Temperature dependence of current-induced effective fields in Pt/GdFeCo

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Ultrafast magnetization dynamics and low disturbing stray fields are two main advantages of antiferromagnetically coupled materials. Recently, there have been intensive studies on antiferromagnets and ferrimagnets indicating that those materials can be facilitated as next generation spintronic materials [1,2]. However, many of the spintronic characteristics, such as current-induced manipulation of the magnetic moments, in those materials have not been fully demonstrated. In particular, how the spin orbit effective field acts on these is of great interest. In this work, we study the current-induced effective fields in the heavy metal (Pt)/ferrimagnet (GdFeCo) bilayer structure by the second harmonic voltage measurement. GdFeCo is a ferrimagnetic material which Gd and FeCo are coupled antiferromagnetically and those net magnetic moments can be tuned by temperature [3]. It is possible to realize a magnetically invisible antiferromagnetic state at magnetic compensation temperature (T_M). We quantify the temperature dependence of the current-induced effective fields across the T_M in the ferrimagnets.

Multilayers of SiN(5 nm)/Pt(5 nm)/$Gd_{25}Fe_{65.6}Co_{9.4}$(10 nm)/SiN(5 nm) were deposited on Si substrate by the magnetron sputtering. The films were then fabricated into a microstrip structure with a Hall bar by photolithography and followed by an Ar ion milling as illustrated in Fig 1 (a). In order to understand the magnetic compensation temperature (T_M), dc measurements of anomalous Hall and planar Hall effects were carried out with varying the temperature. The second harmonic voltage measurements were performed with an ac current with various amplitudes at 337 Hz. The current induced effective fields on GdFeCo and accordingly, the second harmonic voltages were generated and detected by lock-in amplifiers. Then, the damping-like and field-like effective fields ($\Delta H_{DL,FL}/J_e$) were quantified by the method used in Ref [4].

Figure 1(b) shows the anomalous Hall resistance with magnetic field in z direction at selected temperatures. The clear square hysteresis loops indicate that the film has a perpendicular magnetic anisotropy in all the temperature range. The reversed hysteresis loops at T ~120K show that the magnetization compensation temperature (T_M) is around 120 K. As seen in Fig. 1(c), the divergence of the coercivity also indicates the T_M at this temperature. Temperature dependence of the damping-like effective fields ($\Delta H_{DL}/J_e$) across T_M is shown in Fig. 1(d). We found that the field-like effective fields were an order of magnitude smaller than the damping-like effective fields and were comparable to the Oersted field in all the temperature range. The calculated $\Delta H_{DL}/J_e$ increases rapidly around T_M as in Fig. 1 (d). In the framework of the conventional spin transfer torque, $\Delta H_{DL}/J_e$ should be inversely proportional to the net magnetization of GdFeCo. Therefore, our results could imply that reduced net magnetization of GdFeCo is the main factor of the increase of $\Delta H_{DL}/J_e$.

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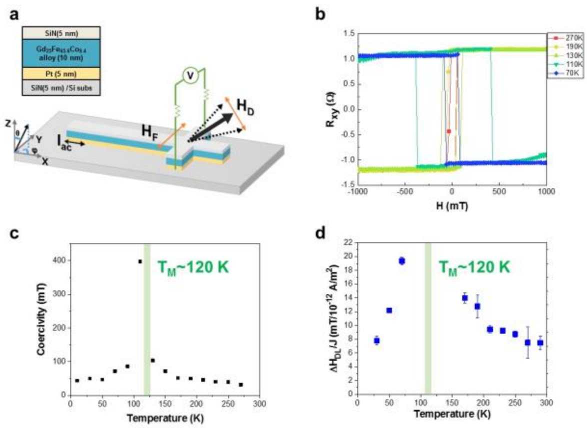

Figure 1: Schematic illustration of the second harmonic voltage measurement setup (a), anomalous Hall resistance at different temperatures with magnetic field in z direction (b), the coercivity (c), and the damping-like effective fields (d) as a function of temperature.