Effect of second order magnetic anisotropy on linear response of magnetic sensors with CoFeB/MgO/CoFeB based magnetic tunnel junctions

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Magnetic tunnel junctions (MTJs) are one of the promising candidates for next-generation magnetic sensor due to its low power consumption, small size and high sensitivity. One remarkable application of MTJ sensors is a current monitoring system in electric vehicle which requires both high sensitivity and low nonlinearity in the range of wide magnetic field of over 1 kOe. However, previous study suggests that sensitivity and nonlinearity are in the relationship of trade-off against effective magnetic anisotropy field, H_k^{eff} which results in a lack of either high sensitivity or low nonlinearity [1]. In this work, we focused on second order anisotropy field, H_{k2} and found that nonlinearity can be reduced by the control of H_{k2} without decreasing sensitivity.

A MTJ with the stacking of Si / SiO_2-sub / Ta(3) / Ru(10) / Pt(2) / $[Co(0.28) / Pt(0.16)]_9$ / Co(0.28) / Ru(0.4) / Co(0.28) / $[Pt(0.16) / Co(0.28)]_5$ / Co(0.28) / Ta(0.2) / $Co_{40}Fe_{40}B_{20}$(1.0) / MgO(2) / $Co_{40}Fe_{40}B_{20}$(1.5) / Ta(5) / Ru(8) (thickness in nm) was deposited by dc/rf magnetron sputtering and patterned into circular junction with 100 μm diameters. Magnetic properties were measured by superconducting quantum interference device (SQUID), vibrating sample magnetometer (VSM) and ferromagnetic resonance (FMR). Also, its magnetoresistance was measured by four-terminal method using physical property measurement system (PPMS) at 50-400 K.

Figure 1 shows normalized conductance curves measured at 50-400 K. The conductance curve at 400 K looks linear with low nonlinearity of 2.0 % which is evaluated from $(G_{exp.} - G_{fit.}) / (G_{max} - G_{min}) \times 100$ (%) where $G_{exp.(fit.)}$ denotes experimental (linear-fitted) conductance curve. However, slight deflections in conductance curves become larger as decreasing temperature, resulting in the large nonlinearity of 7.0 % at 50 K. These results are strongly associated with the modification of H_{k2}/H_k^{eff} in CoFeB depending on the temperature.

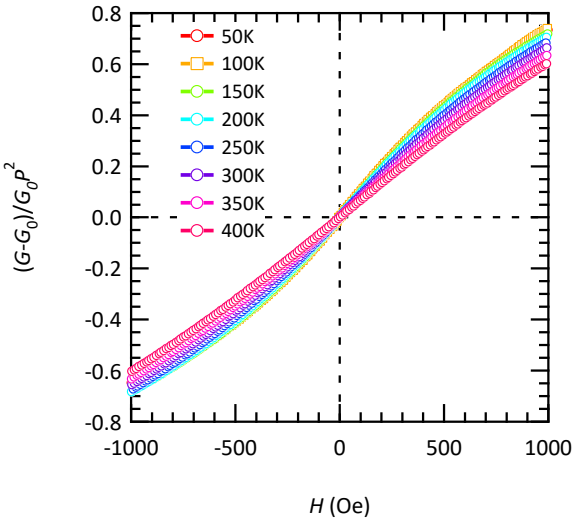

Figure 1 Normalized conductance curves

[1] T. Nakano, *et al.*, Appl. Phys. Lett. 110, 012401 (2017).