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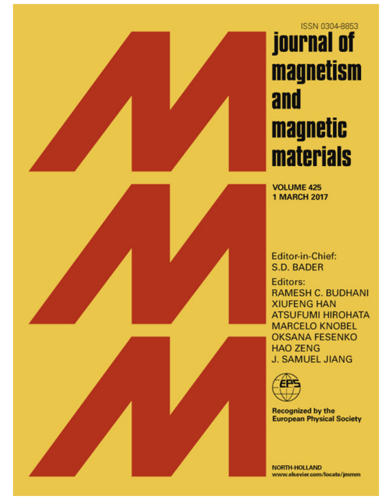

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Asymmetric shift of exchange bias loop in Ni-Ni(OH)$_2$ core-shell nanoparticles

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ABSTRACT: We report the observation of the asymmetric shift of exchange bias loop in Ni-Ni(OH)$_2$ core-shell nanoparticles where the average size of the ferromagnetic (FM) Ni nanoparticles is ~30 nm and the thickness of antiferromagnetic (AFM) Ni(OH)$_2$ shell is ~5nm. The exchange bias (EB) found below Néel temperature (T_N~22 K) of Ni(OH)$_2$ is path dependent, while the coercivity (H_C) increases and decreases for positive and negative bias field respectively. In the present case, we found that the inversion symmetry of hysteresis loop is broken and the shift in EB loop is only observed in descending part of the hysteresis loop, which is conspicuous. We demonstrate that the asymmetric shift of EBs in these core-shell nanoparticles is due to the presence of frustrated super spin glass (SSG) at the interface which influences the reversal mechanism of the hysteresis loop. It is argued that the net interface moment from the SSG at the interface of core-shell nanoparticles sets a unidirectional anisotropy after field cooling, which is thought to be the origin of this path dependency of the EB and observed via descending part of the hysteresis loop, ushering potential for novel spin based applications.

1. Introduction

Interest in ferromagnetic (FM) nanoparticles has increased manifold in the past few years catalysed by virtue of their potential applications in rapidly expanding areas, ranging from ultrahigh density recording media to medicine [1-4]. With the decrease of particle size of the FM nanoparticles, the magnetic anisotropy energy becomes comparable to the thermal energy and the nanoparticles lose their stable magnetic order with random flipping of magnetic moments which leads them to become superparamagnetic. Hence the demand for further reduction of particle size faced a limitation known as 'superparamagnetic limit' [5-9]. Later it was observed that, nanoparticles with the ferromagnetic (FM) core-antiferromagnetic (AFM) shell morphology can overcome the limit where an extra source of anisotropy i.e. exchange anisotropy [9] is generated at the interface leading to the stabilization of magnetization. Two characteristic features, horizontal shift of the hysteresis loop in the direction opposite to the cooling field and an increase in the H_C relative to the bare FM particle are often observed. In most FM-AFM core-shell nanoparticles, the exchange bias (EB) arises from the pinning of magnetic moments at the interface between the two materials [10-12]. Despite the technological importance of EB especially in core-shell nanoparticles where the high degree of disorder is found in coupling between the surface-spins of the shell and core, the physical origin of different EB phenomena is still not fully understood [12-15]. Despite its original invention in nanoparticle systems, in the last few decades, the majority of research on EB has been conducted on flat interfaces in multi-layered thin films due to its important application in magnetic recording technologies [11, 16]. Recently EB in bi-magnetic nanoparticles has