Ferromagnetic resonance induced electrical signals in Pt/(Ga,Mn)As

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The spin pumping [1] and the inverse spin Hall effect (ISHE) [2-6] is employed to generate and detect pure spin current in nonmagnet/ferromagnet bilayer structures [3-6]. In this work, we employ a Pt/(Ga,Mn)As bilayer to investigate possible spin injection from semiconducting to metallic materials.

A 10-nm thick Pt is deposited by sputtering on a 50-nm thick (Ga,Mn)As epitaxially grown on GaAs (001) semi-insulating substrate. The sample is placed near the center of TE_{011} microwave cavity with 9.0 GHz excitation to measure ferromagnetic resonance (FMR) spectrum of the (Ga,Mn)As layer and dc voltage V_{dc} between two In contacts on the Pt layer simultaneously. All the measurements are done at 30 K.

Figure 1 shows the FMR spectra and V_{dc} as a function of out-of-plane direction θ_H of an external magnetic field H. The characteristic dc voltage observed in the vicinity of the resonant field possesses nearly symmetric lineshape, indicating that V_{dc} is dominated by the planar Hall effect (PHE) and/or ISHE [5]. We determine the ratio of the symmetric V_{dc} originated from the PHE to that from the ISHE to be 31:-69. The opposite polarity of the ISHE in the present system to that in Py/Pt may result from the opposite spin polarization at the Fermi level for Py and (Ga,Mn)As. The spin mixing conductance $g^{\uparrow\downarrow}$ at Pt/(Ga,Mn)As interface is determined to be 6.2×10^{19} m^{-2}, which is 13 times greater than that in (Ga,Mn)As/p-GaAs [5], and is comparable to those in Pt/ferromagnetic metals [4]. The result indicates that one can inject spin current from a ferromagnetic semiconductor to a metal with a relatively large efficiency.

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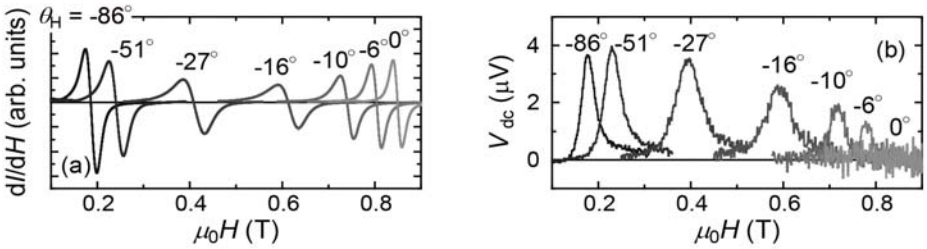

Fig. 1: Magnetic field angle θ_H dependence of (a) FMR spectra and (b) dc voltage measured at 30 K.

References

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