Magnetism at the nanoscale

Michael Farle

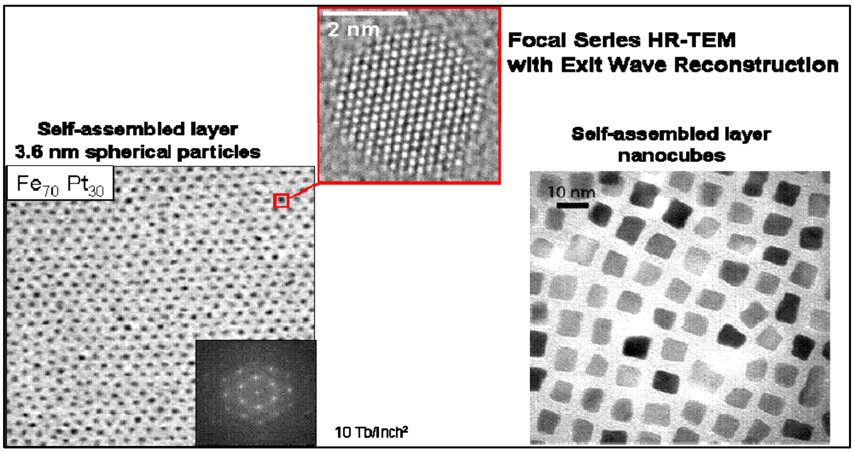
Department of Physics and Center for Nanointegration Duisburg-Essen, University of Duisburg-Essen, Lotharstr. 1, 47057 Duisburg, Germany

**farle@uni-due.de*

Magnetism in structures with dimensions on the few - nanometer scale have been the center of many investigations ranging from topics in spin-torque and spin-injection dynamics and interactions in biomedical applications to the creation of new types of hard, soft or multi-functionalized materials. Such nanostructured "building blocks" offer new exciting possibilities to create new artificial materials like multifunctional hollow magnetic microspheres or luminescent magnetic particles [1,2], some of which will be presented in this talk.

In biological and medical technologies magnetic hybrid or functionalized particles find applications in site-targeted therapy, diagnosis, cell separation and water purification. While most of this work does not require a detailled understanding of the intrinsic magnetism of the nanoparticle, future nanotechnological devices based on one single nanoparticle require the knowledge of local crystal as well as electronic and magnetic structure and surface composition. Based on these microscopic results the collective magnetic response of nanostructured self-assembled hybrid structures can be understood.

Using monodisperse magnetic nanoparticles synthesized by gasphase condensation or organo¬metallic synthesis in well controlled sizes ranging from 2 – 15 nm as examples the theoretical predictions for the individual particle's response (like the magnitude of the magnetic moment and its orbital and spin contributions) as well as the macroscopic response of a collection of interacting nanoparticles will be discussed in relation to experimental observations. Examples on how the magnetic and crystalline interior and surface structure can be calculated and experimentally analysed with sub-Angstrom resolution and with element specificity will be presented: For example, the element-specific magnetism of individual atoms and the interface properties inside a nano¬particle can be studied by combining superparamagnetic resonance and different x-ray absorption spectroscopies. For CoO@Co shell@core hybrid particles it has been shown that apparent „giant" magnetic properties like 300 % enhanced orbital moments in 10 nm Co particles find a simple explanation in conventional solid state physics and crystal field theory [3]. Structural and compositional changes in bimetallic Fe_xPt_{1-x} nano-particles are discussed to highlight the strong correlation between surface properties (ligand covered versus non-oxidized colloidal particles), crystalline structure and magnetism [5]. It is pointed out that non-uniform layer-wise relaxation of the crystal structure or the concentration gradients must be considered in the interpretation of magnetic data and can also be observed in 6 nm FePt nanoparticle by sub-Ångstrom resolved transmission electron micros¬copy [6]. Finally, challenges for magnetic and electronic structure analysis will be pointed out.



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Acknowledgments Supported by Deutsche Forschungsgemeinschaft SFB 445, the National Center of Electron Microscopy, LBL, Berkeley and EU network "Syntorbmag". The research efforts of my colleagues in the research training network "Syntorbmag", of my students and postdoctoral collaborators are thankfully acknowledged.