An investigation of gate-induced modulation of the inverse spin Hall effect in ultrathin Cu

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In spintronics, inter-conversion between spin current and charge current is quite important. The inverse spin Hall effect (ISHE) [1] is an effect that converts spin current to charge current. The efficiency of the conversion is partly determined by spin Hall conductivity (SHC). Recently, it was reported that the conversion efficiency in the ISHE and the SHC was largely modulated in ultrathin (2 nm) Pt [2]. Although electric gating allows modulation of physical properties by charge accumulation [3], metallic bulk materials have large electron density and effects induced by electric gating were believed to be too weak. One exception was modulation of the Curie temperature in ultrathin Co by gating [4], which strongly motivated us and led us to the study of the ultrathin Pt.

In this study, we focused on ultrathin Cu, which possesses a weak spin-orbit interaction, instead of Pt, a strong spin-orbit interaction material. Whereas Cu has been inadequate as a spin-charge conversion material, a frontier study on an observation of large spin conversion efficiency [5] is changing the conventional understanding. Thus, we think it is significant to introduce the same ionic-gating method [2] to the ultrathin Cu study and to carry out further studies. The thin Cu film was deposited on an Yttrium-Iron-Garnet (YIG) substrate by sputtering. The thickness of the thin Cu was changed from 6 nm to 38 nm. From the thickness dependence of the resistivity of the Cu, the surface oxidation layer of the Cu was estimated to be 2 nm and the dependence was well reproduced a model calculation [7]. The spin current injected from the YIG to the Cu was generated by using spin pumping. An electromotive force of 80 nV due to the ISHE was observed from the Cu of 8 nm in thick. When the gate voltage (V_{Gate}) was changed from 0.0 V to 2.0 V, the electric current converted from the spin current at V_{Gate} = 2.0 V increased about 16 % in comparison with that at V_{Gate} = 0.0 V, whereas the resistance of the Cu decreased about 5 % at V_{Gate} = 2.0 V. Such enhancement of the electric current by the positive gating was also observed in the previous study [6], where enhancement of oxidation of Pt allows the similar gate dependence. Further discussion is implemented in the presentation.

References

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