Control of Magnetic properties of spinel ferrite thin film for magnonic applications

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In a magnetic material, the transmission of spin wave does not require electrical current application. The spin-wave-based devices have been envisioned to require much less energy to operate than their electronics counterparts due to negligible Joule heating. As a critical parameter of a spin-wave-applied magnetic material, low Gilbert damping is the requirement for the efficient propagation and modulation of the spin wave. With low damping constant, the spin wave can be propagated in nanoscale devices without the flow of charge for long distance[1]. The garnet-type ferrite has been regarded as a candidate material for the magnonic application because of its high Néel temperature (~600 K) and low damping constant (~10^{-5}). However, the garnet oxides are high cost and have low environmental compatibility because they contain high-cost rare earth. Moreover, they are incompatible with the current silicon-integrated circuit technology, as their epitaxial growth is possible only on the garnet-type substrates. This point becomes a barrier for its application in the fabrication of magnonic devices. Therefore, the other ferromagnetic oxides with low damping property and good lattice matching with conventional crystalline substrates have been strongly desired. Here we choose the spinel-type γ-Fe_2O_3 and $MgFe_2O_4$ as the candidate materials, and deposit some kinds of ferrite magnetic materials, which have high crystallinity, low damping constant, transition temperature much higher than room temperature, and has good lattice consistency with other crystal systems.

Thin films were synthesized on single-crystal substrates of $MgAl_2O_4$ (100) by pulsed laser deposition from a polycrystalline target of stoichiometry γ-Fe_2O_3 or $MgFe_2O_4$. Pulsed laser deposition was performed at O_2 pressure of 1 Pa, and the substrate temperature of 600~800°C. The film thickness was measured by a profilometer.

Structural characterization by XRD reveals that both epitaxial spinel-type γ-Fe_2O_3 and $MgFe_2O_4$ films attain coherent epitaxy. The γ-Fe_2O_3 film of ~50 nm shows soft magnetism with weak spin-orbit coupling, with low coercivity about 60 Oe. And it also shows ferromagnetism property at room temperature shown in Fig. 1.

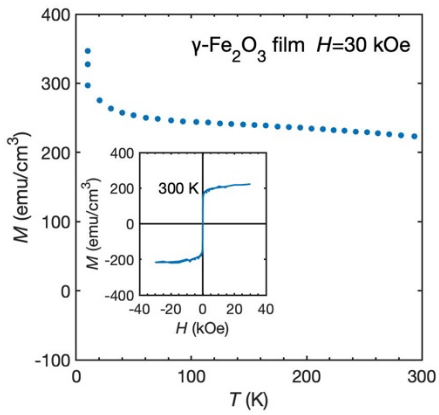

Fig. 1. Magnetic hysteresis loop of γ-Fe_2O_3 measured with a SQUID magnetometer

The Gilbert damping constant is related to the peak-to-peak linewidth, ΔH_{PP}.[2] Coherently strained γ-Fe_2O_3 films show narrow linewidths as shown in Fig. 2, e.g., $\mu_0\Delta H_{PP} \approx 20$ mT at 9 GHz. And the Gilbert damping constant can be calculated as ~0.03, which can ensure spin wave to propagate for several microns.

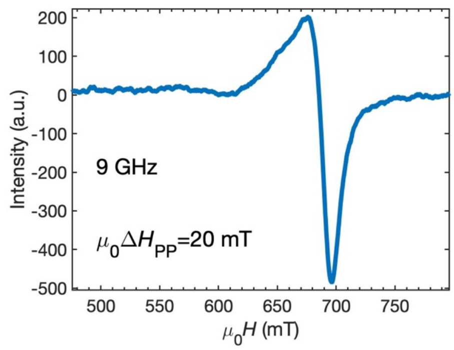

Fig. 2. Out-of-plane FMR spectrum of γ-Fe_2O_3, peak-to-peak magnetic field $\mu_0\Delta H_{PP}$ can be yielded.

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Reference:

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