Spin-orbit torque in structures with magnetization-compensated MnGa/Co_2MnSi

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1. Introduction

MnGa/Co_2MnSi (CMS) bilayer structures, in which MnGa and CMS layers are antiferromagnetically coupled to each other [1], are attractive for the ferromagnetic electrodes of perpendicular magnetic tunnel junctions with high tunneling magnetoresistance because of the relatively large perpendicular magnetic anisotropy of MnGa and the half metallicity of CMS. We have previously shown that the ratio of spin-orbit torque (SOT) per current density in a MnGa/CMS/Ta structure is larger than that in a MnGa/Ta structure [2]. By using magnetization-compensated MnGa/CMS bilayer, further enhancement of the efficiency of SOT generation is expected. In this work, we systematically investigated SOT in MnGa/CMS/Ta structures with various CMS thicknesses (t_{CMS}) including the magnetization-compensation point.

2. Experimental Methods

A wedged structure consisting of MgO buffer (10)/NiAl buffer (5)/MnGa (2.5)/CMS (t_{CMS} = 0-1.7) /Ta (5)/MgO cap (2) from the substrate side was deposited on an MgO(001) substrate (Fig. 1) by using a sliding shutter, where numbers in parentheses are nominal film thickness in nm. The wedged structure was processed into Hall devices with a 5-μm wide channel to investigate the SOT.

3. Results and Discussion

We measured the effective magnetic field $\mu_0 H_{eff}$ (μ_0 is the permeability in vacuum) induced by the interaction between SOT and magnetization in domain walls (DWs) created during the magnetization reversal under in-plane magnetic field $\mu_0 H_x$ along current direction. Figure 2 shows normalized transverse resistance R_{AHE} reflecting perpendicular component of magnetization as a function of $\mu_0 H_z$ under $\mu_0 H_x = \pm 300$ mT for the device with t_{CMS} = 0.6 nm. When current I and H_x are parallel (antiparallel), the center of the hysteresis loop is shifted in the negative (positive) H_z direction. These results are consistent with magnetization reversal through SOT-assisted DW motion under H_x, and the shift amount corresponds to $\mu_0 H_{eff}$. The magnitude of $\mu_0 H_{eff}$ almost linearly increases with H_x at low H_x and saturates at large H_x. We denoted the saturated $\mu_0 H_{eff}$ as $\mu_0 H_{eff}$*. We carried out similar measurements on the devices with t_{CMS} = 0-1 nm and obtained $\mu_0 H_{eff}$* in devices with various t_{CMS}. Figure 3 shows $\mu_0 H_{eff}$* per I ($\mu_0 H_{eff}^*/I$), which is a measure of the efficiency of SOT generation, as a function of t_{CMS}. The value of $\mu_0 H_{eff}^*/I$ is increased by inserting a CMS layer between Ta and MnGa layers, and it takes the maximum in the device with t_{CMS} = 0.6 nm, which is near the magnetization-compensation point. The maximum efficiency is 1.1 T/A, which is ~6 times larger than that in the device with t_{CMS} = 0 nm. These results indicate that the enhancement of the efficiency of SOT generation occurs around the magnetization-compensation point.

References

[1] R. Ranjbar et al., Mater. Lett. **160**, 88-91 (2015)
[2] K. Jono et al., AIP advances. **11**, 025205 (2021)

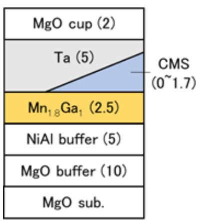

Fig. 1. Stacking structure of the fabricated film.

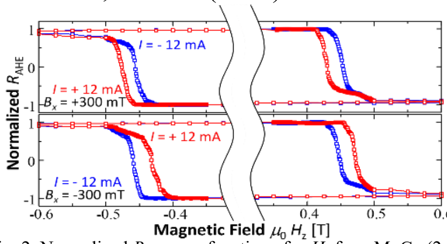

Fig. 2. Normalized R_{AHE} as a function of $\mu_0 H_z$ for a MnGa (2.5) /CMS (0.6)/Ta (5) sample under I = ±12 mA and $\mu_0 H_x$ = ±300 mT.

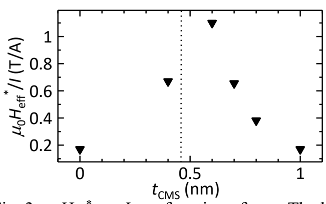

Fig. 3. $\mu_0 H_{eff}^*$ per I as a function of t_{CMS}. The black dotted lines at t_{CMS} = 0.45 nm indicates the magnetization-compensation point.