Magnetic reversal of iron nanowires deposited by Focused Electron Beam Induced Deposition for nanomagnet logic application

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Focused electron beam induced deposition (*FEBID*) is a direct write maskless and resistless nanofabrication method which employs a focused electron beam to induce a local chemical vapour deposition process.[1] The nanoscale controlled production together with the magnetic behaviour in small magnetic elements, 0D to 2D nanostructures, has led to an enhanced research activity in the last few decades, partly stimulated by applications in magnetic recording technology.[2]
In this work iron containing nanostructures were obtained by *FEBID* on Si(100), starting from iron pentacarbonyl.
We have explored the influence of different shapes and 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. 1] and *AFM/MFM* (Atomic/Magnetic Force Microscopy) analyses [FIGG. 2,3] have been performed to gain information on composition, topography and magnetic behaviour. In order to investigate the magnetic properties of the obtained nanostructures the samples were magnetized by applying a uniform external magnetic field (~ 190 Oe) and *MFM* investigations were performed. The phase shift image in FIG. 2, collected during these analyses, revealed the magnetic domains at the edges of the nanowire although in the centre no magnetic forces are detected. This behaviour is due to the vortex state formed by the magnetic moments on the two extremes of the nanowire while in its inside they are parallel to the nanowire axis. The deposition conditions had a significant influence on the magnetic properties of these nanosystems and the deposition time is one of the parameters which affected most their behaviour. The *MFM* measurements performed for the same sample magnetized with opposite magnetic field directions [Fig. 3] revealed the magnetic reversal of the 1 μm long nanowires. 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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[1] I. Utke, P. Hoffmann, J. Melngailis, J. Vac. Sci. Technol. B **26**, 4 (2008)

[2] T. Wang, Y. Wang, Y. Fu, T. Hasegawa, F.S. Li, H. Saito, S. Ishio, Nanotechnology **20**, 105707 (2009)

[3] M.T. Niemier et al. J. Phys.: Condens. Matter **23**, 493202 (2011)

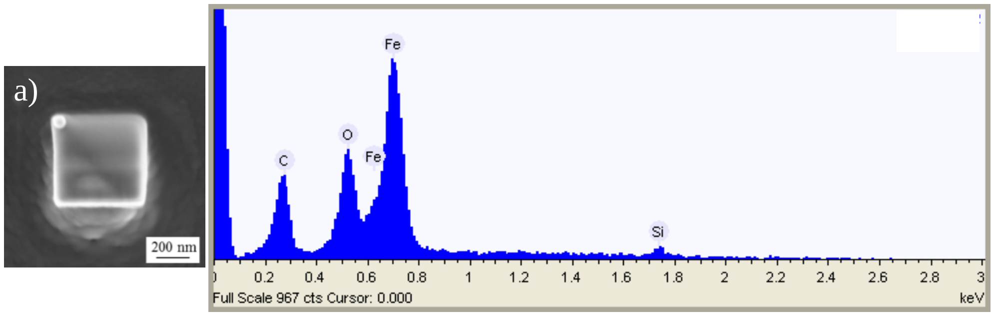

FIG. 1. a) *SEM* micrograph of the deposited area for the *EDX* investigation. The scanning parameters are the same of those used to deposit the nanowires. b) *EDX* spectra of the area reported in Fig 1a) and respective atoms percentage.

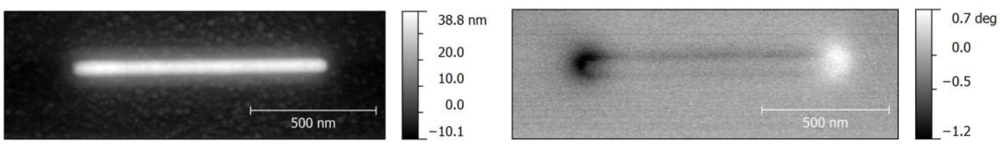

FIG. 2. *MFM* investigation of the 1 μm nanowire deposited for 3 s. Topographic scanning and corresponding phase detection are reported on the right and left images respectively. The bright and dark zones on the phase image reveal the forces between the *MFM* probe and the nanowire.

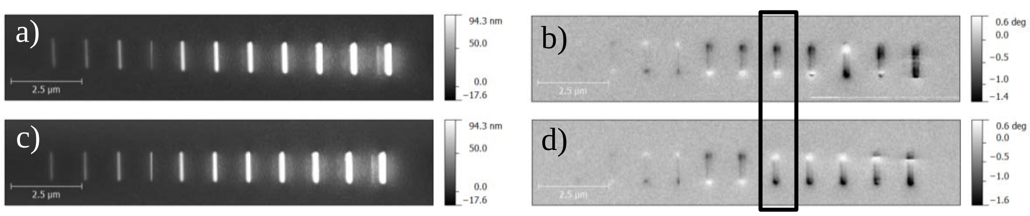

FIG. 3. a), c) topography images of the 1 μm nanowires obtained at different deposition times (1-10 s) and b), d) *MFM* respective phase images which show the magnetic interactions between the sample and the *MFM* tip.
The magnetization field direction for a) and b) is from down to up while for c) and 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.