Magnetic Interfaces and Nanostructures Division
Room: 11 - Session MI+BI+EM+SA-MoA

Role of Chirality in Spin Transport and Magnetism

Moderators: Greg Szulczewski, The University of Alabama, Hendrik Ohldag, SLAC National Accelerator Laboratory

1:40pm **MI+BI+EM+SA-MoA1 Spin Transport and Polarization in Chiral Molecules: Theory and Possible Applications**, ***Karen Michaeli***, Weizmann Institute of Science, Israel **INVITED**

The functionality of many biological systems depends on reliable electron transfer. Unlike artificial electric circuits, electron transport in nature is realized via insulating chiral (i.e., parity-symmetry breaking) molecules. Recent experiments have revealed that transport through such molecules strongly depends on the electron's spin relative to the propagation direction. In the talk I will introduce the mechanism behind this phenomenon, which has been dubbed chiral induced spin selectivity (CISS). The discovery of the CISS effect has raised important questions about the role of spin in biological processes more generally, and suggests the possibility of a new class of organic-based nanoscale devices. I will discuss some of the key developments regarding spin selectivity; I will present new questions that arise from these results and offer ideas for their resolution.

2:20pm **MI+BI+EM+SA-MoA3 Enantio-sensitive Charge Transfer in Adsorbed Chiral Molecules Probed with X Ray Circular Dichroism**, *F.J. Luque*, Universidad Autónoma de Madrid, Spain, *I.A. Kowalik*, Polish Academy of Sciences, Poland, *M.Á. Niño*, IMDEA-Nanoscience, Spain, *D. Arvanitis*, Uppsala University, Sweden, ***Juan José de Miguel***, Universidad Autónoma de Madrid, Spain

Recent studies have shown how layers of purely organic, chiral molecules can induce the appearance of strong spin polarization in initially unpolarized electron currents. [1] Furthermore, spin-polarized photoemission experiments comparing adsorbed films of opposite enantiomers of the same chiral molecule have revealed that they can display different behavior, producing spin polarization along different directions in space instead of simply changing its sign. [2]

In this study enantio-pure ultrathin films of chiral 1,2-diphenyl-1,2-ethanediol (DPED) have been deposited on Cu(100) at 100 K and studied at the MAX-lab synchrotron in Lund, Sweden, using circularly polarized x ray absorption (XAS) at the carbon K edge. XAS excites element-specific core electrons to empty levels in the ground state thus probing the molecule's electronic configuration. The different features present in the absorption spectra have been identified and assigned to specific electronic transitions. The comparison of absorption spectra taken with photons of opposite helicity shows a surprisingly strong dichroism localized at transitions into empty molecular orbitals with π character. Theoretical modeling of the spectra reveals that this response is associated to the charge transferred between the Cu substrate and the adsorbed molecules. This charge is found to be polarized in orbital momentum, and the direction of the polarization is different for the two enantiomers studied: (R,R)–DPED and (S,S)–DPED. These findings indicate that chiral organic layers can play an important role in the emerging field of molecular orbitronics.

[1] B. Göhler V. Hamelbeck, T. Z. Markus, M. Kettner, G. F. Hanne, Z. Vager, R. Naaman, and H. Zacharias, Science **331**, 894 (2011).

[2] M. Á. Niño, I. A. Kowalik, F. J. Luque, D. Arvanitis, R. Miranda, and J. J. de Miguel, Adv. Mater. **26**, 7474 (2014).

2:40pm **MI+BI+EM+SA-MoA4 Evolving of Soliton Phase in Exfoliated 2D $Cr_{1/3}NbS_2$ Nanolayers**, *S. Tang*, Oak Ridge National Laboratory and Central South University, China, *J. Yi*, *R. Fishman*, *S. Okamoto*, *Q. Zou*, Oak Ridge National Laboratory, *D.G. Mandrus*, University of Tennessee, ***Zheng Gai***, Oak Ridge National Laboratory

Cr1/3NbS2 is an emergent quasi-2D material that has recently been attracting wide attentions. Cr1/3NbS2 has both chiral helimagnetic behavior and broken inversion symmetry of Cr atoms, the two necessary conditions for creating Dzyaloshinskii–Moriya interaction in skyrmion. Bulk studies show that a nonlinear periodic magnetic state called a soliton lattice exists in the material. By applying microexfoliation techniques, we successfully prepared thin layers of Cr1/3NbS2 with various thickness from single crystal. When the thickness of Cr1/3NbS2 layer falls into the range around the pitch of its helimagnetic state, kinks of field dependent magnetization start to evolve. The new phase is studied experimentally and theoretically. This research was conducted at the Center for Nanophase Materials Sciences, which is a DOE Office of Science User Facility.

3:00pm **MI+BI+EM+SA-MoA5 Tailoring the Chirality of Domain Walls via Interface Modification**, ***Arantzazu Mascaraque***, *S. Ruiz-Gomez*, *M.A. Gonzalez Barrio*, *L. Perez*, Universidad Complutense de Madrid, Spain, *G. Chen*, *A.K. Schmid*, Lawrence Berkeley National Laboratory, *E.G. Michel*, Universidad Autonoma de Madrid, Spain

The possibility of manipulating magnetic domain walls (DWs) without the intervention of magnetic fields has interest for a wide variety of applications, such as spintronic devices [1]. Applying an electric current to a ferromagnet creates a force that drives the DWs in the direction of the electron motion, the so-called Spin Transfer Torque. However, this effect is weak and high current densities are needed. Recently, it has been discovered that spin accumulation at the edges of a current-carrying non-magnetic material due to the Spin Hall Effect (SHE), can exert a torque on the magnetization of a neighboring magnetic layer [2]. The torque induced by SHE depends on the chirality of the DW and, as most ferromagnetic materials lack a well-defined chirality, the device applications are limited. However, the presence of surfaces and interfaces removes the point-inversion symmetry, giving rise to an additional interaction, the Dzyaloshinskii–Moriya interaction (DMI) that lifts the left-right degeneracy through spin-orbit coupling [3].

In this work, we have modified the interface between the substrate and a non-chiral magnetic layer, in order to investigate in which way DW chirality can be induced and stabilized in the magnetic layer. The experiments were done using the SPLEEM instrument of the Lawrence Berkeley National Laboratory. This microscope can map independently and in real space the three magnetic components of the spin structures. The magnetic system was a (Ni/Co)n multilayer epitaxially grown on Cu(111). It is well known that magnetic films grown on Cu(111) do not exhibit homo-chiral DWs [4]. We have found that this behavior can be changed by modifying the interface. After introducing a thin metal layer (suitable to induce a high DMI) between the substrate and the magnetic layer, we have found relevant changes in the chirality of the DWs of the magnetic layer. Our results demonstrate that the buffer layer influences the spin texture, which evolves from non-chiral Bloch to homo-chiral Néel DWs.

[1] S. S. P. Parkin et al, Science 320, pp190 (2008); D. A. Allwood et al , Science 309 , pp1688 (2005)

[2] I. M. Miron Nat. Mat 9 pp230 (2010)

[3] I. E. Dzyaloshinskii , J. Exp. Theor. Phys. 5, pp1259 (2007),; T. Moriya , Phys. Rev. 120 , pp91 (1960).

[4] G. Chen, et al., Ap. Phys. Lett. 106, 062402 (2015)

3:20pm **MI+BI+EM+SA-MoA6 Spin Transport in an Electron Conducting Polymer**, ***Greg Szulczewski***, *T. Sutch*, *M. Lockart*, *H. Chen*, *P. Rupar*, *M. Bowman*, The University of Alabama

We report results from an electron spin resonance (ESR) study to probe the spin-dynamics in the conducting polymer poly {[N, N9 -bis(2-octyldodecyl)-naphthalene-1,4,5,8-bis(dicarboximide)-2,6-diyl]-alt-5,5 9 -(2,2 9 -bithiophene)} or P(NDI2OD-T2). Chemical reduction of the polymer was achieved by using cobaltacene, which introduces unpaired electrons into the polymer. Continuous wave ESR measurements were done on frozen solutions and thin films over the temperature range of 77 to 300 K. Narrow ESR peaks with broad tails were observed, suggesting strong one-dimensional anisotropic conduction. Electron nuclear double resonance spectroscopy was used to analyze the hyperfine coupling of the frozen solutions. The results indicate a proton hyperfine coupling of 1.5 MHz, which suggests the spins are delocalized over several monomer units. Electron spin echo envelope modulation spectroscopy was measured from 6 to 90 K to investigate the spatial distribution of nuclear spins in the environment of the unpaired electrons spins. The measurements show that spin relaxation increases rapidly when the temperature in increases from 6 to 90 K. A kinetic model that accounts for the spin-dynamics will be presented.

4:00pm **MI+BI+EM+SA-MoA8 Utilizing the Chiral induced Spin Selectivity Effect to Achieve Simple Spintronics Devices**, ***Yossi Paltiel***, The Hebrew University of Jerusalem, Israel **INVITED**

With the increasing demand for miniaturization, nano-structures are likely to become the primary components of future integrated circuits. Different approaches are being pursued towards achieving efficient electronics, among which are spin electronics devices (spintronics) [1]. In principle, the application of spintronics should result in reducing the power consumption of electronic devices.

A new, promising, effective approach for spintronics has emerged using spin selectivity in electron transport through chiral molecules, termed Chiral-

Induced Spin Selectivity (CISS) [2]. Recently, by utilizing this effect we demonstrated a magnet-less magnetic memory [3,4]. Also we achieve local spin-based magnetization generated optically at ambient temperatures [5,6]. The locality is realized by selective adsorption of the organic molecules and the nano particles [7]. Lastly we have been able to show chiral proximity induced magnetization on the surface of ferromagnetic and superconducting materials. The magnetization is generated without driving current or optically exciting the system [8,9].

In the talk I will give a short introduction about spintronics and the CISS effect. Then I will present ways achieve simple spintronics devices utilizing the effect.

[1] S. A. Wolf, D. D. Awschalom, R. A. Buhrman, J. M. Daughton, S. von Molnar, M. L. Roukes, A. Y. Chtchelkanova, D. M. Treger; *Science* **294** 1488 (2001).

[2] B. Göhler,V. Hamelbeck, T.Z. Markus, M. Kettner, G.F. Hanne, Z. Vager, R. Naaman, H. Zacharias; *Science* **331,** 894-897 (2011).

[3] O. Ben Dor, S. Yochelis, S. P. Mathew, R. Naaman, and Y. Paltiel *Nature Communications* **4**, 2256 (2013).

[4] G. Koplovitz, D. Primc, O. Ben Dor, S. Yochelis, D. Rotem, D. Porath, and Y. Paltiel; Advanced Materials (2017).

[5] O. Ben Dor, N. Morali, S. Yochelis, and Y. Paltiel; *Nano letters* 14 6042 (2014).

[6] M. Eckshtain-Levi, E. Capua, S. Refaely-Abramson, S. Sarkar, Y. Gavrilov, S. P. Mathew, Y. Paltiel, Y.V Levy, L. Kronik, R. Naaman; *Nature Communications*. **7**, 10744 (2016).

7] O. Koslovsky, S. Yochelis, N. Livneh, M. Harats, R. Rapaport, and Y. Paltiel, *Journal of Nanomaterials* 938495 **2012** (2012).

[8] H. Alpern, E. Katzir, S. Yochelis, Y. Paltiel, and O. Millo; New J. Phys. 18 113048 (2016).

[9] O. Ben Dor, S. Yochelis, A. Radko, K. Vankayala, E. Capua, A. Capua, S.-H. Yang, L. T. Baczewski, S. S. P. Parkin, R. Naaman, and Y. Paltiel; *Nature Communications*, **8** 14567 (2017).

4:40pm **MI+BI+EM+SA-MoA10 Magnetic Nano Platelets based Spin Memory Device Operating at Ambient Temperatures**, ***Guy Koplovitz***, The Hebrew University of Jerusalem, *Y. Paltiel*, The Hebrew University of Jerusalem, Israel

There is an increasing demand for realizing a simple Si based universal memory device working at ambient temperatures. In principle non-volatile magnetic memory could operate at low power consumption and high frequencies. However, in order to compete with existing memory technology, size reduction and simplification of the used material systems are essential. In our work we use the Chiral Induced Spin Selectivity (CISS) effect along with 30-50nm Ferro-Magnetic Nano Platelets (FMNPs) in order to realize a simple magnetic memory device. The vertical memory is Si compatible, easy to fabricate and in principle can be scaled down to a single nano particle size. Results show clear dual magnetization behavior with threefold enhancement between the one and zero states. The magnetization of the device is accompanied with large avalanche like noise that we ascribe to the redistribution of current densities due to spin accumulation inducing coupling effects between the different nano platelets.

5:00pm **MI+BI+EM+SA-MoA11 Magnetization Switching in Ferromagnets by Adsorbed Chiral Molecules without Current or External Magnetic Field**, ***Oren Ben Dor****, The Hebrew University of Jerusalem, Israel

Ferromagnets are commonly magnetized by either external magnetic fields or spin polarized currents. The manipulation of magnetization by spin-current occurs through the spin-transfer-torque effect, which is applied, for example, in modern magnetoresistive random access memory. However, the current density required for the spin-transfer torque is of the order of 1×10^{6} $A\cdot cm^{-2}$, or about 1×10^{25} $electrons\cdot sec^{-1}\cdot cm^{-2}$. This relatively high current density significantly affects the devices' structure and performance. Here, we present a new effect – that of magnetization switching of ferromagnetic thin layers that is induced solely by adsorption of chiral molecules. In this case, about 10^{13} electrons per cm^2 are sufficient to induce magnetization reversal. The direction of the magnetization depends on the handedness of the adsorbed chiral molecules. Local magnetization switching is achieved by adsorbing a chiral self-assembled molecular monolayer on a gold-coated ferromagnetic layer with perpendicular magnetic anisotropy. These results present a simple low power magnetization mechanism when operating at ambient conditions.

*** Falicov Student Award Finalist**

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