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Thickness dependence of spin relaxation in thin MgO / Pt / GaAs layers

JeongChun Ryu, Atsuya Sasaki, Junichi Shiogai, Makoto Kohda and Junsaku Nitta

Tohoku University
6-6-02 Aramaki-aza Aoba, Aoba-ku, Sendai 980-8579, Japan
Phone: +81-22-795-7317
E-mail: salsberry@s.tohoku.ac.jp

Abstract

We experimentally measured weak localization (WL) / weak anti-localization (WAL) for thin Pt films sandwiched between MgO and GaAs. As the thickness of Pt film becomes thinner, the WL is changed to the WAL. This suggests that spin-orbit interaction (SOI) in MgO / Pt / GaAs layers is modulated by the thickness of Pt.

1. Introduction

To realize metal-based spintronic devices, manipulation of spins in paramagnetic metals is highly required. SOI is an important mechanism to manipulate electron spins since it is controlled by an electric field for semiconductors. Recently, there is an interesting result reported by M. Miron *et al*. [1], which suggests that the Rashba SOI plays a key role in magnetization switching in AlO / Co / Pt layers. Applying this asymmetric interface structure to paramagnetic metals, we can expect to induce the Rashba SOI in an MgO / Pt / GaAs structure. We discussed about spin relaxation in MgO / Pt / GaAs films by using WL / WAL measurements.

2. Spin relaxation in Pt

SOI has great importance for manipulation of the spin information and is closely related to spin relaxation. To evaluate the SOI in thin Pt films, we focus on quantum correction of the conductance, *i.e.* WL / WAL. In the case of weak SOI, positive magneto-conductance is observed around zero magnetic fields, which corresponds to the WL. However, in the case of strong SOI, negative magneto-conductance is observed, *i.e.* WAL. While the dominant spin relaxation in bulk metals is mainly caused by Elliott-Yafet (EY) spin relaxation mechanism associated with the momentum scattering by impurities [2, 3], the Rashba SOI at the metal interface can generate the D'yakonov-Perel' spin relaxation mechanism.

3. Sample fabrication

Thin Pt layers were deposited on *i*-GaAs substrates at substrate temperature T_s = 300 K and 573 K by RF sputtering. Figure 1 shows X-ray diffraction (X-RD) pattern for Pt films deposited at 300 K and 573 K. While the Pt film sputtered at 300 K is oriented to [111] direction, the other films at 573 K are along to [200] direction [4]. If the Rashba SOI exists at the interface, a different strength of SOI is expected in different crystal orientations because the Rashba SOI is the intrinsic effect for the spin orbit mechanism. We prepared 5 samples at each substrate temperature with different Pt thickness, d = 0.5 nm, 1.0 nm, 2.0 nm, 2.5 nm and 3.0 nm. Each Pt layer is covered with MgO layer (2 nm) in order to induce the structure inversion asymmetry for the Rashba SOI at the interface. We performed 4-probe measurement using ^{4}He cryostat at T = 1.6 K.

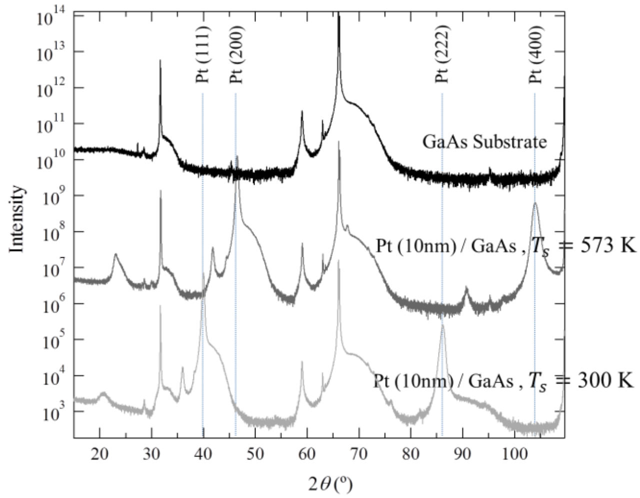

Fig. 1 Comparison of θ–2θ X-RD patterns for the Pt films in different growth temperatures. Each result offsets to vertical direction for the clarity.

4. Results and discussion

First, we measured the resistivity for the sample deposited at 573 K. Figure 2 shows the thickness dependence of the Pt resistivity. Resistivity of Pt linearly increases with decreasing the Pt thickness. In Fig. 2, we plot the mobility of Pt. We note that the mobility μ is determined from $\mu = 1/\rho n e$ where n is the carrier density of Pt [5].

As shown in Fig. 2, the mobility of Pt gradually decreases with decreasing the Pt thickness. These results suggest that the interface scattering becomes dominant in thinner Pt samples. Since such a scattering may affect the strength of Rashba SOI, this result indicates the modulation of the SOI in different Pt thicknesses.

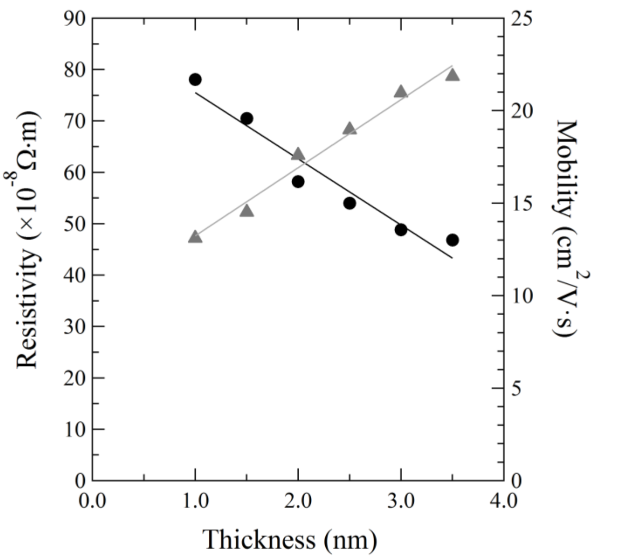

Fig. 2 Pt thickness dependence of resistivity and mobility at T = 1.6 K. Black circle marks show resistivity and gray triangle marks show mobility. Each line is a guide to eyes.

Next, magneto-transport measurement was performed to evaluate spin relaxation time. Transition from WL to WAL was observed with decrease of Pt thickness as shown in Fig. 3. The results are analyzed by the theory of quantum correction of the conductance proposed by Hikami-Larkin-Nagaoka [6]. The WL observed in Pt film with thickness more than 2.5nm is not expected because Pt is well known as the metal with strong SOI [7]. In relatively thick Pt region (d > 2.5nm), spin orbit length L_{SO} is longer than phase coherent length L_{φ} from the WL results. It may indicate that spin relaxation is suppressed in Pt films where thickness is less than mean free path. However, in thinner Pt (d < 2.0 nm), WAL is clearly observed, which means spin orbit length L_{SO} become shorter than phase coherent length L_{φ} . Transition from WL to WAL cannot be explained only by EY mechanism so that there may be an additional contribution to the spin relaxation at the interface.

5. Conclusions

We observed the transition from WL to WAL by decreasing Pt thickness. Our result suggests that SOI is enhanced with decreasing the Pt thickness, which indicates that the additional SOI mechanism at the interface may play a role for the spin relaxation in thinner Pt film (d < 2.0 nm). Now experiment for [111] Pt thickness dependence is undergoing, we will discuss about comparison between the result of [200] Pt films and that of [111] Pt films at the conference.

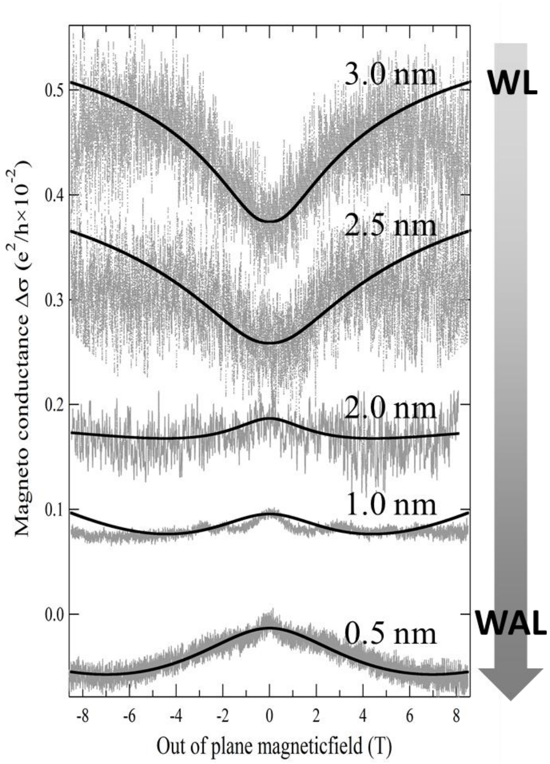

Fig. 3 WL/ WAL curves depending on Pt thickness measured at T = 1.6K. Dark lines are best fitted results based on theory of Hikami *et al.* , [6].

References

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