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Cationic distribution and magnetic properties of cobalt-ferrite thin films probed by x-ray magnetic circular dichroism

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Investigation of the epitaxial thin films of insulating ferromagnets (cobalt-ferrites) has received a renewed attention due to its central role in spintronic devices involving spin Hall effect [1]. The spin magnetoresistance (SMR) is generally known to depend upon the film orientation and consequently the chemical nature of the exposed film surface. Among other recent works on cobalt-ferrite films [2], we report the cationic distribution, especially at the surfaces, due to the fact that the SMR is mainly controlled by the interface orbital magnetic moments.

In this work, we have fabricated the epitaxial CoFe₂O₄ (CFO) thin films on SrTiO₃ for 14 nm and 23 nm thicknesses by pulsed laser deposition. We employ x-ray absorption spectroscopy to investigate the electronic charge distribution and element-specific x-ray magnetic circular dichroism (XMCD) to unravel the spin and orbital magnetic moments of Fe/Co ions and their site occupancy. The 14 nm thick CFO films exhibit non-saturation in the magnetization and reduced moments while the 23 nm CFO film show a bulk-like magnetic moment. The presence of Co²⁺(T_d) and Fe²⁺(O_h) cations owing to the smaller net moment in the CFO films by increasing the antiparallel alignment [which could cause antiphase boundaries] and possible (oxygen) non-stoichiometry of cationic distribution. In addition, the CFO films exhibit anomalous magnetic properties, including a two-step magnetization reversal with different 'magnetic phases'and a reduced coercivity with the thickness. Disentangling the effects of non-stoichiometry and/or antiphase boundaries is explained to discuss these anomalous properties. Our investigations shall offer further insight into the interface, cation ordering, and magnetic properties of cobalt-ferrite films as interesting systems for novel spintronic device applications.

References

[1] M. Isasa, et al., Appl. Phys. Lett. 105, 142402 (2014).

[2] J. A. Moyer, et al., Phys. Rev. B 84, 054447 (2011).

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