Investigation of Trilayer Structure NiFe /Cu/IrMn for High Field-sensitivity Planar Hall Sensor

Tran Quang Hung*, Sunjong Oh, Jong-Ryul Jeong and CheolGi Kim
Center for NanoBioEngineering and Spintronics, Department of Materials Science and Engineering, Chungnam National University, 220 Gungdong, Yuseong-gu, Daejeon 305-764, Korea

* Corresponding author: C. G. Kim, email: cgkim@cnu.ac.kr, tel.: (+82) 42-821-6632

Introduction

The planar Hall effect (PHE) sensor based on magnetic multilayers *ie*., a bilayer or a spin-valve structure has been well developed for bio applications. However, it is revealed from the context that the field-sensitivity of the PHE sensor is normally small. Hence, a novel structure, which can give high field-sensitivity is highly desirable from both fundamental and application point of view.

In this work, we introduced a trilayer structure NiFe/Cu/IrMn to enhance the field-sensitivity of a PHE sensor in which the weak exchange coupling could be obtained by introducing a very thin Cu spacer layer between the ferromagnetic (FM) and anti-ferromagnetic (AF) layers. In order to improve the high field-sensitivity of the PHE sensor based on trilayer structure, we compared the field-sensitivity of the PHE sensors in three samples such as (1) a typical bilayer thin film, (2) a spin-valve thin film, and (3) a trilayer thin film. For optimizing the sensor performance, we varied the thickness of spacer layer in trilayer thin film. The results show that when the thickness of spacer layer (Cu) is small the amplitude of PHE voltage profile is high, and the optimization thickness of spacer layer was 0.12 nm.

Experimental

The cross-junction sensors with junction size of 50 μm×50 μm were fabricated by a magnetron sputtering and a photo lithography system. The active layer of the sensor materials was maintained at 10 nm, the sensor materials are Ta(3)/NiFe(10)/Cu(1.2)/NiFe(2)/IrMn(10)/Ta(3), Ta(3)/NiFe(10)/IrMn(10)/Ta(3) and Ta(3)/NiFe(10)/Cu(*x*)/IrMn(10)/Ta(3) (x = 0.12, 0.18, 0.30, 0.54 nm) respectively. The electrodes of the sensor were made of Au. The sensor was passivated by SiO_2 layer to protect the sensors from the environment. The PHE output voltages were measured by means of a Keithley 2182A Nanovoltmeter with a sensitivity of 10 nV.

Results and Discussion

Fig. 1 shows the PHE voltage (V_{PHE}) profiles of PHE sensor based on three structures, (1) Ta(3)/NiFe(10)/IrMn(10)/Ta(3) thin film, (2) Ta(3)/NiFe(10)/Cu(1.2)/NiFe(2)/IrMn(10)/Ta(3) thin film, and (3) Ta(3)/NiFe(10)/Cu(0.18)/IrMn(10)/Ta(3) thin film. These V_{PHE} profiles show a linear response to a certain points, reach the maximum voltage and decreases the voltage signal when the external magnetic fields continue to be increased. It is illustrated from Fig. 1 that (*i*) the amplitude of V_{PHE} of the sensor using trilayer thin film (about 108 μV) is comparable with that of bilayer thin film and is twice compared with spin-valve thin film. (ii) the extremum field (the field that the maximum voltage of VPHE profile is obtained) of the sensor using trilayer thin film is comparable with that of the sensor using spin-valve thin film and is a about five times smaller than the extremum field of the sensor using bilayer one. Subsequently, the sensor with trilayer thin film have advantages such as high voltage change at small fields and the highest sensitivity among the three investigated structures.

Fig. 2 is the PHE voltage profiles of the sensors based on Ta(3)/NiFe(10)/Cu(*x*)/IrMn(10)/Ta(3) nm (*x* = 0.12, 0.18, 0.30, 0.54). At small fields, the voltage profiles have the same slope (the sensors have the same sensitivity), while the amplitude of PHE voltage profile with *x* = 0.12 is largest because the active current passed through the ferromagnetic layer is largest. Therefore, the optimum structure for the best sensor performance is assigned for the case of *x* = 0.12 nm.

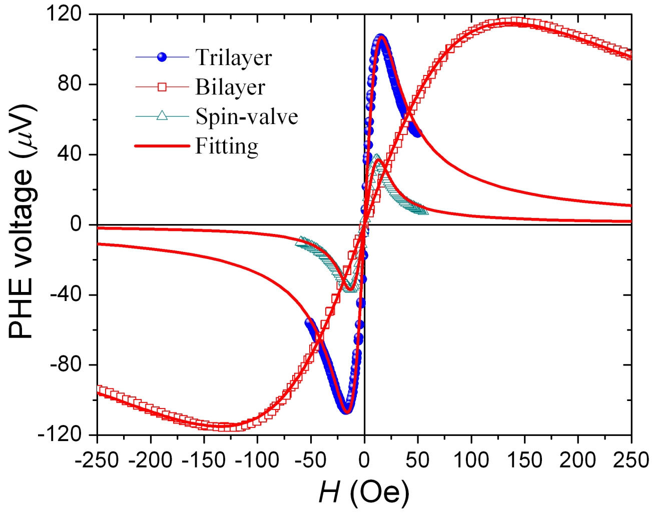

Fig. 1 The PHE voltage profiles of fabricated thin films Ta(3)/NiFe(10)/IrMn(10)/Ta(3), Ta(3)/NiFe(10)/Cu(1.2)/NiFe(2)/IrMn(10)/Ta(3), and Ta(3)/NiFe(10)/Cu(0.18)/IrMn(10)/Ta(3) nm.

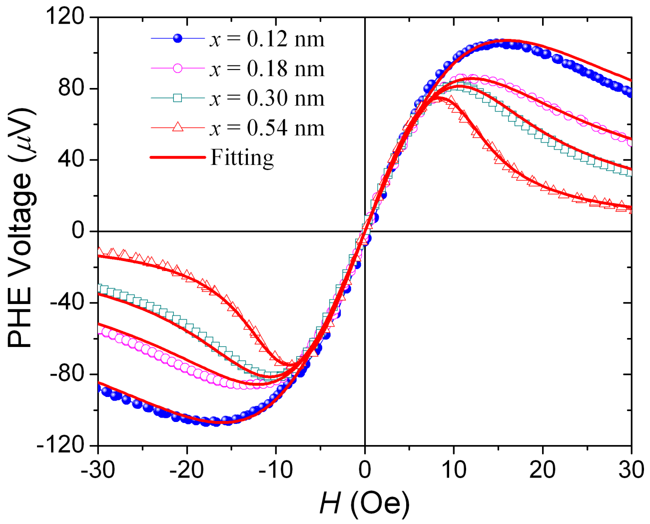

Fig. 2 The PHE voltage profiles of the sensor using trilayer thin films Ta(3)/NiFe(10)/Cu(x)/IrMn(10)/Ta(3) with x = 0.12, 0.18, 0.30, 0.54.

Conclusion

In summary, we investigated field sensitivity of PHE sensor in three samples: (1) a bilayer thin film, (2) a spin-valve thin film and (3) a weak exchange coupling bilayer thin film. The sensor based on bilayer structure with weak exchange coupling has the highest sensitivity employed for high-sensitivity PHE sensor. In addition, when the thickness of the spacer layer is about 0.12 nm the PHE voltage profile has the largest amplitude.

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