Towards Model Hard-Soft Magnetic Nanocomposites Produced by Nano-Fabrication

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Permanent magnets (PM) are key for the development of green energy technologies and robotics. The ideal PM, with a high energy product, $(BH)_{max}$ combines high coercivity (H_c) and a high remanence (M_r). Following the discovery of hard magnetic properties in Nd-poor alloys of approximate composition $Nd_4Fe_{78}B_{18}$ [1], the concept of hard-soft exchange-spring nanocomposites was developed [2], in which a magnetic phase, known to have soft magnetic properties in the bulk, reveals hard magnetic behaviour as a result of interfacial coupling at the nanoscale with a hard magnetic phase. While several fabrication methods have been used to produce hard-soft nanocomposites [3], the magnetic properties achieved so far, do not match expectations, as the size of the soft features is not sufficiently controlled. In this work, we report on the use of nanofabrication to produce model hard-soft nanocomposites with ultimate control of the nanoscaled soft phase.

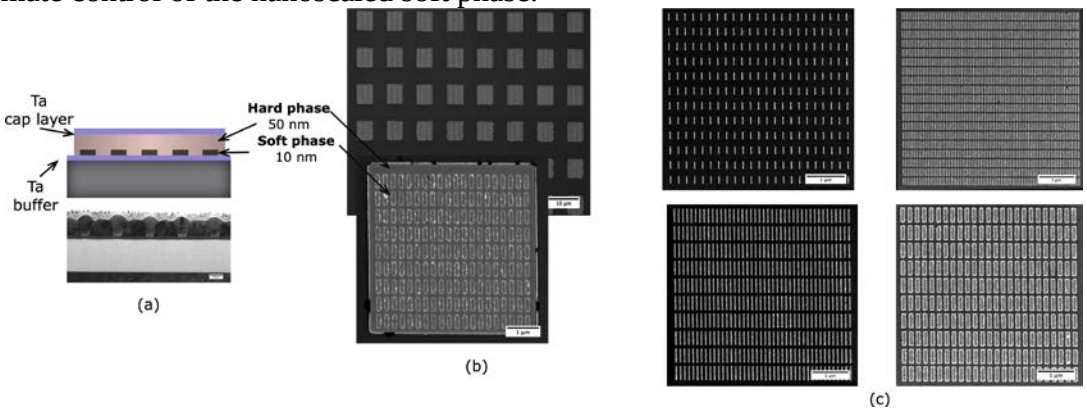

Figure 1: (a) Schematic diagram of soft nanorods (thickness t=10 nm) covered by a hard magnetic layer (t=50 nm) and TEM cross-section image. (b) SEM images of an array of soft nano-rods (main image) and such an array covered with a hard-magnetic patch (zoom). (c) Nano-rod arrays with different feature size.

Elongated Co and FeCo nano-rods (thickness = 10 nm, width = 20-100 nm, length = 200-400 nm and inter-rod distances of the order of the width), capped with a 3nm layer of Au, were produced by e-beam lithography and evaporation. The Au layer was then etched, and a hard magnetic layer (FePt) was subsequently deposited on top of the nano-rods. The hard layer was patterned so as to minimize the surface of the hard phase not covering nano-rods. Samples of large surface area (6 mm^2) of arrays of soft nano-rods alone as well as such arrays embedded in a hard matrix have been fabricated for VSM-SQUID and XMCD measurements. The magnetic properties will be related to characteristics of the nano-structures, derived from SEM and TEM imaging.

References

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