非共鳴条件での磁気抵抗効果による整流効果を用いた磁化反転測定
Measurement of magnetization switching using nonresonant spin rectification effect

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Magnetization switching using spin orbit torque (SOT) [1] has been investigated intensively, because it enables a low power consumption and high endurance magnetoresistive random access memory. For a ferromagnet with in-plane magnetic anisotropy, fabrication of spin valves such as a magnetic tunnel junction is generally required. Such additional and complicated fabrication procedures impede a wide variety of material search for spin orbit materials. In this study, we demonstrated in-plane magnetization switching of a single $Ni_{80}Fe_{20}$ (Py) layer on platinum (Pt) layer by using nonresonant spin rectification effect (SRE). Under the irradiation of microwave with a frequency of several GHz, dc voltage via SRE appears near the ferromagnetic resonance (FMR) field, well known as the spin-torque FMR [2]. On the other hand, non-zero dc voltage, whose voltage level corresponds to the magnetization direction, also appears around zero magnetic field due to the nonresonant SRE[3]. We found that nonresonant SRE was enhanced under the irradiation of microwave with a frequency lower than FMR condition. By using enhanced nonresonant SRE, we demonstrated the detection of in-plane magnetization switching using SOT.

Figure 1 shows a schematic of the fabricated device. Pt/Py/MgO/SiO_2 layers and Au/Ti electrode were fabricated on the MgO substrate. In the magnetization switching measurements, a large magnetic field at $\theta_H = 0^o$ was applied to initialize the magnetization direction. After removing the magnetic field, a low frequency microwave (0.2 GHz) was applied and a dc voltage induced by SRE was measured. After stopping the microwave irradiation, a pulse current was applied into the Pt layer. Magnetization switches to -*y* direction when the SOT generated by the spin Hall effect in Pt and/or Oersted field generated by the charge current in Pt are sufficient. Then, dc voltage induced by FMR was measured again. When the magnetization is successfully switched, a clear difference in dc voltage between before and after application of the pulse current is detected. Figure 2 shows the voltage difference between before and after application of the pulse current as a function of dc charge current. A successful magnetization switching was confirmed above 2.5×10^7 A/cm^2. In the presentation, we will also report the origin of the enhancement of nonresonant SRE.

[1] H. W. Tseng et al., Science **336**, 555 (2012). [2] L. Liu et al., Phys. Rev. Lett. **106**, 036601 (2011). [3] X. F. Zhu et al., Phys. Rev. B **83** 140402 (2011).

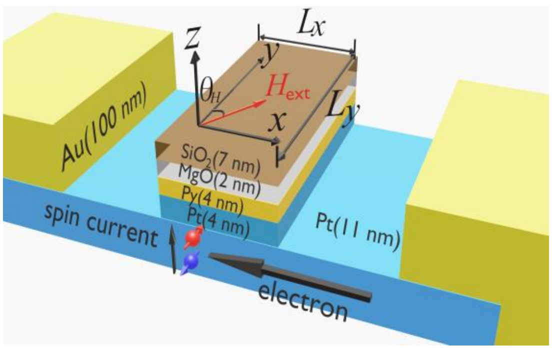

Fig.1. A schematic of device structure for demonstration of current induced magnetization switching.

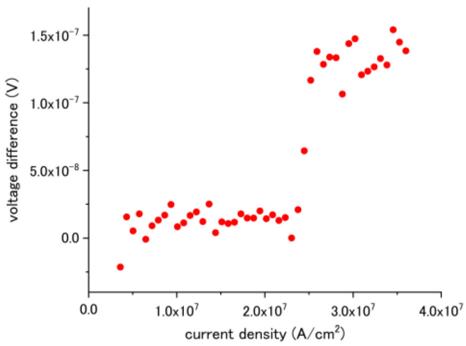

Fig. 2. Voltage difference between before and after application of the pulse current as a function of dc charge current