Focused Electron Beam Induced Deposition as novel nanofabrication approach for magnetic nanosensors and nanomagnet logic

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Focused electron beam induced deposition (*FEBID*) is a maskless and resistless direct write method for potential micro-/nanofabrication.[1] The combination of this technique with the magnetic properties of materials leads to magnetic nanodevices production with several applications in spintronics, sensing, magnetic storage and transport of digital information.[2] In this work iron containing nanostructures were obtained by *FEBID* on pure and gold coated Si(100), starting from $Fe(CO)_5$. We have explored the influence of different scanning parameters on the material properties, focusing on the deposition of nanowires with different length (1 to 3 μm) which are widely used in nanomagnetic logic (*NML*).[3] *EDX* (energy dispersive x-ray spectroscopy) [FIG. 1b)] and *AFM/MFM* (Atomic/Magnetic Force Microscopy) investigations [FIG. 2a),b),c) and d)] have been performed to gain composition and topographic information respectively. As a potential application of the obtained magnetic material we have coated a commercial *AFM* tip with iron by *FEBID* and performed *MFM* scanning with it on a commercial hard disc drive [FIG. 3]. The phase shift recorded reveals the magnetic interaction between the iron coated *AFM* tip and the magnetic grains on the surface of the recorded media. This experiment shows how *FEBID* can be used as a coating technique to successfully produce MFM probes. We will discuss further applications of this techniques for magnetic device fabrication, such as nano-Hall sensors for local external magnetic field probing.[4] To investigate the magnetic properties of the produced nanowires the samples were magnetized by applying an uniform external magnetic field (~ 190 Oe) and *MFM* was performed [FIG. 2a),b),c),d)]. The phase shift images collected during *MFM* investigations [FIG. 2b) and d)] revealed the magnetic properties of the nanostructures. The deposition conditions had a significant influence on the magnetic properties of the nanowires and their effects will be discussed. Concerning the crystalline structure of the deposits transmission electron microscopy (*TEM*) has been performed. We will report further investigations on the magnetic behaviour of the obtained nanowires such as results from Magneto-Optical Kerr Effect (*MOKE*) and their electrical properties by four-probe measurements.

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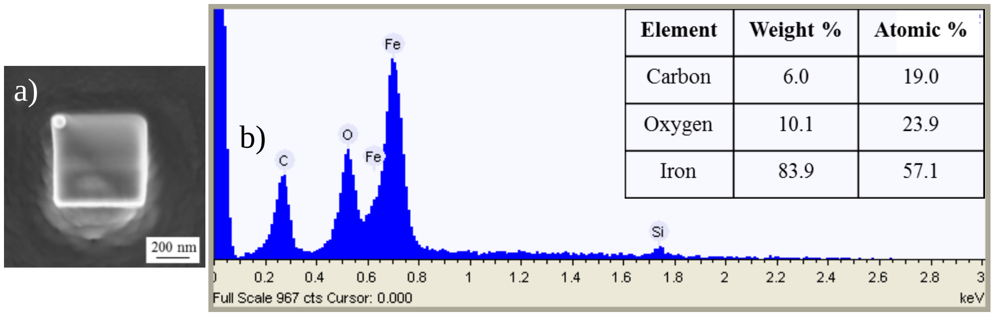

FIG. 1. a) *SEM* micrograph of the deposited area for the *EDX* investigation. The scanning parameters are the same of those used to deposit the nanowires. b) *EDX* spectra of the area reported in Fig 1a) and respective atoms percentage.

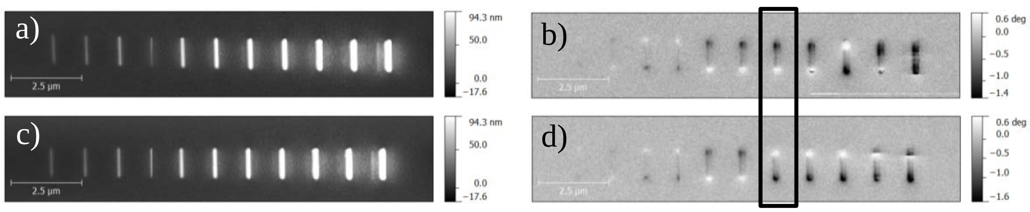

FIG. 2. a), c) topography images of the 1 µm nanowires obtained at different deposition times (1-10 s) and b), d) *MFM* respective phase images which show the magnetic interactions between the sample and the *MFM* tip.

The magnetization field direction for a) and b) is from down to up while for c) and d) is from up to down. In the line marked area on b) and d) is shown the magnetic switching of the 6 s deposited wire.

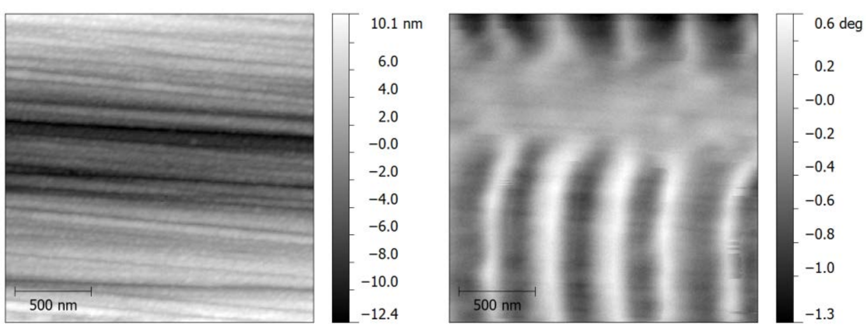

FIG. 3. *MFM* images of a commercial hard disc drive scanned with the iron coated *AFM* tip by *FEBID*. The right and left images show the topography and phase shift respectively. On the phase image the magnetic grains of the recorded media are clearly revealed.