Antiferromagnetic-coupled metallic superlattice with Ir-doped Cu interlayer generating spin Hall effect

[1]Institute for Materials Research, Tohoku University, [2]CSRN, Tohoku University, [3]CSIS, Tohoku University

○ Hiroto Masuda[1], Takeshi Seki[1,2], Yong-Chang Lau[1,2], Takahide Kubota[1,2], Koki Takanashi[1.2,3]

E-mail: masuda1610@imr.tohoku.ac.jp

Recently, antiferromagnetic (AF) materials have attracted much attention in the research field of spintronics due to their low magnetic susceptibility, lack of magnetic stray field, and fast magnetization dynamics [1]. Among various topics of AF spintronics, it is crucial to study the spin-orbit torque (SOT) acting on AF structure to establish the method to manipulate the Néel vector. Therefore, the interaction between SOT and AF structure has been studied using the combination of bulk AF materials and the nonmagnetic materials which have strong spin-orbit interaction such as Pt [2, 3]. However, bulk AF materials are unsuitable for systematic SOT study because they exhibit the complicated magnetic domain structures and uncontrollable AF-coupling strength. On the other hand, antiferromagnetically-coupled metallic superlattices allow us to tune the AF-coupling strength by changing the layer thicknesses. In addition, many interfaces of a metallic superlattice may enhance the spin-orbit interaction, resulting in the enhanced SOT. To realize the metallic superlattice showing strong AF-coupling and large SOT simultaneously, we have paid attention to the Co / Cu-Ir / Co system. The Co / Cu / Co and Co / Ir / Co systems are representatives showing AF-coupling and giant magnetoresistance (GMR), but neither pure Cu nor Ir exhibits the remarkable spin Hall effect. On the contrary, it was reported that the Ir impurity in Cu increased the spin Hall angle (θ_{SH}) up to 2.1 $\pm$ 0.6 % [4]. Therefore, the Co / Cu-Ir / Co superlattice is expected to show both strong AF-coupling and large SOT. In this study, we have investigated AF-coupling for epitaxially grown Co / X / Co tri-layered structures, where X is Cu, $Cu_{95}Ir_5$ and Ir, and estimated the value of θ_{SH} for $Cu_{95}Ir_5$.

The Co (2 nm) / X (t) / Co (2 nm) superlattices were deposited on an Al_2O_3 (0001) substrate / buffer layer (Cr (10 nm) / Au (5 nm) / Cu (35 nm)) using a magnetron sputtering system. The t dependence of AF-coupling strength indicated that AF-coupling for the Cu-Ir interlayer sample was observed in the range of 0.6 nm < t < 1.0 nm although its AF-coupling strength was smaller than those for the Cu and Ir interlayer samples. Moreover, we have estimated θ_{SH} of the present Cu-Ir using Co (2 nm) / $Cu_{95}Ir_5$ (t) bilayer. From the spin Hall magnetoresistance (SMR) measurement, the value of θ_{SH} was estimated to be ~ 4.3 %, which was comparable to the value reported previously [4].

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