Tailoring interfacial properties and spin wave nonreciprocity in magnetic thin film heterostructures by interface engineering

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The interfacial properties, such as perpendicular magnetic anisotropy (PMA), spin-orbit coupling (SOC), Dzyaloshinskii-Moriya interaction (DMI), damping constant in magnetic thin films and their heterostructures can be very efficient ingredients to optimize the performance of spintronics and magnonics devices [1,2]. Therefore, the investigation of the underlying mechanism and figuring out efficient ways to control the interfacial properties is crucial for future applications. Interface engineering can be one of the most promising means to control interfacial properties [3-6].

We show the modulation of interfacial properties and nonreciprocity of magnetostatic surface spin waves (MSSWs) in Ta/$Co_{20}Fe_{60}B_{20}$/MgO/Al_2O_3 heterostructures by dusting CoFeB/MgO interface with ultrathin (0.12 nm) nonmagnetic layers of Ta, Ru, Pt, W, with varying SOC strength and *d*-orbital filling (Fig. 1a). The magnetic damping parameters are measured by broadband vector network analyzer – ferromagnetic resonance (VNA-FMR) technique. The DMI strengths are evaluated by measuring DMI-induced nonreciprocity of MSSWs by employing conventional Brillouin Light Scattering (BLS) spectroscopy.

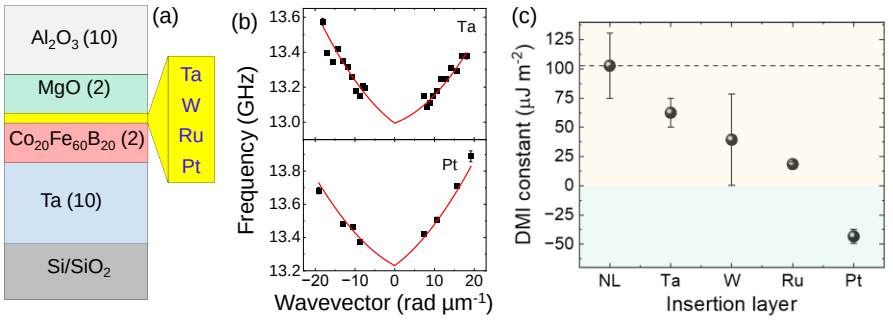

Fig. 1. (a) Structure of the studied samples. **(b)** Dispersions of MSSWs in Ta/$Co_{20}Fe_{60}B_{20}$/MgO/Al_2O_3 heterostructures with Ta and Pt dusting layers at CoFeB/MgO interface. **(c)** Variation of DMI constant with the dusting material at CoFeB/MgO interface.

Magnetometry and VNA-FMR measurements confirm the reduction of saturation magnetization most likely due to the formation of magnetic dead layer and reduction of PMA due to the modification of orbital hybridization and surface oxidation. A significant change in the magnetic damping with the inserted layers occurs because of the reduction of saturation magnetization and PMA, and modification of Rashba SOC coefficient at CoFeB/MgO interface, which affects effective spin mixing conductance ($G_{\text{eff}}^{\uparrow\downarrow}$), spin pumping. The nonreciprocity in MSSW frequency, originates from interfacial DMI, is observed in all the samples. The Ta/CoFeB/MgO heterostructure without any insertion layer shows the highest nonreciprocity. The nonreciprocity gradually decreases with the insertion of Ta, W, Ru layers, and eventually flips its sign with the insertion of Pt layer (Fig. 1b). With the insertion of Ta, W, Ru layers at CoFeB/MgO interface, the overall DMI gradually decreases and eventually alters its sign for the insertion of Pt layer (Fig. 1c). We find a correlation between the *d*-orbital filling of the inserted material and the change in DMI value. We infer that the SOC strength of the inserted material and variation in the diffusion of B atoms at Ta/CoFeB and CoFeB/MgO interfaces may also play crucial roles in determining the change in DMI. Overall, this study shows a guideline to design the future magnonic devices with controllable spin wave properties by interface and material engineering.

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