Novel hedgehog-like magnetic nanostructures studied by liquid nitrogen free EDS and aberration corrected STEM/EELS

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The 'superparamagnetic effect' hinders higher storage densities in modern magnetic recording materials. Patterned media [2, 3], comprising two-dimensional arrays of nanostructures with high magnetic anisotropy, are one of the concepts to provide the required areal density in future magnetic recording devices. Novel hedgehog-like magnetic nanostructures (Fig.1) were created by subsequently depositing a seed layer and a CoPtCr-SiO_2 alloy onto two-dimensional arrays of self-assembled SiO_2 nano-spheres. We found that by tuning the growth conditions single magnetic domain nano-caps with enhanced magnetic coercitivity fields can be fabricated. The element distribution in the active magnetic layers was characterised by different electron microscopic techniques. The results were used to interpret their magnetic switching behaviour and to support micro-magnetic simulations of the necessary energy barrier.

Electron transparent cross sections of the samples with 50 nm particle size were prepared by tripod polishing and a short ion-milling step. Atomic resolution high angle annular darkfield (HAADF) imaging showing Z-contrast, and elemental mapping using Gatan electron energy loss spectroscopy (EELS) were performed using a NION MarkII Cs-corrected dedicated STEM at the UK superSTEM laboratory [1]. An energy dispersive x-ray spectroscopy (EDS) system incorporating a liquid nitrogen free XFlash 5030 silicon drift detector covering a solid angle of 0.12 sr on a conventional Jeol 2200 FS TEM/STEM at the Humboldt University Berlin was used to complement the elemental maps.

EELS spectrum imaging revealed the distribution of Cobalt, Chromium, Ruthenium and Oxygen in the deposited nano-structured system (Fig.2). EDS was used to confirm the distribution of Pt and Ru (Fig.3). The combined spectroscopy data show that the magnetic caps on the SiO_2 spheres consist of a closed textured Co/Pt-containing film on top of which columnar Co/Pt-containing nano-crystals grow with their growth axes perpendicular to the sphere surface, thus forming a hedgehog like structure. EELS spectrum imaging and HAADF in Cs-corrected STEM show, that these magnetic nano-columns grow directly from and coupled to the crystallites of the textured film below, but are separated from each other otherwise by a Cr and O containing nm-layer.

The inclination of the magnetic nano-crystals provides the easier magnetic switching. The coupling to the closed textured Co/Pt layer is responsible for a strong magnetic coupling throughout the whole cap of one nano-sphere.

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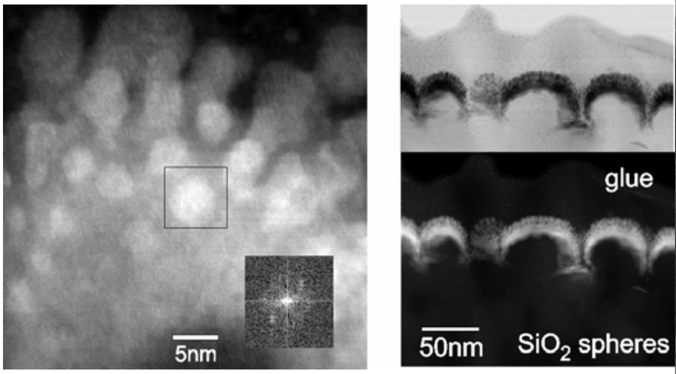

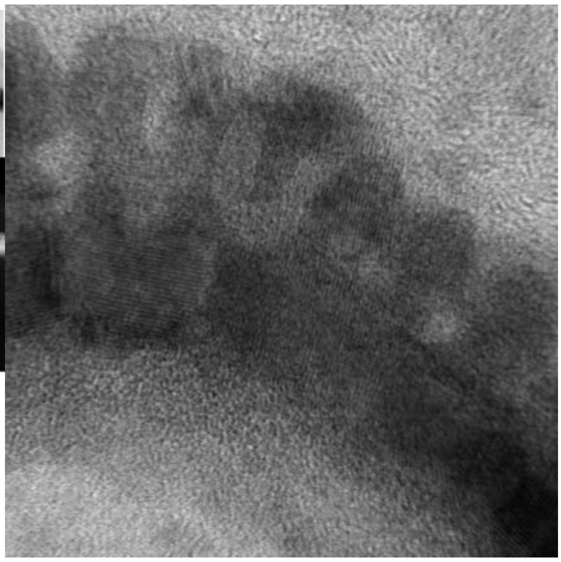

Figure 1. Bright field (upper and right) and HAADF images of the hedgehog-like nanostructures, showing the distribution of high-Z elements (Co/Pt). The inset shows the 3-fold symmetry of a nano-crystal imaged head on.

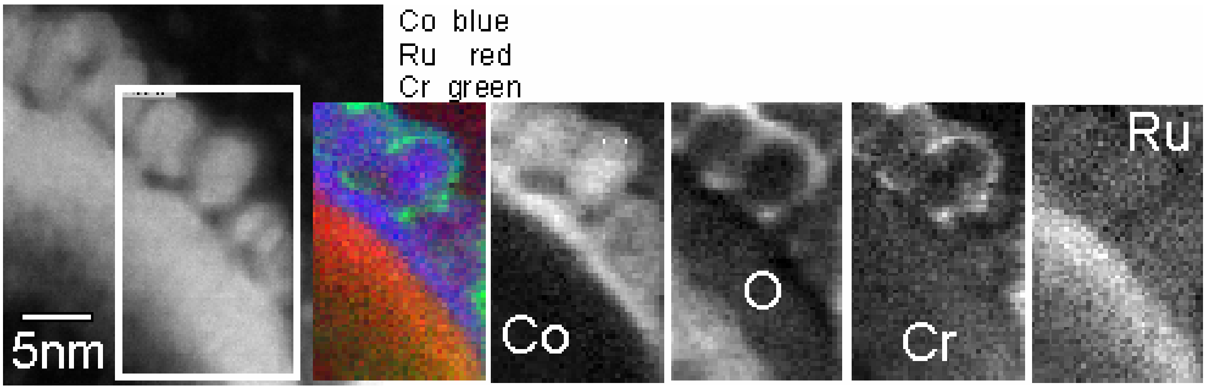

Figure 2. Element map using EELS spectrum imaging in a NION Cs-corrected dedicated STEM.

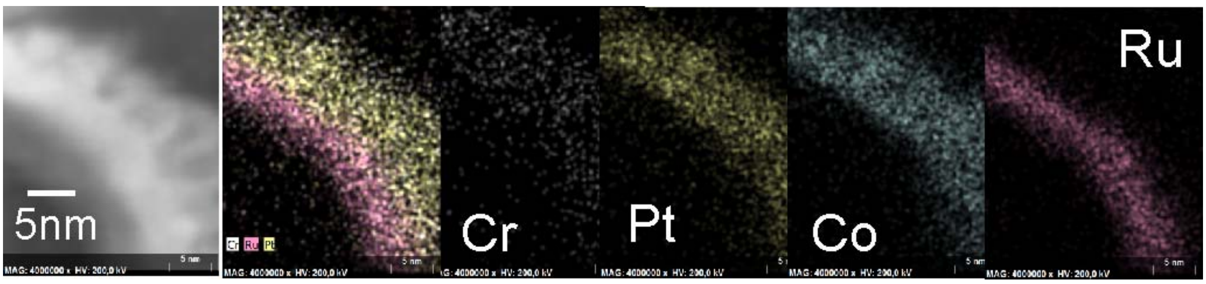

Figure 3. HAADF and liquid nitrogen free EDS map (raw data) of the same sample area in an uncorrected Jeol STEM, the second frame shows Ru, Pt, Cr. Pt appears with Co. Ru is part of the seed layer.

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