SLS Symposium on

Magnetism

Tuesday, June 13, 2017

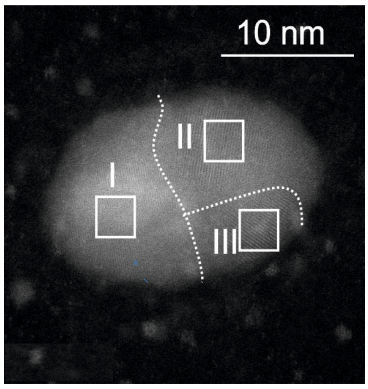
10:00 to 11:45, WBGB/019

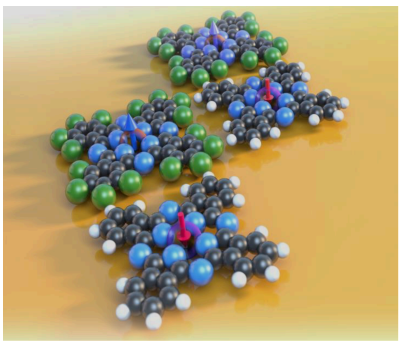
10:00 Studying the correlation of magnetism and atomic structure of individual cobalt nanoparticles
Tatiana M. Savchenko, A. Béché, M. Timm, D. M. Bracher, G. Khadra, A. Tamion, F. Tournus, C. Albin, V. Dupuis J. Verbeeck, F. Nolting, and A. Kleibert

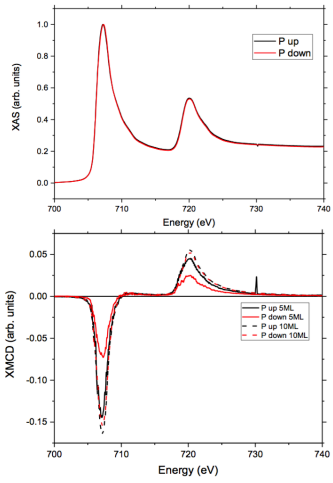
10:30 Unraveling surface enabled phenomena in low dimensional systems
Milos Baljozovic, J. Nowakowski, J. Girovsky, C. Wäckerlin, J. Dreiser, A. Kleibert, S. Decurtins, S-X Liu, P. M. Oppeneer, N. Ballav, T. A. Jung

11:00 Coffee

11:15 Magnetoelectric coupling between ultrathin Fe films and PMN-PT
Sridhar Reddy Avula Venkata, J.Heidler, J.Dreiser, J.Vijaykumar, L.Howald, F.Nolting and C. Piamonteze







Studying the correlation of magnetism and atomic structure of individual cobalt nanoparticles

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Nanosized cobalt particles can be stabilized in various crystal structures, each with distinct magnetic properties [1,2], an aspect that can be explored for applications such as spintronics and data storage [3], where specific magnetic properties are required. However, control over the magnetic properties of cobalt nanoparticles has not yet been achieved, partly due to a lack of knowledge about the detailed relation between structure and magnetism [4]. Indeed, a poorly understood wide dispersion of magnetic properties has been experimentally observed in fcc Co nanoparticles. In particular, the magnetic anisotropy has been shown to vary over five orders of magnitude [5]. Here we address this aspect of nanomagnetism by directly investigating the magnetic response and structure of single nanoparticle by combining X-ray photo-emission electron microscopy (X-PEEM) with high-resolution scanning transmission electron microscopy (HR-STEM), cf. Fig. 1. Our data suggest that for fcc cobalt nanoparticles the magnetic properties are determined by a complex competition of shape, surface and structural contributions, which may mask the expected size dependence of the magnetic properties of nanoparticles, as magnetic energy barriers.

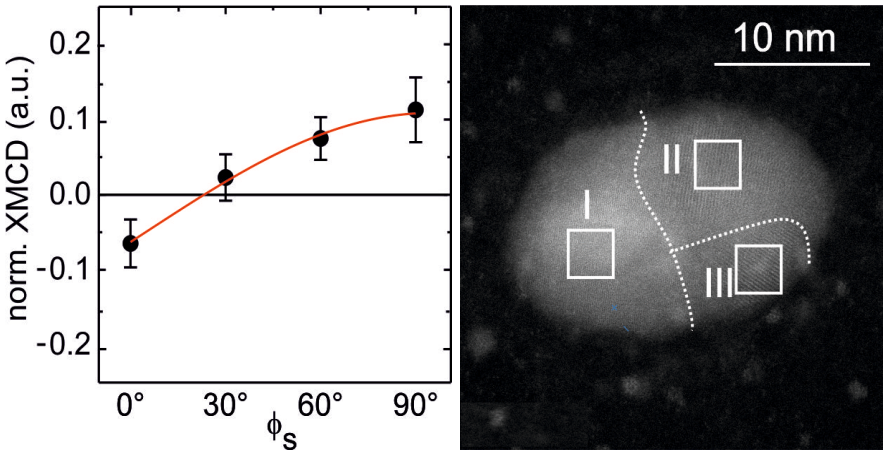

Fig.1. Left: angular dependence of XMCD contrast from an individual nanoparticle shown in the right panel. Right: HAADF STEM image of an elongated nanoparticle with crystalline domains shown with dashed lines and square boxes

References:

[1] O. Kitakami *et al.*, Phys. Rev. B **56** 13849 (1997).

[2] M. Jamet *et al.*, Phys. Rev. B **69**, 493 (2004).

[3] S. Majetich *et al.*, MRS Bulletin **38,** 899 (2013).

[4] A. Kleibert *et al.*, Phys. Rev. B **95**, 195404 (2017).

[5] Oyarzún *et al.*, Sci. Rep. **5,** 14749 (2015).

Unraveling surface enabled phenomena in low dimensional systems

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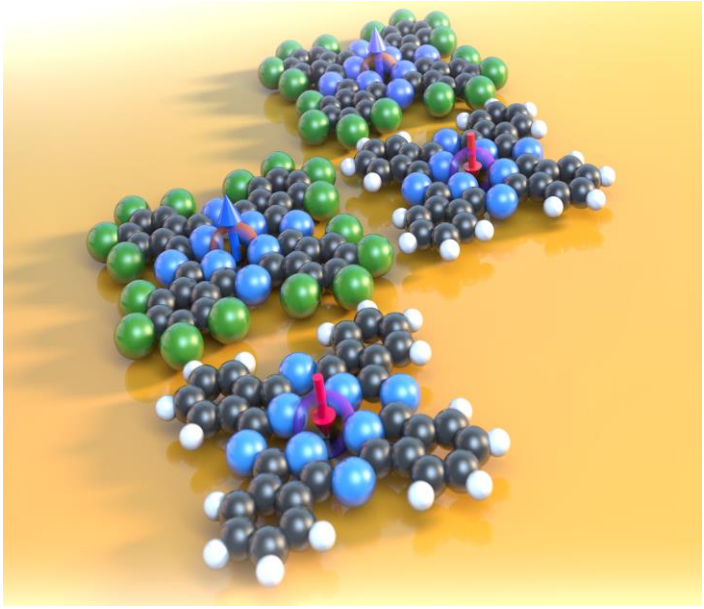

Development of future quantum technologies relies on the detailed understanding of the interaction between different electronic states in atoms or molecules. On-surface atomic and molecular systems provide the particular advantage of addressability together with extraordinary magnetic and quantum properties originating from the reduced dimensionality. These self-assembled systems with their atomically precise architectures help us to better understand the fundamental origins of magnetic interactions in low dimensional magnetic systems and put them into the framework of existing or new to be developed models.

Since the first observation of exchange induced magnetic ordering in paramagnetic porphyrin molecules adsorbed on ferromagnetic cobalt surface, by our group at the SIM beamline of PSI, spin bearing metallo-porphyrin and phthalocyanine molecules were gaining increasing interest. In subsequent experiments we showed that magnetic properties of such molecules on magnetic substrates are determined by the substrate, are stable up to elevated temperatures and can be controllably altered upon exposure to chemical and physical stimuli. This guided us towards the selective spin switching in hetero-metallic magnetic checkerboard layers consisting of coassembled phthalocyanines with different central metal atoms [1].

Further on, we assessed the intra- and intermolecular coupling within the 2D supramolecular spin-architectures on both magnetic and non-magnetic substrates. We found that the selective interaction of the molecules with reactive substrates can lead to their migration /exchange perpendicular to the surface. On non-magnetic substrates we have shown that hetero-metallic self-assembly can also be synthetically programmed on diamagnetic Au(111). In such a 2D spin architecture we demonstrated the first 2D ferrimagnet by its long-range order and remanence. Magnetic ordering here is due to RKKY interaction of Kondo underscreened moments mediated by the surface states of Au(111) [2].

[1] Ballav N., et al., JPCL 4:2303 (2013)
[2] Girovsky, J. et al., Nat. Commun. – just accepted

“Magnetoelectric coupling between ultrathin Fe films and PMN-PT”

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Abstract

Artificial multiferroics are systems of great interest for applications in novel multifunctional devices, where magnetoelectricity emerges due to the interfacial coupling between a ferri/ferromagnetic and a ferroelectric material. Experimental work on Fe/BTO/LSMO heterostructures [1] revealed a change of the tunnel magnetoresistance depending on the BTO polarization which evidenced a change of the Fe spin polarization for different BTO polarization directions. Theoretical calculations for ultrathin Fe films i.e. 1-3 monolayers (ML) deposited on $ATiO_3$ perovskites (A= Pb, Ba) predict a modification of the magnetic structure with the thickness of Fe film [2]. Here, we study ultra-thin films of Fe magneto-electrically coupled with a ferroelectric substrate PMN-PT (001) .We have grown ultra-thin wedge of Fe with thickness varying from 1-ML to 10-ML on PMN-PT (001) under ultra-high vacuum conditions. A conductive top electrode is grown, allowing the switching the ferroelectric polarization of PMN-PT *in-situ*. We employed x-ray magnetic circular di-chroism (XMCD) technique at- the Fe $L_{3,2}$-edges. The measurements were performed at very low temperature (2K) and applied magnetic field of up to 6.8T. The results for the Fe wedge (1-10 ML) show that the thinner part (1 ML) is paramagnetic while the thicker part (>5 ML) is ferromagnetic. Furthermore, we observed a nearly 7% change in remanence moment for 5-ML thick Fe upon switching the ferroelectric polarization of PMN-PT (001) but a small change of 1-2% in remanent moment for 10ML-thick Fe as shown in Figure 1. Applying sum rules [3] the spin and orbital moment of Fe are determined. Using calculations involving the probing depth of total electron yield we propose that the change in magnetic moment comes mostly from the interface between Fe and PMN-PT pointing to a charge doping effect.

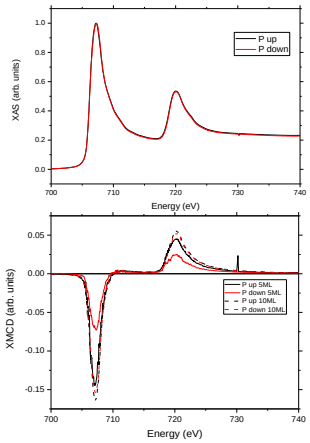

Figure 1. XAS (top) and XMCD (bottom), at the Fe L_3 and L_2 edges for the 5ML and 10ML-thick Fe films. Measured in remanence at 2K along in-plane for two FE polarization directions.

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2. M. Fechner, I. Maznichenko, S. Ostanin, A. Ernst, J. Henk, P. Bruno, and I. Mertig, Physical Review B **78**, 212406 (2008).
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