced in a gold film on top of a ferromagnet. The spin current therefore does not only transport angular momentum to the substrate, but also to a capping layer.

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P-B.106

Spin Superfluid Transport Through Frustrated Triangular Spin Systems

V. M. L. D. P. Goli, A. Manchon

Text Spin superfluid (SSF) transport has received significant attention with its theoretical prediction in ferromagnetic and antiferromagnetic insulators [1-4]. To explore the emergence of SSF transport in the exotic magnetic phases of frustrated spin systems, we investigate the spin transport through the various magnetic structural phases of ultra thin frustrated triangular spin system by using atomistic spin simulations. We consider an easy-plane triangular system with cylindrical geometry, whose open ends are connected to a transversely polarized spin current source and a detector. We probe the spin transmission through triangular spin system and demonstrate the emergence of SSF in the ferromagnetic, 120° antiferromagnetic, canted row-wise antiferromagnetic phases. We find that the spin transport exhibits an algebraic decay as a function of length of the film in all three magnetic phases, which is an evidence for SSF transport. This study demonstrates that the SSF transport is not limited to collinear magnets but extends over non-collinear magnetic phases as well.

References:
[1] J. König, M. C. Bnsager, and A. H. MacDonald, Phys. Rev. Lett. 87, 187202 (2001).
[2] S. Takei, and Y. Tserkovnyak, Phys. Rev. Lett. 112, 227201 (2014).
[3] H. Skarsvåg, C. Holmqvist, and A. Brataas, Phys. Rev. Lett. 115, 237201 (2015).
[4] Alireza Qaiumzadeh, Hans Skarsvåg, Cecilia Holmqvist, and Arne Brataas, Phys. Rev. Lett. 118, 137201 (2017).

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P-B.107

Spin dynamics and anomalous anisotropy gap in the metallic perovskite SrRuO3

K. Jenni, S. Kunkemöller, R. Ewings, A. Schneidewind, Y. Sidis, M. Braden

Text SrRuO3 is one of the very few perovskite metallic ferromagnets; it exhibits anomalous transport, an invar effect, non-Fermi liquid behavior, a magnetic shape-memory effect and it is an important substrate for various oxide heterostructures. Strong spin-orbit coupling (SOC) is visible in the invar effect and the large magnetic anisotropy. Recently, we could grow large single crystals of SrRuO3 using the floating-zone technique in an image furnace [1,2]. We report the first inelastic neutron scattering study of the spin dynamics on single crystals. By detwinning the strongly twinned crystals with a magnetic field, it was possible to investigate the dispersion in two orthorhombic directions. Our results yield the expected quadratic spin wave dispersion of a ferromagnet. However the stiffness constant considerably deviates from an earlier inelastic neutron scattering study on powders and it increases with increasing temperature towards Tc. We also find a non-monotonous temperature dependence of the anisotropy gap which again disagrees with the powder results. The possible relation of the gap and stiffness parameters of the magnon dispersion with Weyl modes will be discussed.

[1] S. Kunkemöller et al. Chrys. Res Tec. 51, 299 (2016)
[2] S. Kunkemöller et al., PRB 96, 220406(R) (2017)
[3] S. Itoh et al., Nat. Commun. 7, 11788 (2016)

Poster Session B

Poster B

P-B.110

Spin transfer torques in interacting wires

H. Kazemi, K. Jägering, N. Sedlmayr, A. Pelster, I. Schneider, S. Eggert

Text Use of a spin polarized current for the manipulation of magnetic domain walls in ferromagnetic nano-wires has been the subject of intensive research for many years. While so far the theoretical investigation has been mostly concerned with the mean-field approximation of the electron-electron correlation, electrons confined to a quasi-one-dimensional wire behave in a fundamentally different way from the standard Fermi-liquid picture. Our goal is to delve into the full quantum investigation of the electron-electron interaction in low dimensions. To this end, first we establish a reference point by solving the scattering problem of a non-interacting tight-binding Hamiltonian including an s-d interaction that couples the domain wall and the itinerant electrons. With this approach the behavior of the adiabatic spin transfer torque has been investigated and the existence of a topological torque has been established. Next, using matrix product states algorithm we make an inquiry into the full quantum effects of electron-electron correlation on spin densities and consequently on spin transport.

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P-B.111

Spin-Torque-Induced Instability in MgO-Based Magnetic Tunnel Junctions

D. Berkov, E. Auerbach, H. Zhivomirov, N. Leder, H. Arthaber

Text MgO-based magnetic tunnel junctions (MTJ) have been widely used in hard disk drives as magnetic read sensors. The most important parameters that determine the read sensors' performance are their resolution, sensitivity, and signal-to-noise ratio (SNR). Higher SNR can be achieved by lowering the total read sensor noise, which includes the thermal, shot, and magnetic contributions. In the present work, we aim to characterize the spin-torque (ST)-induced magnetic noise contribution and explain its origin using micromagnetic simulations. We obtained signal waveforms using a real-time (not sampling!) oscilloscope, an ideal tool for characterization of non-stationary signals in an uncontrolled environment. Then, we optimized the short-time Fourier transform (STFT) technique to extract the ST-induced instability in the MTJ's free layer (FL) dynamics. This instability manifests itself firstly in the low-frequency "tail" of the corresponding spectrum, and secondly in the splitting of the FL mode. The FL mode splitting was also observed numerically with long-time micromagnetic simulations (providing the spectral resolution of ≈1 MHz), which show striking qualitative agreement with the measurements. Our ongoing research is focused on identifying the origin of the metastable states responsible for the abovementioned instability and investigating whether the switching between these states contributes to the read sensors' low-frequency magnetoresistance noise.

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P-B.112

Spontaneous oscillations of the macroscopic magnetization in Pt/Co/Ir/Co/Pt synthetic antiferromagnet with perpendicular anisotropy

G. L'vova, O. Koplak, R. Morgunov

Text Spontaneous oscillations of the macroscopic magnetization were observed in Pt/Co/Ir/Co/Pt synthetic antiferromagnet with perpendicular anisotropy after switching of the reversal magnetic field from the positive saturation value to the critical negative value. Number of the oscillations depends of the thickness of the free Co layer becoming maximal, when thicknesses of the free and pinned layers are same. Oscillations are caused by dipole magnetic interaction between reversal nucleus of the neighboring ferromagnetic layers. Time-domain analysis of the oscillating magnetic relaxation allowed us to propose simple description based on the two successive exponential relaxation processes. Dependence of the time constants of these processes on thickness of the free Co layer was obtained. Approach of the thicknesses of the hard and free Co layers to each other makes easy the magnetic oscillations due to equiprobable nucleation of the magnetic reversal phase in the both layers. Speeds of the direct and backward magnetic relaxations are maximal in bilayer with equal thicknesses of the free and hard layers.

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P-B.113

Stability phase diagrams of magnetic tunnel junction affected by Joule heating

N. Strelkov, A. Chavent, R. Sousa, L. Buda-Prejbeanu, A. Timopheev, L. Prejbeanu, B. Dieny

Text Measured switching voltage-field diagrams of perpendicular MTJ exhibit unexpected behavior at high voltages. The boundaries deviate from the critical lines corresponding to the coercive field, which contrasts with the theoretically predicted behavior of a standard macrospin model. Here we are proposing to modify the model by taking into account the Joule heating during a writing pulse, which reduces the anisotropy, thereby reducing the coercive field during the switching. Our model is based on the experimental studies of temperature dependence of PMA that give an expression for uniaxial anisotropy constant $K=K_0(M_s(T)/M_{s0})^2$ [1]. Supposing that $M_s(T)=M_{s0}(1-T/T_c)^{1/3}$ for anisotropic ferromagnet with Curie temperature T_c [2] and assuming that the temperature varies with voltage as $T\sim V^2$ due to Joule heating, the resulting voltage dependence of the PMA writes $K=K_0(1-k_vV^2/T_c)^{2/3}$. Here k_v is a function of writing pulse duration, thermal capacity of the storage layer and its resistance. It depends on the polarity of the current as suggested by earlier experimental study [3]. Numerical macrospin simulations based on this model reproduce very well experimental data. They are consistent also with the results of linearization of LLG equation in frames of Slavin-Tiberkevich theory [4].

[1] J.Alzate et al APL 104, 112410 (2014)
[2] R.Skomski et al J.App.Phys. 99, 08E916 (2006)
[3] E.Gapihan et al APL 100, 202410 (2012)
[4] A.Slavin, V.Tiberkevich IEEE Trans. Magn. 45 1875 (2009)

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P-B.114

Strain induced modification of spin-orbit torque in heavy metal/ferromagnet heterostructures

E. Schmoranzerova, J. Nath, M. A. Nsibi, I. Joumard, S. Auffret, G. Gaudin, M. Gabor, M. Miron

Text Spin-orbit torques (SOT) provide an efficient tool for magnetization control in MRAM-type devices. Typical structures where the SOT effects are realized are ferromagnets (Co, NiFe…) sandwiched between a heavy metal (Ta, Pt) and a non-magnetic layer (oxides). Physics of the origin of SOTs and, consequently, their efficiency relates to the inversion asymmetry of the structure as well as to the magnetic anisotropy of the FM metal. While the strain-induced anisotropy change is well known in these systems [1], the effect of strain on the inversion asymmetry remains elusive [2]. In our work, we aim to study the effect of strain on SOT using an external piezo stressor to modify properties of Pt/Co/Pt and MgO/Co/Pt multilayers. Our layers are grown by magnetron sputtering on a flexible KAPTON© substrate to ensure the maximum transmission of the strain from the stressor. Depending on the thickness of the Co layer, both in-plane and out of plane FM layers are prepared. The structures are then patterned to Hall cross devices (typical size of 5 µm) for our low-frequency AC transport measurement. By analyzing higher harmonics in transverse Hall voltage under varying external magnetic field, we can distinguish between the different contributions to the SOT and disentangle their strain dependence.

[1] P. M. Shepley et al., Sci. Rep. 5, 7921 (2015)
[2] Q. Wang et al., ArXiv. 1802.01647 (2017)

Poster Session B

Poster B

P-B.115

Temperature and contact geometry dependence of the spin Hall effect versus electric spin injection, probed in an optimized lateral geometry

A. Pfeiffer, R. M. Reeve, M. Kläui

Text The spin Hall effect, intrinsic to non-magnetic heavy metals with large spin orbit coupling such as Platinum and Tungsten, has received remarkable recent interest as an attractive alternative to electrical spin injection for spin current generation. To understand the mechanisms behind the spin Hall effect and compare it to spin injection as a spin current generator we study multi terminal Pt-Py-Cu lateral structures with an optimized kinked geometry. We generate pure spin currents in the copper, via both the spin Hall effect from Platinum and electric spin injection from Permalloy and compare non-local signals and those generated via the inverse spin Hall effect in one single device. We determine a different sensitivity of the observed effects on the interfaces and probe configuration, highlighting the importance of the exact current path for the device behaviour. Furthermore, we determine the temperature evolution of the different signals and find a different dependence for the same generated spin current depending on the employed detection scheme. The results reveal that in addition to the conventionally considered temperature dependence of the spin current transport [1], it is also necessary to take into account the temperature dependence of both the spin current generation [2] and detection mechanisms for a full description of such a device.

[1] K.-W. Kim et al., Phys. Rev. B. **95**, 104404 (2017)
[2] A. Pfeiffer et al., Appl. Phys. Lett. **107**, 082401 (2015)

Poster Session B

Poster B

P-B.116

Theoretical evaluation of vanadyl complexes as single-molecule spin transistors

S. Cardona-Serra, A. Gaita-Ariño

Text The role of Chemistry in the road towards quantum devices is the design of elementary pieces with a built-in function. A brilliant example is the use of molecular transistors as nuclear spin detectors, which, up to now, has been implemented only on [TbPc2]-. The recent progress in the preparation of highly coherent spin qubits based on vanadium dithiolate complexes motivated the theoretical study of vanadyl dithiolates as single molecule transistors. These could give rise to interesting phenomena, such as a compact dual spin filter, the possibility to read and control a triple nuclear spin qubit or even a low-current nuclear spin detection scheme by means of a spin valve effect.

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P-B.117

Tunable Spin Pumping In Exchange Coupled Magnetic Trilayers

M. Ahlberg, M. Fazlali, M. Dvornik, J. Åkerman

Text A cornerstone for the development of spintronic devices is the ability to tailor the magnetic damping and control spin currents. Thin films at ferromagnetic resonance (FMR) leak angular momentum, which may be absorbed by adjacent layers. This phenomenon, spin pumping (SP), is manifested by an increase in the resonance linewidth (ΔH), and the Gilbert damping. Another effect of SP is a dynamical and long-range coupling that drives two magnetic layers into a collective precession when their FMR frequencies coincide. A collective behavior is also found in magnetic trilayers with interlayer exchange coupling (IEC).

In this study we investigate the interplay between IEC and SP, using Co/Cu/Py trilayers, where the Cu thickness (0-40 Å) sets the IEC strength. We employ broadband FMR spectroscopy (3-37 GHz) to explore the frequency (f) and coupling-strength dependence of ΔH. We show that the hybridization between the layers is governed by both the IEC and the field/frequency. The collective nature of the precessions is clear at low fields, as reflected by the signal amplitude and the resonance frequency vs. field. At higher fields, the layers behave as single films. This transition, from collective to single layer precession, is accompanied by changes in the slope of ΔH vs. f, i.e. the damping, and we attribute those changes to the SP between the layers. The results demonstrate that it is possible to engineer a cut-off frequency, below which the spin pumping is effectively turned off.

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P-B.118

Voltage controlled magnetic anisotropy for perpendicular magnetic tunnel junctions with CoFeB/W/CoFeB free layers

N. Tezuka, Y. Mutho, M. Matsuura, S. Sugimoto, T. Irisawa, Y. Nagamine, K. Tsunekawa

Text Voltage control of magnetic anisotropy in thin ferromagnetic films is a good candidate for low power magnetization switching of magnetic tunnel junctions (MTJs). We have reported the perpendicular MTJs with high TMR ratio (248%) and low RA products (10Ωμm2), and thier anisotropy change with voltage[1,2]. In this study, we have investigated in voltage control of magnetic anisotropy for such p-MTJs with various film thickness of CoFeB/W/CoFeB free layer. All the p-MTJ films were prepared on Si-oxide substrates with the use of a CANON ANELVA NC7900 sputtering system. The MTJ structure was : substrate/buffer layer/Co–Pt alloy synthetic antiferromagnetic layer/CoFeB pinned layer 0.9nm/MgO (0.9 or 1.6nm)/(CoFeB t1nm/W 0.6nm/CoFeB t2nm free layer) /MgO ~0.5nm/cap layer. The MR effect was measured at room temperature by four-probe method. It was found that MR curves were dramatically changed by applied bias voltage for a MTJ with MgO thichness of 0.9 nm, while for a MTJ with MgO thickness of 1.6 nm, no such large change was observed. The switching magnetic field of free layer increased with applied voltage in positive bias voltage region, and that decreased in negative bias voltage region, while that of pinned layer changed little with increasing voltage. The volatge dependence of switching field of free layer was almost the same for p-MTJs with various film thickness.
This work was partly supported by KAKENHI.
[1] IEEE Magn. Lett., 7, 3104104 (2016) [2] AIP Advances 8, 055922 (2018)

Poster Session B

Poster B

P-B.119

Analysis of fast precessional switching times distributions for magnetic nanoparticles

M. d'Aquino, C. Serpico, V. Scalera

Text Magnetization switching in nanomagnets is the fundamental issue to deal with in order to obtain high speed and energy-efficient recording devices[1]. To realize fast magnetization switching with greater efficiency, strategies as microwave-assisted switching[2] and precessional switching[3] have been proposed. In particular, the latter occurs by applying a field transverse to the initial magnetization and yields much smaller switching times than conventional switching. However, extremely precise design of the field pulse is required for successful switching. Then, the equilibrium magnetization is reached after quasi-random relaxation from a high-to low-energy state in presence of thermal fluctuations[3]. On the other hand, magnetic recording devices must fulfill strict reliability requirements in terms of very low write-error rates, which can be realized at expense of the write process speed. In this paper, we theoretically analyze the magnetization switching for a single magnetic bit cell subject to applied field pulses and room temperature thermal fluctuations. By using analytical techniques, we derive expressions for the switching times distribution functions in terms of material, geometrical and external field properties. Numerical simulations (macrospin and full micromagnetic) are performed to validate the analytical predictions.

[1] J.-P. Wang, Nature Mater. 4, 191, 2005
[2] C. Thirion et al., Nature Mater. 2, 524, 2003
[3] S. Kaka et al., Appl. Phys. Lett. 80, 2958, 2002

Poster Session B

Poster B

P-B.120

Automated micromagnetic simulations from native EBSD data

M. Gusenbauer, P. Zhao, T. G. Woodcock, T. Schrefl

Text Micromagnetic simulations require a detailed knowledge of the crystallographic structure of the material. In permanent magnets with reduced or no rare-earth elements typically crystallographic features play an important role for the energy density product. In MnAl compounds twinning and antiphase boundaries are known to affect nucleation and pinning fields. Micromagnetic simulations can help to improve the understanding of these effects on the hysteresis properties.
In preliminary studies artificial microstructures have been used for the simulations. Here we take native Electron Backscatter Diffraction (EBSD) data of MnAl microstructures to automatically create high quality finite element meshes with adaptive mesh size. A fast micromagnetic solver, minimizing the Gibbs' free energy, is applied subsequently and computes the hysteresis properties of the microscopic data.
The automated meshing and micromagnetic simulation routine is controlled via a Python script. Dream3D extracts EBSD data and converts them to a pixelated bitmap. Using image manipulation tools, the bitmap is automatically smoothed, corrected and upscaled. Iso2Mesh creates a 3D finite element mesh. An additional airbox, which is required for the stray field computation, is prepared with the Salome tool. The computed coercive fields are in the range of 0.36 T/μ0 to 0.53 T/μ0 depending on the density of defects.
Work supported by the Austrian Science Fund (FWF), Project: I 3288-N36.

Poster Session B

Poster B

P-B.121

Effects of Grain Boundary and Secondary Phase on Magnetic Properties and Recoil Loops in Hot-deformed NdFeB Magnets using Micromagnetic Simulations

Y. Hong, G. Wang, D. Givord, N. M. Dempsey, D. Zeng

Text Hot-deformed NdFeB magnets have attracted considerable attention due to their superior thermal stability and exceptional corrosion resistance. Here the dependence of magnetic properties and recoil loops on the grain boundary phase (GBP) and secondary phases in hot-deformed NdFeB magnets was explored using micromagnetic simulations. By adjusting the parameters of the simulation model, the influence of several factors (thickness and spontaneous magnetization (Ms) of the GBP, Ms, total volume fraction and spatial distribution of the secondary phase), on the main and recoil loops were investigated. A change in thickness and in Ms of the GBP affect the coercivity (Hc) and remanence of the main loop. In particular, an increase of Ms leads to a decrease in the magnet's Hc. The influence of the secondary phase depends on its spatial distribution. Large volume grains result in lower Hc, but the role in decreasing Hc is weaker in contrast to a random distribution of smaller grains of the same overall content. Open recoil loops were interpreted by analyzing the distribution of calculated magnetic moments and energy terms. Opening is not directly related to Hc along the main loop. It is mainly due to small irreversibilities in the dipolar energy of different magnetic configurations that appear along the recoil loop. These are reminiscent of irreversibly phenomena, due to a broad distribution of exchange interactions of different signs, observed in spin glass systems.

Poster Session B

Poster B

P-B.122

Elongated nano-conduits for the fast motion of vortex domain walls

C. Rotarescu, H. Chiriac, N. Lupu, T.-A. Ovari

Text The use of rapidly solidified cylindrical nanowires (100 nm in diameter, tens of cm long) as elongated nano-conduits for domain wall propagation is analyzed from the point of view of their magnetic anisotropy and magnetization process. We propose a micromagnetic model to investigate the role of magnetoelastic anisotropy in the magnetization process of highly magnetostrictive amorphous glass-coated nanowires with cylindrical symmetry. Specifically, a radially distributed magnetoelastic anisotropy term is considered within a finite element micromagnetic description of the rapidly solidified nanowires.
Simulation results show that both the magnitude and shape of anisotropy distribution affect the values of the nucleation and switching fields. The visualization of the magnetic moments configurations at various instants during magnetization is suitable for the study of the domain wall structures.
The main outcome of this work is that it proves, for the first time in rapidly solidified nanowires, the possibility for the spontaneous formation of vortex type structures, such as skyrmion-like or Bloch point wall ones. Most importantly, these structures propagate along the nanowires at magnetization switching, opening up new prospects for their application as long nano-conduits for the fast displacement of vortex walls, of interest for the development of novel magnetic logic devices.

Work supported by UEFISCCDI under project PN-III-P4-ID-PCE-2016-0358 (contract no. 149/2017).

Poster Session B

Poster B

P-B.124

Micromagnetic study of local magnetization reversal in amorphous microwires with small magnetostriction

P. Gawronski, K. Kulakowski, A. Chizhik, A. Stupakiewicz

Text We present the results of micromagnetic simulations of magnetization reversal process in amorphous microwires with small magnetostriction using the mumax^3 software. In our model we approximate the local magnetoelastic anisotropy as uniaxial, with its spatial dependence related to the internal stress distribution in a microwire. The simulated microwire was of cylindrical shape with diameter 1 μm and length 15 μm and was discretized into cells size of 10×10×5 nm^3. For small magnetostriction constant, our simulations reproduce the magnetic domain structure observed experimentally in the surface of microwires with small magnetostriction. We have studied the spatial redistribution of magnetization taken from the volume of the 80×80×100 nm^3, close to the surface of the microwire. We have obtained the local profile of the remanence and the coercive field. The remanence profile gives the information about the periodicity of the magnetic structure. We have found a correlation between the local remanence and the local coercive field as dependent on the distance from the microwire end.

Poster Session B

Poster B

P-B.125

Spin-torque nano-oscillators in magnetic tunnel junction with double reference layers

M. Carpentieri, R. Tomasello, P. Khalili Amiri, Z. Zeng, G. Finocchio

Text A recent technological realization of perpendicular magnetic tunnel junctions (MTJs) with two perpendicular reference layers has opened a new route for scaling the overall size of spin-transfer torque MRAM. This is because for an antiparallel configuration of the magnetization of the reference layers (RL) the two spin-transfer torques add constructively, giving rise to more efficient switching processes of the free layer magnetization as compared to a single MTJ [1]. Here, we use a full micromagnetic code to study a double MTJ with two in-plane RL in antiparallel configuration, generating microwave signals at low drive currents and external fields. The geometry and physical parameters of the investigated device are similar to the one studied experimentally by Zeng et al. [2] with the adding of the second RL. The device has an elliptical cross section of 70x40 nm2 and thickness t=1.60 nm. Our micromagnetic simulations show that it is possible to obtain magnetization oscillations by applying low field (10 mT) and current densities of JMTJ=0.4 – 1.6 MA/cm2. In addition, the power as a function of the source current describes a similar behaviour of that reported in a previous experimental study for single RL MTJ (see Fig. 2 of Ref. 2). From the comparison between the MTJ with single [2] and double RL, we see that the source current is decreased of a factor 5 (from 3.0 to 0.6 MA/cm2).
[1] L. Cuchet et al., JAP, 117, 233901, (2015).
[2] Z. Zeng et al., Sci. Rep., 3, 1426 (2013).

Poster Session B

Poster B

P-B.126

The effects of Surface Roughness on the Magnetisation Dynamics of Thin Magnetic Films

D. Jordan, A. Masood, C. O'Mathuna, P. McCloskey

Text In this paper the effects of surface roughness on the magnetisation dynamics of thin magnetic cobalt films is investigated. This paper utilises the “Object Orientated MicroMagnetic Framework”, OOMMF, to determine the magnetisation dynamics of a thin film which has a surface roughness imposed onto it.

In order to simulate the effect of surface roughness, the thin film is first quantised into N2 regions and a Gaussian distribution for height is then mapped onto this XY plane. Thus, the thickness of the film is controlled by the mean of the Gaussian distribution, and the surface roughness is controlled by the size of each distinct region and the variance of the Gaussian. In this paper, two distinct roughness regimes are investigated. In the first regime, the roughness of the thin film changes on a scale which is less the exchange length, and in the second regime the roughness varies on a scale greater than the exchange length. This is achieved by setting the size of a distinct region to be less than the exchange length, and vice versa. The effects of the two regimes of surface roughness on the coercivity, and on the anisotropy field, on the thin film are discussed in the paper and are then compared against experimental results.

Poster Session B

Poster B

P-B.127

3D localization of the Inverse Faraday effect in magnetophotonic structures

M. A. Kozhaev, A. I. Chernov, D. A. Sylgacheva, A. N. Shaposhnikov, A. R. Prokopov, V. N. Berzhansky, A. K. Zvezdin, V. I. Belotelov, I. Savochkin

Text Optical impact on the spin system in a magnetically ordered medium provides a unique possibility for local manipula-tion of magnetization at subpicosecond time scales that is very promising for magnetic data processing and other magnonics applications. Main mechanism of the optical manipulation is related to the inverse Faraday effect (IFE). Focusing of a laser beam provides 2D localization of the IFE.

Here we used the fs-laser pulses to excite magnetization of the magnetic film placed inside an optical microcavity, i.e. the magnetophotonic crystal (MPC). We have shown that placing a magnetic dielectric film in a microcavity provides a significant enhancement of IFE and its submicron localization along the film thickness. In particular, in our experiments pumping at the microcavity resonance results in 5-time increase of the IFE and provides the IFE localized in a 30 nm-thick layer of the magnetic film.

The enhancement factor is related to the quality factor of the microcavity. Distribution of the IFE magnetic field in the microcavity can be varied with the pump wavelength or the incidence angle of the fs-laser pulses. This feature can be used to access specific spins in the magnetophotonic crystal. The obtained results open a way for the new applications in the areas of magnonics and quantum information pro-cessing.

This work was supported by Russian Science Foundation (17-72-20260).

Poster Session B

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P-B.128

A micromagnetic model for ultrafast spin current-driven magnon dynamics

H. Ulrichs, I. Razdolski

Text Recent experimental reports have demonstrated that optically induced femtosecond spin currents can excite coherent magnon dynamics in the THz frequency range.[1,2] Here I will present a simple micromagnetic (numerical and analytical) model for this process. [3] The basic ingredient of this practically 1d model is a Slonczewski-like spin-transfer torque term. With this, we can reproduce the salient features of the experiments presented in reference [1]. Furthermore, the model provides insight into the factors which govern the spin wave mode-specific excitation efficiency. Lastly, I will discuss results for a collinear spin injection geometry. Our modelling shows that then, a thermally occupied magnon ensemble can be heated or cooled on fs time-scales. HU acknowledges financial support by the DFG within project A06 of the SFB 1073.

[1] I. Razdolski et al., Nat. Comm. 8, 15007 (2017)
[2] M.L.M. Lalieu, P.L.J. Helgers, and B. Koopmans, Phys. Rev. B, 96, 014417 (2017)
[3] H. Ulrichs, and I. Razdoslki, arXiv:1802.01305

Poster Session B

Poster B

P-B.129

A quantitative magnetization analysis of individual domains written in FePt by femtosecond laser pulses

V. Neu, R. John, Y. Tang, Y. Shevchenko, J. Walowski, T. Santos, K. Nielsch, M. Münzenberg

Text The controlled manipulation of magnetic materials not by external magnetic fields but by femtosecond laser pulses – helicity dependent all optical switching – is a branch of magnetism that developed quickly after its discovery [1]. Initially observed in amorphous ferrimagnetic thin films, this effect has recently been found also in magnetic storage material, namely granular $L1_0$ FePt with perpendicular magnetic anisotropy [2,3]. Depending on the helicity of the circularly polarized light, an as-prepared, thermally demagnetized film develops an overall positive or negative net perpendicular magnetization in lines of multiple laser pulses with several hundred repeats and in individually written spots obtained from only few laser pulses. This has been qualitatively confirmed by previous Kerr microscopy images [3].
By applying quantitative magnetic force microscopy (qMFM) this work addresses the magnetization profile across written lines and also individual spots of single laser pulses with high spatial resolution. With the help of calibrated MFM probes the magnetization profiles are quantitatively estimated and associated with the switching probability of individual FePt nanograins or clusters. Complementary Monte-Carlo simulations confirm the clustering of magnetization across grains during the optically excited magnetization process.
References: [1] Stanciu *et al.*, Phys. Rev. Lett **99** (2007), [2] Takahashi *et al.*, Phys. Rev. Appl. **6** (2016), [3] John *et al.*, Sci. Rep. **7** (2017).

Poster Session B

Poster B

P-B.130

All-Garnet Heteroepitaxial Magneto-Optical Photonic Crystals

A. M. Grishin, S. I. Khartsev, V. Ignakhin

Text We survey the cutting edge results on synthesis and properties of all-garnet heteroepitaxial magneto-optical photonic crystals (MOPC) RF sputtered by alternating layers of RE Gallium Garnet and Bismuth Iron Garnet $Bi_3Fe_5O_{12}$ (BIG). BIG combines the record high Faraday rotation (FR, θ_F=8.4 deg/μm at 633nm) with transparency in visible and IR.
Ultimate MO performance was achieved growing all-garnet MOPCs containing BIG in a resonant λ/2 cavity and RE garnets in λ/4 reflectors in Bragg mirrors. In MOPC, due to nonreciprocal ferromagnet's optical properties, FR increases by a factor of *N*, as a number of reflections light experiences bouncing between Bragg mirrors.
Optimization of processing parameters enables achievement of very smooth (rms roughness <1nm) layers with sharp interfaces. Multicolor tunable band pass MOPC filter with 6 pairs of λ/4 $Bi_3Fe_5O_{12}/Sm_3Ga_5O_{12}$ reflectors in 2 Bragg mirrors with a λ/2 BIG in-between microcavity demonstrated the highest FR θ_F=20.5 deg/μm at 750nm, sharp stop band with 1nm wide microcavity mode and peak-to-valley ratio <50dB.
The next generation of MOPCs was engineered substituting Fe^{3+} in BIG with diamagnetic Al^{3+} and Ga^{3+} ions. Due to introduced perpendicular magnetic anisotropy, MOPC owned MO memory. To the date, at λ_{res}=775(640)nm, FR θ_F=14.1(14.8)deg/μm and MO-quality factor *Q*=99.3(46.2)deg represent the highest achieved MOPC performance. Compared to a single layer BIG film, θ_F and *Q* were increased, correspondingly, by the factors of 12 and 2.

Poster Session B

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P-B.131

All-Optical Switching Dynamics in a Ferromagnetic Model System

C. Scholl, H. C. Schneider

Text We present a theoretical study of the effects of polarized optical fields on a ferromagnetic model system. In particular, we consider a Rashba ferromagnet, which includes ferromagnetism at the time-dependent mean-field level and spin-orbit-coupling. The spin-split bands of the ferromagnetic Rashba model are dipole coupled to two "non-essential bands", in the sense of nonlinear optics. We solve the Bloch equations, which include linear and nonlinear optical effects non-perturbatively, and we include incoherent electronic redistribution processes.

Within the framework of the model, we calculate the evolution of the magnetization induced by polarized optical fields and show that, for certain excitation conditions, a polarization dependent switching of the magnetization occurs. As we include the influence of the optical fields and the (mean-field) magnetic dynamics on an equal footing, we can clarify the respective contributions to the magnetization dynamics due to the inverse Faraday effect [1] and the dynamical optical Stark effect, as introduced in [2]. We also discuss the effect of electronic heating, the role of the broadening of the optical transitions as well as the influence of cooling via electron-phonon coupling.

[1] M. Berritta, R. Mondal, K. Carva, P. M. Oppeneer, Phys. Rev. Lett. 117, 137203 (2016)
[2] A. Qaiumzadeh, G.E.W. Bauer and A. Brataas, Phys. Rev. B 88, 064416 (2013)

Poster Session B

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P-B.132

All-optical magnetization switching of FePt magnetic recording media

R. John, J. Walowski, C. Müller, M. Beritta, D. Hinzke, P. Nieves, O. Chubykalo-Fesenko, T. Santos, H. Ulrichs, R. Mondal, P. Oppeneer, U. Nowak, J. McCord, M. Münzenberg

Text Magnetization manipulation is essential for basic and applied research[1]. The energy transfer from the laser-excited electrons to the spins within femtoseconds governs the dynamics and determines the speed of ultrafast magnetization.
A material of interest for magnetic storage is FePt[2].
All-optical writing was shown for FePt nanoparticles by Lambert et al.[3], opening questions about possible extensions of all-optical writing as a general mechanism.
So far, independent writing experiments point to an asymmetric writing per laser shot[4,5,6]. I will review the current understanding of the interaction between ultrafast excitation and heating, how much magnetic dichroism and the inverse Faraday effect influence the process.
Optical effect ab-initio calculations together with thermal modelling, allow determining the switching rates for individual nanoparticles. They provide rates for ensemble switching. We can trace the processes from the beginning of the laser pulse impact[4]. This description allows optimizing the number of shots needed to write themagnetization. Recent development aims to address individual nanosized elements all-optically.

[1] J. Walowski and M. Münzenberg, J. Appl. Phys. 120, 140901 (2016).
[2] J. Mendil et al., Sci. Rep. 4, 3980 (2014).
[3] C.-H. Lambert et al., Science 345,1337-1340, (2014).
[4] R. John et al., arxiv:1606.08723.
[5] M.S. El Hadri et al., Appl. Phys. Lett. 108, 092405 (2016).
[6] Y.K. Takahashi et al., Phys. Rev. Applied 6, 054004 (2016).

Poster Session B

Poster B

P-B.133

Anomalous magneto-optical response of Bi-YIG films with embedded Au nanoparticles

S. Pappas, P. Lang, M. Aeschlimann, E. T. Papaioannou

Text The magneto-optical effects exhibited by ferromagnetic materials can be enhanced by adjacent plasmonic resonant structures [1,2]. In this work, we reveal the anomalous enhancement of the magneto-optical Kerr response (MOKE) of ferrimagnetic bismuth substituted yttrium iron garnet (Bi-YIG) thin films, induced by localized surface plasmons (LSPs) in gold nanoparticles (AuNPs). The resonant frequency of the LSPs has been revealed with the aid of optical uv-vis spectrophotometry. A Bi-YIG sample containing no nanoparticles was also used as a reference. The magneto-plasmonic response was studied with the aid of a spectroscopic MOKE setup operating in the longitudinal mode. The experimental results reveal an anomalous magneto-optical response for the sample containing Au nanoparticles close to the LSP resonances. In order to gain insight into the mechanism of the exhibited anomalous Kerr effect, the magneto-optically induced electric fields in the Near Field region have been simulated and correlated to the corresponding Far Field results.

[1] V. I. Belotelov, I. A. Akimov, M. Pohl, V. A. Kotov, S. Kasture, A. S. Vengurlekar, Achanta Venu Gopal, D. R. Yakovlev, A. K. Zvezdin and M. Bayer, Nat. Nanotechnol. 6, 370 (2011).
[2] M. Rollinger, P. Thielen, E. Melander, E. Östman, V. Kapaklis, B. Obry, M. Cinchetti, A. Garcia-Martin, M. Aeschlimann, and E. Th. Papaioannou, Nano Lett. 16, 2432 (2016).

Poster Session B

Poster B

P-B.134

Au/Tb_xCo_{1-x} layered pillars as tunable magneto-plasmonic resonators

A. Ciuciulkaite, R. Rowan Robinson, O. Lysenko, A. Dmitriev, V. Kapaklis

Text All-optical switching (AOS) of the magnetization in the rare earth-transition metal GdFeCo alloy was first demonstrated in [1] using 40 ps laser pulses. Since then a lot of research effort was focused on understanding AOS mechanism and developing magnetic architectures suitable for application in magnetic memory devices which could exploit magnetization switching induced by laser pulses. In this work, we are going to investigate the magneto-plasmonic behavior of disordered and ordered arrays of thin circular discs prepared by self-assembly and electron beam lithography techniques (EBL). Our magneto-plasmonic structures contain a plasmonic element made of Au and an amorphous TbCo alloy with out-of-plane magnetization. We start by investigating arrays containing randomly distributed plasmonic $Au/Al_2O_3/Tb_{18}Co_{82}/Al_2O_3$ discs. This initial step provides information about a single Au disc plasmon resonance since any possible inter-disc interaction can be neglected in disordered arrays. First results demonstrate a possibility of tuning the plasmonic resonance of pillars via modifying the Au disc diameter. In turn, this allows for investigation of a suitable optical regime for AOS of the magnetization in $Tb_{18}Co_{82}$ layer deposited on top of the Au layer. Furthermore, preparing such discs from the multilayered films by EBL would provide with more precise control over the disc size and a better defined plasmonic resonance.

References:

1. Stanciu et al. Phys. Rev. Lett. 99, 047601 (2007)

Poster Session B

Poster B

P-B.135

Characterization of metasurfaces using Photoelatic Modulators – Advantages and Limitations

I.-A. Chioar, R. M. Rowan-Robinson, P. Vavassori, V. Kapaklis

Text Metasurfaces are nanostructured interfaces that can induce abrupt changes to light wavefronts and polarization through arrays of sub-wavelength scatterers acting as optical antennas. This tailoring largely depends on their size and shape, as well as on the choice of material, all of which can be designed to a high degree using modern fabrication techniques. Furthermore, incorporating magnetic materials in such nano-architectures can render them optically reconfigurable via magneto-optical effects, which can also be enhanced. Such flat metasurfaces offer a vast and exciting playground for both fundamental studies related to light-matter interaction at the nanoscale, as well as technological opportunities for designing a new generation of flat optical components.

Given the large freedom in design, appropriate characterization methods and tools need to be developed that can access various optical and magneto-optical parameters for such metasurfaces. Photoelastic modulators (PEM) are typically employed to determine optical properties, such as linear and circular dichroism/birefringence. However, we have observed that commonly-used/standard methods involving single-PEM optical characterization of periodic arrays of nano-scatteres can be severely affected by artifacts. We will present and discuss advantages, limitations, and different analysis methods that can facilitate access to certain properties of such metasurfaces.

Poster Session B

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P-B.136

Control of spin waves optically excited with spatially modulated femtosecond laser pulse

I. Savochkin, A. Chernov, M. Kozhaev, V. Belotelov

Text Currently spin waves are considered for computation and data processing as an alternative to charge currents [1-3]. Generation of spin waves by ultrashort laser pulses provides several important advances with respect to conventional approaches using microwaves. In particular, focused laser spot works as a point source for spin waves and allows for directional control of spin waves and modulating their spectrum [4].
In the present work we introduce one more method for spin wave control. In particular, we use spatial light modulator to excite magnetization of the sample with several coherent femtosecond laser pulses focused at different spots on magnetic film. Thus we achieve different interference patterns of the magnetization dynamics. It may significantly broaden capabilities of the spin wave based devices.

1. Grundler, D. Nanomagnonics. J. Phys. D: Appl. Phys. 49, 391002 (2016).
2. Khitun, A., Bao, M. & Wang, K. L. Magnonic logic circuits. J. Phys. D: Appl. Phys. 43, 264005 (2010).
3. Sadovnikov, A. V. et al. Voltage-Controlled Spin-Wave Coupling in Adjacent Ferromagnetic-Ferroelectric Heterostructures. Phys. Rev. Applied 7, 014013 (2017).
4. Jäckl, M. et al. Magnon accumulation by clocked laser excitation as source of long-range spin waves in transparent magnetic films. Phys. Rev. X 7, 021009 (2017).

Poster Session B

Poster B

P-B.137

Controlled domain-wall motion in a dielectric iron garnet with femtosecond optical pulses

K. Horabail Prabhakara, T. B. Shapaeva, S. Wang, C. S. Davies, A. Kirilyuk, T. Rasing, A. V. Kimel

Text The concept of racetrack memories exploits magnetic domain wall motion for non-volatile, energy-efficient data storage [1]. In this context, several experiments have demonstrated optical control of static magnetic domain walls in ferromagnets [2]. On the other hand, ferrimagnetic garnets are known to exhibit photomagnetic effects, which enable the spins in these materials to be optically manipulated [3]. Moreover, previous studies also show that ferrite garnets have high and even supersonic domain wall velocities [4]. Here we report about an experimental investigation of the effects of femtosecond laser pulses on a moving domain wall in the dielectric (Bi,Y)3Fe5O12. The domain wall displacement was initiated using a short magnetic field pulse and captured using a magneto-optical double photography technique [5]. The experiment reveals that an ultrashort optical pulse applied during the domain wall motion, is able to slow down that motion. We found that the effect strongly depends on the domain wall velocity and the optical fluence. To explain our observations, we suggest that the mechanism involves the formation of stable, laser-induced vortices in slowly-moving domain walls, as it is well known that the formation of magnetic vortices can dramatically reduce domain wall velocities in garnets [5].

[1] S. P. Parkin et al., Science 320, 190 (2008).
[3] F. Hansteen et al., Phys. Rev. Lett. 95, 047402 (2005).
[5] M.V. Chetkin et al., Zh.Eksp. Teor. Fiz. 94, 164 (1988).

Poster Session B

Poster B

P-B.138

Dependence of the efficiency of spintronic THz emitters on the excitation energy, crystal structure and multilayer stacking.

E. T. Papaioannou, S. Keller, L. Scheuer, G. Torosyan, R. Beigang

Text Recent studies in spintronics have highlighted ultrathin magnetic metallic multilayers as a novel and very promising class of broadband terahertz radiation sources [1,2]. In this work, we reveal the factors that can optimize a spintronic structure based on Fe/Pt films. Fe/Pt is as effective as a THz radiation source when excited either at λ = 800 nm or at λ = 1550 nm by ultrafast laser pulses from a fs fiber laser [3]. Even with low incident power levels, the Fe/Pt spintronic source exhibits efficient generation of THz radiation at both excitation wavelengths. The efficiency of the emitter can be further increased with the crystal structure of the bilayer. Epitaxial grown Pt layers almost double the amplitude of the THz pulse. We attribute this behavior in the different electron scattering lifetimes between epitaxial and polycrystalline layers. Furthermore, we demonstrate how the insertion of a Ta layer in Fe/Pt system can further boost the emission capabilities of the THz source. The efficient THz emitter based on the modification of the crystal structure and the layer stack which can be operated at 1550 nm facilitates the integration of such spintronic emitters in THz systems driven by relatively low cost and compact fs fiber lasers without the need for frequency conversion.

[1] G. Torosyan et al., Scientific Reports 8, 1311 (2018)
[2]T. Seifert et al., Nat Photon 10, 483–488 (2016)
[3]E. Th. Papaioannou et al., http://arxiv.org/abs/1803.08838 (2018)

Poster Session B

Poster B

P-B.139

Detection of short wavelength spin waves by magneto optical effects in the plasmonic crystals

D. Sylgacheva, I. Savochkin, A. Kalish, V. Belotelov

Text Presently the coherent excitation of spin ensembles using plasmonic structures is of prime research importance since it potentially can expand the functionalities of magnonics. Optical visualisation of spin waves of small wavelengths (50 - 300 nm) is not possible by light due to the diffraction limit. However, plasmonic gratings allow it. In this work, gold gratings on magnetic films are investigated, and the optical properties of the plasmonic crystals were studied by simulations and experiments of the transmittance and magneto-optical effects.

The investigations carried out show that when spin waves propagate through a magnetic film with a plasmonic coating, precession of the magnetization can be recorded by measuring the dependence of the Faraday angle or the transverse Kerr effect on time. At the same time, when observed at a wavelength corresponding to the resonance of the magneto-optical effect, the amplitude of the detected signal in the plasmonic crystal exceeds by more than 10 times the amplitude of the signal when viewed with a focused laser beam in a magnetic film without plasmonic coating.

Application of a plasmonic coating to a magnetic film makes it possible to obtain information about the amplitude, wavelength, and frequency of the spin wave propagating in the material much more effectively by a magneto-optical method. There is no need to focus the laser beam into a spot close to the diffraction limit, which greatly simplifies the experimental procedure.

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Poster B

P-B.140

Enhanced Faraday effect in heterostructures based on 2D array of gold nanodisks and a magnetic dielectric layer

D. Krichevsky, A. Kuzmichev, D. Sylgacheva, A. Kalish, V. Belotelov, I. Savochkin

Text Localized surface plasmon resonance is phenomenon caused by electron oscilations in metal nanoparticles. It enables to enhance different optical effect, such as absorption, scattering, luminescence etc. Current technologies made nanoparticles' arrays fabrication possible that allows control of light at nanoscale. At the same time, as it was shown by many researchers, gold nanolayers perforated with subwavelength slits can enhance magneto-optical effects, such as Faraday or magneto-optical Kerr effect. This structures increase optical transparency of the magneto-optical system together with rotation angle value enhancement.
In current research we report on transmission and Faraday angle rotation theoretical calculations of magnetoplasmonic 2D structure based on periodic grating of gold nanodisks on top of a smooth Bi-substituted yttrium iron garnet (BiYIG). It was shown that localized surface plasmon resonance, lattice and waveguiding modes play crucial role in Faraday rotation angle enhancement. Period of nanoparticles in the structure and dielectric surrounding of the nanoparticles were optimized to obtain the highest value of Faraday rotation angle with low optical losses. Theoretical simulation of transmittance and Faraday angle rotation was performed using rigorous coupled-wave analysis and transition matrix method.

This work is supported by Russian Science Foundation (project No. 17-72-20260).

Poster Session B

Poster B

P-B.141

Heat-Assisted Precessional Magnetization Reversal in a Dielectric Iron-Garnet

C. Davies, K. Prabhakara, M. Davydova, K. Zvezdin, T. Shapaeva, S. Wang, A. Zvezdin, A. Kirilyuk, T. Rasing, A. Kimel

Text In heat-assisted magnetic recording (HAMR), magnetization is reversed through the combined action of a laser-induced thermal load and an antiparallel magnetic field[1]. Here, we experimentally and numerically reveal an alternative pathway, using a magnetic field applied perpendicular to the axis of magnetic anisotropy. The laser-induced thermal load destroys the magnetic anisotropy[2], thus triggering large-amplitude precession about the new transient effective field, enabling the magnetization to undergo complete reversal. In our experiment, the sample of Bismuth-doped $Y_3Fe_5O_{12}$, featuring out-of-plane magnetic anisotropy, was exposed to a magnetic field with a strong in-plane (H_x) and a weaker out-of-plane component. To trigger magnetization dynamics, the medium was excited by a single intense ultrashort optical pulse. Despite the intensity distribution of the pump pulse being spatially continuous and Gaussian, we surprisingly form a “bullseye” pattern of magnetic domains. The number of rings increases with both the pump fluence and H_x, and are formed within less than 1 ns after the pulse arrival. We identify that the smooth reversal of magnetization occurs in the absence of ringing, revealing an anomalous increase in the magnetic damping. This is crucial for magnetization to be reversed in the shortest possible time (one-half of a precessional period).

[1] M. H. Kryder et al. Proc. IEEE 96, 1810 (2008).
[2] A. Stupakiewicz et al. Nature 542, 71 (2017).

Poster Session B

Poster B

P-B.142

Influence of nonequilibrium phonons on the magnetization dynamics of itinerant ferromagnets and alloys

I. Klett, S. T. Weber, B. Rethfeld

Text Ultrashort laser pulses affect strongly the magnetization of itinerant ferromagnets [1]. Such ultrafast magnetization changes are widely explained by Elliott-Yafet spin-flip mechanisms.
We have modeled the spin-dependent electron dynamics in laser-excited nickel with Boltzmann collision integrals in Ref. [2]. The demagnetization was explained by a relaxation of the chemical potential of up- and down-electrons. A combination of electron-electron and electron-phonon spinflips yields the largest change of the magnetization. On picosecond timescales, the electrons transfer energy to the phonons, leading to a remagnetization of the electronic system. However, the heated phonons are driven out of equilibrium for a timescale of several picoseconds. The thermalization dynamics highly depend on the nonequilibrium state in the electronic and phononic subsystems.

In Ref. [3] a model for the description of a phonon nonequilibrium and its relaxation was introduced. Phonon-phonon interactions are described with Boltzmann collision integrals.
From this, wavenumber-dependent relaxation times can be extracted. The thermalization of the system is then described within a relaxation time approach. We present first results combining the electron and phonon nonequilibrium dynamics that influence the ultrafast de- and remagnetization in itinerant ferromagnets.

[1] E. Beaurepaire et al., PRL, 76:4250 (1996)
[2] B.Y Mueller et al., PRL, 111:167204 (2013)
[3] I. Klett, PhD Thesis (2017)

Poster Session B

Poster B

P-B.143

Intense laser pulse induced magnetic field and its effect on magnetic domain formation and reorientation

K. Nath, J. Sinha, M. Shaikh, S. S. Banerjee, G. R. Kumar

Text One of the interesting areas in condensed matter physics is to search for different routes to reorient magnetization in magnetic materials at ultrashort time scales. We investigate the interaction of femtosecond high intensity laser pulses with matter which involves resonance absorption, leading to relativistic jets of electron currents. These jets create magnetic field pulses with peak heights of hundreds of mega Gauss and peak widths of femtosecond regime. We irradiate two materials with different magnetic properties: (a) YiG film on GGG substrate and (b) Magnetic tape (consisting γ-$Fe^{2}O^{3}$ particles) with p-polarized femtosecond laser pulse (~10^{16} Wcm^{-2},100fs). Using high sensitivity magneto-optical imaging we observe the emergence of new domain wall excitations near the vicinity of irradiation. We found threshold laser energy for causing these domain wall excitations and a scaling of the domain size with the energy of laser pulse. Micro-magnetic simulations (solving LLG equations) are done to understand the nature of the excitations which reveal the propagation of a disturbance in the magnetic configuration of the film which has the same structure and features as the domain excitation seen in our experiments. From these studies we propose that the excitation of Bloch domain wall is created with this laser pulse irradiation. We believe our work holds the potential to explore new efficient ways of encoding magnetic information which can be useful for magnetic memory devices.

Poster Session B

Poster B

P-B.144

Investigation on magneto-optical properties of Te-based phosphate glass for Faraday rotators

M. Elisa, R. Stefan, I. C. Vasiliu, B. A. Sava, L. Boroica, A. C. Galca, M. Sofronie, V. Kuncser, M. Secu

Text This work is focused on investigation of structural, magnetic and magneto-optical properties of novel Te-based phosphate glass applied as Faraday rotators. The glass belonging to the oxide system 45ZnO 10Al2O3 40P2O5 5TeO2 was prepared by a non-conventional wet route of raw materials processing, followed by melting-quenching-annealing of the final product. Optical transmission reveals significant values over 600 nm wavelengths, satisfying the 650 nm reference wavelength specific to industrial glass as Faraday rotators. Structural analysis performed by FTIR and Raman spectroscopy put in evidence vibration modes specific to TeO3 (pyramid), TeO4 (bipyramid), P-O-P and O–P-O bonds, characteristic for phospho-tellurite vitreous materials.
The magnetic measurements evidenced for the Te doped glass a diamagnetic behavior with a negative, small (in the range of 10-7 cm3/g) and temperature independent susceptibility. The magneto-optical measurements performed by spectroscopic ellipsometry in transmission reveal, in concordance with the diamagnetic behavior, a positive Faraday rotation angle, θF on the entire visible spectral range and its magnitude decreases at increasing wavelength. For our low TeO2 content glass, the calculated Verdet constant was found to be about 0.02 min/Oe cm at 650 nm.

Poster Session B

Poster B

P-B.145

Magneto-Plasmonic Heterostructure with Periodic Array of Triangular Metallic Nanoparticles

A. Kalish, M. Goguev, A. Kuzmichev, I. Savochkin, V. Belotelov

Text Resent research has demonstrated the enhancement of magneto-optical effects plasmonic structures supporting surface plasmon polaritons or localized surface plasmons [1]. Due to symmetry reasons linear-in-magnetization effects associated with in-plane magnetization are prohibited at normal incidence because magnetization reversal is equivalent to rotation of the structure along vertical axis by 180 degrees. That is why the transverse magneto-optical Kerr effect (TMOKE) occurs only at oblique incidence. However for practical reasons it would be useful to observe the TMOKE at normal incidence. For that reason the spatial symmetry of the structure should be broken. In the present work we study non-symmetrical plasmonic structure.
The structures under consideration consist of magnetic dielectric layer and periodic array of metallic nanoparticles of triangular shape on top of it. The metal is gold and the magnetic dielectric is Bi-substituted iron garnet. The substrate is GGG.
The optical and magneto-optical properties of plasmonic structures were calculated by means of rigorous coupled-wave analysis (RCWA). We demonstrate the emergence of the TMOKE in non-symmetrical plasmonic structures at the normal incidence. The spectrum of the TMOKE has a resonance related to the plasmon excitation.
The work is supported by the Russian Science Foundation (project No. 17-72-20260).
[1] V. I. Belotelov, et al., Nature Nanotechnol. 6, 370 (2011).

Poster Session B

Poster B

P-B.146

Magneto-optical constants and their transient changes in ultrafast XUV spectroscopy

F. Willems, C. von Korff Schmising, C. Strüber, D. Engel, D. Schick, I. Radu, S. Eisebitt

Text Ultrafast de- and remagnetization as well as all-optical magnetization switching are important phenomena in a rapidly growing field of fundamental research with great potential for future technology. Of special interest are multi-element samples combining transition metals with rare earths and/or high-Z elements, which can show laser-induced all optical switching. Of special interest is here the understanding of the interplay of different elements in the sample.
Recent developments in laser technology and high harmonic generation (HHG) opened up the field for element specific magnetization probing. In particular, probing via magnetic circular dichroism in absorption has become possible in the extreme ultraviolet spectral range (XUV), providing access to the M-edges of the ferromagnets Fe, Co, and Ni as well as the O- and N-edges of Pt with excellent temporal resolution.
As time resolved XUV spectroscopy becomes more and more popular due to increased availability of HHG sources, it is of great importance to understand the spectroscopic processes at these shallow core-hole resonances and the extractable quantitative information on the magnetization in the sample.
Towards this goal, we carried out static measurements at a synchrotron facility to obtain a complete set of the complex dichroic index of refraction for the transition metals Co, Ni, Fe. Furthermore, in a time resolved experiment we study the transient changes of the absorptive part of the refractive index.

Poster Session B

Poster B

P-B.147

Magneto-optical observations of thin magnetic cylinders: role of topography

K. Richter, O. Vahovsky, R. Varga, A. Thiaville

Text Thin cylindrical wires attract considerable attention due to the interesting features of domain wall motion like absence of the Walker breakdown that makes possible to reach very high domain wall velocities [1]. While several experimental techniques allow for well controllable deposition of magnetic structures with complex geometries [2], a reliable determination of the surface magnetization usually meets several obstacles in case of samples with curved surface. Here, we provide a full analytical calculation of the Magneto-Optical Kerr Effect (MOKE) contrast for cylinders with reduced diameter.

It is shown that the cylindrical shape of sample surface gives rise to a spatial distribution of the planes of incidence that are all tilted each to other [3]. Such mutual orientation of incident rays in combination with circumferential dependence of a local angle of incidence gives rise to apparent magneto-optical contrasts [3,4] that cannot be interpreted well without considering the curved surface of a cylinder. The magneto-optical contrast is calculated for various angles of incidence, directions of surface magnetizations and directions of linear polarizations . Theoretical calculations [3] are tested experimentally.

[1] M. Yan, et al., Phys. Rev. Lett. 104 (2010), 057201.
[2] A. Fernández-Pacheco, et al., Sci. Rep. 3 (2013), 1492.
[3] K. Richter, et al., Phys. Rev. B 96 (2017), 064421.
[4] K. Richter, et al., IEEE Trans. Magn. 50 (2014), 2501404.

Poster Session B

Poster B

P-B.148

Magneto-plasmonic interfaces investigated with MOKE, PEEM and BLS

T. Eul, F. Heussner, M. Hartelt, M. Vogel, T. Fischer, S. Pappas, B. Hillebrands, E. Papaioannou, M. Aeschlimann

Text The field of magneto-plasmonics is growing rapidly nowadays with the main aim to explore the combination of magnetic and plasmonic functionalities in materials, which support magnon and plasmon exciation simultaneously. These materials open new routes in the research of magnetism especially with regard to downscaling of devices.
Here we investigate how the magnetic properties of the ferromagnetic dielectric bismuth substituted yttrium iron garnet (Bi-YIG) can be influenced by localized surface plasmons(LSPs) induced in gold nanoparticles. Using the magneto-optic Kerr effect(MOKE), we show an enhancement of the longitudinal magneto-optical Kerr signal for light close to the LSP resonance. To further analyze the plasmonic properties, we investigate the near field enhancement at the LSP resonance in a photoemission electron microscope(PEEM). Finally, we use Brillouin light scattering(BLS) to study the influence of plasmons on magnonic excitations.

Poster Session B

Poster B

P-B.149

Magneto-plasmonic properties of Au nanoparticles capped with Fe oxide

G. Campo, F. Pineider, A. Caneschi, P. Ghigna, A. Garcia Martin, C. de Julian Fernandez

Text Core@shell nanoparticles, composed by plasmonic noble metals and magnetic Fe oxide moieties, constitute one of the more investigated class of magneto-plasmonic nanostructures. Originally their study was motivated by their novel magneto-optical (MO) properties, but actually they are promising multifunctional nanomaterials to be employed in biomedicine and in photo-magneto-catalysis. In particular, very interesting appears the interaction between magneto-optical characteristics of the magnetic moiety and the plasmonic resonance, which can give rise to new properties and modify the existing ones. In this study we have grown and characterized hybrid nanostructures made of Au core capped by a Fe oxide shell with different thickness. In all samples the magnetic moiety does not show a measurable MO contribution; on the contrary, the result of this combination is an enhancement of the MO response of the noble metal in the surface plasmon region, if compared with the bare Au nanoparticles. X-Ray absorption and Electron Dispersive Spectroscopy characterizations together with magnetic measurements suggest the Fe3+ composition and a miss of magnetic order. Simulations of the plasmonic and MO response were performed considering different hypothesis of Fe oxide dielectric layer. Our study shows that the employment of magnetic oxide capping constitutes a very promising for the design of multifunctional plasmonic nanomaterials. Research supported by EC FP7-214107-2 NANOMAGMA Project

Poster Session B

Poster B

P-B.150

Modeling of Linear and Quadratic MOKE from First Principles, Comparison to Experiment

O. Stejskal, R. Silber, D. Kral, L. Beran, J. Rodewald, T. Kubota, Y. Ando, J. Pistora, J. Wollschläger, M. Veis, T. Kuschel, J. Hamrle

Text We present ab-initio calculations of linear and quadratic MOKE spectra of bcc Fe and Co2MnSi Heusler compound using the WIEN2k code [1]. The spectra are compared to the experiment. We focus on the microscopic origin of the magneto-optical effect by analyzing the properties of the electronic structure of these materials. The magneto-optical transitions are visualised in the Brillouin zone and the key transitions contributing to the linear and quadratic magneto-optical response are identified. We show that the magneto-optical response originates only from limited number of k-points in the Brilllouin zone.

[1] P. Blaha, K. Schwarz, G. Madsen, D. Kvasnicka and J. Luitz, WIEN2k

Poster Session B

Poster B

P-B.151

Nonlinear ultrafast response of thin magnetic films to tailored electromagnetic pulses

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Text We study the response of thin metallic magnetic layers driven by short spatially inhomogeneous electromagnetic fields pulses, beyond the linear response regime. We consider the magnetic dynamics triggered by inhomogeneous intense THz fields as well as the magnetic excitations caused by the induced spatio-temporally dependent, photo-induced current densities and work out how such external perturbation can be utilized for the generation and steering of topological magnetic excitations via tailored optical pulses.

Poster Session B

Poster B

P-B.152

Numerical analysis of the correlation between ferrofluid optical transmission and its intrinsic properties

A. Sanz-Felipe, J. C. Martín

Text The design of ferrofluids with customized magneto-optical properties presents a great interest face to photonic applications. We present a numerical method which predicts the ferrofluid optical transmission after switching the external magnetic field applied. The method considers the ferrofluid particles' size, concentration and magnetic response, the solvent viscosity, the surfactant effect, etc.
The calculation presents two sections. The first one solves the temporal evolution of the nanoparticles' locations, velocities and dipoles' orientation depending on the ferrofluid intrinsic conditions. All the physical interactions between the nanoparticles are considered: dipole-dipole forces, external and internal magnetic fields, Brownian motion and surfactant stabilization. The second section calculates the sample optical transmission by numerical propagation of an electromagnetic wave over the particles' distribution.
On the one hand, the calculations show how small changes in the ferrofluid intrinsic properties may induce different (even opposite) particles' reorganization mechanisms and transmission evolution. On the other hand, experimental measurements and predictions of analytical models provided by the Literature are compared with the numerical calculations. The comparison evidences the validity ranges of both the numerical and the analytical calculation methods.

Poster Session B

Poster B

P-B.153

Optical and Magneto-Optical Characterization of Magnetoplasmonic Nanoantennas

K. Mishra, C. Lumdee, O. Lysenko, I. Zubritskaya, A. Kimel, T. Rasing, A. Dmitriev, A. Kirilyuk

Text With a growing demand for faster data processing, magnetization switching using ultrafast femtosecond laser pulses is a promising alternative to current magnetic storage technologies. While all-optical switching has been successfully demonstrated in Rare Earth-Transition Metal alloy films like GdFeCo, there is potential to reduce bit size, and the minimum threshold fluence required to induce reversal.
One possibility to do this is by integration of the switching medium with plasmonic optical nanoantennas, which can confine the incident electric field below the diffraction limit, and amplify the incident electric field at their resonant wavelength.
We investigate the effect of plasmon resonances in cone-shaped Au nanoantennas on the magnetic and magneto-optical properties of Co nanoparticles, fabricated on the tips of the cones, with the goal to achieve all-optical magnetization reversal of the Co nanostructures.
Magneto-optical spectroscopy shows that the observed Kerr rotation is highly affected by plasmon resonances, both along the cone-axis and across the base. However, a previously unexplored optical anisotropy is observed in a short-range-ordered (amorphous) array of nanocones, leading to a sizeable birefringence even for normally-incident light.
Despite the nanoscopic size, the Co tips show hysteresis, with an in-plane easy axis of magnetization. The hysteresis loop amplitude varies strongly with light wavelength due to resonant near-field enhancement in the nanocones.

Poster Session B

Poster B

P-B.154

Plasmon-induced demagnetization and magnetic switching in nickel nanoparticle arrays

M. Kataja, F. Freire-Fernández, J. P. Witteveen, T. Hakala, P. Törmä, S. van Dijken

Text We report on the manipulation of magnetization by femtosecond laser pulses in a periodic array of cylindrical nickel nanoparticles [1]. By performing experiments at different wavelengths, we show that the excitation of collective surface plasmon resonances triggers demagnetization in zero field or magnetic switching in a small perpendicular field. Both magnetic effects are explained by plasmon-induced heating of the nickel nanoparticles to their Curie temperature. Model calculations confirm the strong correlation between the excitation of surface plasmon modes and laser-induced changes in magnetization.

[1] M. Kataja et al., Appl. Phys. Lett. 112, 072406 (2018)

Poster Session B

Poster B

P-B.155

Quantum many-body dynamics of the Einstein-de Haas effect

J. H. Mentink, M. I. Katsnelson, M. Lemeshko

Text In 1915, Einstein and de Haas [1] and Barnett [2] demonstrated that changing the magnetization of a magnetic material results in mechanical rotation, and vice versa. At the microscopic level, this effect governs the transfer between electron spin and orbital angular momentum, and lattice degrees of freedom, understanding which is key for molecular magnets, nano-magneto-mechanics, spintronics, and ultrafast magnetism. Until now, the timescales of electron-to-lattice angular momentum transfer remain unclear, since modeling this process on a microscopic level requires addition of an infinite amount of quantum angular momenta. We show that this problem can be solved by reformulating it in terms of the recently discovered angulon quasiparticles [3], which results in a rotationally invariant quantum many-body theory [4]. In particular, we demonstrate that non-perturbative effects give rise to angular momentum transfer on femtosecond timescales, even if the electron-phonon coupling is weak.

[1] A. Einstein and W. J. de Haas, Verh. Dtsch. Phys. Ges. 17, 152 (1915).
[2] S. J. Barnett, Phys. Rev. 6, 239 (1915).
[3] M. Lemeshko, Phys. Rev. Lett. 118, 095301 (2017).
[4] J. H. Mentink, M. I. Katsnelson, and M. Lemeshko, arXiv:1802.01638.

Poster Session B

Poster B

P-B.156

Steering of magnetic domain walls by single ultrashort laser pulses

Y. A. Shokr, O. Sandig, M. Erkovan, B. Zhang, M. Bernien, A. A. Ünal, F. Kronast, U. Parlak, J. Vogel, W. Kuch

Text Steering magnetic domain walls by light is of high interest with respect to potential applications in computing technology and data storage. We present a magnetic domain-imaging study by x-ray magnetic circular dichroism photoelectron emission microscopy on a Co/$Fe_{75}Gd_{25}$ bilayer under exposure to single focused ultrashort (100 fs) infrared laser pulses. We find that magnetic domain walls experience a force in the gradient of the laser pulses away from the center of the pulse, which can be used to move domain walls optically into a certain direction. Maximum domain-wall displacements close to 1 µm per laser pulse in zero external field have been observed. Assuming realistic domain-wall velocities, these distances are too long to be traveled by the domain wall during the electronic excitation of the system, and are likely related to the transient lateral gradient in lattice temperature created by the laser pulse. While some theories predict domain-wall motion in the direction to the hotter side of a thermal gradient, a motion towards the colder side can be explained by the torque exerted by magnons that are reflected at the domain wall. We thus attribute the effect to long-wavelength magnons from the spin Seebeck effect reflected at the domain wall. This possibility to steer domain walls by ultrashort laser pulses might open new avenues for writing magnetic information.

Poster Session B

Poster B

P-B.157

Surface plasmon resonances in the diffracted magneto-optical effects.

R. Cichelero, M. Kataja, G. Herranz

Text Magnetoplasmonic crystals coupling plasmons to magneto-optic (MO) activity- have been demonstrated re-
cently to achieve large MO responses and optical nonreciprocity. In the conventional approach, plasmons and
MO are coupled to each other, obviating any eventual effect from other optical phenomena. We have gone a step further to analyse the effect of diffraction in conjunction to plasmons and magneto-optics in a single system.
For that purpose, we analysed diffraction gratings etched into ferromagnetic Au/Co multilayers, mapping out the
transversal magneto-optical Kerr response using angular-resolved spectroscopy. Remarkably, we observe that in
the vicinity of SPP resonances the TMOKE amplitude in the emerging diffracted beams is enhanced up to 3.0%,
pointedly larger than in conventional magnetic materials where the effect is usually less than 0.3%. The reason
of this remarkable enhancement lies on the magnetic field-induced frequency shifts in the energy and angular
spectra of SPP resonances. Our results indicate that one can use magnetic fields to create distinct loss conditions
due to plasmon excitations that can be used to build non-reciprocal, active photonic components of interest for applications in optical networks. At the same time, our approach indicates that exploiting diffraction in conjunction
with plasmon excitations adds superior versatility and flexibility in the design of photonic systems.

Poster Session B

Poster B

P-B.158

Theory of angular-momentum transfer between the electrons and the lattice in 3d transition metals

W. Töws, G. Pastor

Text The present work provides insights into the physical mechanisms responsible for the angular momentum transfer between the electronic degrees of freedom and the lattice during the ultrafast demagnetization of elemental 3d transition metals. To this aim, a model including electron and ion degrees of freedom is rigorously derived from the first-principles Hamiltonian. It is verified that the model dynamics satisfies the conservation of the total angular momentum. Moreover, the commutation relations of the model are used to quantify the transfer rates between the electronic spin, electronic orbital angular momentum, phonon angular momentum and the classical ion angular momentum, as well as to identify the associated mechanisms. Basically two microscopic processes, which govern the angular-momentum dynamics, are revealed. First, the relativistic spin-orbit interaction provides transfer between the spin and electronic orbital angular momentum. Secondly, the motion of electrons within the lattice leads to a transfer from the electronic orbital angular momentum to the lattice, which is built up of both the phonon angular momentum and the classical ion angular momentum. Importantly, it is shown that the excitation of the quantum mechanical phonons is not necessary for angular momentum transfer into the lattice and, thus, for the experimentally observed ultrafast demagnetization.

Poster Session B

Poster B

P-B.159

Top-down fabrication of magnetoplasmonic Au/$Tb_{18}Co_{82}$ nanocone-antennas.

R. M. Rowan-Robinson, A. Čiučiulkaitė, I.-A. Chioar, V. Kapaklis

Text Plasmonics allow for the confinement of light on lengthscales below the diffraction limit. By combining TbCo alloys with plasmonic nano-antennas, all-optical switching can be investigated in the presence of the electromagnetic field enhancement associated with plasmon resonances. Au nanocones have been shown to be highly effective structures for focusing light, concentrating the near-field at the cone tip.

Au/$Tb_{18}Co_{82}$ nanoantennas were fabricated using electron beam lithography to define a hard-mask on the film followed by Ar^+ ion milling. By tuning the mask diameter, either complete or truncated nanocones can be fabricated. The base diameters range between 100 to 200nm and the structures are fabricated in ordered arrays.

The nanostructures are ferromagnetic at room temperature and exhibit perpendicular magnetic anisotropy. We characterise the magneto-optical enhancement as a function of wavelength and incidence angle. An enhancement of the Faraday rotation and ellipticity is observed at the plasmon resonance which facilitates the read-out of the magnetic state. We consider how varying the incidence angle can alter the contributions of vertical and base plasmon modes in the nanoantenna, which could enable the generation of circularly polarized near-fields in the vicinity of the nanocone tip.

Poster Session B

Poster B

P-B.160

Tracing hot electrons during non-equilibrium spin and charge transport

J. Briones, S. Weber, S. Ashok, H. C. Schneider, B. Rethfeld

Text Ultrafast laser excitation of spin carriers leads to electronic energy distributions that are far from equilibrium. We have developed a Monte Carlo trajectory simulation in order to study the spin-dependent dynamics of electrons excited by ultrashort laser pulses at energies of several eVs above the Fermi energy. In the framework of this stochastic model we study electronic interactions and the relaxation of electronic non-equilibrium states in ferromagnetic metals.

We consider the spin dependent electron-electron interaction, as well as spin-dependent inelastic and elastic scattering processes. In a simplified two-band model, we investigate the magnetization dynamics of nickel. The results of this simulation will provide information regarding the time evolution of the electron and hole density, their energy distribution, energy dissipation and the quenching of the magnetization.

We further study how our results compare with more phenomenological descriptions. The extension of our approach to describe the non-equilibrium spin and charge transport and its effect on magnetization dynamics will be discussed.

Poster Session B

Poster B

P-B.161

Ultra-fast buildup of toroidal field in nanostructures driven by topological light fields

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Text The experimental availability of structured light fields for a large set of parameters fueled impressive advance in their use for applications ranging from optical tweezers for microscale objects to electronics and life sciences or quantum information. Our research activities are focused on optical vortices, i.e. photons carrying orbital angular momentum (OAM) to enable photomechanics and novel optoelectronics.

This contribution report on the irradiation of three-dimensional semiconductor rings by radially polarized vector beams. An appropriate combination with conventional linear polarized light pulses renders possible the ultrafast generation of solenoid closed current loops. Thus, a circulating magnetic moment is produced which is accompanied by a toroidal moment associated to the center of structure which is a localized electromagnetic excitation, distinct from the magnetic and electric dipoles. Such a driven toroidal structure exhibits a magnetic vector potential (toroidal magnetic dipole) while the far electric and magnetic fields vanish.

The direction and magnitude of this toroidal moment can be steered and controlled at will on an ultra-fast time scale by means of the pulse parameters making this torus-laser setup to an extraordinary candidate for light confinement, trapping and sensor applications. For instance, toroidal moments reveal a magnetoelectric coupling providing the opportunity for ultrafast magnetic switching by means of an external electric field.

Poster Session B

Poster B

P-B.162

Ultrafast demagnetization including spin and charge transport

S. Ashok, S. T. Weber, J. Briones, B. Rethfeld

Text Spin-resolved transport of electrons after ultrafast excitation of metallic ferromagnets is a hotly researched topic due to its applicability in ultrafast spintronics.

Demagnetization of ferromagnetic materials induced by a femtosecond laser pulse on ultrashort time scales was discovered by Beaurepaire et al. in 1996 [1]. Understanding its mechanism is an important problem in cutting edge physics. Promising models being Elliott-Yafet spin flip mechanism and superdiffusive transport.

A recently proposed μT-model [2] traces the equilibration of chemical potentials and temperatures of spin-up and spin-down electrons seperately. Their dynamics is modelled using coupled transport equations. So far, ultrafast demagnetization using μT-model has been studied only in cases where the thickness of the sample is of the order of penetration depth (where transport of energy and spin-resolved electrons can be neglected). Here we study the dynamics in case of thicker samples and present preliminary results on the influence of spin-and charge-transport on magnetization dynamics.

References:

[1] E. Beaurepaire, J.-C. Merle, A. Daunois, and J.-Y. Bigot, Phys. Rev. Lett. 76, 4250 (1996).
[2] B. Y. Mueller and B. Rethfeld, Phys. Rev. B 90, 144420 (2014).

Poster Session B

Poster B

P-B.163

Ultrafast generation of non-linear spin current in semiconductor nanostructures

J. Wätzel, J. Berakdar

Text Optical vortex light fields , which are experimentally available for a wide range of pulse parameters, open the door to generate photo-currents in open circuit geometries which relies on the fundamental transfer of the optical orbital angular momentum to charge carriers. These whirlpool-like light waves swirl the electronic charge density around ring structures with a well-defined direction and an amplitude set by the vortex topological charge which can be controlled in externally.

Assisted by the spin-orbit coupling in semiconductor heterostructures, this photo-excited charge rotation is accompanied by spin dynamics due to the coupling of the spin state to the orbital angular momentum. Depending on the spin orientation of the charge carriers, the electrons will be deflected to the inner and outer ring boundaries leading to a substantial spin and charge accumulation. This implies a spin-Hall effect (SHE) in dependence on the OAM transferred to the system.

In this contribution I will present results of full-fledged quantum dynamical simulations showing that this SHE is controllable in magnitude and direction on a picosecond time scale by the external pulse parameters. Here, the topological charge should be emphasized since it controls the amount of OAM carried by the optical vortex beam and can be adjusted in a wide range. Associated with the photo-induced SHE is the spin torque that can be used to influence the magnetic dynamics.

Poster Session B

Poster B

P-B.164

Ultrafast laser-induced suppression of perpendicular magnetic anisotropy in a magnetic tunnel junction structure

L. A. Shelukhin, A. M. Kalashnikova, A. V. Azovtsev, K. A. Maximov, R. R. Gareev, V. Zbarsky, M. Münzenberg, N. A. Pertsev

Text One of the fundamental and technological challenges of modern magnetism is to control magnetization of nanostructures at the picosecond timescale. Ultrafast change of magnetic anisotropy induced by femtosecond laser pulses is shown to be a promising way to realize such a control [1,2]. In this work we aim at demonstrating an impact of femtosecond laser pulses on a perpendicular magnetic anisotropy (PMA) – the key contribution to the anisotropy of ultrathin magnetic films.
The sample under study was a magnetic tunnel junction (MTJ) structure Ta/CoFeB/MgO/CoFeB/Ta/Ru grown on a Si substrate [3]. Both magnetic layers are in the vicinity of the thickness-induced spin reorientation transition (SRT) resulting from a subtle balance between the shape anisotropy and PMA. We show experimentally that 170 fs laser pulses launch the magnetization precession in the studied MTJ, and a pronounced *increase* of the precession frequency is observed as the exciting pulse fluence rises. We show that the laser-induced ultrafast quenching of PMA underlies the precession excitation. The laser pulses of a fluence of 2.4 mJ/cm^2 suppress the PMA completely, allowing us to realize the ultrafast laser-driven SRT in the MTJ structure, which offers an approach for control of magnetization in nanostructures.
[1] J. A. de Jong, et al. Phys. Rev. Lett. 108, 157601 (2012).
[2] A. Stupakiewicz, et al., Nature (London) 542, 71 (2017).
[3] R. R. Gareev et al. Appl. Phys. Lett. 106, 132408 (2015).

Poster Session B

Poster B

P-B.165

Ultrafast magnon-phonon dynamics in lateral Galfenol nanogratings

F. Godejohann, A. V. Scherbakov, B. A. Glavin, S. M. Kukhtaruk, A. Nadzeyka, S. Bauerdick, M. Wang, A. W. Rushforth, D. R. Yakovlev, A. V. Akimov, M. Bayer

Text In the ultrafast magnetoacoustics, coherent phonons mediate the effect of ultrashort laser pulses on magnetization. In the simplest case a broad coherent phonon wavepacket modulates the magnetic anisotropy of a ferromagnet and excites the uniform magnetization precession [1]. The situation drastically changes when a nanoscale ferromagnetic pattern is excited [2]. Formation of localized phonon modes and quantized magnon spectra enrich the optically-excited magnetization dynamics and allow achieving desirable response of magnetization.

We examine the phonon-driven magnetization dynamics in optically-excited lateral nanogratings formed by parallel grooves of ~100-nm width and ~10-nm depth milled by focused ion beam in a Galfenol ($Fe_{0.81}Ga_{0.19}$) film on GaAs substrate. We monitor the temporal evolution of magnetization in a pump-probe scheme based on the technique of asynchronous optical sampling. The localized phonon modes, whose frequencies are in the 10-100 GHz range and polarizations are set by the nanograting parameters, drive the magnetization precession within their lifetime up to ~10 ns. By tuning of the magnon spectrum by external magnetic field we control the efficiency of the phonon driving for a specific magnon mode. A theoretical modeling of the spatial-time evolution for the lattice and magnetization supports our experimental observations.
[1]. A. V. Scherbakov et al. Phys. Rev. Lett. **105**, 117204 (2010).
[2] A. S. Salasyuk et al. Phys. Rev. B **97**, 060404(R) (2018).

Poster Session B

Poster B

P-B.166

Ultrafast photo-induced spin polarized currents in nanostructers

M. Kraus, D. Schulze, J. Wätzel, C. Bohley, J. Berakdar

Text We present theoretical predictions on the ultrafast generation of spin-polarized currents and pure spin currents by an appropriate nanostructuring the sample as well as by a spatio-temporal tailoring the driving laser pulses. We consider metallic as well as phase-coherent semi-conductor structures and composite paramagnetic/ ferromagnetic materials.

Poster Session B

Poster B

P-B.167

Anomalous nano-magnetic effects in non-collinear spinel chromite $NiCr_2O_4$

A. Rathi, P. D. Babu, P. K. Rout, V. P. S. Awana, R. P. Pant, G. A. Basheed

Text The nanoscale confinement induces unique magnetic behaviour, different from bulk systems and opens new challenges. The collinear spinel nanoferrites can be successfully explained by fundamental “Ne’el” and “Stoner-Wohlfarth (SW)” models. Here, we investigate, in detail, the magnetism in non-collinear (with geometric spin frustration) nanochromite $NiCr_2O_4$ and compare the results with earlier bulk studies. A finite crystallite size of about 10 nm lowers the cubic-to-tetragonal Jahn-Teller (JT) distortion temperature to $T_{JT} \simeq$ 268 K (from its bulk value of 310 K). Furthermore, the nanoscale confinement gives rise to a significant enhancement in the collinearity of the spin structure, as inferred from considerably reduced spin frustration in the system. This presumably leads to (longitudinal) ferrimagnetic ordering at higher $T_C \approx 100$ K and suppression of (transverse) antiferromagnetic ordering (cf. $T_C \simeq 65$ K and $T_S \simeq 30$ K in the bulk); a transition to the cluster spin glass state occurs at $T_g = 19.0$ K. More surprisingly, the M-H hysteresis loops show an anomalous “pinching” behavior at fields near H_c in the vicinity of T_g; this non-monotonous H_c (T) variation cannot be accounted from the celebrated SW theory. The present study interprets the anomalous H_c (T) behavior in the framework of surface-core magnetic interaction with large surface magnetic anisotropy, and points out the importance of surface effects in nanochromites compared to their counterpart ferrites.

Poster Session B

Poster B

P-B.168

Broadband transverse susceptibility in multiferroic Y-type hexaferrite $Ba_{0.5}Sr_{1.5}Co_2Fe_2O_{22}$

P. Hernández-Gómez, C. Torres, J. M. Muñoz

Text Single phase multiferroics in which ordered magnetic and ferroelectricity coexist, are of great interest for new multifunctional devices; Y-type hexaferrites are good candidates. Transverse susceptibility is obtained when applying a bias DC magnetic field, and AC applied field and response is measured in a transverse direction. It has been proved to be a versatile tool to study singular properties of bulk and nanoparticle magnetic systems, especially to obtain their anisotropy and switching field. Usually is measured with the help of a self-resonant LC circuit, with high sensitivity but with frequency limitations. We have developed a fully automated, broadband system based on a LCR, that allows this measurement in varying ranges of DC and AC applied fields, temperature and frequency with enhanced sensitivity. Transverse susceptibility measurements have been carried out on Y type hexaferrites with composition $Ba_{0.5}Sr_{1.5}Co_2Fe_2O_{22}$, optimal to exhibit multiferroic properties. Polycrystalline ferrites with this composition were sintered in 1050º C-1250º C range. Transverse susceptibility measurements in the temperature range 80-350 K and fields up to ±0.5 T reveal different behaviour depending on the sintering temperature, and the peak related with anisotropy field exhibit four regions with different slopes: positive in 80-130 K, negative in 130-200 K, constant in 200-280 K and negative in 280-350 K, which can be considered a signature of spin transitions in this compound.

Poster Session B

Poster B

P-B.169

Correlation between structural, magnetic and electric properties in multiferroic composites of BaTiO3-BaAl(x)Fe(12-x)O19

L. Panina, M. Salem, E. Truhanova, D. Tishkevich, S. Truhanov, A. Truhanov

Text Multiferroic composites consisting of separate phases with ferroelectric, ferromagnetic and piezoelectric orderings are of considerable interest owing to their strong magnetoelectric interactions. Recently dual ferroic properties have been reported for M-type hexagonal ferrites at room temperature. Barium hexaferrite with a magnetoplumbite structure is a superior permanent magnetic material having high Curie temperature. The discovery of ferroelectric polarization in this compound has generated a renewed research activity on magnetic and electric properties of various substituted hexaferrites with diamagnetic ions. The coexistence of magnetic and electric orderings was also found in these systems. Barium titanate with a perovskite-type structure has a tetragonal symmetry at room temperature and shows decent ferroelectric properties. In the present work we investigate the magnetoelectric properties of composite systems comprising BaFe(11.9)Al(0.1)O19 (BFO) and BaTiO3 (BT) phases with the aim to enhance ferroelectric polarization and to better understand the origin of magnetoelectric coupling. The temperature dependence of permittivity confirmed the transition into ferroelectric state with two critical temperatures for composite systems. They are ascribed to two different mechanisms: structural phase transition for BT and non-centrosymmetric Fe3+ shift in oxygen octahedron for BFO. It was observed that electrical properties critically depended on microstructure parameters.

Poster Session B

Poster B

P-B.171

Deceiving charge-like symmetry in the magneticelectric response of ultrathin Co/Pt/PMN-PT (001) multiferroic heterostructures

M. Foerster, I. Fina, S. Finizio, B. Casals, A. Mandziak, F. Macia, F. Fauth, L. Aballe

Text Multiferroic heterostructures comprised of magnetic systems coupled to piezoelectric [Pb(Mg1/3Nb2/3)O3](1-x)-[PbTiO3]x (PMN-PT, x ≈ 0.32) substrates have been used extensively to investigate strain driven magnetoelectric coupling. In particular, for (011) oriented PMN-PT crystals, large anisotropic in-plane strain is produced [1]. When crossing the ferroelectric coercive field, also direct magnetoelectric coupling, driven by the surface polarization charge of PMN-PT may be observed.
We report an asymmetric magnetic response in ultrathin (0.9-2 nm) Co layers grown on Pt (20 nm) on PMN-PT (011) substrates, a configuration in which PMN-PT surface electric charges are expected to be completely screened by the Pt interlayer. Surprisingly, the magnetic in-plane anisotropy as deduced from the domain pattern observed in Photoemission Electron Microscopy with X-ray circular magnetic dichroism contrast (XMCD-PEEM) indicates clearly and reproducibly a change from low in-plane anisotropy to a dominating uniaxial in-plane anisotropy for oppositely poled remanent ferroelectric states. For our samples, high resolution X-ray diffraction (XRD) measurements reveal an unexpected asymmetric strain response of the PMN-PT (011) substrate itself. These findings call for caution in the interpretation of odd symmetry data obtained on PMN-PT (011) which seem to reveal surface polarization charge driven effects.
References:
[1] T. Wu et al., J. App. Phys. 109, 124101 (2011).

Poster Session B

Poster B

P-B.172

Dielectric behaviour of (x) Ni0.5 Zn0.5 Fe2O4 + (1-x) Pb Zr0.8 Ti0.2O3 Magnetoelectric Composites

C. Kanamadi, B. Bammannavar

Text Magneto electric composites with composition (x) Ni0.5 Zn0.5 Fe2O4 + (1-x) Pb Zr0.8 Ti0.2O3 (PZT-Lead Zirconate Titanate) in which x varies as 0.0, 0.15, 0.30, 0.45 and 1.0 mol % was prepared by the conventional double sintering ceramic technique. The phase analysis was carried out using X-ray diffraction technique, which confirms the absence of any intermediate phases present in the composites. The variation in dielectric constant and dielectric loss as a function of temperature in the frequency range 20 Hz to 1 MHz was studied.

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P-B.173

Dielectric, ferroelectric and magnetoelectric properties of [BZT-0.5BCT]/NZFO thin film deposited by pulse laser deposition

J. Rani, V. K. Kushwaha, C. V. Tomy

Text Magnetoelectric (ME) effect, arising from the interfacial coupling between magnetic and electrical order parameters, allows the control of magnetism by electric field or vice versa, and hence has a strong appeal for emerging device applications such as spintronic devices, ME- sensors, and actuators. Composite material containing ferroelectric and magnetic phase as a constituent phase is a good engineering to achieve high ME effect above room temperature. Here, ME heterostructure [Ba(Zr0.2Ti0.8)O3-0.5(Ba0.7Ca0.3)TiO3]/Ni0.8Zn0.2Fe2O4 bilayer thin film (abbreviated as [BZT-0.5BCT]/NZFO) has been grown on Pt/Si(100) substrate by pulse laser deposition. The XRD-analysis reveals polycrystalline nature of [BZT-0.5BCT]/NZFO heterostructure bilayer film without any intermediate phase. Homogeneous grains with average grain size ~50 nm and very low surface roughness of bilayer film is confirmed by atomic force microscopy. The value of dielectric constant versus frequency is higher for [BZT-0.5BCT]/NZFO film than that of pure ferroelectric [BZT-0.5BCT] film. Magnetic measurements reveal soft ferromagnetic behaviour at low temperature (5K) as well as room temperature (300 K). Magnetic versus temperature measurement shows that the ferromagnetic to paramagnetic transition lies above 400 K. Typical ferroelectric loop has been observed in the deposited film. Large value of ME coupling coefficient (αE) has been observed in transverse as well as in longitudinal direction at 2 kHz frequency.

Poster Session B

Poster B

P-B.174

Dopant-induced distortions in $Bi_{1-x}Y_xFeO_3$ and their incidence in the magnetic structure

M. Graf, S. Di Napoli, M. A. Barral, A. M. Llois

Text In this work we study, by means of *ab initio* calculations, the structural, electronic and magnetic properties of Y-doped $BiFeO_3$ compounds. We determine that there is a morphotropic phase boundary at an yttrium concentration of 19%, where the structure changes from *R3c* to *Pnma*. This structural transition is driven by the chemical pressure induced by the dopant.

By analyzing the evolution of the oxygen octahedral tilts we find an enhanced antiferrodistortive distortion when increasing the Y-doping, together with a reduction of the ferroelectric distorsion, that gives rise to a smaller value of the electric polarization. These cooperative effects lead to a larger canting of the Fe magnetic moments and to a larger ferromagnetic response in the *R3c* phase, as it is observed in the experiments.

Poster Session B

Poster B

P-B.175

Effect of Ca doping on multiferroic properties of BiFeO3

A. Panda, R. Govindaraj

Text In this work the effect of Ca doping at Bi site in BiFeO3 leading to changes in structural, magnetic and ferroelectric properties have been studied in a detailed manner. Ca2+ ion substitute at Bi site leading to formation of phase stablized BiFeO3 due to structural transition from rhombohedral to cubic as Ca2+ dopant concentration increases. It is observed that the multifunctional properties of doped BIFeO3 phase is improved as elucidated using magnetization and ferroelectric studies. The value of magnetization and polarization for 10 % and 20 % doped sample is found to be 0.04 and 0.07 emu/g and 15 and 6 μC/cm2 respectively. The enhancement in magnetization is understood to be due to increased superexchange interaction arising from the increase in Ca doping. The polarisation of lower doping concentration of Ca shows better ferroelectric property, as with increasing doping leakage current grows caused from enhanced induced oxygen defects. So 20 % Ca doped sample shows deteriorated polarization value than that of 10 % doped one. There is also signature of change in polarization value under the application of magnetic field implying the presence of magnetoelectric coupling. It is also reported that the divalent cation doping lowers the transition temperature and hence is a promising room temperature multiferroic material which better suits for applicability of this kind of doped systems.

Poster Session B

Poster B

P-B.176

Enhanced magnetization in calcium doped BiFeO3 nanomaterials

T. Bagwaiya, H. A Reshi, V. Shelke

Text BiFeO3 is widely known multiferroic compound. Although it has very good ferroelectric polarization value, the magnetization value is low due to antiferromagnetic ordering with superimposed spin cycloid. We used joint strategy of particle size reduction and structural modulation to improve the magnetization. Calcium doped Bismuth Ferrite nanoparticles were synthesized by sol-gel route. The Rietveld refinement of X-Ray Diffraction patterns confirmed pure phase formation with distorted rhombohedral (space group R3c) structure. The average crystallite size was around 40 nm. Unit cell volume decreased with increasing doping indicating lattice distortion. The structural modulation was further confirmed by Raman spectra through line width and shifting of phonon frequencies. X-ray photoelectron spectroscopy confirmed the Fe+3 oxidation state and slight shifting of Bi 4f peak indicating the substitution of Ca2+ at Bi-site. The field dependent magnetization measurement showed higher remanence with opening of hysteresis loop.

Poster Session B

Poster B

P-B.177

Enhancement of Multiferroic Properties in BiFeO3 by La Substitution

D. Tripathi, V. Shelke

Text Multifunctional materials have attracted worldwide attention because of simultaneous use of several properties in single device. Multiferroic Bismuth ferrite shows unique magnetic and ferroelectric properties above room temperature. However volatile nature of bismuth, formation of secondary phases and oxygen vacancy are the main obstacles for its synthesis. We have prepared A-site substituted BiFeO3 (Bi1-xLaxFeO3) samples with different substitution levels using solid state reaction method. X-Ray diffractions showed single phase nature with phase transition from rhombohedral to orthorhombic structure for x > 0.2. The structural change was also reflected in Raman spectroscopy measurements. Microstructure of the samples was studied using scanning electron microscopy. Significant enhancement in magnetic moment with weakly ferromagnetic signature, improved dielectric constant and reduced dielectric loss were observed in these samples.

Key words: Multiferroic, solid state reaction method

References:
1.S. Pillai, etal., J. Appl.Phys. 120,164103 (2016)
2.S. Pillai, etal., Appl. Phys. Lett, 102,072907 (2013)
3.S. Pillai, etal., J.Mater.Sci: Mater Electron, 24,2950 (2013)

Poster Session B

Poster B

P-B.178

Exchange coupling in multiferroics/ferromagnet thin film heterostructures deposited by PLD

S. Becker, M. Vafaee, M. Kläui, G. Jakob

Text The interface between multiferroic $BiFeO_3$ (BFO) and various ferromagnets has been target of much research. The interlayer exchange coupling was found to be often weak at room temperature [1] or was reduced after some time because of oxidation of the interface [2]. Here we aim to find a stable exchange bias effect between a multiferroic and a magnetic layer at room temperature.
$Bi_{1-x}Ba_xFeO3$/ferro(i)magnet (x=0, 0.15) as well as $TmFeO_3$ /ferromagnet heterostructures have been fabricated using pulsed laser deposition (PLD).
The influence of Bi substitution by Ba in BFO on the properties has been analyzed. Ferroelectric properties of $Bi_{0.85}Ba_{0.15}FeO_3$ have been proven by piezoresponse force microscopy (PFM). Also $TmFeO_3$, which has orthorhombic structure in bulk, shows a ferroelectric phase when grown stained on $SrTiO_3$ substrates.
As ferromagnetic layer $La_{0.7}Sr_{0.3}MnO_3$ and as ferrimagnetic Sr_2FeMoO_6 have been deposited. High quality crystalline growth of all layers has been confirmed using XRD. Heterostructures have been investigated with regard to the exchange coupling using a SQUID magnetometer.
[1] M. Vafaee Appl. Phys. Lett. 108, 072401 (2016); [2] J. T. Heron, Nature 516, 370 (2014)

Poster Session B

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P-B.179

Exotic magnetism and magnetoelectric coupling in Co-doped MnWO4 studied by resonant magnetic x-ray scattering

J. Herrero-Martín, C. Mazzoli, S. Francoual, J. Strempfer, F. Fabrizi, P. Bencok, P. Steadman, A. Bombardi, A. Mukhin, V. Skumryev, J. L. García-Muñoz

Text Tuning synthesis towards the induction of magnetic frustration and complex magnetic order breaking spatial inversion symmetry is regarded as an effective way of producing multiferroic and magnetoelectric materials. The (Mn,Co)WO4 series has become a reference model for the analysis of the interaction between spins and polar order. Co-doping favors a strong competition between its large magnetocrystalline anisotropy (McA) and Mn-Mn exchange interactions, stabilises a ferroelectric (FE) response at low temperatures and allows the appearance of new magnetic structures (some of them FE). The two different magnetic ions (Mn and Co) occupy the same crystallographic position making this series intrinsically inhomogeneous.
Resonant magnetic x-ray scattering allowed us to investigate the magnetic order in a crystal with Mn0.85Co0.15WO4 critical composition. We found that Co and Mn can arrange antiferromagnetically with spins pointing along different directions. So, Co moments tend to follow their own strong uniaxial McA, while the nearly isotropic charge density distribution around Mn ions permits their moments a large flexibility to adopt a variety of complex structures bearing distinct anisotropies. The macroscopic FE polarization observed compound would then mainly stem from the inverse D-M term associated to Mn spins. This Mn-based effect was in- situ seen in variations of the scattered light polarization by a wolframite crystal as a function of an E-field applied across it.

Poster Session B

Poster B

P-B.180

Features of crystalline and magnetic structure of barium ferromolybdate in a wide temperature range

V. Turchenko, N. Kalanda, M. Yarmolich, M. Balasoiu, N. Lupu

Text The strong correlation between disorder degree of crystal structure of double perovskites and a level of spin polarization of charge carriers as well as phase transition temperature Tc and the saturation magnetization make these materials promising for microelectronic.
The main aim of this work is ascertain regularities of temperature influence to evolution of the crystalline and magnetic structure and magnetoresistive properties of Ba2FeMoO6. The crystalline and magnetic structure of barium ferromolybdate were determined by neutron high-resolution Fourier diffractometer in a wide range of temperatures: from 20 to 473 K. Magnetoresistance was measured by the four terminal method in a wide range of magnetic fields and temperatures.
The homogeneous Ba2FeMoO6 [1] has the cubic structure with SG Fm-3m above Tc~ 317 K that transforms to tetragonal structure with SG I4/mmm lower Tc. The deformation of the symmetric oxygen octahedrons FeO6 and MoO6 was observed in the point of structure transition. According to X-ray data the crystal structure contains ~6% of anti-site disorder. The fastest change of the magnetoresistance was observed in fields B≤0.2 T. The largest magnetoresistive effect was observed in the region with the highest value of spin polarization carriers, which value decreases smoothly from its maximum value at 10 K to zero at the point of phase transition temperature.

[1] V A Turchenko, N A Kalanda, L V Kovalev et al. J. Phys.: Conf. Series 994 (2018) 012014

Poster Session B

Poster B

P-B.181

Hampered magnetic ordering in frustrated triangular lattice 2D compounds A2MnTeO6 (A=Na, Li, Ag, Tl)

G. Raganyan, V. Nalbandyan, M. Evstigneeva, E. Vavilova, E. Anisimova, D. Gafurov, Y. Scurschii, A. Kurbakov, M. Kuchugura, E. Zvereva

Text We report on the static and dynamic magnetic properties of new family triangular lattice 2D magnets A2MnTeO6 (A=Na, Li, Ag, Tl). Specific heat and low-temperature neutron diffraction data reveal an onset of long-range magnetic order for all samples despite of the absence of any clear features on the magnetic susceptibility at low magnetic fields down to 2 K. The temperature dependence of magnetic susceptibility nicely follows the Curie-Weiss law in the high temperature range, but implies the wide range of the short-range magnetic correlations and relatively large negative Weiss temperature, which suggests a predominance of antiferromagnetic exchange interactions and a noticeable spin frustration. In applied magnetic fields the temperature dependence of the magnetic susceptibility is remarkably changed and one can observe a characteristic maximum at Neel temperature. Additional confirmation of the magnetic field effect has been obtained from the ESR data, which clearly show the degradation and disappearance of the resonance signal at helium temperature. The behavior of ESR linewidth has been analyzed in terms of critical broadening and discussed.

Poster Session B

Poster B

P-B.182

Highly efficient and tunable spin-to-charge conversion through Rashba coupling at oxide interfaces

E. Lesne, Y. Fu, P. Noël, S. Oyarzun, J.-C. Rojas-Sanchez, D. Vaz, H. Naganuma, G. Sicoli, J.-P. Attané, M. Jamet, E. Jacquet, J.-M. Georges, A. Barthélémy, H. Jaffrès, A. Fert, M. Bibès, L. Vila

Text An emerging direction in oxide research aims at discovering novel electronic phases at interfaces between two oxide materials. A well-known example is the LaAlO3/SrTiO3 system: while both LaAlO3 (LAO) and SrTiO3 (STO) are wide bandgap insulators, a high-mobility two-dimensional electron system (2DES) forms at their interface. Interestingly, LAO/STO possesses several remarkable extra functionalities, including a gate-tunable Rashba effect, which makes it particularly appealing for spintronics.
The Rashba effect is a manifestation of spin-orbit interaction (SOI) in solids, where the spin degeneracy associated with the spatial inversion symmetry is lifted due to a symmetry-breaking electric field normal to the heterointerface. In a Rashba two-dimensional electron system, the flow of a charge current is accompanied by a non-zero spin accumulation coming from uncompensated spin textured Fermi surfaces. Recently, the converse effect, corresponding to a spin-to-charge conversion through SOI (inverse Edelstein effect or IEE), was demonstrated at Ag/Bi(111) interfaces.
We report the observation of a giant IEE in NiFe/LaAlO3/SrTiO3 heterostructures, with spin-to-charge conversion one order of magnitude more efficient than in previous systems. Moreover the large dielectric constant of the STO substrate and the relatively low carrier density of the LAO/STO 2DES makes it possible to use a back-gate voltage Vg to modulate the 2DES carrier density and electronic properties.

Poster Session B

Poster B

P-B.183

Hyperfine parameters in 57Fe enriched perovskites M(Fe0.5Nb0.5)O3 (M – Pb, Ba) in the range 4.2-533 K

T. Kmjec, K. Závěta, J. Plocek, M. Dopita, M. Cesnek, V. Chlan, M. Adamec, J. Kohout

Text We studied in detail the temperature dependence of hyperfine and structural parameters of Pb/Ba(Fe0.5Nb0.5)O3 (abbr. PFN, BFN) from 4.2 K to temperatures above ferroelectric ordering of PFN with attention to the values of transition temperatures and the differences between the two similar materials. Samples were prepared by enriching Fe2O3 to 20% of 57Fe, synthesis of precursor FeNbO4 and consecutive sintering to final samples.
Powder XRD spectra were acquired at 4.2-300 K by conventional XRD diffractometer and at 300-500K by diffraction of synchrotron radiation. BFN is cubic pure single-phase material with a=8.1195 Å at RT and Fm-3m space group at 4.2-533K and cannot thus evince ferroelectricity. PFN has the Pm3m(cubic) space group at high temperature. At Tm ~375 K, it undergoes a ferroelectric transition accompanied by a structural change to P4mm (tetragonal) and below ~355 K into a R3m rhombohedral structure.
Hyperfine parameters (IS, QS,Bhf) were obtained from Mössbauer spectra at 4.2 – 5533 K. The temperature dependence of Bhf points to antiferromagnetic ordering below TN~25 K and TN~160 K in BFN and PFN, respectively, and spin-glass transition in PFN sample at TSG~XX K . Temperature dependence of IS and QS imply structural transition at ~375 K and ~355 K in PFN sample.
The 207Pb, 93Nb and 137Ba NMR spectra of the samples were measured in a field of 9.4 T at temperatures 10-300 K. The spectra indicate similar sequence of magnetic transitions in both materials on cooling.

Poster Session B

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P-B.184

Impact of the Sr doping on structural and magnetic properties of nanocrystalline $Ba_{1-x}Sr_xCo_{0.9}Mn_{0.1}O_{3-\delta}$ ($0 \leq x \leq 0.5$)

A. Kumar, R. N. Mahato

Text Aim

This work is performed in order to study an effect of Sr doping on structural and magnetic properties of the nanocrystalline $Sr_xBa_{1-x}Co_{0.9}Mn_{0.1}O_3$ ($0.0 \leq x \leq 0.5$) system. In addition, an effect of annealing temperature on structural stacking sequence has also been elaborated in the present system.

Experimental methods

Nanocrystalline $Sr_xBa_{1-x}Co_{0.9}Mn_{0.1}O_3$ ($0.0 \leq x \leq 0.5$) were synthesized by sol-gel method using a stoichiometric ratio of $Sr(NO_3)_2$, $BaCO_3$, $Co(NO_3)_2.6H_2O$ and $C_4H_6MnO_4.4H_2O$ (Sigma Aldrich made). All magnetic and electrical measurements were taken by physical property measurement system (PPMS).

Results

The x-ray diffraction (XRD) patterns of the nanocrystalline $Sr_xBa_{1-x}Co_{0.9}Mn_{0.1}O_3$ ($0.0 \leq x \leq 0.5$) synthesized at 900°C represent 2H-type hexagonal stacking sequence, leading to a framework of face sharing octahedra. However, with an increase in annealing temperature, synthesized sample exhibit hexagonal polytypes (intermediate structures, mixed face sharing and corner sharing octahedra). This structural tuning with annealing temperature largely influences magnetic interaction in the synthesized system.

Conclusions

The magnetic data represent the structural dominance over magnetic interaction in the nanocrystalline $Sr_xBa_{1-x}Co_{0.9}Mn_{0.1}O_3$ ($0.0 \leq x \leq 0.5$). Magnetization suppresses with an increase in Sr doping and samples show semiconducting-like behavior with large magnetoresitive properties near transition temperature.

Poster Session B

Poster B

P-B.185

Influence of orbital ordering on the magnetic hyperfine field in pyrochlore oxides $R_2V_2O_7$ (R = Lu, Yb, Tm, Y) from ab initio calculations

P. Agzamova, A. Nikiforov

Text Vanadates $R_2V_2O_7$ (R = Lu, Yb, Tm, Y) are suitable subjects for investigations of the orbital degree of freedom in magnetic pyrochlore oxides from the viewpoint of its characteristic geometrical structure. These compounds have single t_{2g} electron on the V 3d shell. The R-ion displacement effects on the t_{2g}-level splitting. In this scenario, the change of the orbital ordering for $R_2V_2O_7$ series is expected. The modification of the V^{4+} ions lattice environment can also favour of change of the spin density on magnetic ion nucleus and around it and may effect on the magnetic hyperfine field parameters.
In the present work the influence of the orbital ordering on the magnetic hyperfine field in $R_2V_2O_7$ (R = Lu, Yb, Tm, Y) has been studied from ab initio calculations. The calculations have been performed using the unrestricted Hartree-Fock method and the density functional theory in the CRYSTAL package [1].
We have shown that the orbital ordering effects on the anisotropic hyperfine interaction values on the ^{51}V nucleus which are comparable with isotropic ones. Our results for $Lu_2V_2O_7$ are in a good with experimental data [2].
This work was performed using «Uran» supercomputer of IMM UB RAS in the framework of the State Task of the FASO of the Russian Federation (theme “Diagnostics,” no. AAAA-A18-118020690196-3) and was supported in part by the RFBR no 18-32-00690.

[1] http://www.crystal.unito.it/index.php
[2] T. Kiyama et al, PRB 184422 (2006).

Poster Session B

Poster B

P-B.186

Investigation of structural magnetic and electronic properties of B-site disordered Sm_2NiMnO_6 double perovskite

S. Majumder, R. J. Choudhary, D. Phase

Text The RE_2NiMnO_6 (RE: rare earth) ordered double perovskite is known to show two magnetic phase transitions, one is ferromagnetic (FM) transition at temperature T_C due to Ni^{2+}-O-Mn^{4+} (or Ni^{3+}-O-Mn^{3+}) interaction and another at temperature T_f due to coupling of RE spins with Ni-Mn network. Here we have investigated the structural, magnetic and electronic properties of monoclinic *P21/n* Sm_2NiMnO_6 (SNMO) prepared by solid state reaction route. X-ray photoemission spectroscopy reveals mixed valency of both Ni (Ni^{2+} and Ni^{3+}) and Mn (Mn^{4+} and Mn^{3+}) species. We observe that the presence of intrinsic B-site disordering results in antiferromagnetic (AFM) coupling also, mediated by Ni^{2+}-O-Ni^{2+} (or Ni^{3+}-O-Ni^{3+}) and Mn^{4+}-O-Mn^{4+} (or Mn^{3+}-O-Mn^{3+}) pairs. So the coexistence of FM phase along with AFM phase greatly affects the magnetic properties SNMO system. M-T behavior shows a cusp like trend in the temperature range $T_f<T<T_C$. This weakening of FM interaction vanishes on application of higher magnetic fields. MH isotherms in $T_f<T<T_C$ temperature region exhibit triple coercivity loop behavior. The irreversibility in FCC and FCW paths of MT cycles and deviation of Curie-Weiss fitting of $1/\chi$ suggest the presence of frustrated state. The glassy phase is further confirmed by time decay of thermo-remanent magnetization measurements. Temperature dependent synchrotron angle dispersive X-ray diffraction studies suggest same monoclinic phase across the magnetic phase transition temperatures.

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P-B.187

Magnetic and electronic properties of $Fe_3O_4/SrTiO_3$ heterointerfaces monitored by X-rays

M. H. Hamed, R. A. Hinz, M. Wilhelm, P. Lömker, A. Gloskovski, W. Drube, C. M. Schneider, M. Müller

Text The inverse spinel ferrimagnetic magnetite (Fe_3O_4) with its Verwey metal – insulator transition is an interesting material for spintronic applications. The half-metallicity of Fe_3O_4 and tunable conductivity of $SrTiO_3$ (STO) can be combined in oxide spintronic devices. Challenges to fabricate Fe_3O_4/STO heterostructures are due to the -7.5% compressive lattice mismatch and oxide-oxide interfaces. In this work, we focus on studying and manipulating the magnetic and electronic structure of Fe_3O_4 /STO interfaces.
In order to study the impact of reduced dimensionality at interfaces, Fe_3O_4 films with thicknesses d= 2 - 38 nm are grown epitaxially on Nb-$SrTiO_3$ (001) substrates via pulsed laser deposition. The element-selective electronic and magnetic properties of the surfaces and buried interfaces are obtained by angle-dependent HAXPES and XMCD techniques. By comparison with calculated model spectra, the films exhibit a relative reduction in Fe^{2+} ions with decreasing the thickness to 6% for 2nm film, accompanied with increasing in Fe^{3+} ions in both tetrahedral and octahedral sites to 42% and 52%, respectively. The final calculations suggest the formation of a ferrimagnetic 2 u.c. γ-Fe_2O_3 intralayer at the interfaces. Interfacial redox reaction or STO surface oxygen mobility could account for the formation of this intralayer phase. By annealing at 700 °C, a reduction of γ-Fe_2O_3 intralayer is achieved and fully stoichiometric Fe_3O_4 ultrathin films are fabricated on the STO substrate.

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P-B.188

Magnetic and electronic properties of the ferroelectric−photovoltaic ordered double perovskite CaMnTi2O6

J. Herrero-Martín, J. Ruiz-Fuertes, T. Bernert, M. Koch-Mueller, E. Haussuehl, J. L. García-Muñoz

Text The ferroelectric and magnetic phases of the double perovskite CaMnTi2O6 with A-site order were investigated by soft x-ray absorption and magnetic circular dichroism. All spectra point to a very ionic state of Mn2+ and Ti4+ atoms. The effects of the crystal field produced by O ligands around tetravalent titanium and dissimilar Mn1 and Mn2 sites were investigated. We observed that both the so-called square-planar and octahedrally coordinated Mn sites contribute similarly from a spectroscopic point of view. Multiplet calculations suggest a small O 2p- Ti 3d charge-transfer component probably related to the short apical Ti-O bond in the octahedra suffering from polar Ti4+ displacements. Our analysis of the spin configurations compatible with the acentric structure allowed us to identify P42'm'c as the most likely magnetic space group below T_N. This forces the sign of the magnetic coupling along the Mn columns parallel to c-axis to reverse with respect to the coupling between neighboring columns. Below T_N, the dichroic magnetization loops at the Mn L3 edge are non-linear in the applied magnetic field [-2 T, 2 T] range which may indicate a field-induced weak ferromagnetic state.

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P-B.189

Magnetic and mgnetocaloric effect $La_{0.7-x}Pr_xSr_{0.3}MnO_3$ compounds (x=0, 0.3, 0.5 0.7)

P. D. H. Yen, T. V. Manh, T. D. Thanh, N. T. Dung, W. H. Shon, J. S. Rhyee, S. K. Oh, S. C. Yu

Text In this work, the magnetic and magnetocaloric properties of of $La_{0.7-x}Pr_xSr_{0.3}MnO_3$ (LPSMO) polycrystalline compounds with x = 0, 0.3, 0.5 and 0.7 prepared by a standard solid-state reaction method are investigated. The Curie temperature decreases with increasing Pr concentration from 373, 345, 307 to 264 K when x varies from 0, 0.3, 0.5 to 0.7. The maximum values of entropy change occur near FM-PM phase transition points and are found to be $-\Delta S_{max}$ ~ 4.92, 4.81, 5.56 and 6.4 and J/kg K with an applied field change of 5 T for x = 0, 0.3, 0.5 and 0.7, respectively. The field dependence of maximum entropy change obeys the power law where field exponents n is found to be 0.7, 0.76, 0.69 and 0.6 for for x = 0, 0.3, 0.5 and 0.7. Besides, the Arrott plots confirm a second order phase transition in all samples. Moreover, that ΔS_{max} value varies little in compounds containing partial replacements of Pr for La shows that a possibility of increasing MCE in desired temperature range by creating composites from these compounds.

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P-B.190

Magnetic behavior of $(C_2H_5NH_3)_2CuCl_4$ type multiferroic

P. Šenjug, J. Dragović, M. Kalanj, F. Torić, M. Rubčić, D. Pajić

Text Metal organic compound $(C_2H_5NH_3)_2CuCl_4$ belongs to the family of layered perovskite multiferroic materials. It consists of ferromagnetic layers of corner sharing $[CuCl_4]^{2-}$ octahedra connected by organic ions (two layers of $C_2H_5NH^{3+}$).
In this work we have studied magnetic properties of $(C_2H_5NH_3)_2CuCl_4$ using a SQUID magnetometer and an AC susceptometer. Temperature dependence of magnetization showed existence of antiferromagnetic transition at 10.2K which changes to ferromagnetic transition with application of moderate magnetic field. Hysteresis loops showed ferromagnetic behavior for $T<T_N$ and existence of anisotropy. We have seen no effect of electric field on magnetic behavior at low temperatures, but near structural transition temperatures an anomaly of magnetization was observed possibly because of indirect magneto-electric effect. Results of AC measurements showed no frequency dependence of susceptibility. Obtained temperature dependence of nonlinear susceptibility can be interpreted as a result of successive crossovers between different regimes. This kind of material is interesting because, depending on the organic ion that separates magnetic layers, the spacing between them changes therefore changing the magnetic and electric properties of the compound. Further studies are being made on such compounds with different organic ions.

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Poster Session B

Poster B

P-B.191

Magnetic field at Ce impurities in La sites of $LaBaMn_2O_6$ double perovskites

B. Bosch-Santos, N. M. Nascimento, M. Saiki, E. L. Correa, T. S. N. Sales, L. F. D. Pereira, A. W. Carbonari

Text Magnetic behavior in $LaBaMn_2O_6$ double perovskite compounds has been investigated with various techniques, due to the rich variety of electromagnetic properties, such as a colossal magnetoresistance, charge and orbital ordering, and metal-insulator transition.
In this paper, we have used a nuclear and short-range technique, the Perturbed Angular Correlation (PAC) spectroscopy, to investigate the magnetic hyperfine field at the ^{140}Ce nucleus of Ce impurities occupying La sites. The radioactive 140La nuclei with a half-life of 40.8 h were produced by direct activation of natural La present in the samples through the irradiation with neutrons in the IEA-R1 nuclear research reactor of IPEN. The PAC measurements were carried out with a six BaF_2 detector spectrometer at several temperatures between 10 K and 400 K.
This double perovskite samples were synthesized by sol-gel route. The crystal structure was determined by X-ray diffraction and the analyses showed that this method produced perovskite oxides with cubic structure in Pm-3m space group. This phase occurs due to an oxygen deficiency.
The local properties investigated by PAC spectroscopy revealed a ferromagnetic transition temperature above 300 K and an anomalous behavior of the temperature dependence of magnetic hyperfine field at La sites, which can be ascribed to the contribution of 4*f* band of Ce to Bhf at low temperatures due to the increase in its localized character.

Poster Session B

Poster B

P-B.192

Magnetic properties of Fe_2O_3 nanoparticles in silica matrix

D. Kubániová, P. Brázda, J. Kohout, K. Závěta, T. Kmječ, P. Bezdička, M. Klementová

Text The ε-phase of Fe_2O_3 with its extremely large coercive field value at room temperature, magnetoelectric coupling and millimeter-wave ferromagnetic resonance, have attracted much attention in the recent years due to wide possibilities of its application in high-capacity magnetic recording media and in telecommunication technology. Here we prepare the Fe_2O_3/SiO_2 nanocomposite by sol-gel method and investigate the effect of annealing temperature and Fe_2O_3 mass fraction in the initial mixture on the formation of different ferric oxide polymorphs. The structural and magnetic properties of prepared samples are characterized in detail by combination of X-ray powder diffraction (XRD), high-resolution transmission electron microscopy, magnetic measurements and Mössbauer spectroscopy (MS). The ideal conditions for preparation of ε-Fe_2O_3 rich sample are established with maximal yield of ~90 % and characteristic particle size of ~25 nm. The increasing mass fraction of Fe_2O_3 in the starting material leads to decrease in the appropriate annealing temperature, while the width of the particle size distribution tends to increase. The relative concentrations of the four present polymorphs derived from XRD and MS are in a reasonable mutual agreement. The information on the effective hyperfine fields obtained from MS and hysteresis loops support the concept of core-shell model for ε-Fe_2O_3. The financial support under the grant GAČR 16-04340S is gratefully acknowledged.

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P-B.193

Magnetic properties of Gd_2BaCoO_5 1-D spin chain compound

B. Mali, S. Elizabeth

Text Gd_2BaCoO_5 has been prepared in Ar flow using solid state synthesize method, and the X-ray diffraction data reveal that they crystallizes in the Nd_2BaNiO_5 structural type(space group Immm). The magnetic properties of this oxide have been studied from magnetic succeptibility measurements and one-dimensional antiferromagnetic correlations in the Co^{+2} sublattice are presented around the room temperature, while three dimensional antiferromagnetic interactions due to R^{+3} and Co^{+2} sublattices has been observed at low temperature.

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P-B.194

Magnetic structure in substituted multiferroics-ferroborates Nd(Tb)Fe3(BO4)3 revealed by single crystal neutron diffraction

I. Golosovsky, A. Mukhin, E. Ressouche, V. Skumryev, L. Bezmaternykh

Text Rare-earth ferroborates ReFe3(BO3)4 are a new class of noncentrosymmetric multiferroics with a strong dependence of the electric polarization on the magnetic field, which is important for practical applications. They contain two strongly interacting magnetic subsystems that lead to a complex magnetic behavior, which is characterized by a combination of crystalline anisotropy of the iron sublattice and single-ion anisotropy of the rare-earth ion. The magnetoelectric properties strongly depend on the rare-earth subsystem, magnetic order in which is driven by the iron sublattice.
There are two typical types of antiferromagnetic order: the "easy plane" type, with Fe spins lying within the basal plane, perpendicular to the trigonal axis, and the "easy axis" type, with spin aligned along the trigonal axis. A spontaneous electric polarization appears only in the "easy-axis" state, although the external magnetic field can induce polarization in any state.
We present the single crystal neutron diffraction study of the magnetic order in the mixed system: Nd1-xTbxFe3(BO3)4. In the outermost compositions NdFe3(BO3)4 and TbFe3(BO3)4 the "easy-plane" and "easy-axis" types of the magnetic ordering realized, respectively.
The object of the report is the complex magnetic structures in the mixed compounds and its evolution in the applied magnetic field and temperature.

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P-B.195

Magnetic study on a $Er_2Zr_2O_7$ single crystal

K. Vlášková, P. Proschek, M. Klicpera

Text Cubic $A_2B_2O_7$ oxides with rare earth element A and transition metal B are systematically studied for their structure, diverse ground states and predicted exciting electronic and magnetic topological properties which arise from comparable strength of electron-electron correlations and spin-orbit coupling. The crystal structure of $A_2B_2O_7$ compounds with antiferromagnetic interactions between magnetic ions prevents to find its unique ground state. Such a frustrated state can lead to unusual spin ground states as spin glass, spin liquid or spin ice.

$A_2B_2O_7$ compounds containing Zr as a B element form a pyrochlore structure for A=La-Gd (*F d -3 m*, 227), whereas oxides with A=Tb-Lu crystallize in distorted fluorite lattice (*F m -3 m*, 225). Physical properties studies on heavy rare earth zirconates were so far concentrated mainly on structure stability and its modifications under extreme conditions (pressure, temperature, irradiation) - suitable materials for nuclear waste storage.

We present a low-temperature study on a $Er_2Zr_2O_7$ single crystal for the first time. It orders magnetically around 1 K, which scales with behavior of other heavy rare earth zirconates [1]. Clarification of magnetic ground state of these oxides complements the properties demonstrated e.g. by non-trivial spin ice state observed in $Pr/Nd_2Zr_2O_7$ [2,3].

[1] A. M. Durand et al., *J. Phys.: Cond. Matt*. 20 (2008).
[2] S. Petit et al., *Nature* (2016).
[3] K. Kimura et al., *Nature Communications* (2013).

Poster Session B

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P-B.196

Magnetic, magneto-optical and specific heat studies of the low temperature anomalies in the magnetodielectric DyIG ferrite garnet

A. Boutaba, M. Lahoubi, V. Varazashvili, S. Pu

Text The anomalous magnetic properties of dysprosium iron garnet (DyIG) are not completely achieved as indicated with the magnetodielectric effect reported previously for a magnetic field H ≤ 10 kOe [1], [2]. A peak was observed in the static dielectric constant and magnetic susceptibility at a critical temperature T_C = 16-17 K, the T-region where the well-known first order spin reorientation phase transition was found to occur at T_{SR} = 13.5-14.5 K [3]. We present in this work, low-temperature experimental measurements of isothermal magnetization in a high DC magnetic field H up to 160 kOe, linear magnetic birefringence at λ = 1150 nm under a DC field H up to 21 kOe and specific heat at H = 0. Anomalies are revealed on the T-dependencies of magnetic susceptibility, the slop of the Cotton Mouton effect and the magnetic specific heat contribution due to Dy^{3+} ions at T_{SR} and around the low-temperature point T_B = 42 K predicted by Belov [4]. The results are discussed considering the occurrence of the 'double umbrella' structure of the Dy^{3+} moments below 130 K [5], the paraprocess [4] and the concomitant effects such the Schottky effect which induces a specific heat anomaly near the T-region around the T_B point.

[1] K. M. Song et al., Phys. Rev. B 83, 012404 (2011).
[2] T. D. Kang et al., Phys. Rev. B 86, 144112 (2012).
[3] M. Lahoubi et al., J. Phys. : Conf. Ser. 159, 042108 (2009).
[4] K. P. Belov, Phys. Usp. 39, 623 (1996).
[5] M. Lahoubi et al., J. Phys.: Conf. Ser. 200, 082018 (2010).

Poster Session B

Poster B

P-B.197

Modeling of magnetoelectric, transport and surface properties in superlattices and nanofilms of multiferroics

I. Sharafullin, A. Nugumanov, A. Yuldasheva, A. Zharmukhametov

Text Phase transitions and critical phenomena along with surface effects in multilayer multiferroic ultrathin films draw a vast scientific interest because of a number of unique properties which can be used in nanoelectronic and spintronic devices including those using a giant magnetoresistance effect. Besides naturally occurring multiferroics (crystals with both magnetic and ferroelectric ordering), such as perovskite crystals with transition metal oxides, there is a way to model crystals with desired properties, namely to construct a multiferroic superlattice, which would consist of ultrathin (<10 unit cells thick) magnetic films intersected with ferroelectric films in a periodic manner. Our simulation was held on superlattice with linear sizes LxLxLz, where L=40..400, Lz=4..16. We have obtained phase diagrams for different sets of parameters, as well as temperature dependencies of layers' magnetization, polarization, energy and susceptibilities. They show specific behavior and a variety of phase transitions due to the magnetoelectric interaction. The results of both the monte carlo simulation and of the theoretical calculations using mean-field theory are in a good agreement to each other.

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P-B.198

Nonstoichiometry defects and microinhomogeneities in multicomponent manganites

V. Karpasyuk, A. Badelin, I. Derzhavin, D. Merkulov, A. Pankratov

Text The influence of nonstoichiometry defects and different-valence ions on the formation of microinhomogeneities was established for ceramic manganites of La-Sr system with paired substitution of (Zn^{2+},Ge^{4+}), (Mg^{2+},Ge^{4+}), (Ni^{2+},Ge^{4+}) for manganese. The role of grain microstructure was also considered. Experiments were performed on polycrystalline samples exposed to the heat treatment at a temperature of 1223 K in oxidizing conditions (at a partial pressure of oxygen in the gas phase of P_{O2} = 101.3 kPa) and in a reducing atmosphere (P_{O2} = 10^{-8} Pa). Investigations of experimental samples were carried out by atomic force microscopy, scanning tunneling and scanning electron microscopy.
The existence of microinhomogeneities having different configurations and conductance is related to the association of different-valence ions, cation and anion vacancies. This effect depends on manganese substituents and is most pronounced in manganites containing Zn^{2+} ions (with the highest radius) after annealing in oxygen. In this case, quasi-periodic lamellar formations arise, which represent modulated structures (elastic concentration domains), including secondary modulated ones. Ni-substituted manganites with relatively low strontium content have the highest density and exhibit the least pronounced formation of structure heterogeneity.
Processes of self-organization also take place in the studied manganites, leading to the emergence of regular hexagonal structures.

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Poster B

P-B.199

Onset of ferroelectricity and magnetism in Potassium Sodium Niobate ceramics

K. Shalini, N. V. Giridharan

Text Single- phase multiferroics are predominantly alluring nowadays because of it's multi-functional properties of having more than one ferroic order degree of freedom i.e., ferromagnetism along with ferroelectricity achieved in room temperature meets the current technological needs. The potential applications of multiferroics such as multi-state memories,actuators,sensors,data storage and more importantly it created the huge attention due to that the fundamental exclusion principle between magnetic moment and electric dipole is broken. Main drawback in naturally available perovskite multiferroics is the inability to achieve room or high temperature ferroelectric and magnetic transition temperature. Novel approach to obtain multiferroicity artificially by doping of magnetic cation in B site non-magnetic cation of ABO_3 perovskites. In this report, codopant Fe,Co driven multiferroicity in Potassium Sodium Niobate (KNN) ceramics. Orthorhombic phase confirmation and electronic structure information of $KNaNb_{1-x}Fe_xO_3$ [x = 0.0125, 0.025, 0.05, 0.075, 0.10] ceramics attained from X-ray diffraction (XRD) and X-ray photoelectron spectroscopy (XPS). No deterioration in spontaneous polarization and saturated magnetic hysteresis loop of maximum 2.5 emu/g is established. From direct magneto-electric (ME) study using dynamic lock-in amplifier technique, an appreciable coupling between magnetism and electric polarization acquired. Magnetic domains seen from magnetic force response microscopy.

Poster Session B

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P-B.200

Peculiar space modulated structures in epitaxial bismuth ferrite films

Z. Gareeva, A. Zvezdin, I. Kayumov

Text We report on the novel space modulated structure of cycloidal type that can be realized in the epitaxial BiFeO3 films. The cycloidal state is the ground magnetic state of BiFeO3 stabilized by Dzyaloshinskii – Moriya interaction. Until now, it was believed that polarization is linked with antiferromagnetic order throughout the plane of spin rotation, namely it was considered that polarization always lies in the cycloid spin rotation plane. We show that due to the action of epitaxial strains spin rotational plane of the cycloid deviates from the plane containing intrinsic spontaneous polarization Ps. We found two featured (1-10) and (110) plane cycloids in the (110) oriented BiFeO3 film and considered the action of compressive and tensile deformations on the areas of the cycloids stability. We show that additional magnetic anisotropy induced by strain effects drastically changes space modulated structures, allocates cycloids with the definite directions of spin rotation and electric polarization. These findings being crucial for potential manipulations of electric field-controlled multiferroic states in spintronic and straintronic devices highlight the fundamental difference between magnetoelectric coupling in bulk and films.

Poster Session B

Poster B

P-B.201

Possible multiferroic behavior in bulk SrMnO3 manganites at room temperature

J. L. Izquierdo, V. Isaza Zapata, C. E. Maya, B. Alvarez, M. E. Moncada, O. Morán, I. Supelano, C. A. Parra, A. Astudillo, G. Bolaños, S. Dionizio, A. Gómez

Text The role of the chemical doping on the structure and multiferroic behavior of the challenging SrMnO3 (SMO) manganite is investigated. Until now not enough experimental work has been done regarding the structural instability of SMO to the applied electric field. Polycrystalline SrMnO3 and Sr0.6Ba0.4MnO3 (SBMO) samples were prepared by standard solid-state reaction. Analysis of the XRD patterns indicates that the samples are single phase with 4H-hexagonal perovskite-type structure. The broadening and displacement of the peaks in the XRD diffractograms suggest that the Ba doping leads to a distortion of the perovskite structure of the pristine sample. Magnetic properties of the samples were carefully studied by means of vibrating sample magnetometry. SrMnO3 exhibits AFM transition at TsubN ~280 K. The effect of the Ba-doping is evidenced from the results of the ferroelectric and magnetic measurements. In particular, the ferroelectric behavior at room temperature is considerably improved upon Ba-doping. A maximum remanant polarization value of 1.0 microC/cm2 at a maximum applied field of 7.7 kV/cm is observed for 40 % Ba-doped SMO samples. Furthermore, improved magnetic properties are observed for SBMO samples. Certainly, a maximum value of magnetization of 8x10-3 musubBohr/Mn is obtained at 50 K in an external magnetic field of 30 kOe. These findings suggest that the SBMO system could represent a new class of multiferroic material working at temperatures near room temperature.

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P-B.202

Role of the $BaTiO_3$ polarization reversal in the magnetic structure of $CaMnO_3$

M. Graf, M. A. Barral, S. Di Napoli, A. M. Llois

Text The presence of a strong coupling between magnetism and ferroelectricity enables the conception of a new family of electronic devices where magnetism is controlled through electric fields, or viceversa. One route towards the development of multiferroic materials is by exploring the break of time reversal and space inversion symmetries that occur at the interface between a magnetic and a ferroelectric material. This engineered magnetoelectric coupling could reach values that are orders of magnitude larger than those typical of single phase multiferroics. Furthermore, the properties of each component of the heterostructures can be chosen within a large number of materials, allowing a better optimization of the desired properties.
In this work we obtain, by means of ab initio calculations, the structural, electronic and magnetic properties of $BaTiO_3/CaMnO_3$ heterostructures. We study the effect of reversing the ferroelectric polarization of $BaTiO_3$ on the magnetic structure of $CaMnO_3$, by analyzing the charge transfer through the interface for different interface combinations, namely BaO-MnO_2 and TiO_2-CaO.

Poster Session B

Poster B

P-B.203

Spin transport at a pinned due to rotation of the anti-ferromagnetic moments of CoO across complex oxide interfaces

A. Das, A. S. Goossens, T. Banerjee

Text We study exchange bias effects due to an interfacial antiferromagnetic oxide layer on spin transport across a Co/Nb doped SrTiO3 semiconducting interface. We find clear fingerprints of an exchange bias coupled system in the measured spin voltage with an increasing out of plane magnetic field. The spin voltage measured shows two distinct regimes – at low temperatures the influence of the exchange bias to the change in spin resistance at low in plane fields which evolves into a large change in the spin resistance due to the gradual rotation of the Co moments pinned by the thin antiferromagnetic layer when the applied field is rotated out of the plane. We study this evolution in the spin voltage at different angles and beyond the blocking temperature of the antiferromagnetic layer. We find a significant contribution of a large tunneling anisotropic magnetoresistance at higher temperatures and larger fields. This originates from the 3d-orbital hybridization between Co and Nb:STO and the electric field tuning of Rashba spin-orbit coupling (SOC) across the Nb:STO interface. We also show the changes to the spin voltage induced by tuning the strength of the exchange bias at the interface and discuss how these devices could be useful for spintronic applications.

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P-B.204

Spin-orbit and electronic correlations in multiorbital two-dimensional electron gases formed in oxide heterostructures

P. Martínez-Albertos, P. López-Sancho, M. C. Muñoz

Text We investigate the interplay of spin-orbit coupling (SOC) and electron-electron interaction on the orbital and spin order of the confined two dimensional electron gases (2DEG) formed at the surface or interface of complex transition-metal oxides heterojunctions with perovskite structure. These 2DEGs contain typically either t_{2g} or e_g electrons with a density exceeding 10^{14} cm^{-2}, present a multi-band structure and are spatially confined. Thus, we model the 2DEG within a tight-binding approximation by a multiorbital Hubbard model, which allows to describe the electrostatic confining potentials, SOC and electron-electron interactions on equal footing. We determine the phase diagram at arbitrary filling from Hartree-Fock calculations and show that the model qualitatively capture the correlation between SOC and electron-electron interaction. The emergence of an orbitally-ordered ground-state and the appearance of unconventional magnetic order are predicted. Further, a confinement driven metal-insulator transition (MIT) is anticipated and the correlated evolution of the electronic and magnetic excitations through the respective MITs is discussed. Our results are of general relevance to a broad class of materials exhibiting significant electron-electron and SOC interactions, such as iridates and rutanates and in general 4d and 5d transition metal oxides. They may be useful to engineering novel phases in oxide heterostructures.

Poster Session B

Poster B

P-B.206

Strain, structure, interface, size and band engineering approaches for magnetization improvement in multiferroic BiFeO3

V. Shelke, S. Pillai, D. Tripathi, H. Reshi, T. Bagwaiya

Text Multiferroic is a class of materials, which incipiently exhibits multiple ferroic (electric, magnetic, elastic) orderings. Bismuth ferrite is a classic multiferroic material with lead-free composition and above room temperature transitions. The ferroelectric behavior of BiFeO3 is remarkable in terms of polarization and coercive field values [1]. However, low magnetic moment arising from robust antiferromagnetic ordering is a major concern.
We used several strategies to improve magnetization in BiFeO3 (BFO) compound. The substrate induced strain in BiFeO3 thin films showed limited effect on magnetization value. The structural modification through iso-valent substitution at Bi site could influence the magnetic ordering up to some extent. Alternatively, the bulk interface between two distinct antiferromagnetic grains can impart excess magnetization [2,3]. Finite size effect also alters the spin spiral of BiFeO3 antiferromagnetic ordering [4,5]. Substitution of divalent ion at Bi site in nanomaterial induces structural as well as energy band modulations. It also causes improvement in magnetization value.

References:
[1]Vilas Shelke, et al, Adv. Mater., 23, 669 (2011)
[2]Shreeja Pillai, et al, Appl. Phys. Lett. 102, 072907 (2013)
[3]Shreeja Pillai, et al, J. Appl. Phys. 120, 164103 (2016)
[4]Shreeja Pillai, et al, J. Appl. Phys. 122, 104101 (2017)
[5]H. A. Reshi, et al, Appl. Phys. Lett. 109, 142904 (2016)

Poster Session B

Poster B

P-B.207

Strained epitaxial $Hf_{0.5}Zr_{0.5}O_2$ thin films grown by pulsed laser deposition

P. A. Algarabel, L. Torrejon, E. Langenberg, C. Magen, A. Larrea, J. Santiso, J. Blasco, J. A. Pardo

Text Most of the studies published to date on ferroelectric $Hf_{1-x}Zr_xO_2$ (HZO) refer to polycrystalline films with grain dimensions in the nanometer range. The large surface-to-volume ratio of these grains and the strain imposed by the substrate, have been proposed as stabilizers of the non-equilibrium orthorhombic structure (OS). Its lack of inversion symmetry is believed to be the origin of the ferroelectric behavior of HZO. The possible influence of grain boundaries, oxygen vacancies, impurities and other defects on the stabilization of this OS and its ferroelectric behavior has not been studied. To overcome these limitations, single-crystals and epitaxial films of the pure oxides are needed.

We have carried out a structural and microstructural study by XRD and STEM of HZO thin films grown on YSZ (001) substrates by PLD and determined the conditions for the epitaxial growth of fully coherent monoclinic films. The strains imposed by the cubic substrate on HZO are tensile along a and compressive along b, which gives rise to a distorted monoclinic structure with a = b and higher symmetry than the bulk phase. The films present twin domains with four different orientations confirmed by EBSD. A strong correlation of the domains size with the film thickness and substrate temperature during deposition has been observed. No ferroelectric behavior was detected in any of the films. This fact is ascribed to the relatively low epitaxial strain induced by the substrate on the HZO films.

Poster Session B

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P-B.208

Structural and magnetic characterization of Y-type hexaferrite powders obtained by sol-gel auto-combustion and sonochemistry

B. Georgieva, S. Kolev, K. Krezhov, A. Senyshyn, C. Ghelev, D. Kovacheva, B. Vertruyen, R. Closset, L. M. Tran, A. Zaleski, T. Koutzarova

Text We present results from a study on the influence of the preparation technique on the structural and magnetic properties of $Ba_{0.5}Sr_{1.5}Zn_2Fe_{12}O_{22}$ and $Ba_{0.5}Sr_{1.5}Zn_2Al_{0.08}Fe_{11.92}O_{22}$ powders. Both materials are Y-type hexaferrites known to exhibit multiferroic properties close to room temperature. The powders were synthesized by acetic-acid sol-gel auto-combustion and sonochemical treatment and characterized by X-ray and neutron powder diffraction, scanning electron microscopy and magnetic measurements. The particles of the samples obtained by ultrasonic co-precipitation had the almost perfect hexagonal shape typical of hexaferrites. The Al-substitution in $Ba_{0.5}Sr_{1.5}Zn_2Fe_{12}O_{22}$ resulted in lowering the temperature of synthesis. A strong irreversibility between the ZFC and FC magnetic susceptibility curves was observed. The $Ba_{0.5}Sr_{1.5}Zn_2Al_{0.08}Fe_{11.92}O_{22}$ powders exhibited triple hysteresis loops close to room temperature corresponding to the presence of intermediate magnetic phases between the ferromagnetic and proper-screw spin arrangements. An attempt was made to delimit the regions with stabilized longitudinal conical spin structures, so that magnetically induced ferroelectricity and a finite ME effect due to the modification of the spiral magnetic structures by an external magnetic field could be expected.

Poster Session B

Poster B

P-B.209

Structural and magnetic properties of Co substituted barium hexaferrite thick films

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Text Cobalt substituted barium hexaferrite (BaFe12-xCoxO19 (x = 0.0 - 2.0)) powders were prepared by solid state synthesis method. Structural, compositional and magnetic properties were carried by X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS) and vibrating sample magnetometer (VSM). The XPS analysis of 2p data for substituted sample shows a characteristic peak around 780 eV and 795 eV attributing to Co 2p3/2 and Co 2p1/2 respectively. Peak shift in Fe 2p3/2 and Fe 2p1/2 peaks suggested effective substitution of Co2+ ions. Magnetization found to decrease with Co substitution. A drastic decrease in coercivity was observed. M-T measurement for substituted ferrite shows change in Curie temperature. Further, as prepared powders were screen printed and its micro-structural and magnetic properties were also investigated. Microwave absorption in Kα band found to improve with Co substitution.

Poster Session B

Poster B

P-B.211

Tailoring of room-temperature magnetic order in Fe-doped $ZnAl_2O_4$ ceramics

T. L. Phan, N. Tran, H. S. Kim, L. T. T. Huong, B. W. Lee

Text $ZnAl_2O_4$ is a large band gap with an excellent mechanical resistance, high chemical/thermal stability, and high photocatalytic activity. These properties make it a suitable material for many applications in photoelectronic devices, high-efficient phosphors, and photo-catalysts. Because $ZnAl_2O_4$ is nonmagnetic, a successful fabrication of $ZnAl_2O_4$-based ferromagnets certainly widens remarkably its application range for next-generation innovative devices. To realize this idea, we have prepared $Zn_{1-x}Fe_xAl_2O_4$ (x = 0-0.1) samples by solid-state reactions. X-ray diffractometer, X-ray absorption spectroscopy, Raman and photoluminescence (PL) spectroscopy, and vibrating sample magnetometer were used to study their crystal/electronic structures and magnetic properties. The results reveal all samples crystallized single phase in the Fd3m cubic structure. Fe^{3+} ions incorporated into the $ZnAl_2O_4$ substance and changed the intensity and peak position of Raman modes and PL emission. Particularly, we have found the $x \geq 0.01$ samples having a coexistence of paramagnetism and ferromagnetism with M_s = 5.4~15.6 memu/g and $H_c \approx 0$ Oe. These properties are generated from isolated and coupled Fe^{3+} ions situated at the octahedral and tetrahedral sites of the $ZnAl_2O_4$ structure.

Poster Session B

Poster B

P-B.212

The effect of co-doping on magnetic properties of bismuth ferrite

V. Zhyvulka, I. Makoed, V. Anishchik, A. Ravinski, K. Yanuschkevich, A. Zhyvulka, A. Galias, V. Dziamidzenka, D. Krivchenya, V. Lazenka, V. Moschalkov

Text The aim of the work is to study the crystal structure features and magnetic properties correlations in multiferroics of $R1_xR2_{(0,2-x)}Bi_{0.8}FeO_3$ type (x=0; 0.05;0.10; 0.15, R1, R2 = La, Gd, Dy, Er) depending on the concentrations and types of substitutive rare earth elements cations.
Isovalent substitution of Bi^{3+} cations by rare earth elements ones in the bismuth ferrite leads to suppression of spatially modulated magnetic spin structure and appearance in $R_xBi_{1-x}FeO_3$ (x= 0.05; 0.10; 0.15; 0.20, R=La, Nd, Gd, Dy, Er) compositions of weak ferromagnetic response, the magnitude of which depends on the concentrations of the substituting cations and the values of crystal-chemical characteristics of the studied structures. Systematic changes in the intensity of magnetic interactions depending on the type and concentration of REE cations substituting Bi^{3+} cations are revealed. Is of great interest to continue the research of the bulk and thin-film samples obtained by co-doping of the cationic and anionic sublattices of bismuth ferrite.

Poster Session B

Poster B

P-B.213

The magnetic and dielectric properties of the multiferroic $Pr_{1-x}Ca_xMnO_3$ (x=0.15 and 0.30) at high temperatures

T. Tarasenko, K. Yanushkevich, Y. Radyush

Text The magnetic, resistive and dielectric properties of the $Pr_{1-x}Ca_xMnO_3$ manganites (x=0.15-0.30) are studied in a wide temperature range. Ceramic samples of $Pr_{1-x}Ca_xMnO_3$ were prepared through conventional solid state reaction. In accordance with the X-ray diffraction study the samples are single-phase and have an orthorhombic structure (P_{bnm} - symmetry). The Curie temperature T_C of the appearance of bulk ferromagnetic ordering is 130 K for x=0.15 and 140 K for x = 0.30. All samples under study reveal an unusual high values of specific magnetization σ(T) at $T>>T_C$. Spin correlations that cause the short-range ferromagnetic order are preserved up to 700 K. The temperature dependences of the inverse magnetic susceptibility 1/χ(T) have a typical ferromagnetic form, in which long-range ordering is destroyed, but short-range ordering is still retained. There is some correlation between the temperature dependences of the resistivity and the specific magnetization in temperature region 600-700 K. The strong frequency dispersion of both components of the dielectric constant (ε' and ε'') testifies to powerful polarization of samples, which is typical for inhomogeneous dielectric systems with correlations of polar states of different scale. Thus, these solid solutions exhibit multiferroic properties at $T>T_C$. States with local magnetization in the form of ferromagnetic clusters and high dielectric permittivity coexist in the 'temperature window' $T_C \leq T \leq T^*$.

Poster Session B

Poster B

P-B.214

Theoretical evidence of magnetoelectric coupling in weak-ferromagnetic and double magnetic R3c structures

R. Ribeiro, L. H. S. Lacerda, S. R. Lazaro

Text Multiferroic (MF) materials are important technological materials and largely investigated aiming the development of actuators, magnetic readers, sensors, tunneling, data storage devices, spintronic and others. Our manuscript proposes new MF materials by chemical modification of BiFeO3 (BFO) material resulting on FeAlO3 (FAO), AlFeO3 (AFO), FeVO3 (FVO) and PbFeO3 (PFO). All materials were investigated by a DFT/B3LYP approach employed in CRYSTAL09 software and indicate that all materials are stable at room conditions or high pressures. In terms of magnetism, the FAO, AFO, BFO and FVO are weak-ferromagnetic materials while the PFO shows a ferrimagnetic ordering. In particular, the PFO and FVO exhibit two magnetic atoms within structure and different Ferrimagnetic states were investigated in order to determine the ground magnetic phase. In case of PFO are observed as Fe3+ as Fe2+ species like Fe2O3, such effect is indicate by Bater and Mulliken spin charges. In turn, the ferroelectric properties for proposed materials were higher than for BFO and were ordered in x direction, while magnetism was oriented at [111] direction. Thus, both properties are perpendicular and, consequently, a perturbation in one leads in perturbation in the other, proving that the magnetoelectric coupling is observed in proposed materials. In summary, proposed materials presents excellent properties to development of smart devices and photocatalytic process.

Poster Session B

Poster B

P-B.215

Time-resolved magneto-optical wide-field imaging of domain walls excited by surface acoustic waves

C. Müller, A. Kittmann, P. Durdaut, B. Spetzler, M. Höft, F. Faupel, E. Quandt, J. McCord

Text Recently, surface acoustic waves (SAW) are used to excite and probe the dynamic properties of magnetic thin films [1]. Probing the magnetization response locally reveals further insight of the interaction of magnetic domains and domain walls with periodic strain modulation. The mechanisms of interaction are interesting from a fundamental and relevant from a technological point of view [2]. Here, we temporally and spatially probe the magnetization response of magnetic microstructures in an amorphous FeCoSiB film subject to a varying elastic strain by time-resolved magneto-optical imaging [3]. For this, shear waves are generated in a SAW delay line made of a piezoelectric substrate with 150 MHz [2]. Mediated through magnetoelastic coupling, the varying strain leads to a dynamic change of magnetization within the domains. Moreover periodic domain wall displacements due to dynamic magnetic charge modulation are exhibited. Local magnetic spin-wave like modulations, smaller than the wavelength of the SAW emerge in the proximity of the domain walls. The phase of the magnetization response inside of the domains depends on the exact orientation of magnetization with regard to the SAW. The consequences of the different micromagnetic aspects for the realization to SAW devices [2] will be discussed.
Funding through the CRC 1261 is acknowledged.
[1] Weiler et al. Phys. Rev. Lett. 106, 117601 (2011)
[2] Kittmann et al., Sci. Rep. 8, 278 (2018)
[3] R.B. Holländer et al. JMMM 432, 283–290 (2017)

Poster Session B

Poster B

P-B.216

Two-step magnetic ordering in quasi-one dimensional $LiMn_2TeO_6$

T. Vasilchikova, G. Raganyan, V. Nalbandyan, A. Kurbakov, A. Korshunov, E. Vavilova, T. Salikhov, R. Sarkar, H.-H. Klauss, E. Zvereva

Text We report on the static and dynamic magnetic properties of quasi-1D (II/III) mixed-valent manganese tellurate $LiMn_2TeO_6$, which has been studied comprehensively through the magnetization, specific heat, neutron diffraction, dielectric permittivity, NMR and ESR techniques. The compound was found to order antiferromagnetically in two steps into incommensurate magnetic phase at T_{N1} ~ 20 K followed by commensurate one at T_{N2} ~ 14 K as confirmed from neutron data. Further more applied magnetic field leads to appearance of at least two additional field-induced phases resulting in complicated magnetic phase diagram. ESR studies indicate the presence of strong short-range correlation up to the temperature essentially higher magnetic ordering and short-range antiferromagnetic order maintained by the strong exchange interaction, exists up to much higher fields, of the order of the saturation magnetization field.

Poster Session B

Poster B

P-B.217

A facile synthesis, enhanced optical and magnetic properties of Co doped SrSnO3 nanorods

M. Muralidharan, R. Thiyagarajan, K. Sivakumar, K. Sivaji

Text SrSnO3 is one the important Alkaline earth stannates which has high resistance with diamagnetic nature at room temperature. Here, we prepared Sr1-xCoxSnO3 (x=0, 0.01,0.03 and0.05) in which magnetic property is enhanced by the doping. To understand the magnetic property of prepared samples, the temperature (T) and field (H) dependence of magnetization (M) measurements on prepared samples carried out. M(T) of pure sample does not show any interesting feature till 2 K, but M of Co doped samples are enhanced by Co doping particularly at ~ 40 K. M(H) measurements exhibit the transition from dia- to quasi para- magnetic behavior at 300 K by increasing of Co doping. As on enhanced M at low T by Co doping, M(H) at 2 K exhibit the transition from dia- to ferro- magnetic nature in Co doped samples. At 300 K, the magnetic moments of the dopant are coupled, and the interaction between the spins of F-centre and that of magnetic dopants enhance the M [3]. However, at low T, the dopant electrons are delocalized, and hence, the interaction between the dopant electrons and conduction band electrons are enhanced, subsequently, low T ferromagnetic ordering properly. Thus, Co doped SrSnO3 samples exhibit notable enrichments in the magneto crystalline anisotropy by showing dia- to ferro- magnetic transition which is due to the presence of Co ions and their exchange interaction between host lattices. Such remarkable enhancements in Co doped SrSnO3 might offer a variety of spintronic applications.

Poster Session B

Poster B

P-B.218

Anomalous Nernst effect in $Ir_{22}Mn_{78}/Co_{20}Fe_{60}B_{20}/MgO$ layers with perpendicular magnetic anisotropy

S. Tu, J. Hu, G. Yu, H. Yu, C. Liu, F. Heimbach, X. Wang, J. Zhang, Y. Zhang, A. Hamzic, K. L. Wang, W. Zhao, J.-P. Ansermet

Text The anomalous Nernst effect in a perpendicularly magnetized $Ir_{22}Mn_{78}/Co_{20}Fe_{60}B_{20}/MgO$ thin film is measured using well-defined in-plane temperature gradients. The anomalous Nernst coefficient reaches 1.8 μV/K at room temperature, which is almost 50 times larger than that of a $Ta/Co_{20}Fe_{60}B_{20}/MgO$ thin film with perpendicular magnetic anisotropy. The anomalous Nernst and anomalous Hall results in different sample structures revealing that the large Nernst coefficient of the $Ir_{22}Mn_{78}/Co_{20}Fe_{60}B_{20}/MgO$ thin film is related to the interface between CoFeB and IrMn.

Poster Session B

Poster B

P-B.219

Bulk and edge spin transport in topological magnon insulators

A. Rückriegel, A. Brataas, R. A. Duine

Text We investigate the spin transport properties of a topological magnon insulator, a magnetic insulator characterized by topologically nontrivial bulk magnon bands and protected magnon edge modes located in the bulk band gaps. Employing the Landau-Lifshitz-Gilbert phenomenology, we calculate the spin current driven through a normal metal | topological magnon insulator | normal metal heterostructure by a spin accumulation imbalance between the metals, with and without random lattice defects. We show that bulk and edge transport are characterized by different length scales. This results in a characteristic system size where the magnon transport crosses over from being bulk-dominated for small systems to edge-dominated for larger systems. These findings are generic and relevant for topological transport in systems of nonconserved bosons.

Poster Session B

Poster B

P-B.220

Co2MnSi:Pt multilayers for giant spin Seebeck devices

C. Cox, M. Cropper, A. Caruana, C. Kinane, T. Charlton, K. Morrison

Text The spin Seebeck effect[1] is defined as the generation of a pure spin current (Js) when a magnetised material (such as Co2MnSi[2]) is subjected to a temperature gradient (ΔT) or a thermal current (JQ)[3]. To detect it, a thin non-magnetic layer [NM] such as Pt, is deposited on top of the material of interest, this converts Js into an observable thermoelectric voltage (VSSE) by way of the Inverse Spin Hall Effect (ISHE). We are interested in how this phenomenon might be applied to harvesting waste heat (thermoelectric generators) or spintronics applications (spin current source).
Our work initially encompasses the thin film deposition of highly textured Co2MnSi on amorphous glass substrates using Pulsed Laser Deposition (PLD) and optimisation of the deposition parameters to produce L21 ordered films[4] with structural and magnetic characteristics close to expected bulk values.
Additionally, we will present results on exploring the potential Giant Spin Seebeck Effect (GSSE)[5,6] in SiO2:(Co2MnSi /Pt)n multilayers, where the GSSE is an enhancement of VSSE due to the increase in the volume of the spin injector (Co2MnSi).
References:
1 K. Uchida et al., Nature 455, 778 (2008).
2 S. Bosu et al., Phys. Rev. B 83, 224401 (2011).
3 A.Sola, Sci. Reps. 7, 46752 (2017).
4 M. Jourdan et. al., Nat. Commun. 5, 3974 (2014).
5 R. Ramos et al., APL Mater. 4, 104802 (2016).
6 C.Cox et al., Proc. of SPIE 10357, 1035731 (2017).

Poster Session B

Poster B

P-B.221

Complex DC and THz inverse spin Hall effect in YIG/$Cu_{1-x}Ir_x$ bilayers

J. Cramer, T. Seifert, F. Fuhrmann, G. Jakob, M. Jourdan, T. Kampfrath, M. Kläui

Text The development of efficient generation and detection schemes of pure spin currents is critical for next-generation spintronic applications. The spin Hall effect and its inverse are in the focus of research, as they allow for an effective interconversion of charge and spin currents [1]. We investigate the inverse spin Hall effect in $Cu_{1-x}Ir_x$ alloys deposited as thin films on the insulating ferrimagnet yttrium iron garnet for a large range of Ir concentrations ($0.05 \leq x \leq 0.7$) [2]. Spin currents are thermally triggered via the spin Seebeck effect, either by a DC temperature gradient or by ultrafast optical heating of the metal layer. The generated spin Hall current is detected by electrical contacts or measurement of the emitted THz radiation. With both methods, we observe the same complex, non-monotonous concentration dependence of the spin-converted signal. The coinciding results obtained for DC and ultrafast stimuli emphasize the integrity of the THz SSE mechanism and furthermore show that the studied material allows for efficient spin-to-charge conversion even on ultrafast timescales. Therfore, a feasible transfer of established spintronic measurement schemes into the terahertz regime is enabled.

[1] Sinova *et al.*, Rev. Mod. Phys. **87**, 1213 (2015)
[2] Cramer *et al.*, Nano Let. **18**, 1064-1069 (2018)

Poster Session B

Poster B

P-B.222

Enhancement of the thermoelectric effect via pumping current

T. Ludwig, I. Burmistrov, Y. Gefen, A. Shnirman

Text We consider a single-domain itinerant ferromagnetic quantum dot exposed to a magnetic field and tunnel-coupled to two leads. One lead is an itinerant ferromagnet with a fixed magnetization, the other lead is a normal metal. We discuss the dynamics of the free magnetization of the dot. In a previous work [1] we considered a voltage bias on this system. Here we are interested in persistent precessions maintained by a temperature difference in the leads. We show that the pumping current, induced by the precessing free magnetization, can enhance the thermoelectric effect in comparison to a static situation, i.e. with both magnetizations fixed.

On the technical level, we employ Keldysh formalism in its path integral version to deal with the non-equilibrium situation created by different lead temperatures. We extend the approach of [1] and derive an effective action of the Ambegaokar-Eckern-Schön type which is used to derive the quasiclassical equations of motion, i.e. the Landau-Lifshitz-Gilbert-Slonczewski equation. This approach allows us to investigate the important role of the non-equilibrium electron distribution function for the Slonczewski-spin-torque current and the Gilbert damping.

[1] Phys. Rev. B 95, 075425 (2017)

Poster Session B

Poster B

P-B.223

Epitaxial Yttrium Iron Garnet (YIG) Thin Films Deposited by a Chemical Solution Synthesis

I. Lucas, P. Jimenez-Cavero, J. M. Vila-Fungueiriño, C. Magen, S. Sangiao, P. Algarabel, J. M. de Teresa, L. Morellon, F. Rivadulla

Text In this work we report the fabrication of epitaxial Y3Fe5O12 (YIG) thin films on Gd3Ga5O12 (111) (GGG) substrates by means of Polymer Assisted Deposition (PAD). Cubic YIG is a well known and characterized ferrimagnetic material at room temperature, with excellent magneto-optical properties, high electrical resistivity, and a very narrow ferromagnetic resonance, which makes it particularly suitable for applications devices in spintronics, magnonics and spin caloritronics.

The emergence of all these interesting properties relies on the precise stoichiometry and distribution of Fe3+ ions among the octahedral/tetrahedral sites in the complex structure, which to date has normally hampered the production of high-quality YIG thin films by affordable chemical methods. Compared to using physical vapor techniques such as pulsed laser deposition or sputtering, chemical solution deposition offers important advantages including affordability and scalability for thin-film fabrication.

Here we report the chemical solution synthesis of YIG thin films, with excellent chemical, crystalline, and magnetic homogeneity. The films show a very narrow ferromagnetic resonance, comparable to that obtained from high-vacuum physical deposition methods. These results demonstrate that chemical methods can seriously compete to develop nanometer-thick YIG films with the quality required for spintronic based devices and other high-frequency applications.

Poster Session B

Poster B

P-B.224

Evaluation of metal contact efficiency in hybrids nanostructures by thermomagnetic experiments

A. Anadón, L. Avilés-Félix, J. Gómez, P. Strichovanec, R. Ramos, M. Ibarra, A. Butera, M. H. Aguirre

Text The observation of the Spin Seebeck Effect (SSE) in magnetic insulators has opened the possibility to generate pure spin currents and detected by means of inverse spin Hall Effect (ISHE), with less dissipation losses due absence of mobile charge carriers, and further expand the range of possible materials to study spin mediated thermoelectric conversion. One advantage is the experimental geometry of the SSE, where the thermal and electric current paths are perpendicular to each other, since it could be implemented in thin films and flexible thermoelectric devices. Furthermore, since the heat and electric currents have independent paths, the properties of different materials comprising the SSE hybrid device can be optimized independently. In this sense different possibilities are currently being explored in Fe3O4/metal system, such as increasing the spin current detection efficiency by taking advantage of the spin Hall angle characteristics, spin mixing conductance or spin diffusion length or even the resistivity of different metal contacts. Metals likes Au, Nb, W, Ta are testing in comparison with the classical Pt metal contact. ISHE by thermomagnetic experiments will be compared with ISHE obtained by generation and detection of pure spin currents via spin pumping in ferromagnetic resonance experiments.

Poster Session B

Poster B

P-B.225

Flexible Spin-Caloritronic Devices

M.-S. Jang, H.-J. Ok, K.-S. Lee

Text Flexible thermoelectric generator (TEG) is a fast-evolving research field in a future energy technology for an internet of things (IoT). One of the prominent candidates for a flexible TEG is a spin Seebeck effect (SSE) device. To implement flexible SSE device, a lot of fabrication methods have been developed, such as a pulsed laser deposition, sprayed, and spin coating technologies. However, these methods require high quality substrate. Here, we demonstrate a desirable substrate-free longitudinal SSE device having mechanical flexibility based on polycrystalline $Y_3Fe_5O_{12}$ (YIG). For fabricating flexible YIG sheet, we adopted sol-gel synthesis which enables low-cost mass production. To obtain comparable magnetic properties and a thermoelectric efficiency of polycrystalline YIG, heat treatments were optimized and newly-developed mechanical process was added. For converting spin to charge current through the inverse spin Hall effect in the longitudinal SSE configuration of the flexible YIG sheet, a gold electrode was fabricated on the top surface. For temperature difference $\Delta T = 50$ K, our flexible SSE device generated 2.26 μV stably. By optimizing device structure and electrode materials, the TEG performance of our device will be improved sufficiently. Flexible substrate-free SSE device fabricated by low-cost sol-gel synthesis will open a new way for harnessing spin caloritronic to energy harvesting devices for next-generation smart network devices of IoT.

Poster Session B

Poster B

P-B.226

Investigations of Spin Precession in Perpendicular Magnetic Materials Enabled by Time-Resolved Magneto-Optical Kerr Effect

X. Wang

Text Time-Resolved Magneto-Optical Kerr Effect (TR-MOKE) is an all-optical method based on the ultrafast pump-probe technique that can be used to study the magnetization dynamics of materials, in addition to thermal and mechanical characterization. With optical excitation and the capability of reaching large magnetic fields, TR-MOKE can probe spin precession at high resonance frequencies (up to a few hundreds of GHz), beyond those achievable by conventional Ferromagnetic Resonance (FMR) methods. In this talk, we demonstrate the use of TR-MOKE to study the spin precession of two model material systems with large perpendicular magnetic anisotropy (PMA). The first model system is a series of tungsten (W)-seeded CoFeB thin films, capable of sustaining good PMA after post-annealling at temperatures of up to 400 °C. We measure the Gilbert damping (α) of W-seeded CoFeB films, and attribute the dependence of α on the annealing temperature to two competing effects: the enhanced crystallization of CoFeB and the dead-layer growth occurring at the CoFeB interfaces. The second model system of interest is composed of perpendicular ferromagnetic [Co/Pd]n multilayers with varying anisotropy. We use ultrafast-laser heating to launch acoustic strain waves and capture their coupling with the spin precession in these [Co/Pd]n multilayers. Understandings on such a strain-spin coupling may shed light on manipulating the precession and switching the magnetization in magnetoacoustic devices.

Poster Session B

Poster B

P-B.227

Longitudinal spin Seebeck Effect in epitaxial gamma-Fe2O3 thin films: a quantitative study

P. Jimenez-Cavero, I. Lucas, D. Bugallo, C. Lopez-Bueno, P. Algarabel, R. Ibarra, F. Rivadulla, L. Morellon

Text Spin Seebeck effect (SSE) is defined as the excitation of a spin current in a magnetic ordered material when subjected to a thermal gradient. This has been proved to be carried by magnetic excitations -magnons-, and it is usually detected by its conversion into an electrical current by means of the Inverse Spin Hall effect in an attached metallic and non-magnetic material. Thus, SSE is a complex phenomenon whose output is the result of the interplay between several parameters characterizing magnetic, electrical, magnonic, and thermal properties of the involved materials and interfaces, making its quantitative analysis far from straightforward.

Here we report a series of experiments and analysis for a quantitative analysis of longitudinal SSE (LSSE) in epitaxial thin films of ferrimagnetic insulating maghemite (γ-Fe2O3). The use of an insulating ferrimagnet overcomes theoretical and experimental complications, and brings some advantages for practical applications.

We study the temperature dependence of the stationary LSSE, and correlate it with the thermal conductivity of both the magnetic thin-film and the substrate, measured by the 3ω method. The influence of the magnetic layer thickness is also determined and considered in the analysis. The results are fitted to theory, granting us the access to the value of different parameters influencing the spin transport through the samples and the output ISHE voltage.

Poster Session B

Poster B

P-B.228

Longitudinal spin Seebeck effect detection based on spectrum analysis

C. Romanque, C. Gonzalez-Fuentes, C. Orellana, C. Garcia Garcia

Text Nowadays, the measurement of spin Seebeck effect, the generation of a spin current by a temperature gradient, represent a challenge. Principally, due to the weakness of the effect and the difficulty of achieving a stable control of the temperature gradient. In this work, we present a novel measurement technique based in the spectrum analysis of the signal measured in the longitudinal spin Seebeck effect device, when an external magnetic field varies harmonically and the temperature gradient remains constant. With this technique it is possible discard others contributions to the measured total voltage and identify a signal that is only due to the spin Seebeck effect.

Poster Session B

Poster B

P-B.230

Spin caloritronics in 3D interconnected nanowire networks

T. da Câmara Santa Clara Gomes, F. Abreu Araujo, L. Piraux

Text We studied the magneto-transport properties of 3D interconnected magnetic nanowire networks synthesised by electrodeposition in track-etched polycarbonate templates with crossed nanochannels. The fabrication process offers a wide range of controllable parameters, including the topology, material composition and morphology such as homogeneous nanowires (NWs) and multilayered NWs. The 3D architectures exhibit a good mechanical stability and are self-supported after dissolution of the template. In addition, the local removing of the cathode sputtered on one side of the template for the electrodeposition enables a two-probe design suitable for electric and thermoelectric measurements, with the electric current flow restricted along the nanowires. Various 3D interconnected magnetic multilayered NW networks showing giant magnetoresistance effects in the CPP geometry have been studied. Large magneto-Seebeck and magneto-Peltier effects were detected experimentally. Power factors comparable to that of the widely used thermoelectric material, bismuth telluride, were measured in CoNi/Cu CNW network films, thanks to their low resistivity and high Seebeck coefficient. We also demonstrated high, magnetically modulated power factor, with magneto-power factor ratios up to 140% at room temperature. We determined the Seebeck coefficients of minority-spin and majority-spin electrons using a simple two-current model, which it is also of importance for potential spin-caloritronics applications.

Poster Session B

Poster B

P-B.231

Spin disorder effect on the spectral function of NiMnSb, Mn_2CoAl and CrVTiAl from first principles

R. Kováčik, P. Mavropoulos, S. Blügel

Text The formation of a spin-disordered state due to the local moment fluctuations at elevated temperatures strongly affects the electronic and spin-caloric transport properties of magnetic materials [1,2]. Motivated by these findings, we study how the spectral function changes as a function of temperature. The electronic structure is calculated within the full-potential Korringa-Kohn-Rostoker Green function framework [3]. The temperature induced spin disorder is simulated by the Monte-Carlo method and a set of spin-disordered configurations is used to obtain statistical average of the relevant material properties [1,2,4].

We focus on selected materials from the Heusler family: half Heusler NiMnSb (prototypical half-metallic ferromagnet); inverse Heusler Mn_2CoAl (ferrimagnetic spin-gapless semiconductor); and quaternary Heusler CrVTiAl (fully-compensated ferrimagnetic semiconductor). We point out qualitative differences between the spectral function calculated at T = 0 K, the room temperature and the critical temperature. Furthermore, we compare the density of states calculated by our approach and by the coherent potential approximation.

Support from the DFG (SPP 1538) is gratefully acknowledged.

[1] R. Kováčik et al., Phys. Rev. B 89, 134417, (2014).
[2] R. Kováčik et al., Phys. Rev. B 91, 014421, (2015).
[3] N. Papanikolaou et al., J. Phys.: Condens. Matter 14, 2799, (2002), also see: kkr-gf.org.
[4] Ph. Mavropoulos et al., Phys. Rev. B 69, 125104, (2004).

Poster Session B

Poster B

P-B.233

Terahertz Spin Currents and Spin Hall Effect in β-Tungsten and Au_xPt_{1-x} Alloys

O. Gueckstock, T. Seifert, S. Dapper, S. Prakash Bommanaboyena, B. Gliniors, L. Liensberger, S. Wimmer, L. Nádvorník, M. Wolf, H. Ebert, M. Weiler, M. Meinert, T. Kampfrath

Text The efficient conversion of spin to charge currents by spin-orbit interaction (SOI) will be highly important for future spin-based electronics [1]. Recently, much effort has been devoted to the identification of new large-SOI materials. One promising material is β-tungsten, for which large spin Hall angles (SHA) have been reported [2]. To rapidly characterize the SHA in nonmagnetic (NM) SOI materials, we employ femtosecond optical pulses to trigger ultrafast spin transport from the ferromagnetic (FM) into the NM layer of FM|NM bilayers. Due to SOI, this spin current is partially converted into a transverse charge current which is monitored by detecting the concomitantly emitted THz electromagnetic radiation [3,4,5]. Here, we study THz emission from FM|NM bilayers with cobalt-iron-boron as FM and either β-tungsten with varying oxygen concentration or Au_xPt_{1-x} alloys as NM material. By additionally measuring the THz conductivity of these films, we are able to separate the influence of the spin-Hall conductivity and the longitudinal conductivity to the SHA.

References:
[1] S.A. Wolf et al., Science 294.5546 (2001)
[2] K. Demasius et al., Nature Comm. 7, 10644 (2016)
[3] T. Kampfrath et al., Nature Nanotech. 8, 256 (2013)
[4] T. Seifert et al., Nature Phot. 10, 483 (2016)
[5] T. Seifert et al., SPIN Vol. 7, No. 3, 1740010 (2017)

Poster Session B

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Towards a Standard spin Seebeck Measurement

K. Morrison, A. Caruana, C. Cox

Text It was recently demonstrated that a thermal gradient applied across a magnetic material can result in the generation of a spin polarised current: the spin Seebeck effect (SSE) [1]. This is observed indirectly by placing a heavy metal such as Pt in direct contact with the magnetic material such that a voltage, V_{ISHE}, is generated by the inverse spin Hall effect. One application of this effect is waste heat harvesting technologies (thermoelectrics)[2].

Overall, there are a myriad of variables that affect the magnitude of the observed voltage in a spin Seebeck measurement. This includes, but is not limited to: the thickness of the magnetic material; the thickness of the Pt detection layer; the contact separation; the thermal conductivities of the layers; the spin diffusion length, spin Hall angle and spin mixing conductance; and the roughness of the interface. If we are to start comparing spin Seebeck measurements we need to find a standard measurement (and normalisation) procedure.

Here we will present results from spin Seebeck measurements of bulk and thin film samples, where we demonstrate the importance of the heat flow for normalisation of SSE measurements. Finally, we will discuss the surprising result that the voltage, V_{ISHE}, is scaled not just by the contact separation and device thickness, but the area (of the device) as well.

References:
1) G.E.W. Bauer *et al.*, *Nat. Mater.* **11**, 391 (2012)
2) K. Uchida *et al.*, *Appl. Phys. Exp.* **5**, 093001 (2012)