Ferromagnetic thin film and spin current (4)

Product used : Electron spin resonance spectrometer (ESR)

***** Power dependence *****

Line shape of an electromotive force (*emf*) spectrum using the spin pumping effect by ferromagnetic resonance (FMR) is regarded as a convoluted spectrum consisting of the two emf components, i.e. the inverse spin-Hall emf (V_{ISHE}) and the anomalous Hall emf (V_{AHE}). It is known that this is expressed in eq. (1)[1].

$$V(B) = K_{ISHE}\frac{\Gamma^2}{(B-B_{FMR})^2+\Gamma^2} + K_{AHE}\frac{-2\Gamma(B-B_{FMR})}{(B-B_{FMR})^2+\Gamma^2} \quad (1)$$

K_{ISHE}, K_{AHE} : Scaling factor
Γ : Dumping coefficient (～line width)

Especially, the anomalous Hall effect makes the shape change according to the way of affection of the electric component of microwaves and the properties of samples. Therefore, it is necessary to analyze the obtained spectrum and to distinguish the mixed components by eq. (1). It makes possible to elucidate the effect of the pure spin current.

Sample and method

The dependences of microwave power on FMR spectrum and the emf amplitude (V_{emf}) were measured simultaneously using the same sample reported on JEOL application note [ER190002E].

The power dependence of microwave on FMR and the ISHE (V_{ISHE})

$V_{obs.}$ (Fig. 1) shows is an obtained V_{emf} spectrum by an experiment. V_{ISHE} and V_{AHE} were divided by fitting using eq. (1) after conversion of obtained differential spectrum ($V_{obs.}$) to an integrated one because conventional FMR method adopted a magnetic field modulation scheme.
As shown in Fig. 2, FMR spectra (Fig. 2 (a)) are proportional to the square root of the irradiated microwave power. On the other hand, V_{ISHE} spectra (Fig. 2 (b)) are proportional to the irradiated microwave power[2].

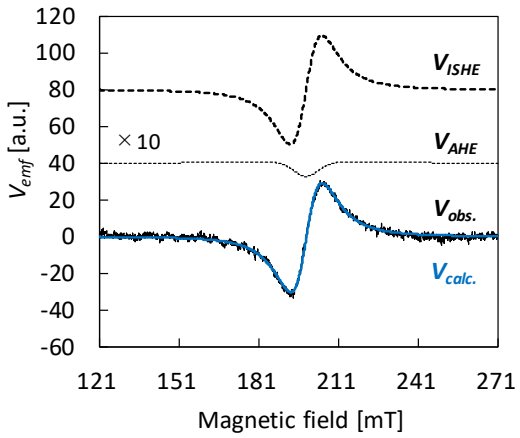

Fig. 1 Spectral deconvolution of V_{emf} spectrum.

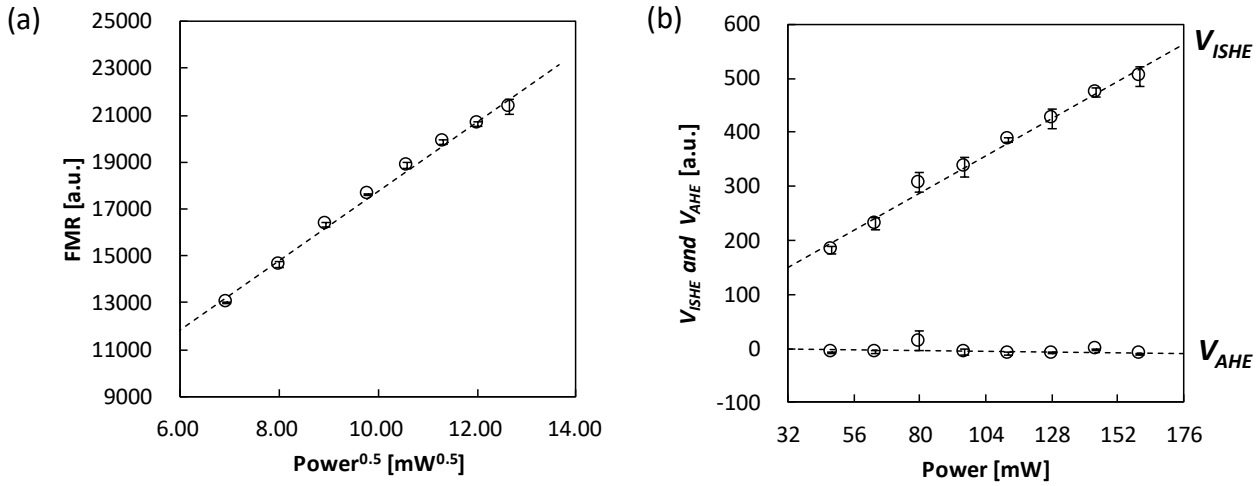

Fig. 2 The irradiated power dependence of FMR spectra and V_{ISHE} spectra.

References

[1] E. Saitoh, M. Ueda, H. Miyajima and G. Tatara, Appl. Phys. Let. 88(2006), 182509.
[2] 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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