Magnetic Interfaces and Nanostructures Division
Room 330 - Session MI-WeA

Spin Landscape II (Magnetic Structures in Real and Momentum Space)

Moderator: Markus Donath, Muenster University, Germany

2:20pm **MI-WeA-1 Exploring Magnetic Reversal Behavior and Domain Structure in Perpendicular Anisotropy Layered Synthetic Antiferromagnets*, Olav Hellwig,*** Chemnitz University of Technology and Helmholtz Zentrum Dresden-Rossendorf, Germany **INVITED**

In atomic antiferromagnets (AFMs) neither the magnetic field reversal behavior nor the magnetic domain structure are easily accessible. The reason for that is the usually very strong antiferromagnetic (AF) exchange interaction, yielding switching fields in the range of many Tesla and the even microscopically compensated magnetic moment without any significant stray fields to detect.

The situation is different in perpendicular magnetic anisotropy layered synthetic AFMs employing interlayer exchange coupled thin film multilayers with a significantly reduced AF-exchange interaction (based on the well-known Ruderman-Kittel-Kasuya-Yosida (RKKY) interaction), which we use here to explore the magnetic reversal behavior and domain structure in layered type AFMs [1-7]. This model system also has the advantages of easy fabrication via conventional sputter deposition techniques and being compatible with smooth amorphous substrates, such as Si/SiO_2 *wafers. Furthermore it is possible to tune the strength of the RKKY-type AF-interlayer exchange continuously via the individual thicknesses of the coupling layers (here are mostly Ru and Ir used).*

The significantly reduced AF-exchange interaction strength becomes now also comparable to other magnetic energy terms, such as the anisotropy or demagnetization energy. This creates - to atomic AFMs unknown and so far unexplored - competitive magnetic energy landscapes. They lead to new reversal modes and domain structures, as we subsequently reduce the strength of the AF-interlayer exchange coupling from its dominating position [5] first below the perpendicular anisotropy energy [1-4,6,7] and second below the demagnetization energy of the layered AF system.

We will discuss the physics behind such new reversal modes and domain structures in perpendicular anisotropy layered synthetic AFMs and highlight potential applications in the arena of nanomagnetism and spintronics. Finally we will also point out in what respect such systems provide design aspects and opportunities beyond the scope of conventional atomic AFMs, in particular in the light of "Imperfectly Perfect Materials".

References:

[1] O. Hellwig et al., Nature Materials 2 (2003) 112.

[2] O. Hellwig, et al., Phys. Rev. Lett. 91 (2003) 197203.

[3] O. Hellwig et al., J. Magn. Magn. Mater. 319 (2007) 13.

[4] O. Hellwig et al., Appl. Phys. Lett. 98 (2011) 172503.

[5] B. Böhm et al., Phys. Rev. B 100 (2019) 40411(R).

[6] L. Koch et al., Phys. Rev. Appl. 13 (2020) 024029.

[7] F. Samad et al., Appl. Phys. Lett. 119 (2021) 022409.

3:00pm **MI-WeA-3 Influence of Underlayer Quality and Sputter Gas Pressure on Structural and Magnetic Properties of Co/Pt Multilayers*, Rico Ehrler*,** *T. Uhlig, O. Hellwig,* Chemnitz University of Technology, Germany

Co/Pt multilayers (MLs) are standard systems for perpendicular anisotropy layered thin films. They are fully tunable via their layer thicknesses and number of repeats and can be easily fabricated using sputter deposition on amorphous substrates. Moreover, they were intensively investigated for their well-ordered stripe domain and bubble states [1,2] and as potential recording media [4]. Synthetic antiferromagnets with perpendicular anisotropy can also be based on these ML systems [5]. The growth conditions of the MLs are of particular importance for fine-tuning their structural and magnetic properties.

As was already shown in the literature, seed layers [4,6] and sputter gas pressure during deposition [1,3] are two very important factors that influence the structural as well as magnetic properties profoundly. The use of a specific underlayer is a common practice to define a crystalline texture for the ML on amorphous substrates. Pt and Pd are widely used as seed layer materials, sometimes in combination with additional, very thin adhesion layers to obtain a good bonding to the substrate [4,6].

For low sputter pressures, the ML is well-defined with sharp interfaces and a continuous, closed film that maintains a laterally continuous strong magnetic exchange. Under these conditions, well-ordered stripe domains and bubble states can form, which can be moved via external fields or currents laterally across the magnetic thin film [1,2]. At high deposition pressures, the MLs grow in a more isolated, granular fashion [1,3]. The layer structure shows a higher degree of disorder and a distinct reduction in the lateral exchange between adjacent grains. Such a microstructure is desirable for magnetic recording media, as it enables the static bit-wise storage of data, where every bit consists of many significantly smaller and magnetically isolated grains [1].

In this context, we will discuss the influence of the Pt seed on the structural and magnetic properties of the Co/Pt ML system, with emphasis on the impact of deposition pressure and adhesion layer. A systematic variation of the underlayer is presented for different ML deposition pressures, changing the characteristics from a continuous thin film to an isolated grain structure.

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[2] K. Chesnel et al., Phys. Rev. B, vol. 98, p. 224404, 2018

[3] J. A. Thornton, Annu. Rev. Mater. Sci., vol. 7, pp. 239–260, 1977

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[5] B. Böhm et al., Phys. Rev. B, vol. 100, p. 140411, 2019

[6] S. Emori and G. S. D. Beach, J. Appl. Phys., vol. 110, p. 033919, 2011

3:20pm **MI-WeA-4 Thickness and Oxygen Growth Pressure Effects on Spontaneous Magnetization Reversal*, Mikel Barry Holcomb,*** *G. Bhandari, N. Mottaghi, R. Trappen,* West Virginia University

Utilizing many techniques (bulk magnetometry, neutron reflectometry and resonant x-ray magnetic scattering), we have discovered and explored spontaneous magnetization reversal in complex oxide La0.7Sr0.3MnO3 thin films. The spontaneous magnetization reversal occurs at low applied fields and originates from the competition between different types of magnetic order. While the overall effect is observed across many sample thicknesses and oxygen growth pressures, these parameters affect the behavior systematically. Films were grown by pulsed laser deposition with reflection high energy electron diffraction to ensure layer-by-layer and high-quality growth.

4:20pm **MI-WeA-7 Thermally Induced Magnetic Order from Glassiness in Elemental Neodymium*, Daniel Wegner,*** Radboud University, Netherlands **INVITED**

I will present results from our most recent spin-polarized scanning tunneling microscopy (SP-STM) study of single crystalline elemental neodymium (Nd) metal, which is a self-induced spin glass in its ground state [1]. Temperature in thermodynamics is synonymous with disorder, and responsible for ultimately destroying ordered phases. We found an unusual magnetic transition where, with increasing the temperature, long-range multi-Q magnetic order emerges from the glassy state [2]. Using temperature-dependent SP-STM, we characterized the local Q order in the spin-Q glass phase and quantified the emergence of long-range multi-Q order with increasing temperature. We developed two distinct analysis tools, which enable the quantification of the glass transition temperature, based on measured magnetization images. We compared these observations with atomic spin dynamics simulations, which reproduce the qualitative observation of a phase transition from a low-temperature spin glass phase to an intermediate ordered multi-Q phase. These simulations trace the origin of the unexpected high temperature order in weakened frustration driven by temperature-dependent sublattice correlations. Our findings constitute an example of order from disorder and provide a rich platform to study magnetization dynamics in a self-induced spin glass.

1. U. Kamber, A. Bergman, A. Eich, D. Iuşan, M. Steinbrecher, N. Hauptmann, L. Nordström, M. I. Katsnelson, D. Wegner, O. Eriksson, and A. A. Khajetoorians, *Science* 368, 966 (2020).
2. B. Verlhac, L. Niggli, A. Bergman, U. Kamber, A. Bagrov, D. Iuşan, L. Nordström, M. I. Katsnelson, D. Wegner, O. Eriksson, and A. A. Khajetoorians, *Nature Physics* (accepted), arXiv:2109.04815 (2022).

5:00pm **MI-WeA-9 Designing Antiferromagnetic Domain Landscapes via Focused Ion Beam Irradiation***, **Fabian Samad**,* Helmholtz-Zentrum Dresden - Rossendorf, Germany*; G. Hlawacek,* Helmholtz Zentrum Dresden-Rossendorf, Germany*; L. Koch,* Technische Universität Chemnitz, Germany*; X. Xu,* Helmholtz Zentrum Dresden-Rossendorf, Germany*; O. Hellwig,* Helmholtz-Zentrum Dresden - Rossendorf, Germany

Layered thin film synthetic antiferromagnets (SAFs) are highly promising candidates for future technological applications, particularly in nanomagnetism and spintronics [1]. Their magnetic properties can be easily tuned by changing the individual layer-thicknesses and also further manipulated post-deposition by applying magnetic fields or electric currents [2]. Antiferromagnetic domains in SAFs are of specific interest, as they possess strongly desirable properties, such as high stability against external magnetic fields, and large domain wall velocities [3]. However, due to the absence of a net magnetization, the deterministic creation of microscopic SAF domains is challenging [2,4].

In this project, we show that ion beam irradiation can be used to ‘write’ complex microscopic SAF domain patterns [5]. For this, we employ a nanometer-focused He+ ion beam, which intermixes the layer interfaces, thus changing the local magnetic properties in a controlled manner. We report highly tunable magnetic and magnetoresistive behavior of the various SAF domain patterns in the presence of externally applied magnetic fields and electric currents.

[1] Duine et al., Nature Phys 14, 217–219 (2018), [2] Hellwig et al., J. Magn. Magn. Mater. 319, 13-55 (2007),[3]Yang et al., Nature Nanotech 10, 221–226 (2015),[4] Albisetti et al., Adv. Mater. 2020, 32, 1906439,[5] Samad et al., Appl. Phys. Lett. 119, 022409 (2021).

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