Perpendicular magnetic anisotropy in TmIG and GdIG thin films

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Yttrium iron garnet (YIG) has been well studied as its low Gilbert damping parameter promises use in spintronic devices and sensors. Recently, research turns towards the similar rare earth iron garnets with a more complex magnetic structure, such as the ferrimagnetic insulators thulium iron garnet (TmIG) and gadolinium iron garnet (GdIG). In thin film form, magnetic shape anisotropy favors an in-plane magnetic easy axis. However, thin films grown on lattice-mismatched sGGG or GSGG substrates exhibit a magnetoelastic anisotropy favoring an out-of-plane easy axis [1,2]. Therefore, tuning of the magnetic easy axis and ultimatelly perpendicular magnetic anisotropy (PMA) was achieved, enabling further research in the field of spintronics.

In our study, TmIG and GdIG thin films were grown epitaxially on sGGG and GSGG substrates by pulsed laser deposition (PLD). To ensure single crystalline growth of stoichometric thin films and a smooth surface morphology the films are prepared at elevated temperatures of $600 - 620°\mathrm{C}$, with low deposition rates of $0.01 - 0.03\,\frac{\mathrm{nm}}{\mathrm{s}}$ and in an oxygen atmosphere of $p_{\mathrm{O}_2} = 0.04\,\mathrm{mbar}$ and $0.02\,\mathrm{mbar}$ for TmIG and GdIG, respectively.

The PLD grown TmIG/sGGG and GdIG/GSGG thin films show PMA around room temperature [1]. Furthermore, for TmIG a gradual strain relaxation with increasing film thickness and a subsequent loss of PMA for 200 nm thick films is observed [1].

The antiferromagnetically coupled Gd^{3+} and the net Fe^{3+} magnetic sublattices of GdIG posses different thermal characteristics, resulting in a magnetic compensation point. The GdIG thin films with thicknesses between 15 nm and 200 nm show a magnetic compensation temperature in the range between 200 K and 300 K, affected by the induced strain as well as the film stoichometry. Additionally, a change from PMA to an in-plane easy axis below roughly 150 K due to the strongly increased magnetic shape anisotropy is observed for the 30 nm thick film. The smooth surface morphology with a root mean square roughness of $0.2 \pm 0.1\,\mathrm{nm}$ is a key prerequisite for future research exploiting surface effects like the inverse spin Hall effect.

References:

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