Ferromagnetic thin film and spin current (5)

Product used：Electron spin resonance spectrometer (ESR)

***** Angular dependence (1) *****

The spectra of ferromagnetic resonance (FMR) usually drastically change its resonant field relative to the applied magnetic field. This is due to the demagnetizing field term originating from the anisotropy of samples. Measurement of the dependence of FMR on angular position relative to the applied magnetic field makes it possible to get information about magnetic parameters of samples (e.g. saturation magnetization, $4\pi M_S$) and to correctly elucidate the angular dependence of the inverse spin-Hall effect.

Fig. 1 ES-UCR3X (Angular rotation device).

Sample and method

FMR spectra were measured with the step size of 15 degree against the applied magnetic field using the angular rotation device (ES-UCR3X in Fig. 1). The sample was the same metallic bilayer thin film reported on JEOL application note[1].

The angular dependence of FMR spectra

The magnetic parameters were estimated as $4\pi M_S$ = 0.344 T、(ω/γ) = 0.32 T using the experimental results as shown in Fig. 2 (a) and the equation (2). Furthermore, it can be possible to calculate the relationship θ_H with θ_M, using the equilibrium condition expressed in eq. (1), as shown in Fig. 2 (b)[2, 3].

$$2\frac{\omega}{\gamma}\sin(\theta_H - \theta_M) + 4\pi M_S \sin(2\theta_M) = 0 \quad (1)$$

Substituting the four parameters to the resonant condition expressed in eq. (2), allows the resonant fields can be calculated[2, 3]. The result of simulation which Fig. 2 (a) shows matches the obtained experimental data very well.

$$\left(\frac{\omega}{\gamma}\right)^2 = \left(H_{FMR}\cos(\theta_H - \theta_M) - 4\pi M_S\cos(2\theta_M)\right)\cdot\left(H_{FMR}\cos(\theta_H - \theta_M) - 4\pi M_S cos^2(\theta_M)\right) \quad (2)$$

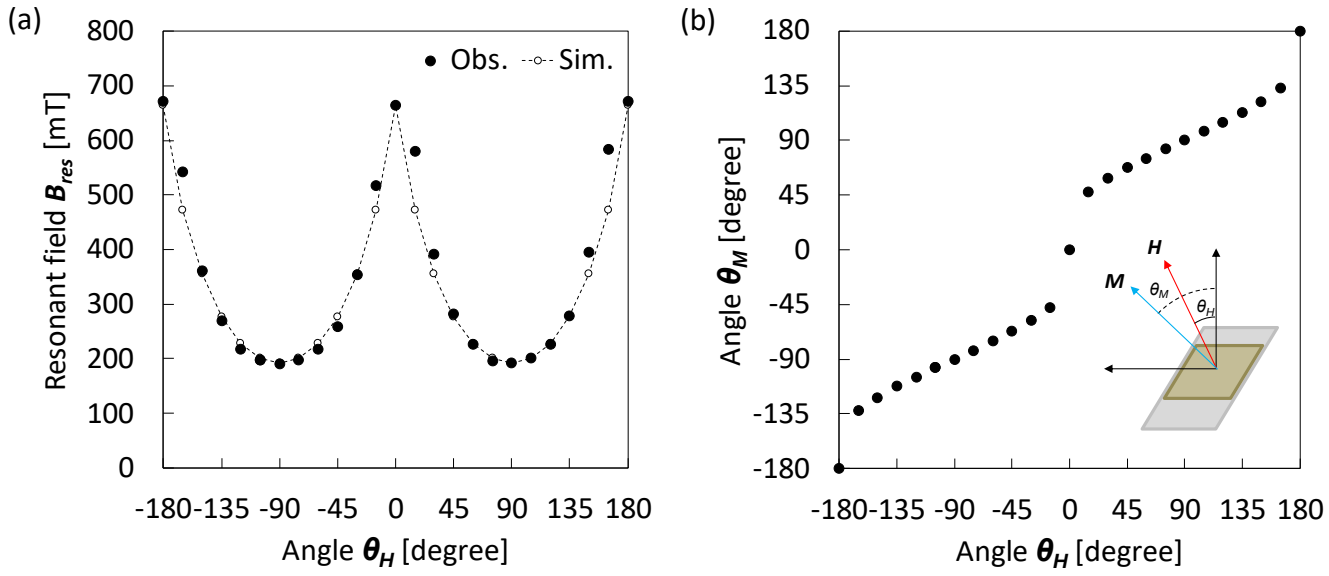

Fig. 2 an experimental result and analysis of the angular dependence of FMR spectra.

References

[1] JEOL RESONANCE Inc. Application note No. ER190002E.
[2] K. Ando, Y. Kajiwara, S. Takahashi, S. Maekawa, K. Takemoto, M. Takatsu, and E. Saitoh, Phys. Rev. B, 78(2008) , 014413.
[3] K. Ando, S. Takahashi, J. Ieda, Y. Kajiwara, H. Nakayama, T. Yoshino, K. Harii, Y. Fujikawa, M. Matsuo, S. Maekawa, and E. Saitoh, J. Appl. Phys. 109(2011), 103913 .

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