Exchange-bias effect in surface-oxidized ferromagnetic nanowires with polycrystalline shells

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We study the exchange-bias effect in ferromagnetic nanowires with cylindrical shape covered by an antiferromagnetic oxide layer using a classical spin model and implementing Monte Carlo simulations. The aim of the study is to elucidate the impact of the oxidized shell and its polycrystalline structure on the magnetic properties and the magnetization reversal mechanism of the nanowire. For a monocrystalline Co/CoO nanowire [1] we find that the coupling to the antiferromagnetic shell leads to suppression of the coercivity and emergence of a weak exchange bias effect. Comparison of the magnetization reversal mechanism in the bare and the surface-oxidized nanowire reveals that the domain wall propagation and annihilation remains the dominant reversal mechanism in surface oxidized nanowires as in their ferromagnetic counterparts. However, the interface exchange coupling introduces a secondary reversal mechanism activated in the central part of the wire with characteristics of coherent rotation, which acts in synergy to wall propagation leading to enhancement of the wall mobility. This effect is more pronounced in nanowires with large exchange bias values and is attributed to the uncompensated interface moments that act as nucleation centers for magnetization reversal. Additionally, we investigate the effect of shell crystallinity studying monocrystalline ferromagnetic wires covered by polycrystalline shells with random anisotropy. As the size of the crystallites decreases we find an increase of the bias field and the coercivity and a concomitant decrease of the domain wall mobility. Furthermore, the shell polycrystallinity is shown to drastically modify the angular dependence of the bias field leading to the appearance of a maximum value for intermediate angles between the wire axis and the normal axis. The optimum angle for maximum exchange bias field is related to the size of the crystallites. Our results compare satisfactorily with recent experiments in Co/CoO nanowires.

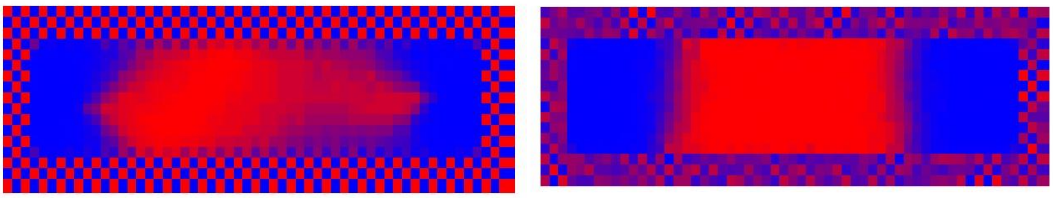

Figure 1. Magnetization profile during reversal for a FM core – AF shell nanowire. The color code (red =+1, blue=-1) indicates the direction of the magnetization along the wire axis. Left panel: A wire with a perfect shell exhibits an additional reversal mechanism. Right panel: A wire with a polycrystalline shell shows purely domain wall propagation.

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[1] A. Patsopoulos and D. Kechrakos, Nanotechnology, 28(28), 285701 (2017)