Inducing out-of-plane precession of magnetization for microwave-assisted magnetic recording with an oscillating polarizer in a spin-torque oscillator

W. Zhou[1], H. Sepehri-Amin[1], T. Taniguchi[2], S. Tamaru[2], Y. Sakuraba[1], S. Kasai[1], H. Kubota[2] and K. Hono[1]

[1]National Institute for Materials Science (NIMS), Tsukuba 305-0047, Japan

[2]National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba 305-8568, Japan

Microwave-assisted magnetic recording (MAMR) is one of the promising technologies for maintaining the continuous increase of the recording density of hard disk drives. One major challenge for MAMR is to generate high frequency (f), large amplitude ac magnetic field (h_{ac}) within a nanosized area, which is expected to be realized with a spin-torque oscillator (STO). Previous studies used a perpendicularly magnetized polarizer to apply spin-transfer torque (STT) to another magnetic layer (field generating layer; FGL), in order to induce the out-of-plane precession (OPP) mode oscillation for h_{ac} generation.[1)] However, this design usually leads to a thick structure that is difficult to be embedded in the narrow gap of the recording head. Recently, Zhu *et al.* proposed a novel design of STO, where only a soft magnetic thin layer is exploited as the polarizer.[2)] The polarizer first has its magnetization reversed to the direction opposite to the magnetic field (H) within the gap due to STT (Fig. 1(b)), then spin-polarizes the current to induce the OPP mode oscillation of FGL (Fig. 1(c)).[3)] In this study, we experimentally demonstrate the OPP mode oscillation using the aforementioned design.

A 7-nm-thick $Fe_{67}Co_{33}$ (FeCo) layer was used as the FGL while a 7-nm-thick $Ni_{80}Fe_{20}$ (NiFe) layer was used as the polarizer, which were separated by 5-nm-thick Ag spacer. For characterization of the microfabricated STO devices, the resistance and the power spectral density (PSD) of the device were measured with increasing bias DC voltage (U) under a constant H. The positive U was defined as the electrons flowing from the NiFe layer to the FeCo layer.

The experimental results shown here were measured from a device with a diameter of ~ 28 nm. The magnetoresistance (MR) ratio of the device is ~ 6.2%. Under H to align the magnetization of both the FeCo and NiFe layers to the perpendicular direction, as U increased, we observed signals of the resistance indicating the reversal of the NiFe layer, followed by the emergence of multiple microwave signals. Figure 2 shows the mapping of PSD under $\mu_0 H$ = 0.81 T tilted 2° from the perpendicular direction. When U > 30 mV, both the NiFe and FeCo layers are in OPP mode oscillation at f_{NiFe} and f_{FeCo}, respectively. And the strong microwave signal marked f_{MR} is due to the MR effect with a unique relationship of $f_{MR} = f_{NiFe} - f_{FeCo}$, as indicated by Fig. 1(d).[4)] Such dynamics were well reproduced by micromagnetic simulation.

References

1) S. Bosu *et al.*, Appl. Phys. Lett., **108**, 072403 (2016).
2) J.-G. Zhu, Joint MMM-Intermag Conference (2016), AB11.
3) H. Sepehri-Amin *et al.*, J. Magn. Magn. Mater., **476**, 361 (2019).
4) W. Zhou *et al.*, Appl. Phys. Lett., **114**, 172403 (2019).

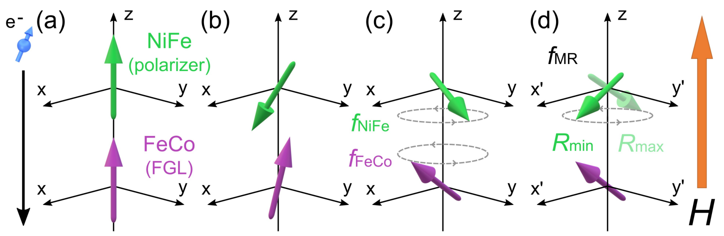

Fig. 1 (a) Schematic illustration of magnetization of both NiFe and FeCo aligned along H. (b) NiFe is reversed by STT. (c) Both NiFe and FeCo are in OPP mode oscillation. (d) If the xy-plane rotates with FeCo at f_{FeCo} around the z-axis, in this coordinate system (x', y', and z), FeCo stays still, while NiFe oscillates with f equal to $f_{NiFe} - f_{FeCo}$, which is also f of the change in resistance due to the MR effect (f_{MR}).

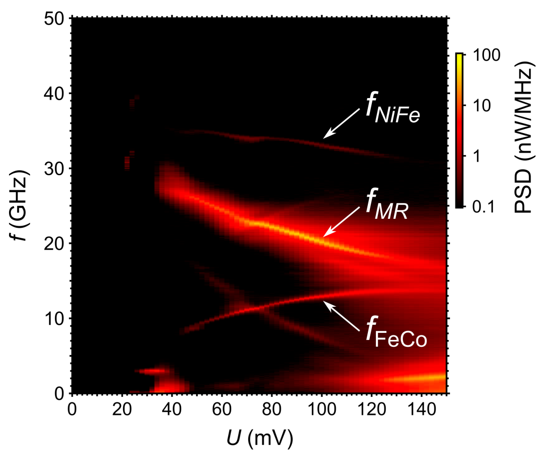

Fig. 2 Mapping of PSD under $\mu_0 H$ = 0.81 T tilted 2° from the perpendicular direction.