Evidence for the Mystery of Concomitant Magnetic Nemory Effect in CrO_2/Cr_2O_3 Core-Shell Nanorods

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Abstract

The origin of the concomitant magnetic memory effect (MME) is still a controversial issue and poor evidence in the observation of nanocrystal systems. We report on a type of concomitant MME driven by first-field-induced unidirectional anisotropy (UA) at the interface of ferromagnetic (FM) CrO_2-core and antiferromagnetic (AF) Cr_2O_3-shell nanorods (NRs), with the effect becoming less significant in pure CrO_2 NRs. We have used an uncommon approach to induce magnetic anisotropy in FM-AF CrO_2-Cr_2O_3 core-shell NRs prepared simply by thermal treatment of as-received CrO_2 NRs. The FM CrO_2-core and AF Cr_2O_3-shell of the core-shell NRs were identified using highly sensitive probes such as synchrotron powder X-ray diffraction, neutron powder diffraction, electron spin resonance (ESR), selective area electron diffraction pattern (SAED), and SQUID magnetometer. To estimate the values of core-diameter $<d_{core}>$ and shell-thickness $<t_{shell}>$ a core-shell saturation magnetization (CSSM) cylindrical model based on the contribution from the saturation magnetization is proposed. The estimated value of $<d_{core}>$ ($<t_{shell}>$) varies from 10.65 nm (8.67 nm) to 4.42 nm (15.3 nm) with the increase of annealing temperature T_A from 450°C to 600°C. To estimate the exchange coupling constant a core-shell anisotropy energy (CSAE) model has been used. The obtained spontaneous EB field of −39 Oe accompanied by an enhanced coercivity of 1151 Oe and having an exchange coupling constant of −0.14 erg/cm^2 at 2 K with blocking temperature (T_B) 221 K confirms the enhanced magnetic anisotropy of CrO_2-Cr_2O_3 core-shell NRs. The cooling field dc MME test carried out on core-shell NRs showed a clear uptrend during the heating process below T_B, whereas above T_B, as thermal energy overcomes the magnetic anisotropy energy, the behavior with the heating process is the same as that of the field cooling process. The present findings show that the first-field-induced UA is linked with the variation of AF anisotropy by the naturally incorporated interface roughness arising from the surface effects associated with finite size resulting in the observation of a concomitant MME. Our results also open a promising route to tailor the magnetic behavior of memory-based devices by taking advantage of the first-field-induced interface exchange coupling that we have evidenced here, an implication of the development of thermal memory devices [1]. Further details will be discussed at the time of the presentation.

Keywords - Magnetic memory effect, FM-AF core−shell nanorods, Exchange coupling, Micromagnetic simulations, Magnetic anisotropy.

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References

[1] A. C. Gandhi, T. Y. Li, J. C. Peng, C. W. Wang, T. S. Chan, J. G. Lin, and S. Y. Wu, Concomitant magnetic memory effect in CrO_2–Cr_2O_3 core–shell nanorods: implications for thermal memory devices *ACS Appl. Nano. Mater.*, vol. 2, no. 12, pp. 8027-2042, 2019.