Temperature driven spin switching and exchange bias in $ErFeO_3$ compensated ferrimagnet

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In single crystals of RFeO$_3$ (R = Nd, Sm, Er) the weak ferromagnetic (FM) moment results from the canted antiferromagnetic (AFM) ordering of Fe spins below $T_N \approx 700$ K due to the Dzyaloshinskii-Moriya interactions, while the opposite compensating paramagnetic moment of R spins appears owing to a strong AFM coupling between $4f$ and $3d$ ions within the unit cell. Due to this mechanism, the Er, Nd, and Sm orthoferrites exhibit a specific T_{comp} at which the two opposite moments cancel each other, so the net magnetization vanishes, and below T_{comp} the FM moment is aligned oppositely to the moderate applied magnetic field, demonstrating a negative magnetization. It was found that the magnetization hysteresis loops of these ferrimagnets are analogously exchange biased around their compensation temperatures T_{comp} [1]. Interestingly, in spite of very different R-Fe interactions, T_{comp} values, and spin-reorientation temperatures, the EB field similarly emerges and diverges upon approaching T_{comp} and changes sign with crossing it.

$ErFeO_3$ exhibits additionally specific phenomenon: temperature driven spin switching and exchange bias [2]. The EB manifests itself as the temperature shift of the hysteresis loops M vs T, which occurs upon successive cooling and heating in a weak magnetic field. The $M(T)$ loops, limiting the region of coexistence of negative and positive magnetization, are shifted towards lower or higher temperatures, depending on the sign of the applied magnetic field, which causes the unidirectional EB anisotropy. The EB anisotropy energy, which contributes to the energy barrier for switching spins to an equilibrium state, determines the shift in the switching temperature T_{sw}.

A model of nonequilibrium thermodynamics of $ErFeO_3$ was proposed. The quantum-mechanical effects in arbitrary magnetic fields related both to the direction of a general quantization axis and an influence of anisotropic exchange interactions on the magnetic structure, spin-reorientation phase transition, spin reversals, and hysteresis were considered. Based on recent experimental data on temperature-induced spin switching, a possible mechanism for the exchange bias of magnetic hysteresis loops is proposed [3].

References:

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