Magnetic Interfaces and Nanostructures Division
Room 201A - Session MI+2D+EM+NS-MoA

IoT Session: Symposium on new Magnetic Materials, Devices and Concepts for the Information Society

Moderator: Hendrik Ohldag, SLAC National Accelerator Laboratory

1:20pm **MI+2D+EM+NS-MoA1 "ZOOMING in on Data Storage and the Superb HDD"*, Roger Wood,*** Western Digital **INVITED**

Get ready for a wild ride starting with the vast distances of outer space and ending with the tiny

distances that separate atoms. For a very different perspective on data storage, each slide in the

presentation looks at things on a scale that is a factor of ten smaller than the previous slide. The

common thread is the technology of information storage. Information storage is what defines human

history and it is the machine-readable data storage developed in the last half-century that provides the

foundation of the modern information age. More than anything, data storage implies magnetic

recording and the hard disk drive. The humble Hard Disk Drive contains such exquisite technologies

and operates at such astounding precision that it almost defies belief. Yet, our industry churns out

these devices by the hundreds of millions and sells them for a few tens of dollars each. Please enjoy

this light-hearted logarithmic romp through storage technology from interstellar space to interatomic

spacings.

(The presentation is based on a talk given at the annual ASME ISPS banquet in Santa Clara, California, in June 2016, while the author was with Western Digital Corporation.)

2:00pm **MI+2D+EM+NS-MoA3 Physics and Applications of Spin-transfer Torques*, Andrew Kent,*** New York University **INVITED**

The magnetization of a magnetic material can be reversed by using electric currents that transport spin angular momentum [1]. This was predicted in magnetic tunnel junctions—two metallic ferromagnetic layers separated by a thin insulating barrier—by John Slonczewski in 1989 and demonstrated experimentally about a decade later. This discovery has had an enormous impact on magnetism research and technology [2], as prior to this the primary means to reorient the magnetization of a magnet was by applying magnetic fields (dating to 1819 and Oersted!). In this talk I will highlight some of the physics and applications enabled by the discovery of spin-transfer torques. This includes recent experiments that create localized spin-wave excitations (magnons droplets) in thin films with uniaxial magnetic anisotropy [3]. Spin-transfer torques also permit study of magnetic analogues of superconductivity, superfluidity and the Josephson effect that promise to increase our understanding of collective quantum effects. They may even enable braiding Majorana fermions [4]. Finally, I will discuss spin-torque switching of perpendicularly magnetized magnetic tunnel junctions [5], the basic device used in spin-transfer torque magnetic random access memories.

[1] A. Brataas, A. D. Kent and H. Ohno, "Current-Induced Torques in Magnetic Materials," Nature Materials **11**, 372 (2012)

[2] A. D. Kent and D. C. Worledge, "A new spin on magnetic memories," Nature Nanotechnology **10**, 187 (2015)

[3] D. Backes, F. Macia, S. Bonetti, R. Kukreja, H. Ohldag and A. D. Kent, "Direct Observation of a Localized Magnetic Soliton in a Spin-Transfer Nanocontact," PRL **115**, 127205 (2015)

[4] Alex Matos-Abiaguea, Javad Shabani, Andrew D. Kent, Geoffrey L. Fatina, Benedikt Scharfa, Igor Žutić, "Tunable magnetic textures: From Majorana bound states to braiding," Solid State Communications **262**, 1 (2017)

[5] C. Hahn, G. Wolf, B. Kardasz, S. Watts, M. Pinarbasi, A. D. Kent, "Time-resolved studies of the spin-transfer reversal mechanism in perpendicularly magnetized magnetic tunnel junctions," Physical Review B **94**, 214432 (2016)

*Work done in collaboration with Dirk Backes, Gabriel Chaves, Daniel Gopman, Christian Hahn, Jinting Hang, Yuming Hung, Ferran Macia, Daniele Pinna, Laura Rehm, Debangsu Roy, Javad Shabani and Volker Sluka at NYU; Georg Wolf, Bartek Kardasz, Steve Watts and Mustafa Pinarbasi at Spin Transfer Technologies Inc.;and Hendrik Ohldag at SSRL

2:40pm **MI+2D+EM+NS-MoA5 Hybrid Magnetic Heterostructures*, Ivan K. Schuller,*** *A. Basaran,* University of California, San Diego*; J. de la Venta,* Colorado State University*; J.G. Ramirez,* Universidad de los Andes, Colombia*; T. Saerbeck,* Institute Laue-Langevin, France*; I. Valmianski,* University of California, San Diego*; X. Batlle,* University of Barcelona, Spain **INVITED**

Hybrid materials allow the engineering of new material properties by creative uses of proximity effects. When two dissimilar materials are in close physical proximity the properties of each one may be radically modified or occasionally a completely new material emerges. In the area of magnetism, controlling the magnetic properties of ferromagnetic thin films without magnetic fields is an on- going challenge with multiple technological implications for low- energy consumption memory and logic devices. Interesting possibilities include ferromagnets in proximity to dissimilar materials such as antiferromagnets or oxides that undergo metal-insulator transitions. The proximity of ferromagnets to antiferromagnets has given rise to the extensively studied Exchange Bias[1].

In a series of recent studies, we have investigated the magnetic properties of different hybrids of ferromagnets (Ni, Co and Fe) and oxides, which undergo metal-insulator and structural phase transitions. Both the static as well as dynamical properties of the ferromagnets are drastically affected. Static properties such as the coercivity, anisotropy and magnetization [2-3] and dynamical properties such as the microwave response are clearly modified by the proximity effect and give raise to interesting perhaps useful properties.

Work supported by US-AFOSR and US-DOE

Selected References:

[1] *Exchange Bias,*Josep Nogues and Ivan K. Schuller, J. Magn. Magn. Mater. 192, 203 (1999).

[2] *Control of Magnetism Across Metal to Insulator Transitions*, J. de la Venta, Siming Wang, J. G. Ramirez, and Ivan K. Schuller, App. Phys. Lett. 102, 122404 (2013).

[3] *Coercivity Enhancement in V_2O_3/Ni Bilayers Driven by Nanoscale Phase Coexistence*, J. de la Venta, Siming Wang, T. Saerbeck, J. G. Ramirez, I. Valmianski, and Ivan K. Schuller, Appl. Phys. Lett. 104, 062410 (2014).

[4] *Collective Mode Splitting in Hybrid Heterostructures*, Juan Gabriel Ramírez, J. de la Venta, Siming Wang, Thomas Saerbeck, Ali C. Basaran, X. Batlle, and Ivan K. Schuller, Phys. Rev. B, **93**, 214113 (2016).

3:40pm **MI+2D+EM+NS-MoA8 Organismic Materials and Intelligence*, Shriram Ramanathan,*** Purdue University **INVITED**

Intelligence in the natural world is panspermic to life, ranging from basic survival skills in non-neural organisms to co-operative foraging and complex mating strategies in higher level animals. We ask the question whether such remarkable features can be implemented in the physical world utilizing adaptive matter. We have identified strongly correlated semiconductors, one class of quantum materials as particularly suited for this effort, owing to their remarkable electronic plasticity. One may refer to these systems as organismic materials that display certain well-defined characteristics of living beings. In this presentation, we will present examples from the animal kingdom focusing on intelligence and episodic memory. Then we will discuss recent collaborative studies on correlated oxides demonstrating ancestral intelligence. We will conclude with examples of neural networks that can be designed with quantum materials that can replicate fundamental animal learning traits. The role of defects, strain and orbital occupancy control in design of electronic plasticity will be highlighted.

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