Electrodeposition of trisegmented magnetic nanowires with antiparallel alignment and zero net magnetization

E. Pellicer[1], J. Zhang[1], J. Nogués[2,3], J. Sort[1,3]

[1]Departament de Física, Universitat Autònoma de Barcelona, E-08193 Bellaterra, Spain
[2]Catalan Institute of Nanoscience and Nanotechnology (ICN2), CSIC and The Barcelona Institute of Science and Technology, Campus UAB, Bellaterra, E-08193 Barcelona, Spain
[3]Institució Catalana de Recerca i Estudis Avançats (ICREA), Pg. Lluís Companys 23, E-08010 Barcelona, Spain

One-dimensional material architectures, such as nanorods and nanowires (NWs), have found widespread applications in several technological areas, such as optoelectronics, magnetism, catalysis, piezo- and thermo-electricity, biosensing, or micro-/ nanoelectromechanical systems (MEMS/NEMS), among others. Specifically, ferromagnetic NWs are being employed as components in information storage and logic devices, spintronics, magnetic sensors, and also as platforms in the biomedical field (e.g., hyperthermia or drug delivery). To further expand the range of applications of conventional (i.e., "single-material") magnetic NWs, several segments comprising different magnetic materials can be incorporated in the NWs' architecture, rendering additional functionalities. The resulting hybrid (i.e., segmented) NWs offer enhanced performance either due to the synergy between the properties of each building block, or due to interfacial effects arising from the interaction between the various magnetic materials comprised in the NWs. Electrodeposition is a versatile, low-cost technique for the production of metallic segmented NWs. Depending on the number (repetition) and length of the segments, one or various electrolytes ("sequential electrodeposition") can be used.

Here, a new strategy to minimize magnetic interactions between NWs dispersed in a fluid is proposed [1-3]. Such a strategy consists of preparing trisegmented NWs containing two antiparallel ferromagnetic segments with dissimilar coercivity separated by a nonmagnetic spacer (Figure 1). In particular, trisegmented NWs containing soft (Ni) and hard (PtCo) magnetic segments separated by Cu (deposited by sequential electrodeposition), exhibit staircase-like hysteresis loops with tunable shape that depends on the relative length of the two magnetic segments, their coercivity, and the respective values of saturation magnetization. Interestingly, fully-compensated trisegmented NWs (with the soft and hard segments antiparallel to each other, like in a synthetic antiferromagnet) can exhibit zero net magnetization after appropriate magnetic cycling (Figure 2). Such artificially-built antiferromagnetic or ferrimagnetic NWs could minimize the problem of magnetic agglomeration, eventually avoiding problems associated with thrombosis and other undesirable diseases in the biomedical arena.

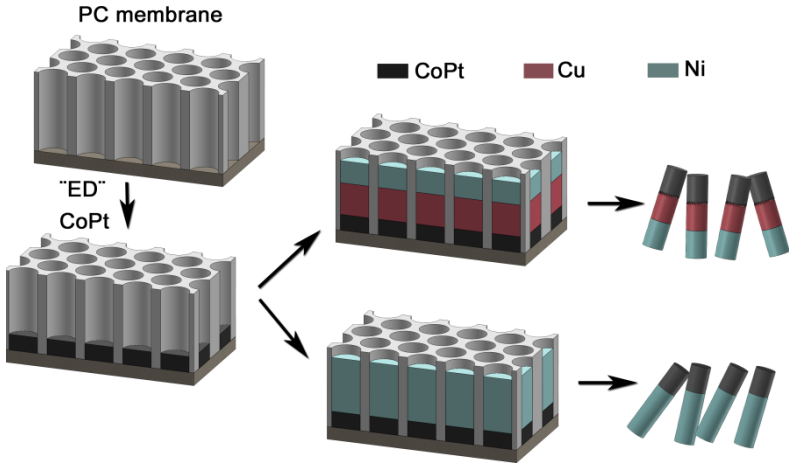

Figure 1: Schematic picture describing the growth of trisegmented CoPt/Cu/Ni nanowires by electrodeposition (ED).

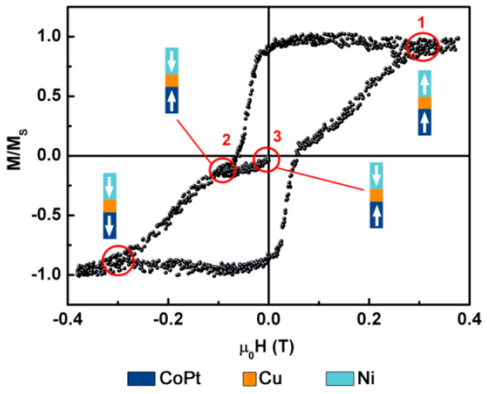

Figure 2: Staircase-like hysteresis loop measured in fully-compensated trisegmented nanowires.

[1] J. Zhang et al. ACS Appl. Mater. Interfaces 8 (2016) 4109.
[2] S. Agramunt-Puig et al. New J. Phys. 18 (2016) 013026.
[3] J. Zhang et al. Adv. Mater. Interfaces 3 (2016) 1600336.