2013 Summer School

June 9-14
Assisi, Italy

Organized in collaboration with:

IEEE MAGNETICS ITALY CHAPTER

UNIVERSITY OF PERUGIA

AIMagn Associazione Italiana di Magnetismo

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Dear Participant,

we are proud to welcome you in Assisi, Italy, where the 2013 Summer School of the IEEE Magnetics Society takes place. This is a very intense week of learning, intended to enrich and strengthen your knowledge about basic and applied aspects of Magnetism. You will be embedded in a rich and stimulating community of colleagues and lecturers, coming from almost one hundred research institutions spread all over the world.

We hope that you will enjoy to spend this week in the UNESCO World Heritage site of Assisi, an ensemble of masterpieces of human creative genius, such as the Basilica of San Francesco, which have made it a fundamental reference for art history in Europe and in the world. It represents a unique example of medieval city, within its environmental setting from its Umbrian-Roman origin, represented in the cultural landscape, the religious ensembles, systems of communication, and traditional land-use.

We believe that the Summer Schools plays a very important role in the international presence of the IEEE Magnetics Society, encouraging the mobility of students, the exchange of knowledge and experience, as well as the promotion of international collaboration in groundbreaking research.

As members of the local organizing committee, our goal is to help you to take the maximum profit from the school, achieving a development of your personal, social and academic skills during this week. As side activities to the scientific program, we propose a couple of social events on Tuesday and Wednesday afternoon, aimed to discover some artistic and historical masterpieces of this region. We hope that you will enjoy these events as well as the whole atmosphere of our School.

Some of us will be present at the School at all times (look for green names within badges!). Do not hesitate to contact us if you need any assistance or further information.

Grazie, e benvenuti ad Assisi!

The 6th IEEE Magnetics Society Summer School Program

June 9, Sunday

6:00 PM Welcome reception and cocktail
6:30 PM Opening ceremony - Mingzhong Wu, Dino Fiorani, Ermanno Cardelli & Giovanni Carlotti
7:00 PM DL Talk - Koki Takanashi
8:00 PM Dinner

June 10, Monday

8:00 AM – 9:00 AM	Breakfast	
9:00 AM – 10:30 AM	Fundamentals of Magnetism I	Albrecht Jander
10:30 AM - 11:00 AM	Coffee Break	
11:00 AM – 12:30 PM	Fundamentals of Magnetism II	Albrecht Jander
12:30 PM – 2:00 PM	Lunch	
2:00 PM – 3:30 PM	Permanent Magnet I	Karl- Hartmut Müller
3:30 PM – 4:00 PM	Coffee Break	
4:00 PM – 5:30 PM	Permanent Magnet II	Karl- Hartmut Müller
5:30 PM – 6:00 PM	Break (drinks/snacks)	
6:00 PM – 7:30 PM	Poster Session I	
7:30 PM – 9:00 PM	Dinner	

June 11, Tuesday

8:00 AM – 9:00 AM	Breakfast	
9:00 AM – 10:30 AM	Magnetization Dynamics I	Giorgio Bertotti
10:30 AM - 11:00 AM	Coffee Break	
11:00 AM – 12:30 PM	Magnetization Dynamics II	Giorgio Bertotti
12:30 PM – 2:00 PM	Lunch	
2.00 PM – 3.30 PM	**Guided visit of St. Francis Basilica and Giotto Paintings**	
3.30 PM – 5:00 PM	Spintronics I	Daniel Bürgler
5:30 PM – 6:00 PM	Coffee Break	
6:00 PM – 7:30 PM	Spintronics II	Daniel Bürgler
7:30 PM – 8:30 PM	Dinner	
8:30 PM – 10:00 PM	Poster Session II	

June 12, Wednesday

8:00 AM – 9:00 AM	Breakfast	
9:00 AM – 10:30 AM	Magnetic Recording I	Stella Wu
10:30 AM - 11:00 AM	Coffee Break	
11:00 AM – 12:30 PM	Magnetic Recording II	Stella Wu
12:30 PM – 2:00 PM	Lunch	
2:00 PM – 8:30 PM	**Group Outing - PERUGIA**	
8:30 PM – 9:30 PM	Dinner	

June 13, Thursday

8:00 AM – 9:00 AM	Breakfast	
9:00 AM – 10:30 AM	Nano-Magnetism I	Beth Stadler
10:30 AM - 11:00 AM	Coffee Break	
11:00 AM – 12:30 PM	Nano-Magnetism II	Beth Stadler
12:30 PM – 2:00 PM	Lunch	
2:00 PM – 3:30 PM	Modeling and Simulations I	Thomas Schrefl
3:30 PM – 4:00 PM	Coffee Break	
4:00 PM – 5:30 PM	Modeling and Simulations II	Thomas Schrefl
5:30 PM – 6:00 PM	Break	
6:00 PM – 7:00 PM	DL Talk - Michael McHenry	
7:00 PM – 8:00 PM	Dinner	
8:00 PM – 9:00 PM	DL Talk - Rudolf Schaefer	

June 14, Friday

8:00 AM – 9:00 AM	Breakfast	
9:00 AM – 10:30 AM	Bio-Magnetism I	Fernando Palacio
10:30 AM - 11:00 AM	Coffee Break	
11:00 AM – 12:30 PM	Bio-Magnetism II	Fernando Palacio
12:30 PM – 2:00 PM	Lunch	
2:00 PM – 3:30 PM	Molecular Magnetism I	Roberta Sessoli
3:30 PM – 4:00 PM	Coffee Break	
4:00 PM – 5:30 PM	Molecular Magnetism II	Roberta Sessoli
5:30 PM – 6:00 PM	Break	
6:00 PM – 7:00 PM	DL Talk - Adekunle Adeyeye	
7:00 PM – 7:30 PM	Best Poster Awards; Closing Remarks (Liesl Folks, IEEE MagSoc President)	
7:30 PM – 8:30 PM	Dinner	

USEFUL INFORMATIONS

POSTER SESSIONS

All the posters should be attached to the panels available in the terrace adjacent to the conference room as soon as you arrive at the School. During the Poster Session of Monday, the posters with ODD numbers will be presented, while those with EVEN number will be presented during the session of Tuesday evening. The poster presenters are kindly requested to be available at their poster for the whole duration of the session. A Poster Award will be given to the presenter who delivers the best presentation in the Poster Sessions.

INTERNET

A complimentary WIFI connection is available in the reception area. Please contact the Reception of the Hotel to get the necessary Password.

TRAVEL EXPENSES

A Travel Expense Report form must be completed in order to have the reimbursement of the expenses. Ask to the Organizers.

MEETING POINTS FOR THE SOCIAL EVENTS

The meeting point for the Guided Visit to St. Francis Basilica on Tuesday and for the Outing to Perugia is at five minutes to 2 p.m at the reception.

GROUP PHOTO

An official picture of the participants to the School will be taken on Thursday, just before lunch. Stay tuned!

PARKING

If you have your own car, please note that parking along the streets adjacent to La Cittadella is possible only if you have a special permission. Contact the Reception of the Hotel for details.

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ABSTRACT BOOK

2013 Summer School

June 9-14, Assisi, Italy

1. Magnetostrictive Galfenol thin films epitaxied on GaAs(001)

Mariana Barturen, M. Marangolo, J. Milano, M. Eddrief, V.H. Etgens, Y. Zheng, M. Sacchi
Instituto Balseiro, Centro Atomico Bariloche, Bariloche, Argentina

Nowadays, an option for reaching smaller sizes in nanodevices could be to control the magnetism by alternative methods than using magnetic fields. One of these possibilities is to make use of the magnetoelastic coupling in magnetostrictive systems, i.e., to handle the magnetic properties by mechanical deformation [1]. We investigated by x-ray diffraction the Ga concentration dependences of the structural properties of Fe1-xGax (Galfenol) thin films grown on a ZnSe/GaAs(001) substrate, a material known for its high magnetostriction. By molecular beam epitaxy (MBE) we grew a series of (001)-oriented layers without in-plane misorientation, ranging from pure Fe up to x=29.4% Ga.[2] We find a strong Ga-induced tetragonal distortion that conserves the pristine Fe in-plane lattice parameters for all Ga compositions. Supported by theoretical predictions [3], we attribute this unusual tetragonal distortion to short-range ordering of Ga-Ga pairs along the [001]-growth direction. The low-temperature and out-of-equilibrium MBE growth regime tends to stabilize a strong deformed tetragonal phase (up to c/a~1.05 for x=29%). This tetragonal structure is fully released by postgrowth annealing. Here we show that the tetragonal distortion combined with the strong magnetostriction induces an out-of-plane component of the Galfenol magnetization and particular features in hysteresis loops. MFM measurements indicate a self-organized striped pattern (period ~150 nm) with rotatable anisotropy (see Fig.1). Self-organization is affected by the the film thickness and the Ga content.

2. Magnetism in Co doped CeO2 nanoparticles

Mariano Andrés Paulin, J. Sacanell and A.G. Leyva
CNEA-CONICET, San Martín, Argentina

Development of spintronics has promoted the study of materials in which magnetism is associated with its electrical properties. Cerium Oxide (CeO2) is one of the most studied materials in this field. In its pure state the system is diamagnetic, but when doped with magnetic elements such as cobalt, the compound presents a paramagnetic or ferromagnetic behavior. It is believed that the great ability to accommodate oxygen vacancies in his structure is one of the reasons for this singular behavior. In this work we study the magnetic properties of CeO2 nanoparticles doped with cobalt as a function of doping, the relative concentration of oxygen vacancies and particle size. Systematic experiments establish a direct relation between ferromagnetism and oxygen vacancies and open a path for developing materials with tailored properties.

3. Antiferromagnetic behavior of V_2O_5/V_2CoO_6 samples synthesized by Pechini Method

Driele von Dreifus, Adriano César Rabelo, Ernesto Chaves Pereira de Souza, Adilson J. A. de Oliveir
Physics Departament, Federal University of São Carlos, Brazil

Nowadays the study of magnetic oxides is an important subject of investigation on magnetic materials because the combination of antiferromagnetic with ferromagnetic materials opens interesting possibilities for applications in storage and processes information. In the present work we show the structural and magnetic properties of V2O5/V2CoO6 samples synthesized via Pechini method. The synthesis consists in adding NH4VO3 to a mixture of citric acid and ethylene glycol that results in a polymer which is eliminated in the calcination process while vanadium ions are oxidized. Cobalt sulfate, 5mol% was added to the solution and the resin obtained was calcined in two steps, first at 110 ° C (1 hour) and 300 ° C (2 hours). The powder was sintered at 500 and 550 ° C during different periods, 2, 4 and 6 hours. X-ray diffraction measurements were analyzed using Rietveld refinement and the results show that when calcination temperature increases the amount of monoclinic V2CoO6 also increases, despite of V2O5 phase represents the most part of the samples, up to 90%. Although the synthesis process have produced large amount of V2O5 phase, which presents paramagnetic behavior, magnetization measurements as a function of temperature with different applied magnetic fields show that the samples exhibit the antiferromagnetic phase with TN=14K (Néel Temperature). This phase was observed for magnetic fields up to 30 kOe. This behavior was recently observed for pure V2CoO6 samples prepared by solid-state reaction from vanadium oxide (V2O5) and hydrated cobalt oxalate. However, our results show that this antiferromagnetic phase presents a metamagnetic transition in function of applied magnetic field which is characterized by a change in the inclination of the magnetization curve at high fields.

4. Spin-Hall Magnetoresistance in Pt onYIG

N. Vlietstra, J. Shan, V. Castel, J. Ben Youssef, B.J. van Wees
Physics of Nanodevices, University of Groningen, Groningen, Netherlands

Spin-Hall Magnetoresistance (SMR) is caused by simultanuous occurrence of the Spin-Hall effect (SHE) and the Inverse Spin-Hall effect (ISHE). By sending a charge current through a material with high spin-orbit coupling (such as Platinum, Pt) a transverse spin current will be created by the SHE. When this spin current is reflected from an interface back into the Pt, it can cause an additional charge current via the ISHE, which is the origin of SMR. The occurrence of SMR in Pt on top of the magnetic insulating material Yttrium Iron Garnet (YIG) will be shown. It is found that the SMR in a Pt strip directly follows the in-plane magnetization direction of the YIG. Results will be shown for different Pt thicknesses [3, 4, 8 and 35 nm] and for two different deposition techniques: e-beam evaporation and dc sputtering, used to grow the Pt layer.

5. A ferrofluid-based planar variable inductor

Babak Assadsangabi, Mohamed Sultan Mohamed Ali, and Kenichi Takahata
Electrical and Computer Engineering, University of British Columbia, Vancouver, Canada

MEMS-based variable inductors have been investigated for various RF applications through different approaches, including the deformation of micromachined coil as well as the displacement of magnetic core and planar coil [3]. However, most of these approaches require complicated processes for the device fabrication. Many of them use electrostatic actuation that requires high voltages in order to achieve a wide tuning range in the inductance, making their designs complex while limiting their applications. The devices based on magnetic actuation generally suffer from scaling effects as the available magnetic force is proportional to the volume of the magnetic material. Ferrofluids are attractive alternative magnetic materials, as a large amount of the fluid can be easily injected inside a cavity, and there have been some studies for their MEMS applications [5]. In this paper, we report the first demonstration of a micropatterened planar variable inductor whose inductance is varied by ferrofluid magnetically actuated over the planar inductor, where the ferrofluid is used as a movable magnetic layer that modifies permeability distribution on the inductor. The continuous modulation of the inductance has been demonstrated with the fabricated device.

6. Spin wave properties of two-dimensional magnetic superlattices

Glade Sietsema, Michael E. Flatte
Physics Deapartment, University of Iowa, Iowa City, United States

We have studied the behavior of spin waves in two-dimensional periodic magnetic superlattices. These magnonic crystals consist of magnetic cylinders arranged in either a square or hexagonal lattice and embedded within a second magnetic material. Spin wave frequencies and linewidths are calculated from the Landau-Lifshitz-Gilbert equations. Dramatic changes in the magnonic spectrum are shown to occur when varying the saturation magnetization and exchange stiffness constants of the two materials. For example, multiple band gaps across the entire superlattice Brillouin zone appear when the saturation magnetization of the cylinders is much larger than that of the magnetic host. Additionally, we use Green's function calculations to examine the superlattice's response to pulse excitations, such as from a spin torque oscillator. The directional dependencies of these excitations is shown to vary with the frequency of the pulse. This work is supported by an ARO MURI.

7. Magnetic properties in multisegmented cylindrical systems with alternating magnetic wires and tubes

Diego Salazar Aravena, R.M. Corona; J. Escrig, J. Bachmann; D. Goerlitz, K Nielsch
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As technology pushes the dimensions of the ferromagnetic structures at the nanoscale, understanding the magnetization processes of these structures is of fundamental interest and key to future applications. Speed limitations in most electronic devices are imposed by the speed at which an information state (eg, a binary 1) can be changed to another state (eg, a binary 0). For devices that use ferromagnetic materials, the question involves knowing the speed at which the magnetization direction of the magnetic element can be reversed. This is a very complex question. For example, we need to know the reversal mechanism to be used for change the direction of the magnetization: the whole element will rotate at the same time, or only a section generate a domain wall will propagate to the rest of the element?. In this way, one can create domain walls, where two oppositely magnetized regions are in the process of reversal of the magnetization [1]. The manipulation of domain walls in nanowires has been proposed as a way to store information [2] or even perform logic functions [3]. On the other hand, Yan et al. [4] have presented numerical simulations on the motion of domain walls in Py cylindrical nanowires. They mention that the transversal wall that appears on these systems is very different from that observed in strips, resulting in the absence of a drop in speed [5]. This introduces a comparative advantage compared to magnetic strip. Following these ideas, in this work we have performed micromagnetic simulations [6] to investigate the process of magnetization reversal of the multi-segmented cylindrical systems with alternating magnetic wires and tubes. We focus on the behavior of the coercivity and remanence, concluding that changing the geometry of these nanoparticles enables us to control their magnetic properties. We note that such structures can be created experimentally by templated electrodeposition.

8. Ferrimagnetic Oxide Films and Wires

R. C. Bradley, M. R. J. Gibbs, T. J. Hayward
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Magnetic nanowires are being studied for a wide range of applications including memory and logic circuits. Central to their use is the control of domain wall dynamics, especially velocity. Much work has been done on metallic nanowires (e.g. Nickel Iron) for high velocity applications, but in the Sheffield group a novel application in quantum information processing requires very low domain wall velocity. In this project we are investigating the possibilities of using ferrimagnetic insulating nanowires (e.g. Fe_3O_4) in this application. This begins with the fundamental study of sputter growth conditions to maintain the correct oxide phase and goes on to consider lithographic patterning and studies of wall dynamics.

9. Reliability analysis and enhancement in STT-MRAM

Wang Kang, Weisheng Zhao
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Spin Transfer Torque Magnetic RAM (STT-MRAM) promises low power, great miniaturization prospective and easy integration with CMOS process. It becomes a strong non-volatile memory candidate for both embedded and standalone applications. However STT-MRAM suffers from important failure and reliability issues compared with the conventional solutions based on magnetic field switching. For example, a read current could write erroneously the stored data, the variability of process and temperature could cause error sensing etc. This paper classifies all the possible failures of STT-MRAM into ''soft errors'' and ''hard errors'',and analyzes their impact on the memory reliability. Based on this work, we can find some efficient design solutions such as error correction code (ECC) to address respectively these two types of errors and improve the reliability of STT-MRAM.

10. Slater-Pauling-Koster Gaps and Pseudogaps in B2 Alloys

Jamileh Beik Mohammadi, T. Mewes ,W. H. Butler ,Behrouz Khodadadi, Nariman Naghib
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The Slater-Pauling [1-4] curve, describing the variation of the magnetic moment with the average number of electrons per atoms in 3d-metals and alloys is familiar to most students of magnetism. The right-hand side of the Slater-Pauling curve can be expressed as stating that when the number of electrons per atom exceeds approximately 8.5, the number of majority electrons is 5.3 representing the filling of the majority d-bands when the number of occupied majority states per atom is 5.3. Additional electrons must fill minority states, because their density is much higher than the majority and therefore the additional energy added is less. The left-hand side of the Slater-Pauling curve can be expressed as the statement that the number of minority-spin electrons per atom is 3, so that added electrons (after 6) are majority electrons. The reason for this rule is less obvious, but a hint was given by Slater and Koster [5] when they observed that B2 alloys with a single type of orbital and nearest neighbor interactions only, there will be a gap in the density of states for half-filling. We have calculated the density of states of B2 (AB) alloys for A=(Cr, Mn, Fe, Co, Rh, or Ru) and B=(Ti, V, Cr, Mn, Fe). For most of these alloys, there is a deep pseudogap at half-filling for one or both of the spin-channels. Usually, the system is able to reduce its energy by adjusting the magnetic moments so that the minority Fermi energy falls in this gap. This leads to the Slater-Pauling 3-minority-electrons-per-atom rule. The replacement of one of the B atoms by a non-transition metal to form a Heusler L21 structure often converts the pseudogap into a gap and generates a half-metal.

[1] J. C. Slater, Journal of Applied Physics, **8,** 835-890 (1937).
[2] L. Pauling, Physical Review, **54**,899-904 (1938).
[3] W. Shockley, Bell Systems Technical Journal **18**,645-723 (1939).
[4] R. M. Bozorth, Ferromagnetism, IEEE Press, Piscataway NJ p.441 (1951)
[5] J. C. Slater and G. F. Koster, Physical Review, **94**, 1498-1524 (1954).

11. Magnetic and Structural Properties for Mn-Al Multilayers

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Because of an increasing demand for rare earth less or free permanent magnets, Mn-based alloys have received much attention. My research topic is on MnAl magnetic multilayer thin films, aiming to obtain high magnetic anisotropy and high saturation magnetization, leading to high (BH)max beyond 20 GOe for MEMS application The τ- phase of MnAl alloy is known to exhibit magnetic anisotropy K as high as 107erg/cc at room temperature, and also a relatively high saturation magnetization Ms of around 500emu/cc. However, there is very little systematic research work towards fabrication of high quality τ- phase thin films. MnxAl100-x (x=20-80) samples were fabricated by using both DC and RF magnetron sputtering methods with base pressure of 10-9 Torr. A systematic experimental study has been being carried out as functions of deposition sequence of Mn and Al, composition, post annealing temperature, annealing time, layer-thickness, and also cooling rate of substrate. Several different substrate-materials are chosen such as glass, MgO and STO. In addition, buffer layers of various kinds (Ru, Cr and W) are used. Measurements of magnetic properties have been carried out by Vibrating Sample Magnetometer (VSM) and Alternating Gradient Magnetometer (AGM). The crystal structure has been characterized by X-ray Diffraction (XRD). Film thickness has been measured by X-ray Reflectivity (XRR) and Spectroscopic Ellipsometer. A preliminary fabrication result shows high coercivity of about 3-4 kOe with Ms of about 400 emu/cc at room temperature for samples thus fabricated. The structure of such multilayers is found to be partially the τ- phase. Further work is in progress to optimize film structure and fabrication condition in order to obtain high magnetic anisotropy and high coericivity in the single phase MnAl films.

12. Scanning tunneling microscopy and spectroscopy of MnPc on noble metal (111) surfaces

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The growth, electronic structure, and magnetic excitations of transition metal phthalocyanine (TM-Pc) molecules adsorbed on noble metal fcc(111) substrates have recently attracted considerable interest. While phthalocyanines with a central ion consisting of Fe, Co, Ni, and Cu have already been studied extensively, only few studies deal with MnPc, even though this molecule carries the highest net magnetic moment in the gas phase (S = 3/2)[1]. This property makes it a promising candidate for the observation of collective interaction phenomena with the substrate, such as the Kondo effect. In this con- tribution we present low-temperature (T = 5K) scanning tunneling microscopy and spectroscopy data of Mn-Pc adsorbed on Au(111) and Cu(111). The tunneling spectra of Mn-Pc show a distinctly asymmetric conductance around the Fermi level. Our results indicate that this feature critically depends on the chemical state of the tip. By systematically modifying the coupling strength between the molecule and the substrate we will discuss under which conditions the Kondo effect can be observed.

13. Integration of magnetic thin films into on-chip inductor: NiFe vs CoZrTaB

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Incorporating ferromagnetic materials into on-chip inductors for integrated voltage regulator application is an important approach for improving the inductance, quality factor and, most importantly, silicon chip-area efficiency. Soft magnetic alloys are selected for on-chip inductors due to their high permeability, low coercivity and low temperature preparation. In our work, two soft magnetic alloys, Ni-Fe and Co-Zr-Ta-B were integrated into on-chip spiral inductors at 100 µm scale. By patterning and laminating the magnetic films, enhancement in both inductance and quality factor have been observed at frequencies as high as several GHz. We demonstrated significantly larger increases in L and Q above 1 GHz for inductors using Co-Zr-Ta-B as compared to prior efforts thereby making the added processing cost worthwhile. Inductors with different materials and patterning strategies are compared to investigate the factors affecting the inductor performance. Inductor with laminated Ni-Fe film shows large enhancement of 6X in L at 200 MHz. A 4-turn rectangular spiral inductor with Co-Zr-Ta-B achieved a maximum 9.1X inductance increase and a 3.9X increase in the Q-factor at 1 GHz. Compared to Ni-Fe, inductors with Co-Zr-Ta-B have better frequency response. Therefore, Co-Zr-Ta-B is more suitable for higher frequency applications. The inductance and quality factor begin to drop above 1 GHz due to eddy current in the magnetic material, skin effect and ferromagnetic resonance effect. One way to suppress the eddy currents is to minimize the size of magnetic via which refers to the region where the two magnetic levels contact each other. Finger-shaped magnetic via have been used to cut off the eddy current loop in magnetic via while keeping the magnetic flux continuous. The inductors with finger-shaped magnetic via have better frequency response and higher quality factor at high frequencies.

14. Ultrahigh frequency and wide-range tunable microwave detector based on spin valve

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Spintronics devices, such as spin valve and magnetic tunnel junction, are able to detect microwave due to ferromagnetic resonance (FMR) and rectification effect. However, the working frequency of microwave detector based on Spintronics devices depends on saturation magnetization of the material and external magnetic field. It requires very large external magnet to go up to high frequency, which limits its application. We used exchange coupled layers as free layer in spin valve. Two modes were observed. The frequency can go up to 33GHz. The high frequency mode is determined by the exchange coupling of the two magnetic free layers which is controlled by thickness of spacer layer. The tuning of the high frequency mode is achieved by using NiCu as the spacer and controlling the temperature of the sample. The high frequency mode was shifted from 25 GHz to 12 GHz in the temperature range from 0 ºC to 80 ºC.

15. Synthesis and Magnetization Reversal of Intersecting Cobalt Nanowire Networks

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Interconnected magnetic nanowire networks offer an exciting platform for the exploration of nanomagnetism as well as spin and charge transport in constricted dimensions. In this work we report the synthesis and investigation of a novel Co nanowire network realized by electrodeposition into nuclear track-etched membranes. Polycarbonate membranes (3-6 microns thick) were first irradiated with energetic Xe6+ ions at normal incidence and multiple 45 degree azimuthal angles. The total irradiation density was 2x109 tracks/cm2. Following a UV/ozone treatment, NaOH was used to preferentially etch the latent tracks of ion damage, creating intersecting nanopores in the polycarbonate matrix. A thin, nonmagnetic layer was then sputtered onto one side of the now- porous membrane to be used as a working electrode. Cobalt was then electrochemically deposited from a sulfate electrolyte into the pores, filling the membrane with an ultralow density, interconnected wire network. Structural properties of the networks were characterized by x-ray diffraction and electron microscopy. Magnetization reversal in these nanostructures was studied using vibrating sample magnetometry and the first order reversal curve (FORC) technique. Angular dependence of coercivity and remanence were investigated in particular and compared to data from membranes with only normal irradiation, demonstrating the effects of the wire intersections.
This work has been supported by DTRA #BRCALL08-Per3-C-2-0006 and NSF DMR-1008791.

16. Synthesis and Characterization of Multifunctional Metal-Doped Barium Titanate anocrystals

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Ferroelectric perovskite-phase oxides ABO3, with their easy and low-cost preparation, high chemical stability and structural robustness are naturally suited for the design of multifunctional materials by cationic doping for the design of multifunctional materials required by the increasing tendency towards miniaturization of the electronic circuitry. In this work we present preliminary results on the site-specific doping of the Ti4+ ions in aggregate-free, monodisperse BaTiO3 colloidal nanocrystals by using a low temperature phase transfer route. A detailed study of the structure of the properties of solid solutions BaTi1-xMxO3 (M=Mn, Fe, Co, Ni, with x=0.5-7%) was performed and showed that a substitutional ordering occurs in these phases with the transition metal ions incorporated into the perovskite crystal lattice by replacing the titanium ions. In addition of exhibiting strong correlation phenomena, such as the simultaneous presence of ferroelectricity and magnetism at room temperature, the band gap in these compounds can be finely tuned in a wide range. As such, these materials are very attractive for applications in a wide range of advanced technologies, such as photocatalysis, energy conversion and water splitting applications.

17. Calculation of the Electric Field Induced by Transcranial Magnetic Stimulation

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The calculation of electromagnetic fields in biological tissue is a main task of biological- and electrical engineering. The core theme of the poster is the calculation of the induced electric field with a finite-element method in the frequency domain by using the software package Comsol Multiphysics 4.2. By means of an analytic reference, the numeric solutions were validated. Moreover, the behaviour of electromagnetic fields in the time-domain together with the influence of dispersive material properties of human brain tissue, including particular effects and special cases are investigated.

18. Voltage-Induced Switching of Nanoscale Magnetic Tunnel Junctions

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Electric field control of magnetism can dramatically improve the energy efficiency of spintronic devices, enhancing the performance of magnetic memories. More generally, it expands the range of applications of nonvolatile spintronic devices, by making them energetically competitive compared to conventional semiconductor solutions for logic and computation, thereby potentially resulting in a new generation of ultralow-power nonvolatile spintronic systems. Magnetic tunnel junctions (MTJs) have emerged as the building blocks of spintronic circuits due to their large magnetoresistance, and possibility of integration with silicon transistors. The use of spin-polarized currents to switch magnetization in MTJs, however, limits their energy efficiency. In this work, we report on the electric-field-induced manipulation and switching of nanoscale MTJ devices, which exhibit voltage-controlled magnetic anisotropy (VCMA) at the CoFeB-MgO interface. Our devices, 170 nm by 60 nm elliptical nanopillars with a Fe-rich CoFeB free layer, where designed to have an MgO tunneling barrier thick enough (1.3-1.5 nm) to make current-induced torque negligible. We study the effect of free layer thickness and applied voltage over the state of the free layer, and demonstrate VCMA-induced, thermally-activated switching with voltage pulses ~ 1 V down to 10 ns, assisted by a small (few 10 Oe) in-plane external magnetic field applied to the device. The dependency of the required switching voltage on pulse duration is found to fit accurately into a thermal activation model. Also, we observe a clear trade-off between the switching voltage and the external magnetic field which assists the reversal process. To eliminate the need for external magnetic fields, we demonstrate that by properly tuning the free layer thickness and using nanosecond voltage pulses, bidirectional VCMA-induced switching for a fixed magnetic field can be obtained where switching in one direction utilizes precessional (resonant) switching, meanwhile switching in the opposite direction is obtained in the thermally-activated regime.

19. Magnetization Dynamics and Spin Seebeck Effect in Magnetic Thin Films

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Magnetic ultrathin films with perpendicular anisotropy have potential applications in high-density, fast-switching magnetic memories. This presentation reports on ferromagnetic resonance (FMR) in CoFeB films which are about 1 nm thick and have strong perpendicular magneto-crystalline anisotropy. The samples were a multi-layered structure of Si/SiO2/Pd(3nm)/CoFeB(1nm)/MgO(1.6nm)/Pd(3nm). The FMR measurements were carried out by placing the film sample on a co-planar waveguide (CPW), magnetizing the film with an out-of-plane magnetic field, and measuring the transmission coefficients of the film/CPW structure with a vector network analyzer. The measurements were conducted over a frequency range of 10-33 GHz. The fitting of the measured FMR field vs. frequency responses with the Kittel equation yielded effective anisotropy fields that were close to the values obtained from the hysteresis loop measurements of the films. The linear fitting of the FMR linewidth vs. frequency responses gave rise to an effective Gilbert damping constant range of 0.01-0.02. The fitting also indicated a strong contribution (200-500 Oe) to the FMR linewidth from film inhomogeneity.

20. Exchange bias of mu-metal thin films

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The exchange bias of the soft ferromagnet mu-metal, $Ni_{77}Fe_{14}Cu_5Mo_4$, with the metallic antiferromagnet $Fe_{50}Mn_{50}$ has been studied as a function of ferromagnet thickness and buffer layer material. Mu-metal exhibits classic exchange bias behavior: the exchange bias (HEB) and coercive fields scale inversely with the ferromagnet's thickness, with HEB varying as the cosine of the in-plane applied field angle. While the exchange bias, coercivity, and exchange energy are greatest when the buffer layer material is (111) oriented Cu, amorphous Ta buffers allow the mu-metal to retain more of its soft magnetic character. The ability to preserve soft ferromagnetic behavior in an exchange biased heterostructure may be useful for low field sensing and other device applications.

21. Novel Magnetic Nanostructured Multilayer for High Sensitive Magnetoresistive Sensors

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The critical parameters for a high sensitive magnetoresistive sensor include high permeability, good linearity and low noise. All these parameters are related to better control of the magnetic nanostructured of multilayers in magnetic tunnel junctions (MTJ). The sensitivity of the sensor is related to large tunnel magnetoresistance ratio (TMR) and low saturation magnetic field (Hs) in free layer of MTJ junctions, which means high susceptibility. The linear nonhysteretic response of the sensor is related to both low coercivity field (Hc) in free layer, and also good orthogonal magnetization configuration between free layer and pinned layer. The noise of the sensor is related to the interface between the layers and their nanostructures. In this poster, we presented a few projects that improve the sensitive magnetoresistive sensor through the variation of magnetic nanostructures in the magnetic tunnel junctions. These magnetic nanostructures are varied by annealing temperatures, different annealing environments, the thickness of the free layer in MTJ, as well as through the exchange interaction using ferromagnetic- ferromagnetic coupling within the free layer of MTJ. We show a magnetoresistive sensor with a sensitivity as high as 1916 %/mT. This magnetic sensor only dissipates 20 μW of power while operating under an applied voltage of 1 V.

[1] S. H. Liou, Xiaolu Yin, S. E. Russek, R. Heindl, F. C. S. Da Silva, J. Moreland, D. P. Pappas, L. Yuan and J. Shen, IEEE Trans. on Magnetics, **47**, 3740(2011).
[2] Xiaolu Yin, S. H. Liou, IEEE Sensors 2012 Conference, 2090 (2012).

22. Thermal evolution of the magnetic and structural properties of nanostructured near-equiatomic MnAl

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Near-equiatomic nanostructured MnAl and MnAl(C) alloys are under investigation as potential advanced permanent magnetic materials due to their high coercivity values, moderate maximum energy products, and low costs [1]. Our research is focused on the thermal evolution of magnetic and structural properties in rapidly-solidified nanostructured $Mn_{55}Al_{45}$ ribbons fabricated via melt-spinning. As-quenched $Mn_{55}Al_{45}$ exhibits a large exchange bias shift of ~13 kOe in the magnetization loop at 10 K. X-ray diffraction analysis reveals a phase-separated microstructure consisting of two dominant hexagonal phases, identified as metastable ε-MnAl phases, with slightly different unit cell volumes. These data suggest that nanoscopic fluctuations in local Mn content cause a structural and magnetic phase separation into Mn-poor ferromagnetic regions of ε-MnAl and Mn-rich antiferromagnetic ε-MnAl regions. Exchange interactions between these regions result in the large exchange bias. Magnetic measurements show the as-quenched ribbons contain a small amount of an additional ferromagnetic phase, magnetically-decoupled from the ferromagnetic-antiferromagnetic ε-phases. The amount of the ferromagnetic phase, identified as the L10-structured τ-MnAl phase, is estimated as ~0.1% based on a saturation magnetization of 95 emu/g [1]. Ribbons subjected to isochronal annealing treatments in the temperature range 250-350 °C display a rapid reduction of the exchange bias, accompanied by the growth of the ferromagnetic τ-phase. X-ray diffraction confirms the growth of τ-MnAl at the expense of the ε-phases. Differential scanning calorimetry measurements verify the onset of a two-step exothermic transformation in this temperature region. Kissinger analysis indicates an 18% reduction in the activation energy of the ε -> τ transformation in rapidly-solidified $Mn_{55}Al_{45}$, from 154 kJ/mol [2] to 126 kJ/mol, resulting in the start of the transformation at 295 °C (~100 °C lower than previously reported).

[1] F. Jimenez-Villacorta et al., Appl. Phys. Lett. **100**, 112408 (2012).
[2] C. Yanar et al., Metall. Mat. Trans. A **33**, 2413 (2002).

23. MnAlC permanent magnets with transition metal additives

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MnAlC samples were created by rapid solidification techniques and the composition was optimized for highest τ phase content. Once the optimum composition was established at Mn54Al43C3 the addition of other period four transition metals (Fe, Co, Ni) were investigated. The samples were made from the composition Mn54-xAl43C3Ax . The ε phase was achieved with rapid solidification. However the transition from ε phase to the L1¬0 τ phase stopped as additive concentration increased and the samples instead changed to a B2 structure. The change from the formation of the L10 phase to the B2 structure occurred at difference percentages depending on the transition metal added. The highest percent of Fe before the sample changed from the L10 phase to B2 phase was 6% Fe. Fe reduced the saturation magnetization as proposed by the theoretical calculations.

24. Advanced permanent magnets based on L10-structured materials

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Current advanced permanent magnets rely on the high magnetocrystalline anisotropy donated by rare-earth elements to achieve high energy products. Transition metal compounds forming the tetragonal, chemically-ordered L10-phase exhibit strong uniaxial magnetic character [1] and are thus good candidates for rare-earth-free permanent magnet construction. Among these alloys, L10-FeNi has recently attracted attention due to availability of the constituent elements. However, L10 formation in FeNi is kinetically limited due to low atom mobility below the order-disorder temperature (320 °C) [2] and hence this phase has never been produced in large quantities under laboratory conditions. Studies of the model L10-type compound FePd modified with Ni were carried out to gain insight into phase formation and magnetism in the FeNi system. Alloys of compositions Fe50Pd50-xNix (x = 0-5 at%) were synthesized via arc-melting and annealing at 500-550 °C for 100 h. The L10-phase was successfully obtained in all compositions as evidenced in x-ray diffraction results by the appearance of superlattice peaks and splitting of the Bragg fundamental fcc peaks. Magnetic measurements indicate a significant increase in the anisotropy field upon achievement of the L10-structure. Results from magnetic force microscopy performed on annealed Fe50Pd50 indicate the formation of coherent boundaries in L10-FePd due to variants and lattice twinning, as revealed by the "fir tree" domain arrangement characteristic of uniaxial magnetocrystalline anisotropy. Thermal analysis studies indicate that Ni addition decreases the FePd chemical order-disorder temperature while increasing the Curie temperature. Decreasing heats of transformation from the L10 to the fcc phase with increasing Ni are consistent with decreasing L10-phase stability. The outcome of this investigation highlights the need to enhance diffusion by means of nonconventional processing techniques to pursue the L10-phase in FeNi.

[1] K. Barmak, et al., J. Appl. Phys. **98**, 033904 (2005).
[2] C.-Y. Yang, et al., J. Phase Equil.**17** (6), 522 (1996).

25. Integration of a Spintronic Interface for Nanomagnetic Arrays for Information Processing

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Magnetic tunnel junction (MTJ) based logic devices are an attractive technology since they are non-volatile, high speed, high density, reprogrammable, and have been successfully integrated with CMOS in commercially available Magnetic Random Access Memory (MRAM). One form of MTJ based logic devices is magnetic quantum cellular automata (MQCA[1], which utilizes dipole interactions between closely spaced MTJ pillars to perform logic functions and is capable of performing the primitive Boolean logic operations[2]. Previous experimental demonstrations of MQCA have used external magnetic fields to set the input states of magnets and read schemes such as magnetic force microscopy and the extraordinary Hall effect [3] to determine the output state these devices. However, these methods are not easily scalable and an electrical based input/output (I/O) scheme is required to interface this technology with supplementary electrical components. In this study, we demonstrated an electrical based I/O scheme using spin transfer torque (STT) to program individual MTJ elements and magneto resistance measurements to read the output of individual elements. We fabricated MTJ pillars 50 nm x 80 nm and 70 nm x 100 nm in size with spacing between individual elements of 5 nm to 30 nm. We demonstrated the amount of current needed to STT program individual devices with and without a clocking field, and the effect of spacing and number of elements in an array on the required current for programming. The experimental demonstration of an electrical based I/O is a significant advancement toward applications of MQCA logic devices as it will allow easier integration with current technologies.

[1] R. Cowburn and M. Welland, Science, vol. **287**, pp. 1466-1468, (2000)
[2] A. Imre, et al., Science, vol. **311**, pp. 205-208, (2006)
[3] M. Becherer, et al., Solid-State Electronics, vol. **54**, pp. 1027-1032, (2010)

26. Parametric Pumping of Spin Waves by Acoustic Energy

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Spin waves are propagating disturbances in the ordering of magnetic materials. However, very large intrinsic spin wave damping in most materials does not allow spin wave propagation to be observed over distances of few tens of microns. A uniquely low value of magnetic damping in Yittrium Iron Garnet (YIG) allows propagation of spin waves over distances of few centimeters. Bulk Acoustic Waves generated by acoustic transducers can be used to parametrically amplify spin waves propagating through YIG films, with acoustic waves at frequency '2f' amplifying spin waves at frequency 'f'. Here we have discussed about the measurement of spin waves in YIG films, modelling and fabrication techniques of Bulk Acoustic Wave transducers, and how the acoustic waves can be efficiently coupled into the YIG film so as to parametrically amplify the spin waves.

27. Tunable linear magnetic field sensors based on magnetic tunnel junctions with double pinned layer

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Magnetic sensors based on AlOx-barrier magnetic tunnel junctions (MTJs) and MgO(001)-MTJs, with double pinned layer have been fabricated. Both the detective and the reference layers were pinned by IrMn AFM layer indirectly and directly, respectively. The perpendicular configuration can be realized through two-step post-annealing technology with different IrMn thicknesses. The reference layer was pinned by IrMn directly with the structure IrMn(15nm)/CoFeB(3nm) whereas, the detective layer was pinned by IrMn indirectly with structure CoFeB(3nm)/Ru(t)/IrMn(6.5nm). The exchange bias between ferromagnetic and antiferromagnetic layer can be tuned by inserting a nonmagnetic layer with different thicknesses. By controlling the thickness of Ru layer (tRu), the sensitivity and the field range of the magnetic sensor can be tuned. The largest sensitivity 0.6%/Oe of magnetic sensors based on AlOx-MTJs was obtained for a 1.8Å Ru insertion layer. The field sensitivity of magnetic sensors based on MgO(001)-MTJs can reach 26%/mT for a 0.3nm Ru insertion layer with similar structure.

[1] Qin-Li Ma, Hou-Fang Liu and Xiu-Feng Han, Chinese patent, No. 201010195799.6
[2] X. F. Han, Khalid Javed, Q. L. Ma et al, to be submitted to Applied. Phys. A (Invited review paper).
[3] J. Y. Chen, J. F. Feng and J. M. D. Coey, Appl. Phys. Lett. **100**, 142407(2012).

28. Interaction on resonance frequencies of Fe nanoparticle/paraffin composites in the centimeter and millimeter wave range

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Resonance properties have been studied for Fe nanoparticle/paraffin composites with various volume concentrations over the centimeter (0.5-18GHz) and millimeter (26-40GHz) wave range. The resonance frequency of Fe nanocomposites shifts significantly with the change in the concentration of Fe nanoparticles, when compared to micron-scale Fe particle composites between 0.5-18GHz. The conventional explanation of the shift is the interfacial effect, which can be deduced by the Maxwell-Garnett mixing rule or other mixing formulas. However, the dipole interaction of Fe nanoparticles plays an important role except for the interfacial effect in this case. The nanoparticle dipole interaction was controlled by the distance between the adjacent nanoparticles. Nanocomposites consisting of high Fe volume fraction lead to a relatively strong particle dipole interaction and correspondingly a large exchange coupling energy among the nanoparticles. This exchange coupling increases the intrinsic magnetic moment of Fe nanoparticles. More importantly, magnetic coercivity can be reduced by stronger dipolar interaction, which has been verified using a Monte Carlo simulation technique. The reduced coercivity indicates the red shift of resonance field according to the Gilbert equation. Recent experiments and numerical computations show that multi-resonances can be excited by non-uniform spin-wave resonances. We have found this phenomenon to be true in the frequency range between 26-40 GHz. However, the shift of the resonance frequency is different to those in the 0.5-18 GHz range. The dipole interaction between the neighboring nanoparticles serves to promote the magnetic moment in parallel orientation and thus decreases surface anisotropy. Therefore, the resonance frequency will shift to higher frequencies with an increase in the volume fraction based on the exchange resonance mode associated with surface anisotropy.

29. Modeling of the laser-heating induced ultrafast demagnetization dynamics in ferrimagnetic thin films

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Ultrafast demagnetization by laser pulses introduces the technological possibility for controlling the magnetic properties of materials on sub-picosecond regime. In this paper, the demagnetization dynamics of amorphous ferrimagnetic TbFeCo alloy is modeled by using the stochastic Landau-Lifshitz-Gilbert equation on an atomistic level. The transition metal (Fe,Co) and rare earth (Tb) atoms are constructed by two different sub-lattice systems. Our simulations show that the full demagnetization on the sub-picosecond time scale requires the temperature is above the Curie temperature and the net magnetization of TbFeCo is determined by its composition. A series of snapshots clearly demonstrate the laser-heating induced microscopic demagnetization processes.

30. Magnetization Reversal in Antiferromagnetically Coupled [Pt/CoFeB]N1/Ru/[CoFeB/Pt]N2 Structures

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The synthetic antiferromagnet (SAF) has been widely used as the reference layer in in-plane magnetized giant magnetoresistance (GMR) structures. Recently, GMR devices showing a perpendicular easy axis have received increasing interest for realizing high density spin-torque memories, due to the great advantages including good magnetic thermal stability and low critical current. In this work, the interlayer coupling and magnetization reversal behaviors in the CoFeB/Pt based SAF samples with perpendicular magnetic anisotropy (PMA) have been investigated in detail. The interlayer coupling strength Jex displays an oscillatory behavior as a function of Ru thickness, with a period of 0.7 nm and a maximum AF coupling strength of Jex=0.09 erg/cm2 at the first AF peak. The magnetic hysteresis loops display distinct magnetization switching procedures, with or without reversal of the net magnetic moments depending on the repetition numbers of the two multilayers. A magnetic dead layer with a thickness <0.5 nm exists mainly at the CoFeB/Ru interface. MFM images suggest the formation of stripe domains for samples with relatively large N, accompanied by a bow-tie shape loop. The Jex exhibits a strong temperature dependence, which decreases to nearly zero at 400 K.

31. Angle dependence of phase noise in a magnetic tunnel junction based spin torque nano-oscillators.

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Spin torque oscillators (STOs) are nano-sized devices based on the phenomena of spin-transfer torque.(1, 2) The spin torque can excite the magnetization precessional motion in the GHz frequency with wideband frequency tunability.(3, 4). Phase noise of these STOs is an important parameter for applications. However studies of phase noise are rather limited.(5-7) In this work, we will discuss phase noise as a function of angle between free and reference layer in a magnetic tunnel junction (MTJ) based STOs. In contrast to Ref 8 we mixed down the signal from a MTJ-STO and record time traces with a digitizer. The lengths of the traces were 50 us. This allows us to study phase noise for frequencies below 100 kHz , which was not accessible in the previous work by Quinsat et al.(8).Our results show a significant decrease of white noise when the free layer is aligned antiparallel to the reference layer, which is consistent with reduced mode-hopping at this angle.(9)

[1] L. Berger, Phys. Rev. B **54**, 9353 (1996).
[2] J. Slonczewski, J. Magn. Magn. Mater. **159**, L1 (1996).
[3] W. Rippard, M. Pufall, S. Kaka, S. Russek, and T. Silva, Phys Rev Lett **92**, 027201 (2004).
[4] S. Bonetti, P. Muduli, F. Mancoff, and J. Åkerman, Appl. Phys. Lett. **94**, 102507 (2009).
[5] M. Keller, M. Pufall, W. Rippard, and T. Silva, Phys1 Rev1 B **82**, 1 (2010).
[6] M. W. Keller, A. B. Kos, T. J. Silva, W. H. Rippard, and M. R. Pufall, Appl Phys Lett. **94** (2009).
[7] M. Quinsat, et al., Appl. Phys. Lett. **97** (2010).
[8] M. Quinsat, et al., Appl. Phys. Lett. **97**, 182507 (2010).
[9] P. K. Muduli, O. G. Heinonen, and J. Akerman, Phys. Rev. Lett. **108** (2012).

32. Ferromagnetic Resonance Study on a Grid of Permalloy Nanowires

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Magnonics is a relatively new field of research and technology which is magnetically analogus to photonics. In similarity to photonics, the periodic structures are more promising for the magnonics band structure engineering. Due to this, the investigation of various periodic structures has drawn much interest in this field. We report ferromagnetic resonance (FMR) study on a grid formed with permalloy nanowires to understand the spin wave dynamics[2]. The presence of two sets of magnetic nanowires perpendicular to each other in the same device enables better control over spin waves. The grid was fabricated using e-beam lithography followed by DC-Magnetron sputtering and liftoff technique. It has dimensions of 800±10 and 400±10 nm as periods along X and Y directions with permalloy wires of width 145±10 nm. FMR studies were done at X-band (9.4 GHz) with the field sweep up to 1 Tesla. The in-plane angular variation of resonant fields shows that there are two well separated modes present, indicating two uniaxial anisotropy axes which are perpendicular to each other. The variation in the intensities in the FMR signal with respect to the grid angle is used to describe the spin wave confinement in different regions of the grid. We also explained the asymmetry in the magnetic properties caused by the geometrical property of the rectangular grid and the origin for the peak splitting for the modes occurring at higher resonant fields. Micromagnetic simulations based on OOMMF with two dimensional periodic boundary conditions [2] are used to support our experimental findings.

[1] D. Venkateswarlu et al., IEEE Trans. Magn., (Under Review).
[2] D. Venkateswarlu et al., IEEE Trans. Magn., vol. **48**, no. 11, 2012.

33. Nanofabrication of manganites and magnetic tuning

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The colossal magnetoresistance (CMR) of manganites is believed to be closely tied to electronic phase separation (EPS). Spatial confinement is a very useful route to gain deeper insight into the nature of EPS. Several exotic phenomena have been reported when the spatial dimension is reduced to the characteristic EPS length scale. With the help of nanofabrication, one can further reduce the spatial dimension of manganites to smaller scale and explore emergent phenomena as well as the potential for device applications. For this, various nanofabrication methods need to be developed to confine the manganites. In this poster, we will introduce four methods including e-beam lithography, SPM-based lithography, Focused-ion beam lithography, X-ray lithography to nanofabricate manganites, and the smallest length scale achieved is around 100 nm, which is already smaller than some materials' characteristic length scale of EPS. We have investigated the effect of spatial confinement on manganites. Moreover, we have deposited ferromagnetic nanodots on the fabricated manganites nanostructures to tune the metal-insulator transition and CMR of the materials.

34. Co-existence of multiple magnetic states in Ni/Bacterial cellulose composite– A flexible magnetic-

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Bacterial cellulose, a white jelly like reticulate hydrogel abundantly synthesized by a large variety of bacteria, has been made magnetic by insitu reduction of NiCl2 within the reticulate structure of BC. This reduction reaction was carried out in two different environments – (a) ambient atmosphere at room temperature and (b) Ar atmosphere at ~ 3°C. Resulting magnetic hydrogel from reaction (a) was converted to xerogel by air and oven drying processes and aerogel by freeze drying process. X-ray diffraction studies of all these three dried gels shows the coexistence of Ni and Ni(OH)2 along with crystalline BC. To avoid the surface oxidation of Ni particles during drying process, Ni/BC hydrogel from reaction (b) was converted to aerogel and X-ray diffraction pattern of this aerogel shows only Ni. Scanning and transmission electron microscopy of Ni/BC gels from both reactions (a) and (b) show different size distributions of Ni particles ranging from 3.2 nm to 140 nm. Hysteresis with coercivity varying between 60 G and 110 G in field dependent magnetization and blocking temperature between 15 and 20 K in temperature dependent magnetization indicate the presence of superparamagnetic and ferromagnetic phases of Ni. In all the cases irreversibility in ZFC and FC above TB is indicative of interparticle magnetic interactions which have been investigated by temperature dependent a.c. susceptibility studies in the frequency between 1 and 104 Hz. The rate of shift of Tf peak with frequency, $\Phi = \Delta Tf / [Tf \Delta \log(f)]$ is found to be in spin glass range. The anisotropy energy density determined using the Vogel-Fulcher relation was found to be ~ 105 Jm-3. These magnetic studies show the co-existence of multiple magnetic states - ferromagnetic, superparamagnetic and super spin glass in Ni/BC gels.

35. Effect of Cr_2O_3 fabrication condition on magnetic properties of ferromagnetic/Cr_2O_3 interface

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Cr_2O_3 is a typical material that has Magnetoelectric (ME) effect. ME effect has been paid much attention to apply for nonvolatile memory. In this study, we made Cr_2O_3 thin film by post-annealing and investigate the influence of Cr_2O_3 fabrication condition on blocking temperature (TB) and exchange bias field (Hex) toward perpendicular direction. The film design was Al_2O_3 substrate/Cr_2O_3 50/Co_3Pt 3/Ru 2/Ta 3nm. Samples were fabricated by an Ion Beam sputtering (IBS) method at room temperature (RT). As deposited Cr_2O_3 layer was not crystallized. After deposition, we post-annealed Cr_2O_3 substrate/ Cr_2O_3 film in oxygen atmosphere. During post-annealing, crystallization of Cr_2O_3 was occurred. We could make (0001) oriented or random oriented Cr_2O_3 by post-annealing process. In fabrication process, the atmosphere during sputtering (with or without O2) strongly affects the conditions of Cr_2O_3 layer. When Cr_2O_3 target was sputtered with O_2 flow (Ar : O2 = 8 : 1), the as-deposited product was (001)-oriented CrO3. By high temperature annealing in O_2 flow, (0001) oriented Cr_2O_3 layer was formed. In (0001) oriented Cr_2O_3 film, we observed sudden onset of Hex at 70K and Hex = 436Oe. We call this Hex sudden onset temperature TB. On the other hand, When Cr_2O_3 was sputtered without O_2 flow, the as-deposited product was amorphous Cr-oxide. By high temperature annealing in O_2 flow, crystallization and crystal growth occurred, and polycrystalline Cr_2O_3 layer with grain size of ~50 nm was formed. We observed small Hex and high TB = 290K, which is near Neel temperature (TN), in this film. These phenomena were explained by Meiklejohn and Bean's exchange anisotropy model. We found that the origin of Hex of (0001) oriented or random oriented Cr_2O_3 would be uncompensated Cr spins on oblique C-plane and R-plane, respectively.

36. Universal correlated velocity and domain wall spin structure oscillations probed by direct imaging

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Magnetic memory, sensing and logic devices based on the motion of magnetic domain walls (DWs) rely on the precise control of the position and the velocity of individual magnetic DWs. Varying DW velocities have been predicted to result from intrinsic effects, such as oscillating DW spin structure transformations and extrinsic pinning due to imperfections. We use direct dynamic imaging of the nanoscale spin structure to investigate these predictions, revealing universal oscillating domain wall motion. As the origin, the oscillating magnetostatic energy reservoir is identified, which scales with the DW velocity. Imaging wall motion in rings with varying width, we correlate the velocity with the wall energy revealing wall inertia. This inertia also explains our observation of extrinsic pinning-dominated DW propagation at low velocities, while we are able to achieve reproducible wall motion for fast walls that overcome defect-pinning. We can thus obtain the necessary reliable high speed DW manipulation required for magnetic devices.

37. Magnetooptical studies of Ga irradiated ultrathin Co films

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Modification of magnetooptical properties of magnetic thin films by means of Ga+ ions homogenous irradiations and created by Focus Ions Beam (FIB) nanopatterning have gain lots of interests due to its fundamental research and potential applications in spintronics. Effects of Ga+ ion irradiations on magnetooptical and magnetic properties of ultrathin Pt/Co(d)/Pt film will be discuss in this study. FIB techniques was used to produce : (i) squares of micrometer size with different Fluences (F); (ii) stripes with different periods and irradiated 'F'. Samples were studied by using different experimental techniques including: (i) polar and longitudinal Kerr (PMOKE and LMOKE respectively) effects using both magnetooptical magnetometer (with focused laser beam) and polarizing optical microscopy; (ii) atomic force microscopy (AFM) and magnetic force microscopy (MFM); (iii) Brillouin Light Scattering (BLS) spectroscopy with time and space resolution option. Cobalt thickness d was chosen to be higher than thickness corresponding to the transition from perpendicular to in-plane magnetization state. Stripes with different Ga F were created by homogenous Ga irradiation. PMOKE studies showed that with increase in F: (i) two branches of out-of-plane magnetization states were created, (ii) Kerr rotation increased; Similar results were as already reported in PRB 85, 054427 (2012).

38. Optically Induced Magnetization Dynamics in Multilayers with High Perpendicular Magnetic Anisotropy

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Since the discovery of perpendicular magnetic anisotropy (PMA) in metallic multilayers, this phenomenon has been a subject of great interest. Magnetic multilayers with PMA have attracted attention due to their potential applications in patterned magnetic media, magnonic crystals and spin transfer torque magnetic random access memory (STT-MRAM) [1]. From the application point of view, all potential applications demand exploration of rich spin wave bands, large and broadly tunable precession frequencies, small damping values and a correlation between the PMA and damping. PMA has been observed in various magnetic multilayers due to the broken symmetry at the magnetic/nonmagnetic interface and also due to the d-d hybridization at the interface. Co/Pd and Co/Pt multilayers are promising candidates in this field. Here, we report an all-optical time-resolved study of collective picosecond magnetization dynamics in [Co/Pd]8 multilayers with varying cobalt layer thickness and dipole-exchange spin wave spectra in a series of CoO capped [Co(t)/Pt(7Å)]n-1 Co(t) multilayers, where the total Co moment (n×t) is constant. In the case of the [Co/Pd]8 multilayers, the variation of the precession frequency with the Co layer thickness due to the variation of the PMA and the correlation between damping and the PMA are investigated [2]. The experimental results are analyzed by the macrospin formalism. On the other hand, in [Co(t)/Pt(7Å)]n-1 Co(t) multilayers, in general the spin-wave spectra consist of two intense peaks and additional lower intensity peaks [3]. The observed spin wave modes are modeled by discrete dipole approximation to get their physical origins. Acknowledgements: We gratefully acknowledge the financial assistance from Department of Science and Technology, Govt. of India (grant nos. INT/EC/CMS (24/233552), SR/NM/NS-09/2007) and the European Community's Seventh Framework Programme (FP7/2007-2013) under Grant Agreement n°233552 for DYNAMAG project.

[1] Y. Huai, F. Albert, P. Nguyen, M. Pakal and T. Valet, Appl. Phys. Lett. **84**, 3118, (2004).
[2] S. Pal, B. Rana, O. Hellwig, T. Thompson, and A. Barman, Appl. Phys. Lett. **98**, 082501 (2011).
[3] S. Pal, B. Rana, S. Saha, R. Mandal, O. Hellwig, J. Romero-Vivas, S. Mamica, J. W. Klos, M. Mruczkiewicz, M. L. Sokolovskyy, M. Krawczyk and A. Barman, J. Appl. Phys **111**, 07C507 (2012).

39. Superspin Glass Mediated Giant Spontaneous Exchange Bias in a Nanocomposite of $BiFeO_3$-$Bi_2Fe_4O_9$

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We observe an enormous spontaneous exchange bias (30-60 mT) - measured in an unmagnetized state following zero-field cooling - in a nanocomposite of $BiFeO_3$ (94%)-$Bi_2Fe_4O_9$ (6%) over a temperature range 5-300 K. Depending on the path followed in tracing the hysteresis loop - positive or negative - as well as the maximum field applied, the exchange bias (HE) varies significantly with |−HEN| > |+HEP|. The temperature dependence of HE is nonmonotonic. It increases, initially, till 150 K and then decreases as the blocking temperature TB is approached. All these rich features appear to be originating from the spontaneous symmetry breaking and consequent onset of unidirectional anisotropy driven by ”superinteraction bias coupling” between ferromagnetic core of $Bi_2Fe_4O_9$ (of average size 19 nm) and canted antiferromagnetic structure of $BiFeO_3$ (of average size ~112 nm) via superspin glass moments at the shell.

40. The effect of a copper interface layer on spin injection from ferromagnet to grapheme

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Lateral graphene-based spin-valve devices with ferromagnet-Cu-graphene contacts have been fabricated using both sputtering and e-beam evaporation techniques. Cu was chosen as the material for the interfacial layer because of its spin-preservation characteristics. Four-terminal devices with or without Cu interfacial layers have been fabricated by both e-beam evaporation or sputtering on mechanically exfoliated graphene sheets. Non-local transport measurements were performed at temperature from 4.2 K to 250 K. A potential barrier of 33 meV was derived from the temperature-dependence contact resistance for the evaporation-deposited devices with Cu interfacial layers. Our results show that a Cu interfacial layer can help alleviate the conductance mismatch problem in spin injection from ferromagnet to graphene and moderately enhance the spin injection efficiency.

41. The study of switching field distribution of Co/Pd based bit patterned media

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Bit-patterned media (BPM) based on a single-bit-per-island may be a promising candidate for perpendicular magnetic recording at the Tb/in2 level. A key issue in BPM is that the switching field distribution (SFD) needs to be sufficiently narrow to secure exact addressability. However, the mechanism of magnetization reversal processes is not fully understood. The sample used in this study is an ordered arrays (11x11 islands) of isolated magnetic islands fabricated on perpendicular Co/Pd multilayer magnetic films by e-beam lithography. Magnetic reversal of individual islands is observed through MFM. Demagnetization and SFD are studied using the obtained intrinsic SFD to verify if dipole-dipole interactions contribute to the SFD broadening. The range of single domain island size, demagnetization effect, dipolar interactions and SFD are studied by the simulation based on Landau-Lifshitz-Gilbert equation. The parameters for simulation are obtained from experimental results. We find that dipole-dipole interactions cause a significant SFD broadening. The interaction among islands broadens relative SFD (SFD/Hc) from 12% to 20% when dipolar interactions are considered. Optimized pattered structure with a minimized SFD and maximized data storage densities is found to have an island size of 10 nm and islands separation of 20 nm. The simulated relative SFD is 9.2%, which is below the threshold of 10% for 1 Tb/in2 patterned area. Moreover, temperature effect and angle dependence of critical fields and SFD are studied by both experiment and simulation. From our observation, when temperature increases from 77 to 300K, the critical field of patterned area decreases from 13 to 11 kOe as thermal energy assists islands reversal. Absolute SFD decreases from 2.6 to 2.2 kOe. SFD/Hc keeps constant at different temperature. Although critical fields and absolute SFD vary with angles, relative SFD is independent of the field angle. The relative SFD derived by simulation agrees well with our experimental observations.

42. Highly (001)-oriented thin, smooth, and continuous L10 FePt film by introducing an FeOx cap layer

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We present a highly (001)-oriented thin, continuous L10 FePt film with a smooth film surface by introducing an FeOx cap layer. All samples were deposited on Si||SiO2 substrates with a layer structure of FePt (4 nm)/FeOx (Y nm), where Y ranges from 0 to 1.3 nm, followed by annealing at 500 0C for 10 seconds. Wide angle XRD scans of all annealed samples show superlattice (001) peaks, suggesting ordered FePt films. A smooth film surface is confirmed by observing satellite peaks around (001) peaks in scans of samples with a 0.5-nm-thick and 0.9-nm-thick cap layer, respectively. From the rocking curves of (001) peaks, a full-width at half-maximum value of 2.50 is obtained in the sample with a 0.9-nm-thick FeOx layer. TEM plan-view images reveal the significant agglomeration in the bare FePt film and a continuous FePt layer using a 0.9-nm-thick FeOx layer. The suppressed agglomeration is attributed to the inhibited surface diffusion when using a capping layer. The corresponding high resolution TEM cross-sectional images illustrate a narrower (001)-orientation angular distribution in a less-agglomerated FePt film, revealing that the inhibited agglomeration can further narrow the easy axis distribution. In addition, the x-ray absorption spectra of capped samples reveal the absence of shoulders beside the Fe L2,3-edge after annealing, indicating the reduction of Fe oxides to Fe during post-annealing. Oxygen could leave from Fe oxides via O2 desorption, creating vacancies to further promote the L10 ordering. Therefore, the introduction of a thin FeOx cap layer can suppress the agglomeration and maintain the highly (001) L10 phase.

43. Room-temperature hysteretic magnetoresistance in graphene/graphite

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Ferromagnetism and magnetotransport in carbon-based materials provide a route to novel magnetic materials and spintronics devices without 3d elements. Both theroies and experiments have shown that edge states and defects in highly oriented pyrolytic graphite (HOPG) and graphene may induce ferromagnetic behavior. Magnetoresistance (MR) has been studied graphite and graphene, however, few report shows the hysteresis of MR. We have observed hysteresis behavior in MR of graphene samples at room temperature (RT). The single layer graphene (SLG) was synthesized by chemical vapor deposition (CVD) on copper foil and transferred to Si/SiO2 wafer. The gold wires were patterned as the electrodes. The resistance R of the graphene sample shows magnetic hysteresis behavior with sweeping the magnetic field perpendicular to the film. Zero field R difference between the ascending and descending field branches ΔRH=0 has a maximum about 100 Ω (0.5% of R) at the drain voltage of 1.1 V. Raman spectum shows the existence of HOPG as well as SLG in the measured region. The observed hysteretic MR may relate to the edge state or defect induced ferromagnetism in the SLG and HOPG structure. Our result is important to the further understanding of the ferromagnetic behavior and magnetotransport properties in the two dimentional carbon structures.

44. High coercivity, granular L10 FePt media sans spacer materials using Ar-He sputtering gas

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FePt media is considered as a suitable candidate to achieve ultra-high areal densities beyond 1 Tb/square inch in hard disk drives employing heat assisted magnetic recording (HAMR) [1]. It is, therefore, essential to fabricate granular L10 FePt films, which are well-ordered, have high out-of-plane coercivities and lower grain sizes, all of which should be attained simultaneously [1]. Spacer materials which are generally used to fabricate granular L10 FePt media, such as C and MgO amongst others, produce smaller grain size, however, at the cost of reduced out-of-plane coercivity [2,3]. In this work, we investigate a spacer-less method in which addition of helium to argon sputtering gas results in a significant improvement in the chemical ordering, magnetic and microstructural properties of FePt. These enhancements are due to the modification in the ion current density caused by helium. The excited metastable helium species in the plasma is capable of ionizing argon atoms, thus, creating additional Ar+ ions apart from those generated conventionally via electron-impact ionization. This increase in the ion flux of the plasma is responsible for providing the Fe and Pt atoms optimal adatom mobility to arrange into a well-ordered L10 FePt film. It was seen that the chemical ordering improved as helium amount was gradually increased from 0 to 0.5 to 1%. Compared to the L10 FePt media deposited in argon, the FePt films sputtered in argon-1% helium environment exhibited an increment in the out-of-plane coercivity from 15 to 22 kOe. Furthermore, transmission electron microscopy equipped with electron energy loss spectroscopy confirmed the attainment of highly exchange decoupled grains along with a reduction in size from ~40 to ~24 nm, both achieved without the addition of any ternary elements/additives.

[1] Proc. IEEE **96**, 1810 (2008).
[2] J. Appl. Phys. **99**, 08F907 (2006).
[3] Appl. Phys. Express **1**, 101301 (2008).

45. Momentum transfer between magnetic domain walls due to topological repulsion

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Magnetic domain wall (DW) research has been gaining much interest from the scientific community due to its possible application as non-volatile magnetic memory devices. The realization of such devices requires the full understanding of the DW dynamics under all possible driving mechanisms. Aside from the technological motivations, the complexity of DW dynamics is attractive from fundamental point of view. For instance, a moving DW has been observed to possess a mass, which allows the DW to move under its own inertia after the external driving force has been removed. Interactions between objects with mass have been known to conserve the total linear momentum of the system. However, in the case of DW-DW interaction, the theory of linear momentum conservation has yet to be constructed. In this work, we report on the mechanism where linear momentum transfer between DWs can be achieved. We investigate the interaction between a remote-driven DW and a group of static DWs. The interaction results in the static DWs to move together with the remote-driven DW. The linear momentum of the remote-driven DW is transferred to the static DWs, and the total linear momentum of the system is found to be conserved in the process. By analyzing the structure of the DWs, we find that the linear momentum transfer is mediated via a repulsion force that is generated between the DWs. The repulsion force is found to originate from the exchange energy contribution in the magnetization dynamics. Prior to our investigation, DW driving has mainly been attributed to the application of field or current. The results have brought up the importance of exchange interaction as a DW-driving mechanism in a system where multiple DWs are concerned.

46. Design and Instrumentation of an Advanced Magnetocaloric Direct Temperature Measurement System

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A novel magnetocaloric temperature change test system with fully controlled field, temperature, and time capabilities is designed and analyzed. This test system allows the detailed observations of the applied field effect, sample temperature effect, and time effect on the testing magnetocaloric material. The effectiveness of this test system was evaluated by testing the MCE within sample of Gd turnings. The magnetocaloric temperature change measurements, TTemp, at various H and Temp was measured and showed numerical and characteristic agreements with literature, thus provided evidence that this test is capable of making conventional measurement as well as new measurements on the material’s dynamic time effects.

47. FE based self-consistent treatment of magnetization dynamics caused by spin transfer effects

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Up to now the spin transfer effects were introduced in micromagnetism by means of two local contributions called adiabatic term and non-adiabatic term related to phenomenological constant whose value is open to debate. Besides, the theoretical models were applied for simple geometries with homogeneous current flow. In order to design realistic spintronic devices with strong current and magnetization gradients imposed by system properties or geometry the additional length scales as well as self-consistent interaction between transport and dynamics equations should be considered. We present the advanced model which couples Landau-Lifshitz-Gilbert equation (LLG) for magnetization dynamics with the diffusive transport equations introduced in [1]. In this self-consistent treatment all non-linear diffusive terms are taken into account. The implementation was realized as an add-on module to our micromagnetic finite element (FE) software FEELLGOOD which faithfully describes any complex geometry (nanoconstrictions, circular cross-sections etc.). To overcome the problem of magnetization renormalization (proper to most of existing FE software) and to treat correctly the magnetization dynamics for realistic damping factors we choose to deal with vector test functions belonging to the tangent plane to the local magnetization. At each time step the local torque is determined from the spin accumulation distribution and then injected into the LLG equations. By choosing the different types of domain walls moving in a nanostrip under the action of homogeneous or non-homogeneous spin-polarized current we present a comparative study between simplified and coupled models. We show that spin diffusion terms are not negligible contrary to the hypotheses made in the basic model [1]. We discuss how these terms and current distribution affect the wall motion and its velocity.

[1] S. Zhang et al. Phys. Rev. Lett. **88**, 236601 (2002).

48. Generalized Magneto-Optical Ellipsometry (GME) as a characterization tool for magnetization reversal

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Generalized Magneto-Optical Ellipsometry (GME) has emerged during the last several years as a methodology to characterize magnetic materials with a high degree of precision by means of utilizing the magneto-optical Kerr effect [1]. Compared to other magneto-optical characterization methods based on the same effect, GME has two key advantages: it can measure both the optical and magneto-optical constants, and it allows full vector magnetometry, all with one simple experimental setup. In our most recent works, we have extended the capabilities of the GME technique to the study of magnetization reversal, with the possibility of performing quantitative 3D vector magnetometry, as well as adding the ability to analyze systems with both magneto-optical activity and optical anisotropy simultaneously [2]. Besides this, we have also improved the technique itself enhancing its data set reliability [3]. In the future, we plan to enhance the potential of this technique for the purpose of exploring the possibility of depth profiling of the magnetization vector, thus, gathering information that is not available by conventional bulk magnetometry measurements.

[1] A. Berger and M. R. Pufall, Appl. Phys. Lett. **71**, 965 (1997).
[2] J. B. González-Díaz, J. A. Arregi, E. Bergaretxe, M. J. Fertin, O. Idigoras, and A. Berger, J. Magn. Magn. Mater. **325**, 147 (2013).
[3] J. A. Arregi, J. B. Gonzalez-Diaz, E. Bergaretxe, O. Idigoras, T. Unsal, and A. Berger, J. Appl. Phys. **111**, 103912 (2012).

49. Preparation of FeRh Thin Films

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High quality equiatomic FeRh thin films with varying thickness have been prepared on MgO (100) substrates via molecular beam epitaxy (MBE). The optimization of the stoichiometry was monitored using XRD, RBS and AES while the magnetic properties were probed in a SQUID. XRD results evidence a well-ordered CsCl-type crystal structure. By increasing the annealing temperature of the films, the structural quality of the films also increase. Moreover, the known first order phase transition at ∼350 K from an antiferromagnetic (AF) to a ferromagnetic (FM) state slightly shifts towards higher temperatures. M-H loops of films annealed at 800 °C or 850 °C recorded at 300 K show an opening, which is likely related to the magnetic field-induced AFM-FM phase transition. Residual low-temperature ferromagnetic moments are related to disorder or Fe diffusion towards the interfaces.

50. Relaxation processes near phase transitions in advanced magneticaloric materials

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The research in the field of the new technology of refrigeration at room temperature based on magnetic materials with phase transitions (PT) attracts much attention last years. In spite of the fact that magnetic PT were investigated theoretically and experimentally for a long time, at the moment there is no deep understanding of the kinetic phenomena occurring with magnetic PT, which is crucial in development of this technology. It is very important to know the fundamental physical restrictions on speed of relaxation processes of order parameter (magnetization) near critical point of PT. Theoretically [1], relaxation processes near the 2d order PT point are described by Landau-Khalatnikov equation: $d\eta/dt = -\gamma(\partial\Omega / \partial\eta)$, where η – order parameter, t – time, Ω – thermodynamic potential, γ – kinetic coefficient. The aims of present work were the following: 1) To develop the experimental method for the measurement of the time of establishment of the equilibrium value of order parameter after fast heating and cooling of the sample in the form of thin plate near PT critical temperature. 2) To estimate achievable magnitude of power-to-weight ratio of magnetocaloric refrigerator or thermal pump with working made of different magnetic materials.

[1] L.D Landau, I.M. Khalatnikov, Doklady Akademii Nauk USSR, **96**, 469 (1954).

51. Fabrication of magnetic micro/nano-tweezers functionalized and dispersed in solution for bio

C. ISS, H. Joisten, T. Dietsch, S. Leulmi, P. Sabon, Y. Hou-Broutin, T. Livache, J. Fauer-Vincent, R. Calemczuk, C. Benoit, D. Peyrade, S. Auffret, E. Gautier, and B. Dieny
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In biotechnologies, magnetic particles are more and more used for targeted drug delivery, cell sorting, cancer treatment, oriented growth of biological tissues. Most of these particles are made chemically, following a bottom-up approach. In this work, a novel kind of magnetic micro/nanoparticles elaborated by a top-down approach were proposed and developed. This approach allows the realization of more complex particles, in particular tweezers made of two mobile micromagnets on top of each other and bound on one of their sides by a flexible hinge. These magnetic micro/nano-tweezers are designed for reversible seizing at micro/nanoscale. The control of their opening/closing is based on the magnetostatic interaction between the two bounded micromagnets. At zero field, these two magnets tend to have antiparallel magnetization and attract themselves so that the tweezer is closed. Under magnetic field, the magnetizations of the two magnets are brought in parallel alignment so that they repel each other, yielding the opening of the tweezer. On top of that, proper surface functionalization provides the tweezers tunable chemical properties to interact with specific biological species besides ensuring biocompatibility with living organisms. This technique could also enable fundamental study of molecular bonds strength within biological complexes. With their ability to grab, move and release biological samples at micro and nanoscale, these magnetic tweezers constitute a very promising tool when deployed in microfluidic biochips (attached to the substrate or released in solution). Moreover, they could open new prospects of applications beyond state of the art in biotechnologies, medicine, nano-mechanics, -optics and –robotics. This work is partially funded by the French National Research Agency within the NANOSHARK project conducted in collaboration between SPINTEC, LTM and SPRAM.

52. Spin-Hall effect influence on the damping parameter in metal-ferromagnetic interfaces

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Recently, attention has turned to developing ideas and systems where spin transfer torque (STT) can be achieved bypure spin currents. A two-layered structure consisting of a 2.1 µm YIG film and with a 13 nm Pt film sputtered on its surface was investigated using the resonator technique. With this method, electromagnetic waves reflections from the Pt layer are absent, in contrast to the external antenna excitation method. The experiment was carried out in the X- frequency band. The dependencies of frequency and FMR linewidth on current strength J, its direction, and external magnetic field H direction were measured. It was found that spin current, magnetic field and conductance current (opposite to electrons flow) directions forms a right-handed triple of vectors. With a current density of 1000000 A/cm2, a relative change in FMR linewidth reaches 10% at maximum. The FMR resonance magnetic field, within the limits of experimental accuracy due to the influence of Oersted field ~1 Oe, does not change. The physical mechanism, which causes the FMR linewidth to change, is interfacial spin scattering due to s-d exchange interaction between d-electrons in the YIG and s-electrons in the Pt, which are concentrated near the YIG-Pt interface due to the Spin Hall Effect. From this measurements we were able to determine the spin orbit constant for Pt.

53. Wavelength-dependent MOKE measurements of remote plasma sputtered L10 ordered FePt

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For the next-generation high-density magnetic data storage media, materials with high magnetocrystalline anisotropy (K1) are required and L10 ordered FePt is currently the leading candidate material [1]. The fabrication of chemically ordered L10 FePt remains challenging since high temperatures are required. Here results using remote plasma sputtering, which offers an unusual degree of control over the sputtering parameters, are presented. Control of sputtering parameters has the potential to tune the film growth of metallic materials as has been demonstrated for grain size distributions [2]. Despite the unique control that is provided during the sputtering of FePt, annealing is still required. In this work both continuous thin films and patterned islands are studied in order to i) understand the fundamental magnetic properties of remote plasma sputtered FePt and ii) assess its potential Bit Patterned Media (BPM). The chemical ordering of FePt is both detected by changes in the crystal structure and the magnetic properties of the material. These changes in the crystal structure of FePt are also accompanied by changes in its electronic structure, which lead to Magneto-Optical Kerr Effect (MOKE) spectral changes [3]. In order to measure these changes, a novel MOKE system has been built with four lasers of different wavelengths, and focussing allows measurements over lateral dimensions of a few microns. The combination of these measurements provides the most complete MOKE characterisation of the behaviour of the magnetic materials.

[1] D.Weller, A.Moser, IEEE Trans. Mag. **35**, 4423 (2000).
[2] K.O'Grady et al., J.O.A.A. **7**, 5 (2005).
[3] D.Weller et al., IEEE Trans. Mag. **37**, 4 (2001).

54. A Study of Magnetic Anisotropy Control of FeSiB Magnetostrictive Thin Film

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Magneto-Impedance (MI) sensors are used for various applications. It is important to induce the easy axis of magnetic anisotropy in transverse direction for increase of the sensitivity of MI sensor. However, to induce the anisotropy in transverse direction is difficult due to the large demagnetization field. Therefore, we propose new and simple transverse magnetic anisotropy control method to use the difference of thermal expansion coefficient and inverse-magnetostriction. First, we fabricated the sensor as a bi-layer structure (magnetic / conductive layer). After fabrication, we annealed the bi-layer thin film to release the local stress, which was induced during the deposition. During annealing process, the bi-layer thin film had bending deformation because of the difference of the thermal expansion coefficient between two layers. The bending deformation generates inner stress in the layers. The magnetic anisotropy of magnetic layer (FeSiB) can be controlled by the inner stress, because FeSiB is magnetiostrictive material. Consequently, according to the combination of difference of thermal expansion coefficient, we can effectively induce the transverse magnetic anisotropy. As the experimental results, when thermal expansion coefficient of conductive layer (Molybdenum : 5.4x10-6/K-1) was lower than magnetic layer (FeSiB : 6.5x10-6/K-1), the transverse magnetic anisotropy was induced. Also, the minimum magnetic anisotropy (Hk) is required, because Hk acts as a bias. Therefore, low Hk value aids to develop high performance MI sensor. The Hk value is determined by ratio of thickness of two layers. We have studied to establish relationship between ratio of thickness and induced Hk value. Our research can provide very effective method to induce transverse magnetic anisotropy for improve the sensitivity of MI sensor, besides the magnetic anisotropy (Hk) can be controlled simply through adjusting ratio of the thin films thickness. Therefore, this research is well worth for the high sensitivity sensor.

55. Synchronous Non-Volatile Logic Gate Design based on Resistive Switching Memories

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Emerging non-volatile memories (NVM) based on resistive switching mechanism (RS) such as STT-MRAM, OxRRAM and CBRAM etc., are under intense R&D investigation by both academics and industries. They provide high write/read speed, low power and good endurance beyond mainstream NVMs, which allow them to be embedded directly with logic units for computing purpose. This integration could increase significantly the power/die area efficiency, and then overcome definitively the power/speed bottlenecks of modern VLSIs. We presents firstly a theoretical investigation of synchronous NV logic gates based on RS memories (RS-NVL). Special design techniques are proposed to optimize the structure and to adapt to different resistive characteristics of NVMs. To validate this study, we simulated a non-volatile full-adder (NVFA) with two types of NVMs: STT-MRAM and OxRRAM by using CMOS 40 nm design kit and compact models. They show interesting power, speed and area gain compared with synchronized CMOS FA.

56. Magneto-optical activity and plasmonic resonances in Ni nanostructures

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A linearly polarized light incident on metallic nanoparticles can excite localized electron charge oscillations known as localized surface plasmon resonances (LSPRs). Plasmon excitation in ferromagnetic nanoparticles offers an interesting possibility to combine the excitation of such LSPRs with the magneto-optical properties of the material considered, resulting in a modification of the magneto-optical activity with respect to the bulk and film cases. Plasmonic excitations in Ni and other ferromagnetic materials are much more strongly damped than those in noble metals. Therefore many magnetoplasmonic devices investigated so far consist of hybrid structures of noble metals and ferromagnetic materials. However, we discovered new interesting magnetoplasmonic effects in purely ferromagnetic nanostructures, like the effect of the shape anisotropy on the polarizability phases of such nanoparticles. We use Ni nanodisks on a glass substrate to create a magnetoplasmonic device where the magneto-optical activity is modified by the presence of plasmonic excitations. Two different nanoparticle geometries are explored: circular and elliptical. Different sizes of both circular and elliptical particles allow us to combine nickel MOKE properties with variable plasmonic excitation spectrums. The extinction and magneto-optical experimental spectra of the nanoparticles show clear resonance peaks and features that shift as a function of particle size and shape. A model is developed to explain the physics involved and the numerical calculations performed are in very good agreement with the experiments.

57. Magneto-optical properties of GdFeCo alloy thin films and Gd/FeCo multilayer structures

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Opto-magnetic recording has sparked great interest in recent years as it has the potential for high density, ultrafast recording. It has been proven that all optical magnetic recording is feasible by using an intense femto-second laser pulse to generate magnetisation reversal but research is still required to obtain a more practical and efficient method for this to become a commercial recording mechanism. This project involves identification of novel magnetic materials that could be used to enhance and improve all optical magnetic recording. The materials described below will be evaluated as part of an EU Framework7 project in collaboration with Radboud University. GdFeCo alloy thin films of 50nm have been deposited onto SiO_2 substrates using a magnetron co-sputtering system. This technique allows for investigation of compositions of the alloy, the compositions investigated were $Gd_xFe_{90-x}Co_{10}$ where x = 15 - 30. The crystallographic structure of these alloys were characterised using x-ray diffraction and it was found that GdFeCo produced an amorphous surface when grown on SiO_2 with a 5nm Tantalum seed layer. The magnetic properties were investigated using a heated vibrating sample magnetometer. This gave analysis of the compensation temperature of the GdFeCo alloys. It was found that increasing the Gd percentage reduced the compensation and Curie temperature of the alloy and therefore to obtain perpendicular anisotropy at room temperature, alloys with less than 25% Gd were required. Having established alloy performance we are now forming Gd/FeCo multilayer structures to artificially alloy the elements to elucidate important coupling terms to the system. The next system to be evaluated will be FeRh.

58. Magnetic properties of Fe-(Pt,Pd) thin films patterned by self-assembling of polystyrene nanospheres

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Arrays of monodisperse magnetic nanoparticles with high magnetic anisotropy are studied for magnetorecording. In this frame, polystyrene nanosphere (PN) lithography has been exploited for magnetic thin films nanostructuring on large scale to prepare submicrometer arrays of dots/holes [1,2]. Such a technique is presently considered a valid alternative to conventional e-beam lithography due to its low-cost and large covering area for a variety of applications. Patterned L10 FePt films were obtained by assembling commercially available PN monolayer, with two diameter 100 ÷ 500 nm(reduced by RIE), on a continuous thin films (thickness 10 nm). Dot arrays (diameter 80 ÷ 400 nm) were obtained by submitting the film to sputter etching with Ar+ ions [1]. Conversely, arrays of antidot in Fe50Pd50 sputtered thin films (thickness 50 nm) on a Si substrate have been created using PN as diffraction masks in combination with a mercury lamp [2]. A monolayer of PN (diameter ≈ 800 nm) is deposited on a layer of resist and is exposed to an UV lamp. In this way, the individual spherules in the self-assembled planar array behave as optical lenses to generate regular diffraction patterns on the photoresist. At the end of the process, holes (diameter ≈ 300 nm) are generated in the magnetic film [2]. In this case, the order-disorder transformation towards the L10-ordered tetragonal phase has been induced by post deposition annealing in vacuum. Sample microstructure was studied by means of SEM and AFM microscopy in all studied films. Room-temperature hysteresis loops were measured by an AGFM magnetometer confirming the presence of the tetragonal phase in all patterned samples. MFM microscopy was exploited to study the magnetic domain pattern revealing a complex multidomains structure in both compositions. The effect of patterning on the magnetic properties of the Fe47Pt53 and Fe50Pd50 thin film will be studied in details.

[1] P. Tiberto, L. Boarino, F. Celegato, M. Coisson, N. De Leo, F. Vinai, J. Appl. Phys. **107**, 09B502 (2010).
[2] P. Tiberto, L. Boarino, , F. Celegato, G. Barrera, M. Coisson, N. De Leo, F. Vinai, P. Allia, App. Surf. Science, **259**, 44-48 (2012).

59. Antiferromagnetic Spintronics

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Spintronics is a branch of electronics that aims to make use of the magnetic (spin) rather the electric (charge) properties of an electron. Spintronic devices are used in present (hard-drive read heads) and emerging data storage applications (magnetic random access memory) and may even find application in information processing (spin-transistors). Transport characteristics of the overwhelming majority of modern spintronic devices are governed by ferromagnetic materials. Much less attention has been paid to antiferromagnets due to zero net magnetization which makes investigation of the magnetic order much harder. Recent experiments [1] suggest that antiferromagnets can also be used as active components of spintronic devices. We aim to investigate antiferromagnets electrically using microwave techniques and magnetoresistive detection of magnetic resonance similar to the case of ferromagnets [2]. Antiferromagnetic resonance has long been predicted [3] and experimentally confirmed [4] using microwave cavities. Investigation of antiferromagnetic resonance using oscillating electric current could become a powerful tool for understanding magnetism and spin dynamics in this type of materials.

[1] Park, B. G., Wunderlich, J., Marti, X., Holy, V., Kurosaki, Y., Yamada, M., Yamamoto, H., Nishide, A., Hayakawa, J., Takahashi, H., Shick, A. B., Jungwirth, T. A, Nature Materials **10**, 347351 (2011).
[2] Fang, D., Kurebayashi, H., Wunderlich, J., Vyborny, K., Zarbo, L. P., Campion, R. P., Casiraghi, A., Gallagher, B. L., Jungwirth, T. & Ferguson, A. J., Nature nanotechnology **6**, 413-417 (2011).
[3] Kittel, C., Phys. Rev. **82**, Issue 4, 565-565 (1951).
[4] Johnson, F. M. & Nethercot, A. H. et al., Phys. Rev. **114**, 705716 (1959).

60. Grain Size Effects in Exchange Bias Elements

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For conventional recording and MRAM applications an understanding of the behavior of exchange bias in submicron elements is required. Despite developments in lithography in the past decade a coherent understanding of the systems remains illusive. There are reports of both increase and decrease in the magnitude of the exchange field (Hex) in such systems [1]. Baltz et. al. reported that for a constant element size Hex was independent of the antiferromagnetic (AF) layer thickness[2]. However a decrease in the measured blocking temperature (Tb) was also observed [2]. A simple grain cutting model was found to agree with these measurements [3]. Using the York protocols [4] we now report of the validity of the grain size distribution model for nanoelements. It is a modification of the York Model of exchange bias taking into account the restricted size distribution in nanoelements. This leads to a wide distribution of exchange bias fields. In small elements produced by sputtering through masks a restricted grain size distribution will be presented. For example in a 100nm square element only 100 grains will be contained withing each element. This will not be representative of the full grain size distribution leading to a distribution of Hex and Tb across the elements. This in turn will lead to a broadening of the distribution of Tb across the film as a whole. However the value of Hex will be unaffected if all the AF grains are thermally stable at the temperature of measurement as reported by Baltz et. al. [2]. The theoretical model described in [3] will be compared to experimental data in the poster.

[1] J. Nogues et. al. Phys. Rep. **422**, 65 (2005).
[2] V. Baltz et. al. Phys. Rec. Lett. **94**, 117201 (2005).
[3] G. Vallejo-Fernandez, J. N. Chapman Appl. Phys. Rev. Lett. **94**, 262508 (2009).
[4] G. Vallejo-Fernandez, L. E. Fernandez-Outon, K. O'Grady J. Phys. D:Appl. Phys. **41**, 112001 (2008)

61. Influence of hot electrons on the ultrafast quench of magnetization in Ni

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Since the first investigation of ultrafast magnetization dynamics in 1996[1], the question on the driving mechanism(s) is still not resolved entirely. According to the predicted superdiffusive spin transport[2], we investigate the influence of hot electrons on the relative demagnetization. Magnetization dynamics of polycrystalline nickel film is measured using the all-optical pump-probe technique for various pump pulse fluences. The theoretical description of the microscopic processes in these dynamics has the challenge and complexity of the parallel treatment of photons, electrons, phonons and magnetic correlation of the system. At the same time different length and time scales are involved. To clarify the influence of hot electrons on the relative demagnetization, experiments with temporarily stretched pump pulses from 50 fs up to 2.5 ps are performed. These results are compared to simulations based on the Landau-Lifshitz-Bloch equation, which is based on the thermal model, and featured by the consideration of two spin temperature dependent relaxation times $\tau_\perp$ and $\tau_\parallel$. The electron temperature is needed as input for the simulations and obtained from independent experiments on reflectivity dynamics. Compared to experiments, performed using ultrashort 80 fs pump pulses containing same energy per pulse, a lower maximum electron temperature is reached, but it is maintained for a longer time with longer pump pulses. Performing the experiment for different pump fluences, we measured a higher relative demagnetization at higher fluences.

[1] E. Beaurepaire, J.-C. Merle, A. Daunois, and J.-Y. Bigot, Phys. Rev. Lett. **76**, 4250–4253 (1996).
[2] M. Battiato, K. Carva, and P. M. Oppeneer, Phys. Rev. Lett. **105**, 027203 (2010).

62. An efficient inverted hysteresis model with modified switch operator and derivative weight function

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A new inverted hysteresis model is proposed for implementation of hysteresis model into FE codes. According to different path of H(B) curve from B(H) curve, a modified switch operator is introduced in the integration calculation. The new switch operator remains the wiping out and congruency properties of the inverted model. It also guarantees the symmetry and total positiveness of weight function in the Preisach plane. The corresponding weight function is formed with derivative analytic function. It performs with good continuity and symmetry. This makes it possible to implement the inverted model in numerical analysis without an iterative procedure. The identification work was done by means of measured major loops. A Limited number of parameters are determined by the Newton method algorithm to optimize the mean squared error (MSE) between the measured and simulated data. The inverted model was verified for both soft and hard magnetic materials. Besides major hysteresis loops, minor loops and first-order reversal curves (FORCs) can also be simulated. By comparison, the simulation results produced by the inverted hysteresis model show good agreement with measurement data.

63. Fully Coupled Approaches For Finite Element Micromagnetics

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Micromagnetics is a continuum model of magnetic materials and is commonly used in many areas of magnetism, such as in the design of new magnetic devices and in the interpretation of measurements. Even basic micromagnetic problems are multi-physics models because at least exchange and magnetostatic fields must be included. Many interesting applications of magnetism can be more accurately represented by multi-physics models, for example heat assisted magnetic recording involves modelling both heat flow and finite temperature micromagnetics. It has been shown that a fully coupled (monolithic) approach to multi-physics simulations can improve solver robustness and convergence speed, especially for numerically hard problems.[1] Monolithic approaches also result in a fully implicit time discretisation, meaning time step sizes are limited only by the physics and the desired accuracy. Similar approaches for finite difference (i.e. strong form discretisation) micromagnetic models have also been shown to conserve important physical properties (with an appropriate time integration scheme).[2] To make such monolithic approaches computationally feasible for large problem sizes good preconditioners are needed, both for individual sub-problems and for the resulting coupled system. Current preconditioners for the Landau-Lifshitz-Gilbert equation are only effective in the case of very small time steps, the long time step regime is more difficult. Algebraic multigrid based preconditioners are known to be very effective for the Poisson problems in magnetostatic calculations. We have implemented a hybrid finite element/boundary element micromagnetic model using the multi-phyics finite element library oomph-lib. We are currently investigating a block-based preconditioner for the Landau-Lifshitz-Gilbert equation with large time steps. We are also investigating methods for conservation of the physical properties mentioned above within a weak form discretisation (i.e. standard finite elements).

64. Magnetic Films of Charge-transfer Salts Fabricated Using Organic Molecular Beam Deposition

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Charge-transfer salts based on Manganese tetraphenylporphyrin (MnTPP) and tetracyanoethylene (TCNE) have shown unusual magnetic properties, such as high coercivity and large remanent magnetization[1]. Yet, to date, the magnetic charge-transfer salts of the [MnTPP][TCNE] family have been primarily synthesized via solution processes, which can lead to intercalation of unwanted solvent molecules as well as complex solvent-induced pseudo-polymorphs. Thus, a solvent-free strategy is used in order to obtain analogues of [MnTPP][TCNE] in the form of thin film, which can be incorporated into existing device structures and allow us to exploit the magnetic properties for molecular spintronics. Specifically, the techniques we use to synthesize the thin films of charge-transfer salts are Organic Molecular Beam Deposition and Organic Vapor Phase Deposition. Both techniques offer very distinct growth conditions as well as good control over the growth process, leading to high quality organic thin films. As a result, thin films of charge-transfer salts fabricated using co-deposition of an electron donor and acceptor, MnTPP-Cl and TCNQ, respectively, are studied spectroscopically, morphologically and structurally using a variety of characterization techniques, including UV/visible spectroscopy, Nomarski microscopy, scanning electron microscopy, atomic force microscopy and X-ray diffraction. In particular, evidence of charge-transfer reaction present in the thin films of the charge-transfer salt could be provided using Infrared Spectroscopy. Finally, the magnetic properties of the thin films are obtained using SQUID magnetometry. [1] Rittenberg, D.K., et al., Advanced Materials, 2000. 12(2): p. 126-130.

65. Collective Magnetic Vortex Dynamics in Pairs, Chains and Two-Dimensional Arrays of Circular Nanodots

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Arrays of small magnetic disks (dots) in the vortex state attract nowadays considerable interest due to their possible applications as patterned magnetic recording media, logic operation devices, and magnonic crystals. Vortex state is characterized by in-plane curling magnetization in the main dot area (typical radius is 100-500 nm) and a small vortex core (~10 nm) in the center with perpendicular magnetization characterized by polarity. In a single dot the excitation of the vortex core by applied external magnetic field or electric current leads to its gyrotropic motion providing the narrow frequency linewidth and quite high power output. In the pair of laterally separated magnetic dots the movements of one vortex core can generate the movement in the other due to the presence of interdot magnetostatic interaction. Such coupled vortices are considered now as the promising candidates for spin-torque nano-oscillators emitting microwaves or transferring a microwave signal. In the present work we explore the influence of the magnetostatic interaction on the vortex dynamics for different arrangements of magnetic dots. We start from a pair of interacting magnetic vortices and use the multipole expansion of magnetostatic energy to explore its dependence on the interdisk distance and estimate the importance of different multipole moments. Then we extend our calculations of the vortex gyrotropic eigenfrequencies for coupled 2D dot arrays (square and hexagonal) and 1D dot chains. The group velocity of the collective vortex excitations in the vortex dot arrays is found to be essentially higher than the maximal Walker velocity for the vortex/transverse domain walls propagation in magnetic nanostripes with the similar sizes. Although square array is a typical geometry nowadays for investigation, the hexagonal dot lattices and linear dot chains with alternating vortex core polarities are found to be more interesting for study having larger maximal group velocity.

66. Heating effects in microwave excited ferrimagnetic strutures in a wide range of magnetic fields

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Precessing magnetic moments can generate heat due to the decay of the precessional motion and the following transfer of energy into the phonon system. The generation of heat by this mechanism is of high interest for the deep understanding of the properties of spin dynamics and is already used for application. We show an additional mechanism for the transfer of energy from the magnon to the phonon system. We placed a polycrystalline disc of yttrium iron garnet (YIG) in an external magnetic field and excited it with high power microwaves. The temperature of the disc was monitored with an infrared camera. Besides large heating at the ferromagnetic resonance (FMR) we show an unexpected heat generation with applied microwave frequencies around 3.5 GHz for magnetic fields between 0 and 200 Oe far below the FMR. In spite of practically the same absorption of microwaves the heating becomes smaller with higher magnetic field values in the mentioned range. The behavior can then be understood by resonant magnetic excitations of the grain structure inside the polycrystalline material. This assumption can be confirmed by a comparison to the behavior of a monocrystalline YIG structure and by an excitation of the polycrystalline sample by microwaves of higher frequencies. Financial support by Deutsche Forschungsgemeinschaft (DFG) within priority program SPP 1538 "Spin Caloric Transport" is gratefully acknowledged.

67. Thermally Excited Ferromagnetic Resonance in MgO-based MTJs

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Spin polarized currents can exert a so-called spin-transfer torque to the magnetic moment of a ferromagnetic layer. One application of this phenomenon is the spin torque nano-oscillator (typically an MgObased magnetic tunnel junction (MTJ)) which can act as a tunable microwave emission source. However, a more detailed understanding of the spin-torque physics is needed. For example, the spin torque bias dependence of the two spin torque components (in-plane and fieldlike) is still widely discussed in the community. We present results for MgO-MTJs obtained by thermally excited ferromagnetic resonance (TE-FMR). With the help of TE-FMR, the bias dependence of the two spin-transfer torques can be determined from the peak position and linewidth. Microwave measurements were carried out in the frequency range of 1-9 GHz at positive and negative magnetic fields and for different dc current values. Analyzing these data, we could separate the in-plane and field-like spin torque components and determine their bias dependence.

68. Fast Magnetic Separation Nanotechnology for Water Remediation and Nuclear Fuel Recycling

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The greater quantities of wastewater generation and the more stringent regulations for wastewater discharge call for a more effective and efficient treatment process to overcome the drawbacks existing in the traditional methods. Novel magnetic nanosorbent — surface functionalized magnetic nanoparticles conjugated with specific metal chelators — has been developed for separation of metal ions from aqueous systems, which offers a simple, fast, effective, and environmentally benign technique in wastewater and spent nuclear fuel treatment. In this paper, we have coupled DTPA chelators to double coated magnetic nanoparticles (dMNPs), and shown that the dMNP-DTPA conjugates are an effective and excellent sorbent material for cadmium (Cd) and lead (Pb) adsorption. The adsorption of Cd or Pb onto the dMNP-DTPA conjugates was fast which reached the equilibrium in 30 min and strictly conformed to the pseudo-second-order-reaction mechanism. The calculated sorption capacities were 8.06 mg/g for Cd and 12.09 mg/g for Pb. With a saturation magnetization of ~20 emu/g, dMNP-DTPA conjugates can be easily manipulated and separated from solution in less than 1 min by applying an external magnetic field with a field gradient of above 300 G/mm. The results of the magnetic separation dynamics provide useful data for the future magnetic separation device design in a continuous flow system. By tailoring the surface functionality of the magnetic nanosorbents, this kind of separation nanotechnology has also been applied for uranium or other value element recovery from spent nuclear fuel.

69. The quality of the interfaces influencing the magnetic properties of thin layers Pt/Co/Pt

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Magnetic layers, whose properties are modulated periodically on a scale of dozens nanometers, are interesting materials that can be researched in the field of nanomagnetism. If applied in spintronics, as magnetic recording media or magnonic crystals, they are also very promising. This work discusses the structure of interfaces in Pt/Co/Pt layers in connection with its impact on the analysed system's magnetic properties. Interface quality testing was carried out using atomic force microscopy (AFM) and reflected high-energy electrons diffraction (RHEED) at every stage of the production of the structure. Depending on the conditions of formation of the Pt buffer its surface is smooth or regular undulations of period approximately 50 nm appear on it. The topography of the buffer has key influence on the growth of the Co layer deposited on the buffer, and as a consequence – on the magnetic properties of the Pt/Co/Pt system. It is particularly expected that in-plane magnetic anisotropy will appear. Such a system can therefore be regarded as a self-organizing magnonic crystal that makes it possible to modify magnetic properties of the propagating spinwaves. Moreover, we have performed initial attempts to modify periodically magnetic properties of the systems that have been irradiated by e-beam, light and ion-beam. Such an irradiated structure is intended to produce a regular pattern of out-of–plane magnetised dots arranged in a matrix of in-plane magnetized layer. We have also involved numerical methods in order to complete our investigations. This work was supported by the "Statistics and dynamics of magnonic and magnetophotonic crystals - SYMPHONY" project* of the Foundation for Polish Science TEAM programme, co-financed by the European Union from European Regional Development Found (ERDF).

70. Magnetization reversal by spin accumulation in a semiconducting ferromagnetic film

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In spin electronics, new information processing paradigms are based on the ability to manipulate magnetic states by spin polarized currents. In in-homogeneously magnetized magnets, essentially two competiting mechanisms are predicted to switch magnetization: the torque due to spin transfer between the itinerant carriers and the magnetic atoms and the accumulation of minority spins carriers. However, the interpretation of magnetization switch observed in nanopillar magnets or in tracks are more complex and can also involve magnetic excitations and nucleation processes. In this article, we show a first clear signature of the contribution of spin accumulation to magnetization reversal. A contact between a gold wire and a single (Ga,Mn)(As,P) ferromagnetic semiconducting layer with perpendicular anisotropy is crossed by a DC-current. This results in stochastic nucleation of domain walls. An in-plane applied magnetic field used to decrease spin accumulation by Hanle effect is shown to strongly reduce the probability of magnetization reversal.

71. Electromagnetic modelling of superconducting materials

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In this poster, we present the work done at the Udine University on the electromagnetic modelling of superconducting strands and cables. In particular, the activity is focused on Nb3Sn wires that play a central role in the design of the next generation of magnets for fusion (e.g. ITER project) and particle accelerators (e.g. Large Hadron Collider). The thermal stability of these strands has been studied in adiabatic conditions through an original numerical model based on the cell method. The longitudinal velocity of propagation of the resistive zone, due to local thermal perturbations, has been studied with impressed current and magnetic induction. A strong effort has been put in the correct definition of the material cryogenic properties that influence very deeply the behaviour of the superconductor. A wide bibliographic investigation has shown that, in several cases, researchers adopt quite different values for the same material properties, with consequently different results in the stability analyses. Another important topic of the electromagnetic modelling is the understanding of the voltage-current characteristic of superconducting materials, that has a dramatic impact also on the resistive zone propagation velocity. As it is well known, the type II superconductors show an apparent resistance and longitudinal electric field which depend in a non-linear way on the current. Many different models have been developed to analyze this phenomenon. Some of them are based on statistical descriptions of the critical current distribution along the strand. We have compared and further developed some of these statistical models and analyzed their impact on the performance description of the superconductor.

72. Vortex Domain Wall Logic-Gate Simulation

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The anticipated features of spintronic devices such as low power consumption and data non-volatility [1], have stimulated researchers to study and investigate the field of nanomagnetism and spintronics extensively. Here we present micro-magnetic simulations of a novel nanomagnetic logic-gate architecture that utilizes the magnetisation structure of vortex domain walls (vDW) in planar magnetic nanowires to store and process information. The internal magnetization structure of the vDWs has either a clockwise or anticlockwise orientation, and these two spin structures are used to represent binary data (1 and 0). vDWs representing input data are propagated through artificially defected Permalloy nanowires using a swept magnetic field. Each vDW interacts with defect and junction sites in a manner depending on their internal magnetisation state. The distinct pinning/depinning behaviour resulting from these interactions then determines the magnetization state of the outputted vDW. We exploit this behaviour to successfully demonstrate the operation of NOT, NAND and FAN-OUT logic-gates. These basic logic-gates can then be used to build any logical architecture, and extended networks of nanowires could be used to perform basic spintronic calculations.

[1] D. A. Allwood, et al., "Magnetic domain-wall logic," Science, vol. 309, pp. 1688-1692, Sep 2005.

73. Two-magnon scattering and mode-splitting in 1-dimensional quasi-magnonic crystals

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The magnetic relaxation in quasi 1-dimensional periodic nanostructures (magnonic crystals) is investigated by ferromagnetic resonance (FMR). In thin ferromagnetic films, the magnetization dynamics are governed by intrinsic effects like Gilbert damping and spin-pumping but also by extrinsic effects like two-magnon scattering due to inevitable defect structures. By using nanoscale periodically modulated magnetic films we are able to artificially create and thus control those defect structures necessary to induce two-magnon scattering. The results are compared to available analytical theory [1]. The magnetic modulation was created by lithographically defined stripes and subsequent ion beam irradiation. The ion beam energy was chosen such that the ions create a magnetic perturbation at the surface. This slightly reduces the saturation magnetization in the irradiated stripes and hence the effective magnetic thickness. These stripe defects resemble a periodic dipolar scattering potential, which couples the uniform with the final-state magnons in the two-magnon scattering process. Broadband ferromagnetic resonance is used to measure the resonance field H_{res} and linewidth ΔH for different field directions and frequencies. The frequency-dependent measurements with the external magnetic field aligned parallel to the stripes show only a single resonance mode and linear increase of ΔH. Therefore the magnetic relaxation is purely Gilbert-like. With the magnetic field aligned perpendicular to the periodic structure the frequency dependence exhibits a rich mode-splitting, which can be calculated analytically. This work was supported by the DFG grants FA 314/6-1, FA314/3-2.

[1] P. Landeros and D. L. Mills, Phys. Rev. B **85**, 054424 (2012).

74. Spin Current controlled 360 Domain Wall motion in Patterned Nanostripes

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In the past 10 years different types of racetrack memories and logical devices based on Transverse Magnetic Domain Walls (TWs) have been proposed by S. Konishi, Stuart S.P. Parkin and R. Cowburn amongst others. In an effort to overcome the long range interaction of TWs thought their stray field, a composite object made of two TWs, named 360º Domain Walls (360º DWs), has been proposed as a possible alternative, by Gonzalez et al, and Muratov et.al. In this poster I would like to present the results obtained of coherent 360º DWs motion on Permalloy patterned stripes with several triangular notches. This design could be the basics of a 360º DWs based racetrack memory or for magnetic data storage. The distance between the notches is about two, three and four times the 360º DW length, which is about 110nm. This supposes a higher DW storage density when compared to the devices proposed by S. Parkin where only 1 DW per micron can be successfully stored. Furthermore we found that for deeper notches a higher spin current was needed to depin the walls, but this also implied that a shorter spin current pulse was needed to move the walls from one notch to another. Although the results look promising there are still challenges ahead, such finding a method to lower the operative spin current density, which for this case is about 3-8x10^-12 A/m^2, and a reliable mechanism for a controlled and localized nucleation of 360º DWs.

75. Production and magnetic characterization of exchange-coupled NiFe/IrMn and IrMn/NiFe films

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Nowadays, several advanced magnetic and magnetoelectronic devices rely on interface exchange coupling (EC) between different magnetic phases. To optimize the performances of such devices it is important to control the EC strength to tune the anisotropy, a key technological parameter. In fact, the exchange interaction across the ferromagnetic(FM)/antiferromagnetic(AF) interface gives rise to an additional source of anisotropy and determines the onset of the exchange bias effect. In this context, we studied EC in continuous films with AF/FM and FM/AF configurations, grown by dc-magnetron sputtering, with Ir25Mn75 as AF and Ni80Fe20 as FM. All the samples were deposited on a 5 nm thick Cu underlayer to favor a fcc (111) orientation. We started our investigation studying and comparing the effects of EC on the macroscopic magnetic properties (exchange fied Hex, coercivity, HC, squareness) of a number of samples grown in different values of a magnetic field applied along the film plane (Hdep= 0, 200, 800 Oe) and having different thickness of the AF layer tAF (3, 6 and 10 nm; the thickness of FM was 5 nm in all the samples). At fixed tAF, we focused on the effect of the configuration (AF/FM or FM/AF), as well. Hysteresis loops were measured by magneto-optic Kerr effect (MOKE) and SQUID in the 5-300 K temperature range, after field cooling and zero-field cooling. These data will be presented and discussed together with the preliminary results that will be obtained after submitting the samples to the nano-patterning process by EBL lithography. This activity is developed within the project FIRB2010 NANOREST funded by MIUR.

76. Toroidal superconducting magnets with support structure placed inside torus

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Superconducting magnetic energy storage is effective device that can provide power flow stabilisation in large power systems. The toroidal magnets with different configuration of coils and a new mechanical support system inside torus are investigated. The proposed support system consists of spokes and it solves two mechanical problems: elimination of bending moments in the support system elements and ensuring a uniform mechanical stress in all spokes and the supporting structure. Support system requirements as well as the volume of a superconducting winding and size of toroidal system are analyzed. The volume of the support system with spokes is significantly smaller in comparison with conventionally supported O-shaped coils. The racetrack-shaped torus support system requirements are approximately the same as the corresponding values for O-shaped torus with spokes and for geometrically more complicated well-known D-shaped toroidal system. The volume of superconducting winding of toroidal system with racetrack coils is considerably lesser in comparison with usual O-shaped coils and approaches to theoretical minimum that realised for D-shaped torus. The toroidal magnet with racetrack coils has minimal radial sizes as compared with other researched configurations of Superconducting magnetic energy storage.

77. Jacobian-enhanced nudged elastic band simulator for computing energy barriers in magnetic systems

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The thermal stability of magnetic media is more important as the size of the magnetic structures decreases. The calculation of the thermal stability requires the estimation of the transition rate, such calculations require the knowledge of the most probable path between an initial and a final state also known as minimum energy path (MEP). To serve this purpose in the nudged elastic band method (NEB) the path is discretized into magnetic states called images. From an initial guess path we apply an iterative algorithm to move the images in such a way that at the end at any point in the path the gradient of the energy is only pointing along the path [1] These kinds of calculations are computational intensive since to reach a good resolution of the energy landscape a considerable number of images has to be used and the number of the unknowns in the system increases proportionally. Thus large scale system analysis becomes very complicated. Several important points need to be addressed to allow for a NEB solver to be used for complex magnetic systems, including efficient discretization, fast computation of the energy, and efficient stepping algorithm. The structure can contain any materials, any coupling, and several anisotropy types. The energy is evaluated using the effective field evaluation methods similar to those used in the high-performance FastMag simulator [2]. These methods are implemented on massively parallel Graphics Processing Unit (GPU) computing architectures as well as on multi-CPU systems.

[1] R. Dittrich, T. Schrefl, et al, Journal of Magnetism and Magnetic Materials **250**, L12–L19 (2002).
[2] R. Chang, S. Li, et al, "FastMag: Fast micromagnetic simulator for complex magnetic structures (invited) (vol 109, 07D358, 2011)," Journal of Applied Physics 110, no. 3, 2011.

78. Magnetization reversal mechanism in exchange-biased FeMn/FeCo systems

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Several spintronics devices are based on the exchange interaction between an antiferromagnetic (AFM) and a ferromagnetic (FM) film in a bilayer structure. Such interaction causes a shift of the FM hysteresis loop along the magnetic field axis, known as exchange bias (EB) effect. FeMn and FeCo are good candidates as AFM and FM materials, respectively, since they can manifest EB at room temperature when coupled together. We present an extensive study of Cu/FeMn/FeCo/Cu stacks grown by rf magnetron sputtering on silicon. After optimization of the growth parameters of each individual layer, in order to deepen the understanding of the magnetization reversal mechanism at the FM/AFM interface which leads to EB, we have monitored the magnetization response under different conditions, revealing the presence of training effects, aging, and relaxation processes. These observations, in conjunction with first order reversal curves (FORC), are used to interpret and single out the symmetric/asymmetric different processes taking place during the ascending and descending branches of hysteresis, establishing the role played at the interface by distinct contributions controlling the magnetization reversal. In addition, we propose for the first time a study done with the help of new investigation techniques typical of nonlinear systems.

79. Exchange Bias of Co/CoO Films on Periodically Modulated Substrates

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The exchange bias phenomenon has extensively been studied due to its applications in magnetoelectronics devices, but its complete understanding is still lacking. To achieve the full understanding of EB, besides studies on thin film ferromagnetic-antiferromagnetic bilayers and ferromagnetic nanoparticles coated by an antiferromagnetic layer, other structures such as nanowires and nanostructured 2-D networks have also been explored. Here, we report a new system that exhibits enhanced exchange bias – periodically modulated thin films. The samples were prepared by self-assembling monodispersed polystyrene particles. Comparing to the flat film with the same thickness, the coercivities (Hc) of modulated films are dramatically increased (more than doubled) with a slight change of the squareness. The exchange bias (He) is also greatly increased, especially for thick (> 20nm) films. In addition, the exchange bias increases with the wavelength of the modulation. The large Hc and He increases can be attributed to the angular distribution of the spins of Co atoms in CoO located on the surface, and the better sampling of this distribution in the modulated films.

80. Factors affecting Transitions in Nanostructured FeRh

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Material systems possessing magnetostructural transitions are of particular interest for potential devices requiring functional effects upon the application of small stimuli such as temperature, strain, or magnetic field. Bulk equiatomic FeRh has a first-order magnetostructural phase transition on heating through Tt ~370 K, comprising of a transition from antiferromagnetic to ferromagnetic behavior accompanied by a ~1% unit cell volume expansion. [1] Modification of the FeRh Tt may be achieved through strain. [2] It is anticipated that nanostructured FeRh will exhibit an altered magnetostructural transition due to an enhanced surface to volume ratio and additional strain considerations. In this study, the nanostructuring of FeRh in an embedded copper matrix has been explored in the context of strain and size effects. Nanostructured FeRh films were synthesized through room temperature RF co-sputtering at 50W of arc melted FeRh chips on a copper target. Post deposition annealing was done under vacuum from 300ºC to 1000ºC at increments of 100ºC. The influence of growth conditions and post growth annealing temperatures on the structure and phase evolution of the films was investigated using Scanning Electron Microscopy (SEM), Atomic Force Microscopy (AFM), and X-ray Diffraction (XRD). The magnetic character was then probed using both Magnetic Force Microscopy (MFM) and Superconducting Quantum Interference Device (SQUID) magnetometry in fields up to 5T and temperatures ranging from 10K to 350K. Significant changes are observed in morphology and structure in addition to noted differences in magnetic character as a function of annealing temperature. Upon heat treatment, FeRh particles begin to form in the surrounding matrix; sizes range from roughly 50 to 200 nm. In this manner, insight into the strain character and magnetic properties may be obtained to facilitate tailoring of nanostructured FeRh for applications such as next generation magnetic memory storage or advanced sensor devices.

[1] J.S.Kouvel,J.Appl.Phys.**37**,1257(1966).
[2] J.W.Kim,Appl.Phys.Lett. **95**, 222515(2009).

81. Structural Characterization of Co Thin Films with Metastable bcc Crystal Structure Formed on GaAs Si

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Tri-layer films consisting of MgO and metastable bcc-Co layers have been attracted much attention, since the films show high TMR ratios [PRB, 70, 172407 (2004) etc.]. In order to apply metastable films for practical applications, it is important to understand the formation conditions. Thin bcc-Co films have been prepared on GaAs single-crystal substrates [PRL, 62, 2480 (1989) etc.]. In the present study, Co films were deposited on GaAs substrates of (100), (110), and (111) orientations using an UHV magnetron sputtering system equipped with an in-situ RHEED facility. The influences of film thickness and substrate temperature on the structure were investigated. bcc-Co single-crystal films were obtained in early stages of film growth on all the GaAs substrates at RT. The metastable structure was stabilized through hetero-epitaxial growth. With increasing the thickness, the bcc structure transformed into more stable fcc structure though atomic rearrangement in the close-packed planes. The transformation crystallographic orientations were determined by RHEED and pole-figure XRD. When the films were deposited at temperatures higher than 200 °C, Ga atom diffusion from the substrates into the deposited films occurred regardless of the substrate orientation. A Co-Ga alloy phase with B2 structure was formed around the Co/GaAs interfaces. The magnetic properties were investigated by VSM and FMR. The in-plane magnetization properties of bcc-Co films reflected the magnetocrystalline anisotropy of bulk bcc-Co crystal which was predicted by a computer simulation.

82. BLS investigations of perpendicular standing spin waves at Au and Ag particles on top of a NiFe film

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In the last decades localized plasmons excited in metallic nanoparticles providing a local field enhancement were used to increase the signal strength and spatial resolution like in the case of surface enhanced Raman spectroscopy. We present Brillouin light scattering (BLS) studies of perpendicular standing spin waves in a thin Ni81Fe19 film with single Au and Ag nanoparticles on top. An increase of the BLS signal as well as a frequency shift of the spin waves due to the metal nanoparticles is observed. To describe this, and besides their plasmonic properties, other influences of the nanoparticles on the magnetization dynamics have to be taken into account. In order to identify the contributions to the observed signal changes, investigations using different materials, sizes and shapes of the structures have been performed.

83. Spin-dependent transport properties derived from MgO/CuPc hybrid structures

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For the past few years, each interface of ferromagnetic metal(FM)/organic semiconductor(OSC) and oxide/OSC has some improvement in understanding with spectroscopic measurement. Recently, conceptually new properties at an organic/inorganic hybrid interface have been reported like considerable spin-selection ability. [1] And, they are strongly related to transport mechanism. However, understandings in real-operating devices are still lack due to difficulties to combining every phenomenon derived from each part. In this work, we try to understand the role of Cu-phthalocyanine(CuPc) and MgO layers in Fe(001)/MgO(001)/CuPc/Co magnetic tunnel junctions (MTJs). The thin epitaxial Fe(001) film was grown on Si(001) substrate with MgO(001) buffer layer. A 1.6 nm thick epi-MgO(001) layer was utilized as a tunnel barrier. Then, the CuPc layers with different thickness were inserted between the MgO(001) barrier and the poly-Co FM electrode. They are prepared in ultra-high vacuum inorganic/organic dual molecular beam epitaxy chamber. We carried out I-V measurement under various magnetic field and temperature for MTJs with and without MgO(001) layer. We observed ~ 200 % magnetoresistace at 77 K and abrupt change of junction resistance at 220 K. In addition, comparative study of CuPc films prepared by in-situ and ex-situ process was carried out. Moreover, the interfacial properties which are of critical importance for the spin transport, the in-situ surface electronic and chemical analyses were carried out for thin CuPc films grown on both of the MgO(001) and Fe(001) layers by using Metastable De-excitation Spectroscopy (MDS). The electronic band structure at the MgO(001)/CuPc interface will be discussed in a comparison with the Fe(001)/CuPc electronic band structure features. The abrupt change of junction resistance appeared at 220 K from I-V characteristics is also compared with MDS experiment carried out as a function of temperature.

[1] S. Sanvito et al., Nature Physics 6, 562 (2010)

84. Effect of interparticle interactions and size dispersion in magnetic nanoparticle assemblies

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Magnetic nanoparticles (NPs) have a growing interest due to their potential applications in spintronics or biology. In all cases, the understanding of their magnetic properties is essential to use them in a proper way in those applications. Interparticle interactions in magnetic nanoparticles are studied by dc and ac magnetization measurements. For non-interacting nanoparticles, while the anisotropy constant of the nanoparticles Keff=1.6*10^5 erg/cc is accurately determined by fitting zero-field-cooled and field-cooled measurements, we show that Keff values deduced only from time relaxation measurements must reqiure simultaneous adjustments of the complex susceptibility by taking into account the size distribution of nanoparticles. This leads to Keff=1.7*10^5 erg/cc in agreement with dc measurements. For interaction nanoparticles, comparisons with theoretical models show that energies due to magnetic dipolar interactions can only be predicted for weak and moderate interactions. We have demonstrated that time relaxation measurements in NPs assemblies require careful analysis in order to extract correct values of the anisotropy constant. This accurate determination has to be crossed with the adjustment of the complex susceptibility which allows taking into account the size distribution of NPs. Although time relaxation measurements can be fitted by the widely used Vogel-Fulcher’s expression, we argue that the Dormann-Bessais-Fiorani’s model is more appropriate since it clearly gives a quantitative estimation of the induced interaction temperature.

85. Geometry Tuneable Magneto-Optical Kerr Effects in Nickel Nanowire Arrays

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We investigate the magneto-optical properties of arrays of nickel nanowires embedded in an anodised aluminium oxide template grown directly onto glass/silicon substrate by magnetron sputtering. The wires are grown using a self-assembly bottom up technique which provides uniform, quasi-hexagonal arrays over a large area, quickly and at low cost. The tuneability of the magneto-optic response of the arrays is investigated by varying the nanowire dimensions; diameter, length and inter-wire spacing. This type of structure has potential applications in high density magneto-optical data storage (potential for 10^11-12 wires per square inch), ultrafast magneto-plasmonic switching and optical components for telecommunications. In conjunction with simulations and numerical calculations it has been demonstrated that the system acts as a sub-wavelength light trap with enhanced magneto-optical properties at wavelengths directly proportional to the spacing between the wires. Changes in dimensions of the nickel wires on the order of tens of nanometres caused a spectral blue-shift in the peak magneto-optical response of 270 nm.

86. Phase transitions and magnetic properties of Ni-Co-Mn-Al Heusler alloys

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Off-stoichiometric Ni2Mn2-xAlx (x = 0.5 - 1.2) and Ni2+y(Mn1.3Al0.7)1-y/2, (y = 0.04 - 0.12) alloys were prepared to locate the composition range which likely to form the ferromagnetic ordered L21 phase through low-temperature thermal annealing. In the Ni2Mn2-xAlx (x = 0.5- 1.2) series, the alloy partially transformed to the ferromagnetic phase in the narrow composition range of x = 0.8 – 1.1. For the Ni-enriched composition series, Ni2+y(Mn1.3Al0.7)1-y/2, (y = 0.04 - 0.12), magnetic ordering was not observed and the magnetic susceptibility proportionally decreased with the Ni concentration. It was concluded that moving away from stoichiometric composition would likely increase the disordering of Mn and Al site occupation and is not conducive to achieving ferromagnetism in Ni2MnAl. Structural and magnetic phase transitions of Ni1.7Co0.3Mn1+xAl1-x (x = 0.22 – 0.3) alloys were characterized to evaluate the magnetocaloric effect (MCE) of the alloys. The Curie temperature remained at ~ 360 K regardless of the composition whereas the Al fraction determined the temperature and extent of the metamagnetic-type martensitic transition. The alloy with x = 0.26 had the highest peak magnetic entropy change (|ΔSM|pk) of 2.1 J kg-1K-1 and refrigerant capacity (RC) of 49 J kg-1 at an applied field of 10 kOe originating from the martensitic transformation. The extrapolated RC values at 50 kOe were comparable to other Ni-Mn-X alloys chiefly due to the relatively wide operating temperature range. In the case of the alloy with x = 0.3 whose MCE mostly depended on the magnetic transition may serve as a better magnetic refrigerant in spite of its relatively low |ΔSM|pk and RC because of the large thermal and magnetic hysteresis that typically accompanies the martensitic transition. Our result suggests that it should be possible to fine-tune the composition of the quaternary NiCoMnAl alloy to attain optimal magnetocaloric effect near room temperature.

87. Characterization of double barrier magnetic tunnel junctions by current-in-plane tunneling

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For single barrier tunnel junctions, the barrier properties can be assessed just after deposition by measuring electrical transport in full sheet samples. Such measurements are performed with a multi-contact probe with various spacing between contacts. The resistance area product (RA) and magnetoresistance ratio (MR) can be extracted from the voltage variations versus probe position on the sample surface using current-in-plane tunneling (CIPT) technique implemented in Capres set-up. The CIPT technique leads to a significant gain of time since it allows assessing the good quality of the stack prior to microfabrication of the pillars. In this work, we developed an analytical model which allows extending this technique to double barrier diffusive stacks. Our study shows that specific features appear in DBMTJs that are described by introducing two typical length scales. We first check that the model was robust enough to recover already known results for single barrier tunnel junction for example. Then we give a physical interpretation to the two new length scales introduced in the model. Thus, we can clearly understand how electrons travel in these complicated structures depending on the spacing between contacts. The final step is to show that the model is compatible with Capres device. So we confronted our calculation to Capres measurements on unpatterned DBMTJ and provide a fitting procedure to determine the parameters for both junctions (RA1; RA2 and MR1; MR2) just after deposition.

88. Development of a Band-gap Measurement Technique for Half-Metallic Ferromagnetic Ultrathin Films

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Spintronics is a new and active developing field that aims to realise high performance electronic devices. The potential advantages of spintronics are: non-volatile memory, high storage density, high data processing speed and low power consumption. In order to achieve these advantages, there are three key requirements for spintronic devices: high spin polarisation, high Curie temperature (Tc) and control of interface structure. Half-metallic ferromagnets (HMFs) can fulfil these requirements due to their ability to exhibit 100% spin polarisation at the Fermi level (EF). The HMFs are new class of materials that have unique band structures; the majority spin band (usually represented as spin-up band) have metallic band structure while the minority spin band (spin-down band) have semiconducting band structure with a band gap at EF. Therefore, HMFs can be considered as an ideal spin injector into semiconductors and eventually increase the spin-injection efficiency of the spintronic devices. There are four categories of materials that are theoretically predicted to be HMFs; Heusler alloys, zinc-blend compounds, oxide compounds and perovskites. In this study, Co-based full-Heusler alloys are used due to good lattice constant matching with major III-V semiconductors, high Curie temperature (greater than 950K for Co2MnSi),1 and the ability to control spin density of states (DOS) at the EF.1 The main aim of this study is to develop a new technique to directly measure the band-gap of the Heusler alloys. Circularly polarised infrared (IR) light will be used to excite only minority spins in the Heusler alloys. By controlling the wavelength of the IR light, the excitation energy can be matched to the half-metallic band-gap. This technique will allow us to characterise the width of the minority spin band-gap in the Heusler alloys. This technique will accordingly provide feedback to growth to achieve 100% spin polarisation as a prerequisite for spintronics devices.

89. Reconfigurable magnonic crystals based on arrays of identical magnetic nanodots

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Arrays of magnetic nano-dots, coupled by dipole-dipole interaction, are one of the types of magnonic crystals (MC) - structures with periodic variation of magnetic parameters. It has been shown recently that such arrays can form a novel type of artificial materials – dynamic MC – since static magnetic configuration (ground state) of an array is not unique and can be tailored to the demand [1-2]. In this paper we present a method of ground state switching of identical magnetic nanodots array. An array can be easily switched into ferromagnetic state and into some demagnetized state by application of a short magnetic field pulses with typical duration about tens of nanoseconds. By means of numerical simulations we have shown, that structure of a final demagnetized state, which consists of clusters with ideal local antiferromagnetic (AFM) periodicity, significantly depends on length of field pulse’s trailing front – as field decreases slowly, as a final state becomes more regular. We also present an analytical theory which allows one to relate properties of a final state, such as state’s correlation function and linewidth of ferromagnetic resonance, with parameters of field pulse and dots array. These properties are mainly determined by linear stage of growth of instable spin waves (SWs) under time-dependent field at the trailing front of a field pulse and significantly depend only on SW group velocity and a rate of field decreasing. Although one cannot switch a large array (thousands of dots) into a perfect AFM state due to thermal fluctuations, from the point of microwave properties it is enough if cluster sizes A~50 dots, that can be achieved by application of field pulse with typical duration about 50 − 100 ns.

[1] J. Topp, et al., Phys. Rev. Lett. **104**, 207205 (2010).
[2] S. Tacchi, et al., Phys. Rev. B **82**, 184408 (2010).

90. Write Errors in Exchange Coupled Composite Bit Patterned Media Recording

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Estimates for the volume of data stored globally are around 600 exabytes and are constantly growing. The increasing amount of data stored brings associated costs of energy and size and so methods of increasing areal densities are being continually sought. There are currently two factors that limit the density of recording systems - transition noise and the superparamagnetic limit. To address these problems while continuing to increase densities there are two methods that have been suggested; to use exchange coupled composite materials and to pattern arrays of single domain islands. These can be combined together to create exchange coupled composite islands (ECC-BPM), helping to further increase density while keeping achievable write fields. Before ECC-BPM could be used there are problems with this system that must be addressed. A major consideration is that, unlike in conventional media, the write head must be synchronized with the islands, and variations between islands can cause write errors. This project investigates the ability to address individual islands in ECC-BPM using a statistical model previously developed and a quasi-static (drag) measurement system for writing and reading ECC-BPM media samples. We have investigated island variations and their effect on the write window for a given bit error rate(BER). The effect of a very small change in the tail of island parameter distributions showed a significant change in the bit error rate of an ECC BPM system. This work covered island position and anisotropy variations, and expanded to include an investigation of asymmetrical island diameter distributions. Further work will investigate optimization of write window and head positioning and study the relationship between the coercivity of the medium, the maximum head field gradient and the switching position for cross- and down-track islands.