Study of magnetic properties at the interface in ultra-thin CoFeB films using a high sensitivity VNA-FMR spectrometer

S. Tamaru and T. Yamamoto
(Spintronics Research Center, Advanced Industrial Science and Technology (AIST), Tsukuba, Ibaraki, 305-8568 Japan)

Dynamical properties of ultra-thin magnetic films are attracting increasing attention with the advent of various MTJ based spintronic devices such as spin transfer torque magnetic random access memory (STT-MRAM) or voltage torque magnetic random access memory (VT-MRAM), in which the free layer is a CoFeB film with a typical thickness of approximately 1 nm or even less. It has been observed that many magnetic properties are dependent on the film thickness in the nanometer scale [1]. In addition, VT-MRAM takes advantage of the change of perpendicular magnetic anisotropy (PMA) by the application an electric field at the CoFeB/MgO interface [2]. Thus, these devices require thorough understanding of the interfacial magnetism.

Ferromagnetic resonance (FMR) is the most commonly used measurement for the study of magnetization dynamics. FMR provides various magnetic properties, some of which, such as the damping parameter or Lande *g* factor, cannot be obtained by other characterization techniques. It is highly desirable to perform broadband FMR measurement to characterize a magnetic thin film. However, such a measurement on an ultra-thin film has been difficult, mainly due to the lack of sensitivity or broadband measurement capability in conventional FMR spectrometers.

We have developed a high sensitivity vector network analyzer ferromagnetic resonance (VNA-FMR) spectrometer as shown in Fig. 1 to overcome this difficulty. In this system, a low frequency modulation field is applied to the sample in addition to a DC bias field (H_B) while a VNA measures the S-parameter, and the modulation frequency component of the S-parameter is extracted by a numerical data processing equivalent to lock-in detection, which significantly enhances the sensitivity while maintaining the broadband coverage.

Using this system, we measured FMR on a series of ultra-thin CoFeB films with thicknesses ranging from 1.5 nm down to 1.1 nm under H_B applied along the out-of-plane (OOP) direction. Fig. 2 is the FMR spectra on a 1.5 nm thick CoFeB film as a function of frequency and H_B, which shows a clean Kittel mode FMR signal. The gyromagnetic ratio that contains Lande *g* factor can be determined from the slope of the peak frequency vs H_B plot. Fig. 3 shows the value of *g* as a function of CoFeB thickness. The value of *g* increases as the thickness decreases, which suggests that the orbital angular moment is not completely quenched at the interfaces due to broken symmetry, which could be the cause of the increase of PMA or damping parameter previously reported in [1].

In the presentation, we will first introduce the high sensitivity VNA-FMR developed in this work, then report the FMR measurement results on CoFeB films over wide range of thicknesses and deposition conditions to explore the change of magnetic properties at the interface.

This work was supported by JSPS KAKENHI Grant Number 18K14118.

[1] S. Ikeda, et al., Nat. Mater. 9.9 (2010): 721-724.
[2] T. Nozaki, et al., Micromachines 10.5 (2019): 327.

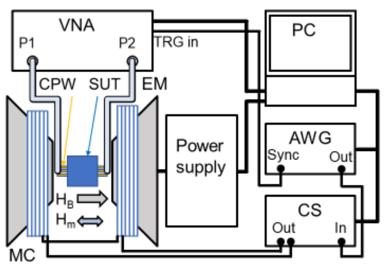

Fig. 1, Block diagram of the VNA-FMR with field modulation detection developed in this work.

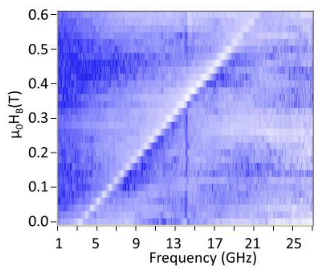

Fig. 2, FMR spectra on a 1.5 nm thick CoFeB film under OOP H_B.

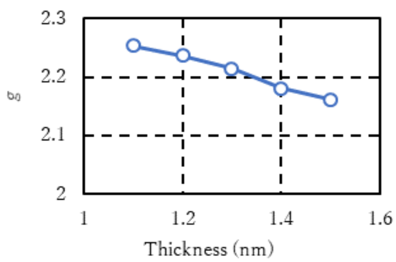

Fig. 3, Lande *g* factor as a function of CoFeB thickness.