Scale-up synthesis & alignment of magnetic nanowires via polyol process: A bottom-up approach for nanostructured rare-earth free permanent magnets

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Abstract
The numerous mechanical and green energy applications of rare-earth permanent magnets, as well as their limited supply, led to the study of novel permanent magnets based on materials' shape and magnetocrystalline anisotropy. The present work describes the synthesis of high aspect ratio magnetic cobalt nanoparticles through the polyol method, which provides good control of the particles shape, size and crystal structure. Manipulating the synthesis conditions that influence the nucleation and growth step we obtained anisotropic nanoparticles, monodisperse in size, with diameter and length in the range 10-20 nm and 50-200 nm respectively (fig.1a) [1]. Such building blocks are promising candidates for permanent magnet applications, since their long axis is parallel to the c axis of a well crystallized hcp structure. Aiming to the production of a macroscopic magnetic material, we developed the scale up of the polyol process for the synthesis of tens grams of cobalt nanorods. Since the key for a high energy product is the alignment of its building blocks packed with a high volume fraction [2], we aligned the Co nanowires under an external magnetic field (1T). The resulting dense and highly textured macroscopic magnetic structure (fig. 1b,c) provided squared magnetization loops with Mr/Ms higher than 96% and μ_0Hc of 0.5 T (fig. 2a). Detailed analysis of the nanowires orientation and organization in their macroscopic magnetic structure was evidenced by Small Angle Neutron Scattering measurements. Thanks to the combination of the magnetic and thermogravimetric ananlysis, the magnetic cobalt volume fraction could be determined. The B(H) curve and the corresponding (BH)max could then be deduced (fig. 2b), with a maximum obtained value of (BH)max at 160 kJ.m^{-3}.

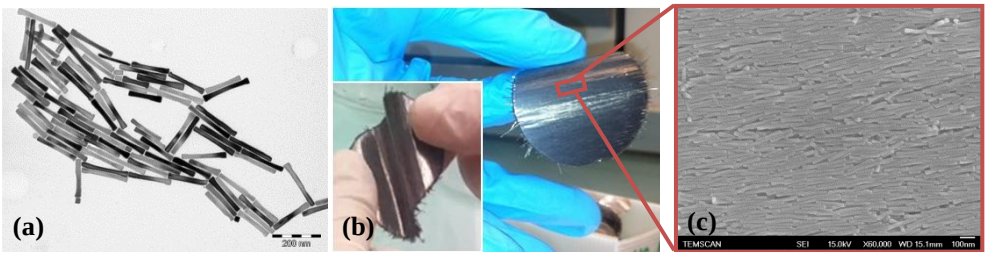

Figure 1: (a) TEM image of Co nanowires (d=22 nm, l=160 nm) ; (b) macroscopic magnetic structure as a result of the nanowires alignment ; (c) SEM image of the same rods.

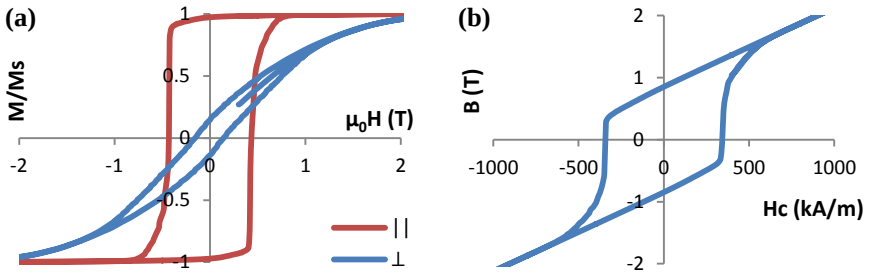

Figure 2: (a) Hysteresis loops of the Co macroscopic magnetic structure measured with the applied field parallel and perpendicular to the alignment ; (b) B(H) loop of the same Co nanowires.

References

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