Spin-orbit-torque induced magnetization switching for an ultra-thin MnGa/Co_2MnSi bilayer

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1. Introduction

A MnGa/Co_2MnSi bilayer is expected to be a promising ferromagnetic electrode for a perpendicular magnetic tunnel junction (p-MTJ) with high tunnel magnetoresistance and high thermal stability due to the half-metallic nature of Co_2MnSi (CMS) and relatively large perpendicular magnetic anisotropy (PMA) of MnGa. Although a p-MTJ with MnGa/CMS electrodes has been demonstrated[1], the thickness of MnGa was larger than 10 nm, which is not applicable to the spin-transfer-torque induced or spin-orbit-torque (SOT) induced magnetization switching. The purpose of this study is to clarify the magnetic properties and SOT-switching characteristics for an ultra-thin MnGa/CMS bilayer.

2. Experimental Methods

A layer structure consisting of (from the substrate side) MgO buffer (10)/NiAl buffer (5)/ MnGa (2)/CMS (1)/Ta (5)/MgO cap (2) was deposited on a (001)MgO single-crystal substrate. The numbers in parentheses are nominal thicknesses in nanometers. The CMS layer was deposited on the half area of the substrate by using a slide shutter [Fig. 1(a)] to precisely evaluate the influence of the CMS on the magnetic properties and SOT-switching characteristics. The layer structure was processed into Hall devices with a 5-μm-wide channel to investigate the SOT-switching characteristics.

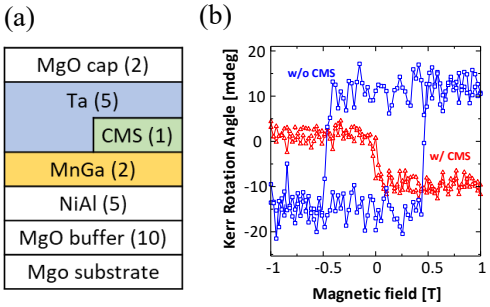

Fig. 1. (a) Stack structure of the fabricated film. (b)MOKE signal MnGa/CMS and MnGa as a function of out-of-plane Magnetic field.

3. Results and Discussion

Figure 1(b) shows MOKE signals for a MnGa with and without CMS. Both curves show clear PMA characteristics. The VSM measurements showed the reduction of the saturation magnetization in the MnGa/CMS compared with MnGa without CMS (*not shown*), indicating that the MnGa and CMS are antiferromagnetically coupled each other.

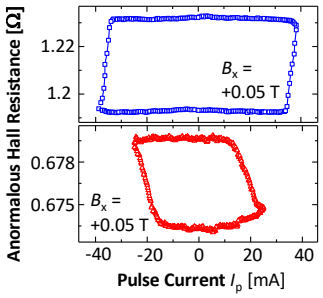

Fig. 2. Anomalous Hall resistance of (a) MnGa and (b) MnGa/CMS as a function of pulse current I_p with the duration of 100 μs under $B_x = +0.05$ T.

Figure 2 shows current-induced magnetization switching for (a) MnGa/Ta and (b) MnGa/CMS/Ta. We observed clear SOT switching due to the spin current generated in the Ta layer for both MnGa/CMS/Ta and MnGa/Ta. Interestingly, the switching current for the MnGa/CMS/Ta is approximately two-times smaller than that for the MnGa/Ta. These results indicate that combining CMS with MnGa is effective in reducing the saturation magnetization and SOT-switching current due to the antiferromagnetic exchange coupling between CMS and MnGa.

References

[1] Mao, S. *et al.*, *Sci Rep* **7**, 43064 (2017).