Spin and Topological Phenomena in Low Loss Ferromagnetic Insulator Thin Films

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Ultra-thin ferromagnetic insulators with low magnetic damping enable emergent magnetic and topological phenomena at interfaces but also can efficiently generate and control pure spin currents, thereby changing the landscape of spin wave devices. We have developed a new class of nanometer thick low loss spinel ferrite thin films with Gilbert damping parameter as low as $\alpha \sim 2 \times 10^{-4}$. By incorporating a high spin orbit coupled overlayer, we can electrically detect spin waves generated in the spinel ferrite and find efficient spin pumping from these spinel ferrites into the adjacent layer through measurement of the spin-mixing conductance, Gilbert damping enhancement and electrical voltage peaks that appear at ferromagnetic resonance. We also demonstrate that we can efficiently switch the magnetic state of the ferromagnetic insulator via spin-orbit torque switching or electrical current in an adjacent high spin orbit coupled metal. Both magnesium aluminum ferrite and lithium aluminum ferrite exhibit low magnetic loss but the latter shows bulk saturation magnetization even in films four-unit cells thick. Compositional studies of aluminum doping in these ferrites suggests that minimizing disorder and strain correlates with low loss and bulk-like saturation magnetization. These spinel ferrite-based bilayers are also an excellent model system for the demonstration of fluctuation driven topology. Surprisingly we find definitive magnetotransport signatures of topology in the paramagnetic state of the spinel ferrite. We performed a detailed transport study as a function of field, temperature, field angle and ferrite thickness and found novel scaling behaviors consistent with fluctuation driven topology as predicted by Monte Carlo simulations.