Microstructure dependent magnetization dynamics of polycrystalline YIG thin films

Satya Prakash Pati and Yasushi Endo
(Tohoku University)

Studies on microstructure-dependent magnetization dynamics of yttrium iron garnet (YIG, $Y_3Fe_5O_{12}$) have received considerable attention after it was first studied by Lecraw et.al.[1]. YIG has been proved to be an efficient material for magnonics and spintronics application after discovery of spin pumping [2], spin seebeck effect [3] and spin hall magnetoresistance [4] phenomena. Being a magnetic insulator, YIG often considered as the best medium for spin-wave propagation due to its very small intrinsic damping parameter in bulk ~3×10^{-5}[5]. Moreover, for device application, it is required to fabricate YIG thin films over a metallic electrode without affecting its damping parameter. In this study, we report the use of a platinum electrode to control the microstructure as well as Gilbert damping parameter of polycrystalline YIG films.

Amorphous YIG films (t_{YIG}=400,100 and 50nm) were deposited on Al_2O_3 (0001) substrates without and with a Pt (25 nm) buffer layer by RF magnetron sputtering at room temperature while maintaining a base pressure of ~4.0×10^{-4} Pa. YIG deposition was performed at an RF power of 180 W in a mixed gas of Ar = 3.8 SCCM and O_2 = 1.2 SCCM. The deposition rate was 2.17 nm/min. The as-deposited YIG films were post-annealed at various temperatures (973–1173 K) in air for three hours. X-ray diffraction (XRD) and X-ray fluorescence (XRF) were used to analyze the structure and composition, respectively. The surface morphology of the films was studied by atomic force microscopy (AFM). VSM was used to investigate the static magnetization properties while magnetization dynamics of films were estimated by the field domain ferromagnetic resonance (FMR) spectra using the coplanar waveguide (CPW).

Figure 1 compares the AFM image of 100-nm thick YIG films without and with the buffer layer exhibiting surface roughness 4.50 nm and 2.47 nm, respectively. The grain size of the YIG film with the buffer layer is much larger than that of the YIG film without the buffer layer, and the average values are several hundred nanometers. This result means that the Pt buffer layer improves the grain size and surface roughness of the post annealed YIG film. Figure 2 shows the thickness dependence of Gilbert damping parameter (α) in YIG films without and with the Pt buffer layer. In every case, α increases as the film thickness decreases. Their values of the films with the buffer layer become lower than that of films without the buffer layer, and are very close to the bulk value [5]. For example 100-nm thick YIG film has α~3.5×10^{-4} and 11.4×10^{-4} for the Pt-buffered and non-buffered cases, respectively. This result may be extrinsic in origin, as Pt-buffered films have both larger grain size and lower roughness, thus lower α, however due to the high structural in-homogeneity in the films without the buffer layer have higherα. On the basis of these results, it is revealed that the damping parameter can be significantly reduced by improving the surface morphology by using a Pt buffer layer which may act as a lower electrode in magnonics and spintronics applications.

This work was partly supported by JSPS KAKENHI Grant Number JP26289082, JP17H03226, JP17F17070 from MEXT, Japan and Murata Science Foundation and ASRC in Japan. S. P. Pati would like to thank JSPS for the international post-doctoral research fellowship (ID no: P17070).

References

[1] R. C. Lecraw *et.al.*, Phys. Rev.110, 1311(1958).
[2] Y. Kajiwara *et al.*, Nature 464, 262 (2010).
[3] K. Uchida *et al.*, Nat. Mater. 9, 894 (2010).
[4] C. Hahn *et al.*, Phys. Rev. B 87, 174417 (2013).
[5] M. Sparks, Ferromagnetic-Relaxation Theory (McGraw Hill, New York,(1964).

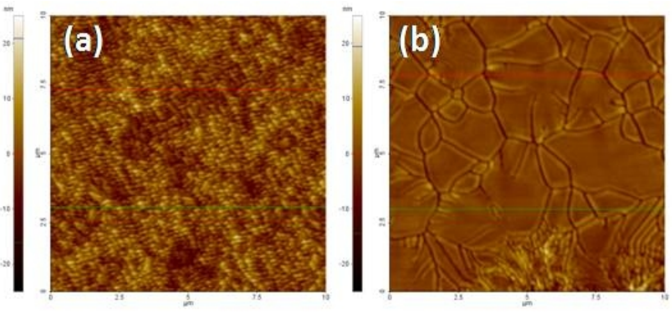

Fig. 1 AFM image of (a) Al_2O_3(sub)/YIG(100) and (b) Al_2O_3(sub)/Pt(25)/YIG(100) post annealed at 1173 K .

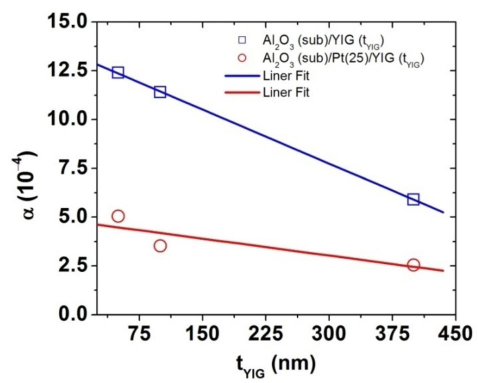

Fig. 2 Thickness (t_{YIG}) dependent Gilbert damping parameter (α) of YIG film without and with a Pt buffer layer.