Electron and Ion Beam Induced Deposition of Nanosuperconductors and Nanomagnets

R. Córdoba and J. M. De Teresa
Instituto de Ciencia de Materiales de Aragón (ICMA), CSIC - Universidad de 50009 Zaragoza, Spain
Departamento de Física de la Materia Condensada, Universidad de Zaragoza, 50009 Zaragoza, Spain

rocorcas@unizar.es

In this contribution, we show an inclusive scenario of electron and ion beam nanofabrication to grow in a single-step nanosuperconductors and nanomagnets. To this specific purpose, we utilize focused electron or ion beam induced deposition (FEBID/FIBID) techniques by using as a primary beam, heavy ions (Ga^+ FIBID), light ions (He^+ FIBID) and electrons (FEBID).
First, we focus on magnetotransport studies in nanosuperconductors grown by Ga^+ FIBID. Particularly, we propose a route to transfer information carried by the non-local vortex motion through long distances (3 and 10 micrometers) in sub-50 nm nanowires [1] and we introduce a method to pattern sub-10 nm superconducting nanowires [2].
Second, we present the vertical growth of superconducting hollow nanowires like nanotubes as small as 32 nm in diameter and with an aspect ratio (length/diameter) of as much as 200 by using He^+ FIBID. We will highlight their specific growth method, superconducting properties and microstructure [3].
Finally, we show an original hybrid system (superconductor/ferromagnet) formed by a high-temperature YBCO superconducting film, patterned with antidots, and with FEBID nanomagnets grown inside them [4,5].
The fabrication of such advanced functional materials is at the cutting edge of nanofabrication methods based on focused beams of charged particles for the development of the broad field of planar (1D and 2D) and out-of-plane (3D) nanosuperconductivity.
Acknowledgement: "This project has received funding from the EU-H2020 research and innovation programme under grant agreement No 654360 NFFA-Europe."

---

[1] Córdoba, R. et al. *manuscript in preparation*
[2] Córdoba, R.; Ibarra, A.; De Teresa, J. M. *manuscript in preparation*
[3] Córdoba, R.; Ibarra, A.; Mailly, D.; De Teresa, J. M. M. *Nano Lett.* **2018**, acs.nanolett.7b05103.
[4] Córdoba, R.; Sharma, N.; Kölling, S.; Koenraad, P. M.; Koopmans, B. *Nanotechnology* **2016**, *27* (35), 355301.
[5] Rouco, V.; Córdoba, R.; De Teresa, J. M.; Rodríguez, L. A.; Navau, C.; Del-Valle, N.; Via, G.; Sánchez, A.; Monton, C.; Kronast, F.; Obradors, X.; Puig, T.; Palau, A. *Sci. Rep.* **2017**, *7* (1), 5663.

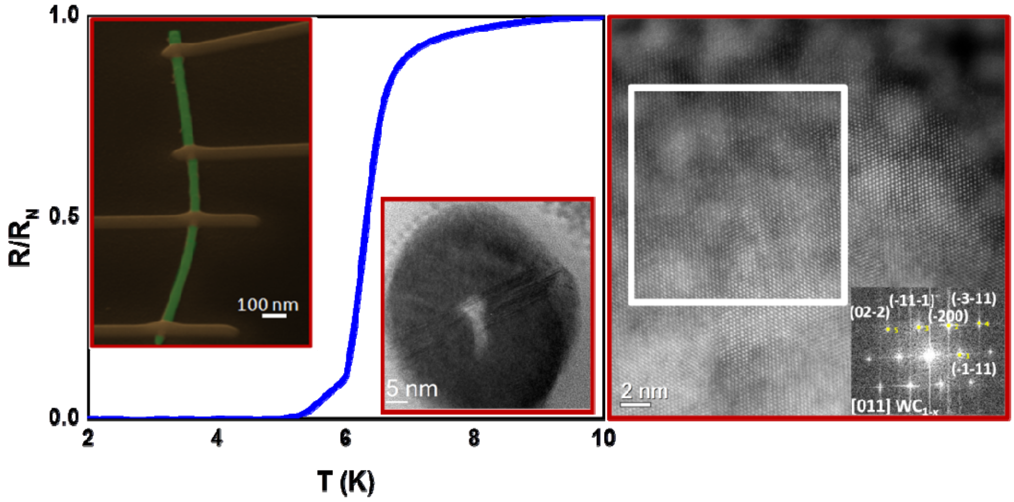

Figure 1: Normalized resistance for a hollow nanowire as function of temperature. Insets show an SEM image of a hollow nanowire connected by using four Pt FIBID contacts and a HR(S)TEM image of a cross sectional view of a typical nanowire [3].

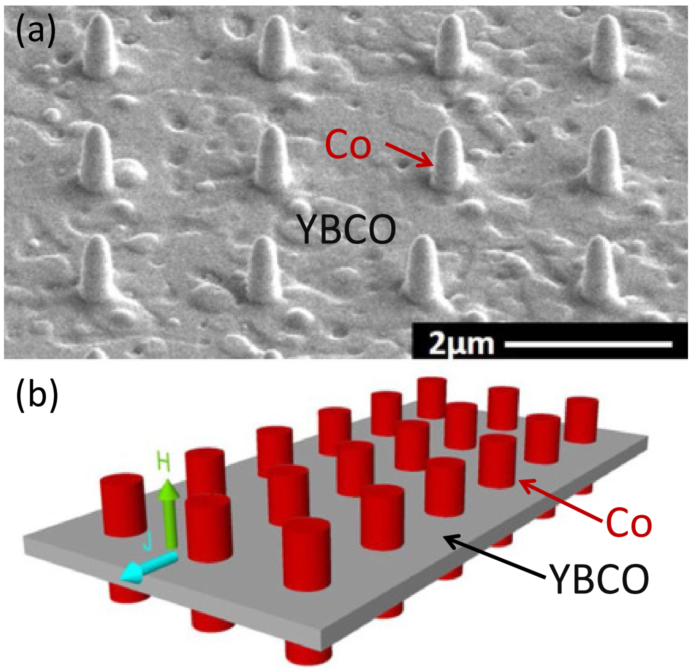

Figure 2: (a) Tilted SEM picture of YBCO transport bridges patterned with an array of antidots filled with Co nano-rods. (b) Schematic representation (not at scale) of transport bridges shown in (a), with the direction of applied electric current and magnetic field indicated [5].