Effects of Sputtering Ar Gas Pressure in The Exchange Stiffness of $Co_{40}Fe_{40}B_{20}$ Thin Films

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I. Introduction

Recently, the magnetic properties of CoFeB are actively studied because it is possible candidate materials for the spin transfer torque magnetic random access memory (STT-MRAM) application due to the large tunneling magneto-resistance and perpendicular magnetic anisotropy. However, only a few researches have been found for the exchange stiffness constants of CoFeB [1]. The exchange stiffness constant is very basic physical quantity and related with the exchange energy, or Curie temperature of the materials. In spite of the importance of the exchange stiffness constant, there is no systematic study about the exchange stiffness constant dependence on the fabrication processes such as Ar gas pressure. Furthermore, recently, it is predicted that the switching current density depends on the exchange stiffness constant [2]. In this work, we investigate the dependence of the exchange stiffness constants on the Ar gas pressure. We employ the Brillouin light scattering (BLS) to measure the surface and standing spin waves (SSW) modes of magnon in Co40Fe40B20 thin films, from the resonance frequencies we can determine the exchange stiffness constants.

II. Experiment

$Co_{40}Fe_{40}B_{20}$ thin films were fabricated on Si(100) substrate using a dc magnetron sputtering system. The Ar gas pressure during sputtering processes was varied with 1.5, 4.5, 7.5, 10 mTorr. The thickness of $Co_{40}Fe_{40}B_{20}$ thin films was fixed at 25 nm and Ta (5 nm) layers were used as seed and capping layers. The magnetic properties of the samples 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} with the angle of incident as 45o.

III. Results

The frequencies of the Damon-Eshbach(DE) and the first standing spin wave mode versus the applied magnetic field is plotted in Fig. 1. The frequencies of each modes are analyzed using [4]

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

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

H is the applied magnetic field, γ is the gyromagnetic ratio, d is the thin film thickness, n is the number of order for standing spin wave mode, $4\pi M_s$ is the saturation magnetization, A is the exchange stiffness constant.

The saturated magnetization was determined by DE mode, and the exchange stiffness constant was determined by 1st standing spin wave mode. Fig. 2. is the exchange stiffness constant as a function of Ar gas pressure. We found that increasing Ar gas pressure, exchange stiffness constant decrease from 1.41 to 0.98 × 10^{-11} J/m. We believe that these results are caused by the variation of micro-structure with sputtering Ar gas pressures. It is physically reasonable because exchange stiffness constant is related with the number of nearest neighborhood magnetic atoms.

IV. Summery

In summary, the BLS experiments was applied to investigate the magnetic properties of $Co_{40}Fe_{40}B_{20}$ thin films. We find that the exchange stiffness constant decrease with increasing Ar gas pressure.

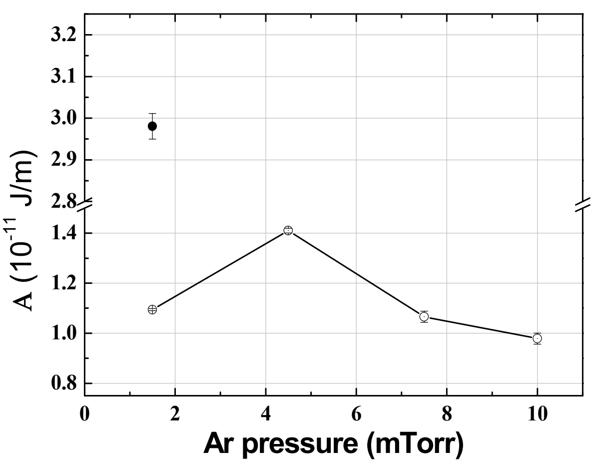

Fig. 1. Exchange stiffness constant in $Co_{40}Fe_{40}B_{20}$ and $Co_{90}Fe_{10}$ films as a function of Ar gas pressure. The closed circle is $Co_{90}Fe_{10}$ film and the open circle are $Co_{40}Fe_{40}B_{20}$ films.

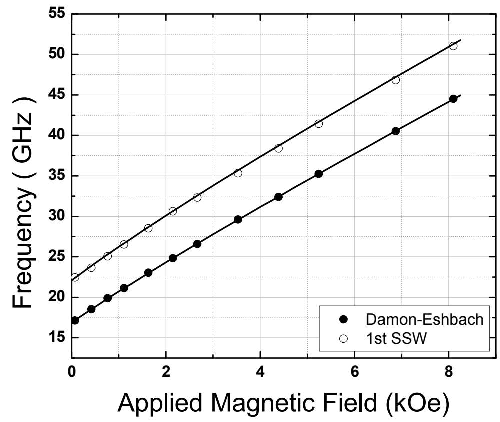

Fig. 2. Variation of spin wave frequncy with an applied field for the 1.5 mTorr $Co_{40}Fe_{40}B_{20}$ film. The closed circle are Damon-Eshbach mode and the open circles are 1st order SSW mode. The lines are fitted curve.

V. Reference

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