Focused electron beam induced deposition and etching of functional materials

J.M. De Teresa[1,2], R. Córdoba[2,3], A. Fernández-Pacheco[1,2,3], L. Serrano[1,2], F. Schoenaker[1], M.R. Ibarra[1,2,3]

[1]Instituto de Ciencia de Materiales de Aragón, Universidad de Zaragoza-CSIC, Zaragoza, 50009, Spain

[2]Departamento de Física de la Materia Condensada, Universidad de Zaragoza, 50009, Spain

[3]Instituto de Nanociencia de Aragón, Universidad de Zaragoza, Zaragoza, 50018, Spain

deteresa@unizar.es

Many working devices in the field of nanotechnology rely on the top-down approach for their creation. This implies the use of thin-film growth techniques in tight cooperation with micro- and nano-lithography techniques. The method of choice should address crucial aspects such as resolution, roughness, shape, materials involved, cost, etc. Optical lithography is normally preferred down to the micron scale and electron-beam lithography below the micron scale. However, some of the involved steps are critical and the final sample nanometric features can be far from ideal. In order to circumvent the annoying use of resists, direct patterning by focused-ion-beam is not rare, but this technique can strongly modify the properties of the materials, restricting its use. It is in this context that focused-electron-beam-induced-deposition (FEBID) and focused-electron-beam-induced-etching (FEBIE) techniques are becoming promising routes for the direct growth or patterning of functional nanostructures in a single step. These techniques do not involve the painful use of resists, etching or lift-off processes, whereas maintaining the high lateral resolution down to the nanometric scale. In the present contribution, we will show successful examples of the use of FEBID and FEBIE for the creation of functional nanostructures. The deposition or etching experiments have been carried out by means of a field-emission-gun scanning electron microscopy (SEM) and gas injectors which permit to deliver precursor gas to the area of interest.

Cobalt-based nanostructures have been grown by FEBID using $Co_2(CO)_8$ as the precursor gas on Si substrates or insulating Si//SiO_2 substrates. Our previous work has shown that Co by FEBID can be grown with high purity, showing remarkable properties for applications in magnetic sensing, storage and logic [1-4]. In the present contribution we show the successful growth of cobalt nanowires with lateral size down to 30 nm, which could be used for highly-integrated domain-wall manipulation. Besides, for the application in Hall sensing, we have grown Co squares with lateral size around 100 nm plus narrower contact lines to permit injection of current from opposite edges of the square and measurement of voltage from the remaining two contacts.

Titanium is a relevant technological material due to its extraordinary mechanical and biocompatible properties, its nanopatterning being an increasingly important requirement in many applications. We report the successful nanopatterning of titanium by means of Focused Electron Beam Induced Etching using XeF_2 as a precursor gas [5]. Etch rates up to 1.25 x 10^{-3} μm^3 s^{-1} and minimum pattern sizes of 80 nm were obtained. Different etching parameters as beam current, beam energy, dwell time and pixel spacing are systematically investigated, the etching process being optimized by decreasing both beam current and beam energy.

References

[1] A. Fernández-Pacheco et al, J. Phys. D : Appl. Phys. **42**, 055005 (2009).
[2] A. Fernández-Pacheco et al, Appl. Phys. Lett. **94**, 192509 (2009).
[3] A. Fernández-Pacheco et al, Nanotechnology **20**, 475704 (2009).
[4] S. Sangiao et al, Solid State Communications **151**, 37 (2011).
[5] F. Schoenaker et al, submitted to Nanotechnology (2011).

Figures

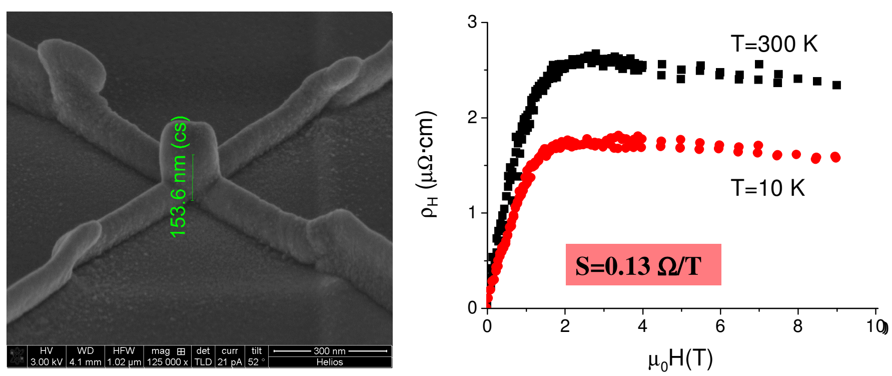

Figure 1: One of the grown Hall devices based on Co by FEBID and its Hall characterization.

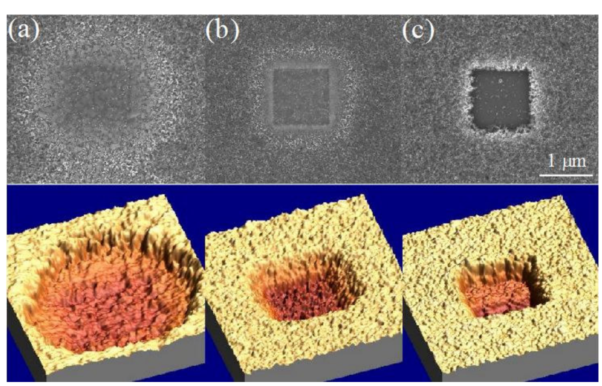

Figure 2: SEM (top) and AFM (bottom) images of Ti etchings made with 2 kV electron beam energy and different beam currents and etching times. (a) Beam current of 1.35nA and a 30 s etching time. (b) Beam current of 318 pA and a 105 s etching time. (c) Beam current of 5.4 pA and a 600 s etching time.