Electrical Spin Injection into δ-doped n-type Germanium Using $Co_2Fe_{0.4}Mn_{0.6}Si$ Heusler Alloy Film

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Spin injection into semiconductor has been demonstrated by some groups using non-local and/or local Hanle measurements. However, observed spin signal was small because of low spin injection efficiency from ferromagnetic materials to semiconductor. In order to enhance spin signal drastically, Co-based Heusler alloys are promising materials as a spin injector because of its high spin polarization [1-2]. In addition, due to the inversion symmetric crystal and high carrier mobility, germanium is also an attractive material for semiconductor-spintronics. In this work, we have observed spin accumulation signal in δ-doped n-type Ge, and systematically investigated bias current dependence of 3-terminal Hanle effect signals.

We fabricated following stacked structure: Mg(0.8)/MgO(0.75)/$Co_2Fe_{0.4}Mn_{0.6}Si$(CFMS)(30)/ Ta(5) (unit in nm) on δ-doped n-type Ge. All thin films were prepared by sputtering method in a high vacuum of pressure below 10^{-6} Pa. The Mg layers were inserted into Ge/MgO interface to improve crystallinity of MgO and CFMS layers. The devices were prepared using optical photolithography methods and Ar milling. Fig. 1 shows the sample structure and measurement geometry in 3-terminal method.

Fig. 2 shows the bias current dependence of Hanle effect signals measured at temperature of 10 K. As shown here, the signals clearly increased with increasing bias current. We will discuss the origin of the observed bias current dependence.

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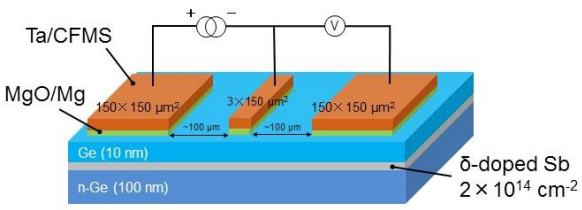

Fig. 1: Sample structure and measurement geometry in 3-terminal methods.

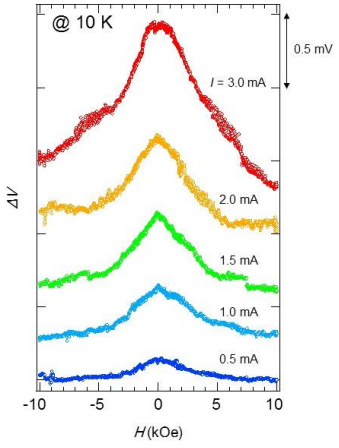

Fig. 2: Bias current dependence of 3-terminal Hanle effect signals.