Determination of the Exchange Stiffness of Py Films Using Brillouin Scattering

Jaehun Cho, Nam-Hee Kim, Mool-Bit Kang and Chun-Yeol You*
Division of Physics, Inha University

I. Introduction

The exchange stiffness constant A is a fundamental material parameter in the study of magnetism. It is commonly determines from experimental data from the spin-wave stiffness constants D. There are various techniques for measuring D, inelastic neutron scattering experiments[1] or spin-wave resonance experiments[2]. Brillouin light scattering (BLS) widely has been used as a powerful tool to analyze thin films magnetic properties such as the saturation magnetization, magnetic anisotropy energies, spin wave dispersion relations, and exchange stiffness constant. The spin wave resonance frequencies are measured via inelastic scattering of monochromatic light with the magnon, spin wave quanta, in a BLS experiment. In this work, we studied the fundamental magnetic properties of Py thin films, including effective magnetization and stiffness constant A by employing BLS. We also compare the results of the BLS with Vector network analyzer ferromagnetic resonance (VNA-FMR) measurements.

II. Experiment

The magnetic properties were measured by a BLS and VNA-FMR, respectively. In BLS magnetic properties were studied by a Sandercock (3+3) type Fabry-Perot interferometer[3]. The light source is a single frequency 514.5 nm an Argon ion laser with output power of about 160 mW. Back scattering geometry used to observe the light scattered by thermal excitations with an in-plane wavenumber q// = 1.727 × 10^5 cm^{-1} or 1.221 × 10^5 cm^{-1} with the angle of incident as 45^o or 30^o respectively. In VNA-FMR, the probe is brought in contact with the sample, and the FMR measured as the VNA sweeps the frequency (30 GHz bandwidth) while we apply as in-plane magnetic field (H_{DC}).

III. Results

Figure 1 shows typical BLS spectrum for the 30 nm thickness Py with different applied field(216450 and 385950 A/m). The peaks labeled B1 and S are the first order bulk standing spin wave and Damon-Eshbach (DE) surface wave[4] respectively. To investigate the surface dispersion relation, the spin wave frequency for each mode is measured as a function of the field, as displayed Fig. 2. Then the frequencies of the DE surface spin wave and bulk spin wave are analyzed using[5]

$$f_{DE} = \frac{\gamma}{2\pi}\left[H\left(H+4\pi M_s\right)+(2\pi M)^2\left(1-e^{-2q_{//}d}\right)\right]^{1/2} \quad (1)$$

$$f_{Bulk} = \frac{\gamma}{2\pi}\left[\left(H+\frac{2A}{M_s}\left(q_{//}^2+(\frac{n\pi}{d})^2\right)\right)\left(H+\frac{2A}{M_s}\left(q_{//}^2+(\frac{n\pi}{d})^2\right)+4\pi M_s\right)\right]^{1/2} \quad (2)$$

And we analyze resonance frequency for FMR data with Kittel equation,

$$f_{kittel} = \frac{\gamma}{2\pi}\left[H(H+4\pi M_s)\right]^{1/2} \quad (3)$$

H is the applied magnetic field, γ (=2.322 × 10^5 m/(A·s)) is the gyromagnetic ratio, d is the thin film thickness, n is the number of order for bulk peaks, $4\pi M_s$ is the saturation magnetization, A is the exchange constant. We obtained $4\pi M_s$ is 698692 ± 4695 A/m from BLS, and 807711 ± 4814 A/m from VNA-FMR, A is 0.918 ± 0.006 × 10^{-11}J/m (bulk value is 1.14 × 10^{-11}J/m[6]) for 30 nm Py film.

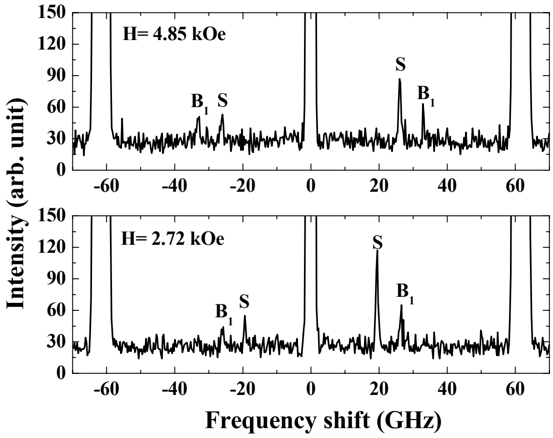

Fig. 1. Brillouin spectra of an 30- nm thick Py film with a difference magnetic field. S and B1 indicate a DE and a first bulk modes.

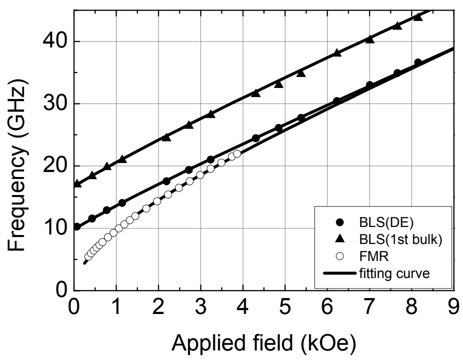

Fig. 2. Variation of spin wave resonance frequency with an applied field for the 30-nm thick Py film.

IV. Reference

[1] A. Michels, J. Weissmuller, A. Wiedenmann, J. G. Barker, J. Appl. Phys **87**, 5953 (2000).

[2] C. A. Bauer and P. E. Wigen, Phys. Rev. B **5**, 4516(1972).

[3] J. R. Sandercock: in Light Scattering in Solids III, ed by M. Cardona and G. Guntherodt (Springer-Verlag, Berlin, 1982) p. 173.

[4] R. W. Damon and J. R. Eshbach, J. Phys. Chem. Solids. **19**, 308 (1961)

[5] R. E. Camley, J. Magn. Magn. Mater. **200**, 583 (1999).

[6] V. S. Sperious, S. S. Parkin, and C. H. Wilts, IEEE Trans. Magn. **23**, 2999 (1987)