Spin Hall magneto resistance in epitaxial Ta thin films

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1. Introduction

Spin Hall magneto resistance (SMR)[1,2] is one of the effective ways to evaluate the spin Hall angle (SHA) in nonmagnetic materials. Here, we report enhancement of SMR in an epitaxial Ta/CoFeB system and the observed enhancement suggests contributions from bulk and interface to spin Hall effect.

2. Experimental procedure

We made the following two different layer structures by radio frequency magnetron sputtering: (A) Al_2O_3 (0001) substrate / epitaxial α-Ta (*d* nm) / CoFeB(1 nm) / AlO(2 nm) and (B) Si substrate / SiOx / amorphous Ta (*d* nm) / CoFeB (1 nm) / AlO (2 nm). The crystal structures of Ta under layers were confirmed by X-ray diffraction and *in-situ* reflection high energy electron diffraction methods. Magneto resistance measurement was performed at room temperature.

3. Results

According to the experimental result shown on Fig.1, the enhancement of SMR amplitude, which directly reflects the information of SHA, is a strong evidence that the epitaxial Ta has larger SHA than that in the amorphous Ta below $d = 3$ nm. The SHA was extracted by fitting theoretical formula to the experimental results [2], and the obtained SHA for both epitaxial and amorphous Ta were 0.13 and 0.08, respectively. Since sheet conductance for epitaxial and amorphous Ta in $d < 3$ nm show similar values obtained from Fig.2 (92.8 μΩcm for epi-Ta, and 95.1 μΩcm for amo-Ta), we cannot explain the enhanced SMR amplitude in terms of the intrinsic and/or side jump contributions. The possible origin of this enhancement of SHA in epitaxial Ta might be due to the interface contribution to spin Hall effect.

[1] H. Nakayama, *et al.,* Phys. Rev. Lett. **110**, 206601 (2013).
[2] J. Kim *et al.*, Phys. Rev. Lett. **116**, 097201(2016).

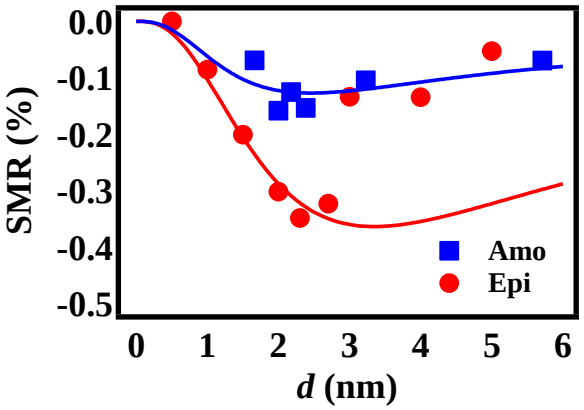

Fig. 1, Ta layer thickness dependence of SMR ratio for both epi-Ta (Red) and amo-Ta (blue). Solid lines indicate theoretical formula.

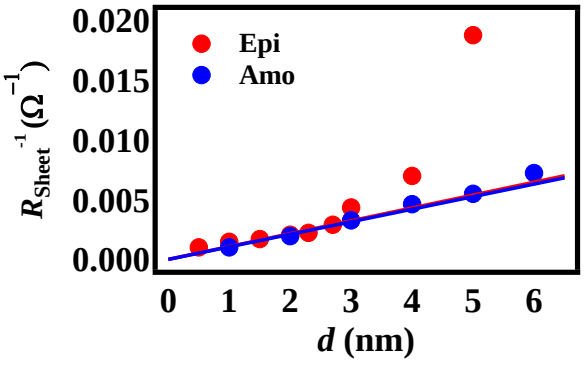

Fig. 2, Ta layer thickness dependence of the sheet conductance for both epi-Ta (Red) and amo-Ta (blue). Solid lines represent the linear fitting to the experimental data in order to estimate the resistivity of the Ta layers. In case of epi-Ta, it was limited the fitting range to $d < 3$ nm.