Exchange bias and reversal mechanism in nanocrystalline $Ni_{80}Fe_{20}$ / α-Fe_2O_3 thin films

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Hematite, α-Fe_2O_3, is a naturally abundant oxide on Earth and Mars and has been one of the most studied antiferromagnetic materials. Recently, there has been renewed interest in hematite systems at nanometre dimensions which exhibit the magnetic exchange bias effect for potential uses as a component in biomedical nanoparticles[1,2] and spin-valves[3,4]. We conducted a polarized neutron reflectometry experiment on the D3 reflectometer at the Chalk River labs to investigate the exchange bias effect in a 25 nm thick film consisting of small hematite grains (3-12nm) coupled to a ferromagnetic nickel alloy. A horizontally shifted magnetic hysteresis loop at 5K (Figure 1) measured with SQUID magnetometry and neutron asymmetry is a clear signifier of a strong exchange bias effect. Interestingly, the first four magnetic reversals are different giving evidence of isothermal magnetic training. Fits to the full reflectometry pattern (Figure 2) provide insight into the origin of the exchange bias by suggesting that a small percentage of uncompensated moments are present at the hematite interface. Studying the neutron-spin flip signal of system during reversal at points H_1 and H_2 reveals a symmetric in-plane rotation at both coercive fields (Fig 3) as opposed to domain wall motion. This suggests that domain wall pinning/depinning cannot be the primary mechanism for exchange bias using hematite as the antiferromagnet.

References

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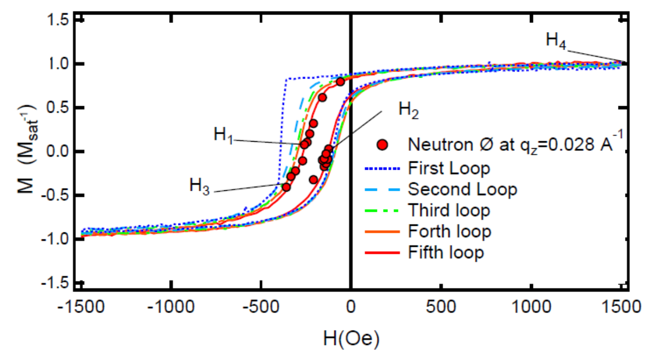

Fig. 1 Comparison of SQUID and neutron assymetry for trained hysteresis loop.

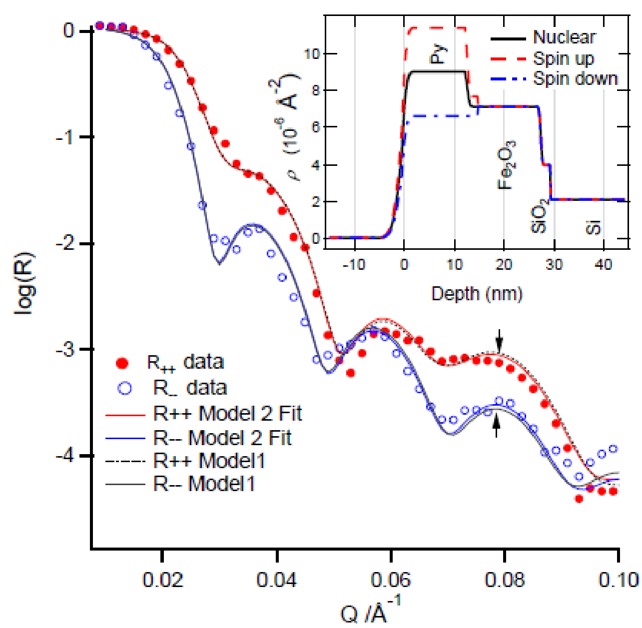

Fig 2 Polarised neutron reflectometry pattern and magnetic depth profile.

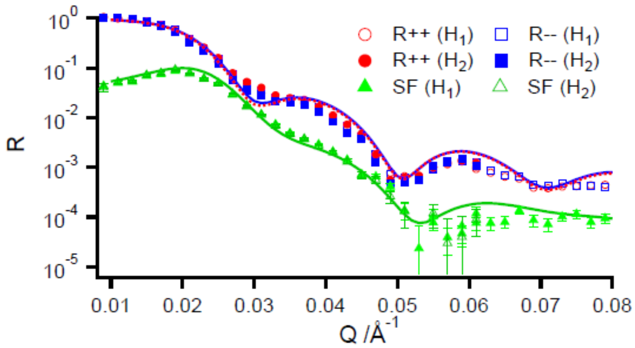

Fig 3 Polarized neutron reflectometry and spin flip signal. Data for each of coercive fields has been superimposed to emphasize symmetry.