A new characterization method for spin-torque oscillator (STO) using injection locking

Nagarjuna Asam[1], Hirofumi Suto[2], Shingo Tamaru[3], Hossein Sepehri-Amin[1], Tomoya Nakatani[1], Weinan Zhou[1], Hitoshi Kubota[3], Yuya Sakuraba[1]

[1]Research Center for Magnetic and Spintronic Materials, National Institute for Materials Science, 1-2-1 Sengen, Tsukuba, Ibaraki, 305-0047 Japan
[2]Corporate Research and Development Center, Toshiba Corporation, 1, Komukai-Toshiba-cho, Saiwai-ku, Kawasaki, 212-8582, Japan
[3]Research Center for Emerging Computing Technologies, National Institute of Advanced Industrial Science and Technology, Central 2, 1-1-1 Umezono, Tsukuba, Ibaraki 305-8568, Japan
E-mail: ASAM.Nagarjuna@nims.go.jp

Spin-torque oscillator(STO) is a spintronic device that generates radio-frequency (RF) oscillating magnetic field for Microwave-Assisted magnetic recording (MAMR) application[1]. This STO is usually placed between the write pole and trailing shield of the recording head, but RF signal is heavily attenuated by connecting STO directly to a radio-frequency (RF) characterization device such as spectrum analyzer via the write-head assembly, making it difficult to inspect the frequency of oscillating magnetic field. Therefore, we are proposing a new experimental method to characterize the oscillation frequency of spin-torque oscillator using injection locking from externally RF magnetic field, which can be utilized without connecting a RF-compatible electric circuit with the STO.

When an STO is under oscillation, it can undergo injection locking to an externally applied oscillating magnetic field[2] whose frequency(f_{ext}) is close to the original oscillation frequency(f_{STO}). This changes the trajectory of magnetization oscillation and hence the dc resistance of the STO. If we can detect the change of dc resistance of the STO as an indicator of injection locking, this technique allows us to identify the frequency at which injection locking occurs. Thus, we can characterize the oscillation frequency of the STO without measuring the RF output from the STO. To demonstrate this experimentally, we fabricated the STO of a NiFe/Cu/CoFe stacking structure, so called all-in-plane STO [3][4]. We fabricated an STO pillar of around 40nm in diameter and also designed a co-planar waveguide on top of it insulated by SiO_2.To apply external RF field and measure a change of dc resistance between off and on parts of the pulse (ΔR) by using a lock-in amplifier, we applied a pulsed RF electrical excitation to the co-planar waveguide, with frequency f_{ext} and pulsed at 1MHz.

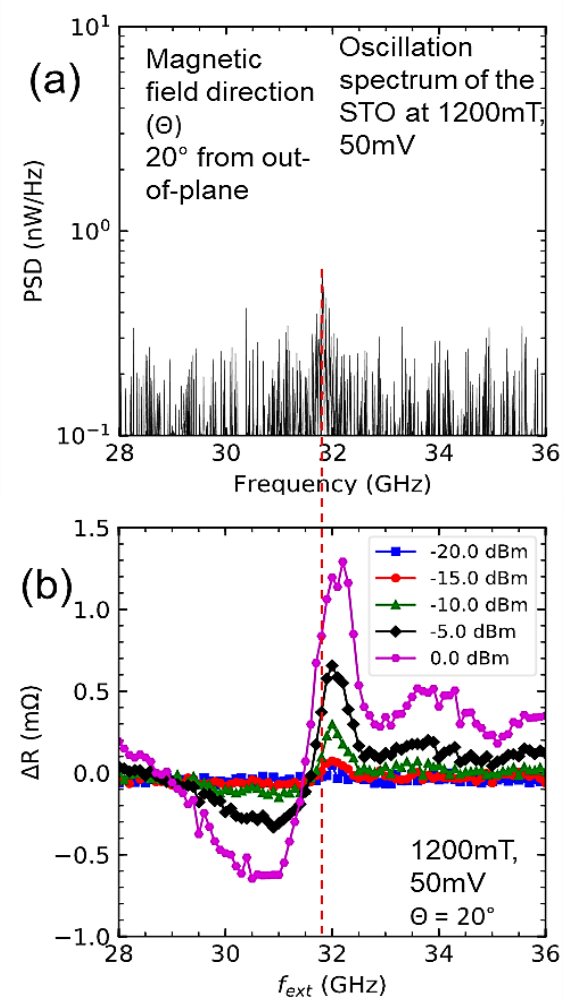

Figure 1 (a) Typical oscillation spectrum of the STO (b) Change of resistance upon injection locking under the same conditions

Figure 1(a) shows a typical RF output spectrum of the STO at 50mV of bias voltage and 1200mT of magnetic field, showing a tiny peak around 32GHz. Figure 1(b) shows the value of ΔR as a function of f_{ext} measured by proposed new technique. Clear dip and the peak of the ΔR indicates an occurrence of injection locking, and the change of ΔR and lock-range frequency enhances with increasing applied RF magnetic field. We can use the injection locking frequency as a representation of actual oscillation frequency of magnetization in the STO. Using this method, there is no need to electrically connect the STO to a spectrum analyzer via an RF-compatible electrical circuit, thus beneficial for inspecting a magnetization oscillation in the product-level STO for MAMR assembled with a write-head.

[1] J. G. Zhu, X. Zhu, and Y. Tang, *IEEE Trans. Magn.*, vol. 44, no. 1, pp. 125–131, 2008.
[2] M. Tortarolo *et al.*, *Sci. RepoRts* |, vol. 8, p. 1728, 2018.
[3] H. Sepehri-Amin *et al.*, *J. Magn. Magn. Mater.*, vol. 476, pp. 361–370, Apr. 2019.
[4] W. Zhou *et al.*, *Appl. Phys. Lett.*, vol. 114, no. 17, p. 172403, Apr. 2019.