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A mechanism of exchange bias in nanoscale lamellar exsolution systems of paramagnetic ilmenite in antiferromagnetic hematite

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Below the ilmenite ordering temperature of 57 K, we observed large shifts of the hysteresis loops in mineral and rock samples containing nanoscale exsolution structures of ilmenite in hematite. Here we present a micromagnetic model of such lamellar interface moments from ilmenite lamellae in a hematite matrix. The lamellae are either planar, parallel to (0001) of the rhombohedral oxide, or finite isolated nanodots or disks. The characteristic length scale of the response of the antiferromagnetic matrix to such an isolated embedded nanomagnetic structure is the AF-domain wall width $\gamma_{\mathrm{AF}} = \sqrt{A/K}$. If the typical lamella size ϵ is $\ll \gamma_{\mathrm{AF}}$, the lamella is comparable to a spherical defect (nanodot) with characteristic total moment $m \propto \epsilon^2$. The AF-sublattice-spin variation then is one-dimensional, depending only on the radial distance from the defect. The lamella acts as a seed, which by exchange coupling creates a long range (as compared to ϵ) spherical AF-spin deflection. Our studies clearly demonstrate that this system can produce strongly shifted hysteresis loops. We give a systematic overview over the properties of such nanodots, nanodisks, and lamellae, and discuss how to extend this approach to cover also unstructured clouds of nanodots or highly structured arrays of nanodisks or nanosheets.