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Spin wave propagation in magnetic bilayers with $L1_0$-MnGa

S. Mizukami[1], T. Kubota[1], R. Ranjbar[1,2], S. Iihama[2], A. Sugihara[1], Q. Ma[1], Y. Ando[2], K. Suzuki[1], X. Zhang[1], and T. Miyzaki[1]
[1]WPI-AIMR, Tohoku Univ., Katahira 2-1-1, Sendai 980-8577, Japan
[2]Dept. of Appl. Phys., Graduate School of Engineering, Tohoku Univ., Aoba 6-6-05, Sendai 980-8579, Japan
E-mail: mizukami@wpi-aimr.tohoku.ac.jp

Spin wave in magnets has attracted much attention for the use in advanced information devices, such as spin wave information bus and majority logic gate proposed [1]. Most of the works focus on magnetostatic volume or surface spin wave in films of soft magnetic metals or insulators, because those have relatively high phase/group velocity and can be easily accessed by microwave instruments. However, the operation speed and devices size are limited since their spin wave has low-frequency and long wave length. Thus, it is interesting to investigate spin wave in other types of magnetic materials, for example, perpendicularly magnetized films or hybrid films of in-plane and out-of-plane magnetized layers. We report the spin wave propagation characteristics investigated by microwave and ultrafast pump-probe optical techniques in bilayers using MnGa with a large perpendicular magnetic anisotropy.

The bilayer films were fabricated by UHV-magnetron sputtering. The films were then patterned into the planar devices with coplanar wave guides as the input and output antenna of microwave [2]. The spin wave propagation are characterized by transmission and reflection measurement using a vector-network analyzer as well as the space- and time- resolved magneto-optical Kerr effect measurement based on a microscope all-optical pump-probe technique with spot size of pump (probe) beam of about 3 (1) μm. Out-of-plane magnetic field was applied by electromagnets in the both set-ups.

Fig. 1(a) shows polar MOKE loop for a Co/MnGa bilayer exhibiting the shape superposed by those of in-plane Co and out-of-plane MnGa layers. This bilayer has the weak interfacial anti-ferromagnetic coupling [3]. VNA-reflection measurement shows the single and broad absorption peak when the out-of-plane applied field is more than 2 T, being attributed to spin precession in Co layer [Fig. 1(b)] [4]. While, spin wave propagation signals were unable to be observed in the VNA-transmission measurement for the devices in any fields, even for the devices with antenna distance of 17 μm, implying that the spin-wave propagation length may be much smaller.

Figure 2 shows time-resolved MOKE of the device with different distance L between pump and probe beam spots. When the center of probe and pump beam spot coincide (L=0 μm), the time-resolved MOKE shows ultrafast demagnetization at zero delay time and then the very fast (70 GHz) and slow oscillation (7 GHz) follow with the exponentially decaying background. Fast (slow) oscillation is mainly attributed to that of MnGa (Co) spin precession in the bilayer. Temporal change in Kerr rotation is still observed at L=2 μm, and exhibit the wave packet-like shape, which may be attributed to the propagating spin wave in the bilayer. The signal magnitude at L=4 μm become two times smaller, indicating that the propagation length of spin wave is about 4 μm.

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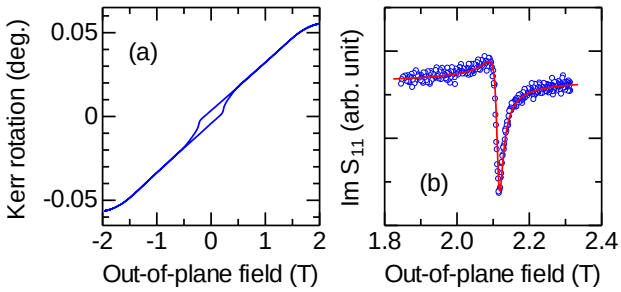

Fig. 1(a) Polar MOKE loop and (b) VNA-reflection measurement at input microwave frequency of 6 GHz in the device based on the Co/MnGa bilayer.

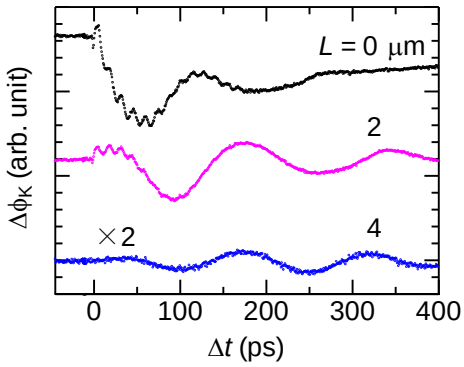

Fig. 2(a) Microscope TRMOKE measurements of the devices based on the Co/MnGa bilayer with different distance L between pump and probe beam laser spot.

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