On the Magnetic Properties of Clean Iron Nanostructures Fabricated by Focused Electron Beam Induced Processing

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We aim towards the fabrication of novel functional materials via focused electron beam induced processing (FEBIP) techniques in ultra-high vacuum (UHV). One mask-less, "direct-writing" method in this regard is electron beam induced deposition (EBID).[1] In EBID, a focused electron beam is used to locally decompose certain precursor molecules adsorbed on a surface. The non-volatile dissociation products form a deposit, while the volatile fragments are pumped off. In our UHV approach to EBID we are able to fabricate basically pure iron deposits from the metal-organic precursor iron pentacarbonyl ($Fe(CO)_5$) and thus overcome hitherto existing limitations concerning rather low purities of the corresponding deposits in high vacuum environments. [2] In addition the iron deposits continue to grow autocatalytically (AG) at room temperature in UHV as long as $Fe(CO)_5$ is dosed.[3,4] In this way it is possible to fabricate ferromagnetic iron nanostructures with controlled thickness, shape and lateral dimensions as small as 15 nm.

The corresponding Fe nanostructures produced via EBID and subsequent AG in UHV were investigated with Scanning Transmission X-ray Microscopy (STXM) at the PoILux beamline at the Swiss Light Source. The spatial resolved X-ray absorption spectroscopy (XAS) data provided valuable information on the bulk and interface composition of the Fe nanostructures (Fig. 1). From this type of data it is also possible to extract the linear absorption coefficient μ for Fe nanostructures, allowing for the direct evaluation of the layer thickness.[5]The STXM instrument at the PoILux beamline also enabled to image magnetic domains of individual Fe-deposits via X-ray magnetic circular dichroism (XMCD) while applying a variable magnetic field (Fig. 2). By systematic variation of the external magnetic field the hysteresis loops of individual iron deposits can be extracted and the corresponding magnetic properties like coercivity can be quantified (Fig. 3)

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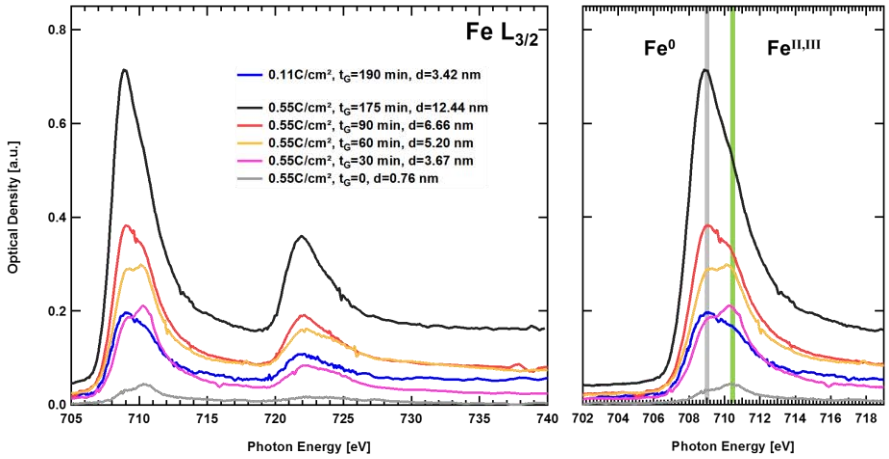

Fig. 1: Fe L-edge X-ray absorption spectra of deposits fabricated via EBID plus autocatalytic growth using $Fe(CO)_5$ with different growth times. Two main peaks are presented at L3-edge, corresponding to Fe^0 and $Fe^{II, III}$ oxidation state respectively.

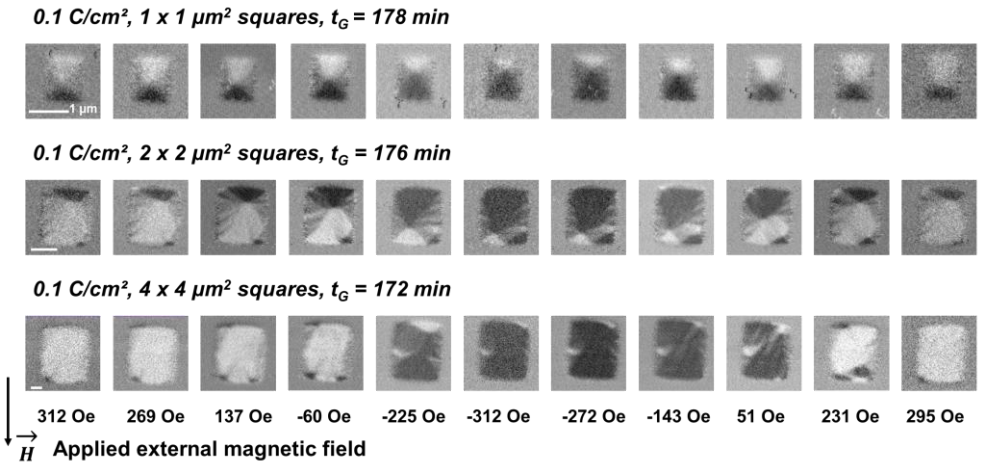

Fig. 2 STXM images with XMCD contrast on different square deposits fabricated with EBID plus autocatalytic growth with the precursor $Fe(CO)_5$.

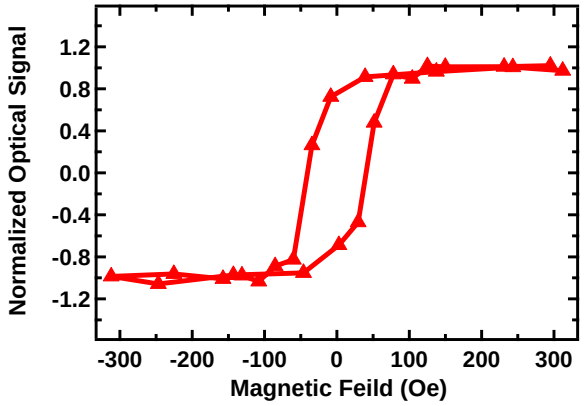

Fig. 3 Hysteresis curve of 4 x 4 µm² Fe square structure with a thickness of ~ 16 nm as extracted from the corresponding XMCD data.