Realization of Ferromagnetic Resonance in 1nm Co ultrathin film

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Physics in nanometer-thick films has been attracting many researchers because of abundant spintronics nature. In ultrathin films, some physical properties, such as the electric resistivity and the Curie temperature [1,2], are tunable. In addition, by decreasing a thickness of metallic films and using an external electric field, the control of these physical properties has been realized. For example, modulation of the spin-charge current conversion in the 2 nm-thick Pt film was reported [1], and Chiba et al. carried out the modulation of the Curie temperature in the 0.4 nm-thick Co ultrathin film [2], which expands the possibilities of controlling the magnetism. Whilst ultrathin ferromagnetic (FM) films have these potentials, it is not easy to realize the uniform magnetization precession in the ultrathin FM film, which have hampered the observation of the magnetization dynamics. In this research, we successfully demonstrate the ferromagnetic resonance (FMR) in a 1 nm-thick Co film by inserting the Ta buffer layer beneath the Co layer.

We prepared SiO_2 (cap)/Co (t_{Co})/SiO_2 substrates (Sample A), where t_{Co} were 1, 2, 3 and 5 nm by using magnetron sputtering. Furthermore, we also fabricated a SiO_2 (cap)/Co (1 nm)/Ta (3 nm)/SiO_2 substrate (Sample B). FMR spectra were measured in the electron spin resonance (ESR) system at room temperature. The sample was placed in the center of the cavity (TE_{011}), and the external DC magnetic field (H_{ex}) and AC magnetic field (h_{rf}) were applied along in-plane of the film as shown in Fig. 1. In Sample A with t_{Co} = 2 nm or less, the half-width at half-maximum of the FMR spectrum was broadened, which implies that realization of the FMR in the ultrathin Co film is more difficult than that in the bulk system. Figure 2 shows a comparison of FMR spectra between Sample A (t_{Co} = 1 nm, black line) and Sample B (red line). As shown in Fig. 2, clear FMR signal of Sample B was observed and its half-width at half-maximum was comparable to that of the bulk Co system. The results indicate the possibilities of magnetization-dynamics control in the ultrathin Co film down to 1 nm by inserting Ta buffer layer. A more detailed discussion will be given in the presentation.

[1] S. Dushenko *et al.*, Nat. Commun. **9,** 3118 (2018). [2] D. Chiba *et al.*, Nat. Mater. **10**, 853 (2011).

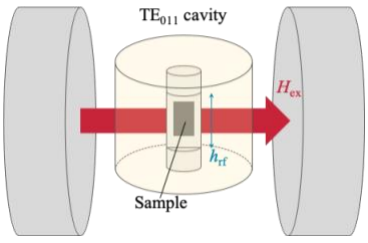

Fig. 1

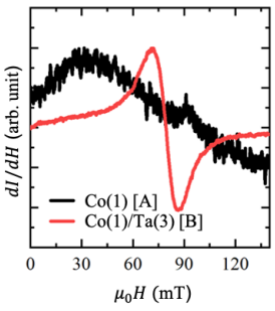

Fig. 2

Fig. 1 ESR measurement setup

Fig. 2 FMR signals of Sample A (t_{Co} = 1 nm, black line) and Sample B (red line)