Determination of the spin relaxation mechanism in oxidized Cu thin films

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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$_2$O) 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$_2$O 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$_2$O, Cu thin film (7-10 nm) was oxidized by exposing in $P_0 = 7.5 \times 10^{-2}$ Pa at 100 °C 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$_2$O 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 during sputtering.

For the Cu/Cu$_2$O 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].