Magnetic Interfaces and Nanostructures Division
Room A210 - Session MI+2D-WeA

Emerging Multifunctional Magnetic Materials II

Moderators: Valeria Lauter, Oak Ridge National Laboratory, Axel Hoffmann, Technical University of Berlin

2:20pm **MI+2D-WeA1 Field and Current Control of the Electrical Conductivity of an Artificial Two-Dimensional Honeycomb Lattice*, Deepak Singh,*** University of Missouri **INVITED**

Two-dimensional magnetic nanostructured geometry, such as an artificial magnetic honeycomb lattice, provides facile platform to explore many novel properties of magnetic materials in one system. Originally envisaged to explore the physics of effective magnetic monopoles and magnetic field-induced avalanche of Dirac string, artificial magnetic honeycomb lattice has emerged as a key playground to discover new and exotic magnetic phases, such as magnetic charge ordered state and the spin solid state, in disorder free environment. We have created a new artificial permalloy honeycomb lattice of ultra-small connected element, with a typical length of ~ 12 nm, in this pursuit. Using neutron scattering and complementary measurements on the newly created honeycomb lattice, we have investigated emergent phenomena of short-range quasi-spin ice and long range spin solid order. Additionally, two new properties of Wigner crystal type state of magnetic charges and magnetic diode-type rectification are discovered in the newly created artificial honeycomb lattice. The new findings create a new vista for the next generation design of spintronics devices in this two-dimensional frustrated geometry. Research at MU is supported by the U.S. Department of Energy, Office of Basic Energy Sciences under Grant No. DE-SC0014461.

3:00pm **MI+2D-WeA3 Emergence and Dynamics of Magnetic Order in Metamagnetic Nanostructures*, Vojtech Uhlir,*** CEITEC BUT, Brno University of Technology, Czech Republic **INVITED**

The advantage of ferromagnetic materials is the nonvolatility of the information encoded in the internal magnetic configuration, which can be used for memory storage, logic and sensing devices. Antiferromagnets are another class of magnetic materials that features nonvolatile magnetic ordering, yet its applications have been largely overlooked until recently [1]. In materials featuring a first-order metamagnetic phase transition between the antiferromagnetic (AF) and ferromagnetic (FM) states, the nature of the phase transition can be tuned by strain, pressure, chemical doping, temperature, as well as magnetic and electric fields, potentially offering very high recording densities and huge changes in the order parameters controlled with very low power.

Moreover, metamagnetic materials are outstanding candidates for finding and exploiting new functionalities and emergent phenomena on the mesoscale [2,3]. For instance, the transition from the AF order to FM order in sub-micron-wide FeRh wires becomes greatly asymmetric when comparing the heating and cooling cycles [3,4]. This recovery of the abrupt transition in nanostructures could lead to low-energy, efficient routes to control magnetic properties, leading to potential applications, for instance, in spintronics.

Furthermore, we show the dynamic response of the electronic and magnetic order to ultrafast laser excitation can be followed by time-resolved photoemission electron spectroscopy [5], which unlike techniques probing the total magnetization in the sample provides a direct comparison to the dynamic response of the structural order.

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4:20pm **MI+2D-WeA7 Time Dependence in $La_{0.7}Sr_{0.3}MnO_3$ Thin Films with Magnetic Competition*, Mikel B. Holcomb,*** *R.B. Trappen, N.M. Mottaghi, S.F. Yousefi, G. Cabrera, G. Bhandari, M.S.S. Seehra,* West Virginia University

$La_{0.7}Sr_{0.3}MnO_3$ is a strongly correlated ferromagnetic system, commonly proposed for many magnetoresistance applications. Utilizing many techniques (bulk magnetometry, neutron reflectometry and resonant x-ray magnetic scattering), we observe magnetic competition between different magnetic phases in many samples under various growth conditions. This competition results in inverted hysteresis loops (common in superparamagnetic nanoparticles) and negative remanent magnetization. While transmission electron microscopy images show pristine epitaxial growth, the data supports that there are regions of different magnetic order. This results in interesting magnetic measurements, that share similarities with ferrimagnets with competing magnetic lattices. In this talk, the time, field and temperature dependence of these samples will be discussed to help understand this phenomenon. Sample growth and optimization were supported by NSF (DMR-1608656), national facility measurements and theory were supported by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences under Award Number DE-SC0016176, and optical measurements by American Chemical Society (PRF #56642-ND10). **We acknowledge the support of the National Institute of Standards and Technology, U.S. Department of Commerce, in providing the neutron research facilities used in this work.**

4:40pm **MI+2D-WeA8 Optically Induced Magnetization through Spin States at Perovskite/Ferromagnetic Interface Revealed by Neutron Magnetoreflectivity Studies*, Bin Hu,*** University of Tennessee Knoxville **INVITED**

This presentation reports an optically induced magnetization at perovskite/ferromagnetic interface realized at room temperature. By using neutron magnetoreflectivity measurement, it was found that a circularly polarized light of 405 nm induces a magnetization with the thickness up to 5 nm into the surface of perovskite ($MAPbBr_3$) film underneath of ferromagnetic Co layer at room temperature. On contrast, a linearly polarized light does not generate any detectable magnetization within the perovskite surface in the $MAPbBr_3$/Co sample during the neutron magnetoreflectivity measurement. This observation provides an evidence to show optically induced magnetization on the perovskite surface in contact with Co surface. Furthermore, the $MAPbBr_3$/Co interface demonstrates a magneto-capacitance phenomenon, indicating that the electrical polarization on perovskite surface is coupled with magnetic polarization on the Co surface. On the other hand, a circularly polarized light leads to spin states in hybrid perovskites through photoexcitation. The observed magnetization indicates that circularly polarized light-generated spin states can directly interact with electric-magnetic coupling, leading to an optically induced magnetization.

5:20pm **MI+2D-WeA10 Effect of Interlayer and Underlayers on the Microstructure and Magnetic Softness in FeGa-based Ferromagnetic Composites*, Adrian Acosta,*** *K. Fitzell,* University of California, Los Angeles*; C. Dong,* Northeastern University*; M. Zurbuchen, N.X.S. Sun, J.P. Chang,* University of California, Los Angeles

Magnetoelectric materials provide the ability to efficiently control magnetism with electric fields, which is key to circumvent the size and efficiency limitations of traditional electric dipole antennas. Strain-mediated multiferroic antennas, composed of individual ferromagnetic and piezoelectric phases, have recently generated a lot of interest due to the potential to reduce the size of antennas by up to 5 orders of magnitude through the coupling of magnetization and electric polarization via strain at the interface. However, this requires a low-loss magnetic material with strong magnetoelastic coupling at high frequencies.

Galfenol (Fe81Ga19 or FeGa) is a promising candidate material due to its large magnetostriction (~275 ppm in polycrystalline bulk) and large piezomagnetic coefficient (>2 ppm/Oe) but is highly lossy at high microwave frequencies. Previously, nanoscale laminates were fabricated via DC magnetron sputtering of FeGa with NiFe as an interlayer material resulting in a composite with a small coercive field (<20 Oe), narrow FMR linewidth (<35 Oe), and high relative permeability (>1000) [1]. In this work, the enhancement in soft magnetic properties is correlated to the microstructure of these composites by TEM analysis where the nanolayering strategy promotes the formation smaller grain sizes. Optical magnetostriction measurements displayed an enhanced magnetostriction beyond that expected from averaging the individual FeGa and NiFe phases, indicating an interfacial contribution present leading to increase of the overall magnetostriction. The magnetostriction sensitivity peaks at a lower magnetic field (23 Oe for FeGa/NiFe multilayers vs 56 Oe for FeGa). To delineate the impact of the microstructure of FeGa on the soft and functional magnetic properties, FeGa was sputter deposited onto several materials (NiFe, Ta, Cu, and Al_2O_3) as underlayers on a Si substrate which can directly influence the polycrystalline structure and enhance its soft magnetic properties [2]. XRD and AFM are used to show the dependence of the coercivity, FMR linewidth, and magnetostriction on the texture, internal stress, grain size, and surface roughness of the FeGa film with the different underlayer materials.

Integration of these engineered composites into a strain-mediated multiferroic shear wave antenna design further demonstrates the potential of FeGa-based laminates for use in microwave communications systems for implantable medical devices.

References:

[1] Rementer, C. R., et al. (2017). *Applied Physics Letters* 110(24): 242403.

[2] Jung, H., et al. (2003). *Journal of Applied Physics* 93(10): 6462-6464.

5:40pm **MI+2D-WeA11 Tunable Spin-polarized Edge Effects in Transition Metal Dichalcogenides on FM and AFM Substrates**, *N. Cortes,* Universidad Tecnica Federico Santa Maria, Chile*;* ***Oscar Avalos-Ovando,*** Ohio University*; L. Rosales, P. Orellana,* Universidad Tecnica Federico Santa Maria, Chile*; S. Ulloa,* Ohio University

We explore proximity-induced ferromagnetism (FM) and antiferromagnetism (AFM) on transition metal dichalcogenide (TMD), focusing on molybdenum ditelluride (MoTe2) ribbons with zigzag and/or armchair edges, deposited on either a FM or an AFM substrate, e.g. such as FM europium oxide and AFM manganese oxide. A three-orbital tight-binding model allows to model MoTe2 monolayer structures in real space, incorporating the exchange and Rashba fields induced by proximity to the substrate. For in-gap Fermi levels, electronic modes in the nanoribbon are strongly spin-polarized and localized along the edges, acting as 1D conducting channels with tunable spin-polarized currents. We also study the effect of atomic defects on the 1D conducting channels and on the spin-polarized currents, finding that even in the presence of either Te and/or Mo vacancies, the spin-polarized current is nonvanishing. Hybrid structures such as the MoTe2/FM-substrate and/or MoTe2/AFM- substrate configuration can serve as building blocks for spintronic devices and provide versatile platforms to further understand proximity effects in diverse materials systems.

[1] N. Cortes et al, Phys. Rev. Lett. 122, 086401 (2019).

[2] N. Cortes et al, in preparation (2019).

N.C. acknowledges support from Conicyt grant 21160844, DGIIP and the hospitality of Ohio University. L.R. and P.A.O. acknowledge FONDECYT grant 1180914 and DGIIP USM internal grant. S. E. U. and O. A.-O. acknowledge support from NSF DMR-1508325.

6:00pm **MI+2D-WeA12 Magnetocaloric Properties of Thin Film $La_{0.7}Sr_{0.3}MnO_3$: Magnetic Field Dependence and Effects of Superparamagnetism**, ***Navid Mottaghi***[1]*, M.S.S. Seehra, C.-Y. Huang, S. Kumari, S. Yousefi Sarraf, G. Cabrera, G. Bhandari, R.B. Trappen, M.B. Holcomb,* West Virginia University

$La_{0.7}Sr_{0.3}MnO_3$ (LSMO) with Curie temperature $T_C \approx 370$ K is one of the manganites which has been of interest for applications in magnetic memory devices and spintronics.[1] The magnetic properties of LSMO thin films are also known to depend on the thickness of the films.[2] Recent magnetic investigations of a 7.6 nm LSMO film grown by pulsed laser deposition (PLD) showed it to have a $T_C \approx 290$ K with a magnetic dead layer $d \approx 1.4$ nm which demonstrated behavior consistent with containing superparamagnetic (SPM) spin clusters with blocking temperature $T_B \approx 240$ K.[3,4] Here we report magnetocaloric properties of this LSMO thin film for temperatures $T \leq T_C$ in magnetic fields H up to 4 kOe. In particular, magnetic entropy $S_M(T, H)$ is evaluated from the isothermal plots of magnetization (M) vs. H at different temperatures (Fig. 1) using the Eq. $\Delta S_M (T,H)= \sum_i [(M_{i+1} (T_{i+1}, H) - M_i (T_i, H))/(T_{i+1}-T_i)] \Delta H$. The H-dependence of $\Delta S_M (T,H)$ is analyzed using the relation $(-\Delta S_M)=aH^n$, where a is a constant and n =2/3 is expected at $T = T_C$.[5] Our fit of the data to this Eq. for several $T \leq T_C$ in Fig. 2 shows $n \sim 1$ for $T < T_C$ with the magnitude of n increasing for $T > T_C$. This deviation of n from n = 2/3 is likely due to presence of SPM spin clusters in the dead layer for $T < T_C$. The larger magnitudes of n for $T > T_C$ is due to the Curie-Weiss variation of the magnetization in this regime.[5]

References

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[1] **Falicov Student Award Finalist**

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