Determination of the spin relaxation mechanism in oxidized Cu thin films

○Ryoto Enoki[1], Hiromu Gamou[1], Makoto Kohda[1, 2], and Junsaku Nitta[1, 2]
[1]Department of Materials Science, Tohoku, University, Sendai 980-8579, Japan
[2]Center for Spintronics Research Network, Tohoku University, 980-8577, Japan
E-mail: ryoto.enoki.p7@dc.tohoku.ac.jp

1. Introduction

Cu thin films have long spin relaxation lengths because of their weak spin orbit interaction (SOI). However, it has been discovered that the spin-torque efficiency of Cu is enhanced by oxidation recently [1]. In addition, the origin of spin-orbit torque in naturally oxidized Cu and Cu oxide fabricated by reactive sputtering are different *i.e.* bulk or interface.

In this research, we have clarified the spin relaxation mechanism for both naturally oxidized Cu (Cu/Cu_2O) and reactively sputtered Cu oxide (CuO_x) in order to determine the origin of spin relaxation mechanism in each type of films. This approach can provide further comprehensive study of the enhancement of spin-orbit torque in oxidized metal system.

2. Experimental procedure

Both Cu/Cu_2O and CuO_x thin films were deposited on SiO_2 substrate at room temperature by RF sputtering machine. CuO_x films (9.5 nm) were prepared by varying oxygen gas flow between 0.3 and 0.6 SCCM during the sputtering. On the other hand, in order to make Cu/Cu_2O, Cu thin film (7~10 nm) was oxidized by exposing in $P_{O_2} = 7.5 \times 10^{-2}$ Pa at 100 ℃ for 10 Minutes inside the sputtering chamber.

To evaluate spin-orbit length which is inversely proportional to the strength of SOI, we focused on quantum correction of the conductance, i.e. weak anti-localization (WAL). The results of magneto-conductance were fitted by Hikami-Larkin-Nagaoka formula [2].

3. Result

Measured magneto-conductance for CuO_x and Cu/Cu_2O thin films are shown on Figs. 1(a) and (b), respectively. From these figures, the shape of magneto-conductance were different depending on oxygen gas flow and thickness of Cu respectively.

The relationship between spin-orbit length and oxygen pressure during sputtering for CuO_x is shown in Fig. 2. From this figure, it is found that the spin-orbit length becomes shorter as increasing oxygen pressure in CuO_x. This result indicates the strength of SOI in CuO_x can be tuned by controlling partial oxygen pressure of during sputtering.

For the Cu/Cu_2O shown in Fig. 3, spin-orbit length is proportional to diffusion constant, indicating that spin relaxation mechanism is expected to be Elliot-Yafet mechanism [3].

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[2] S. Hikami et al., Prog. Theor. Phys. **63**, 707 (1980).
[3] R. J. Elliott, Phys, Rev. **96**, 266 (1954).

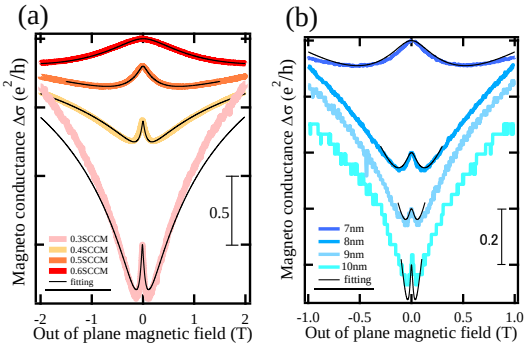

Fig. 1, Magneto-conductance of (a)CuO_x and (b)Cu/Cu_2O respectively at T = 2 K.

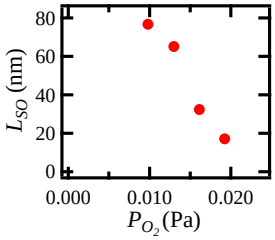

Fig. 2, Spin-orbit length as a function of O_2 pressure in 9.5 nm CuO_x.

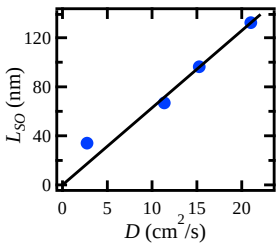

Fig. 3, Spin-orbit length as a function of diffusion constant for Cu/Cu_2O films.