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Gate control of magneto-transport properties in Ta thin film

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1. Introduction

All metal spin field effect transistor [1] is expected as one of the solutions of room temperature operation and it is necessary for realizing this device to manipulate spins in metal system. It has been considered that gate control of spin orbit interaction (SOI) in metal has great difficulty because of its large carrier density, however, it became possible to manipulate magnetism throughout an electric double layer (EDL) [2, 3]. Applying EDL structure, SOI in metal also can be controlled by electric field in case that SOI is proposed by Rashba SOI. Therefore, in this study, we investigated gate voltage dependence of SOI parameters in Ta thin film which has strong SOI utilizing EDL transistor structure.

2. Experimental procedure

Ta thin film was deposited on Al_2O_3(0001) substrate by Radio-Frequency sputtering machine. During the deposition, the substrate temperature was kept to be 500℃. The thickness of the film is 1nm. On the top of the sample, AlO layer (2 nm) was covered in order to prevent surface oxidation.

The shape of the sample is a simple Hall-bar fabricated by photo lithography and Ar ion milling. An ionic liquid *N*, *N*- diethyl- *N*- (2-methoxyethyl)- *N*- methylammonium bis- (trifluioromethylsulfonyl)- imide (DEME-TFSI) was mounted to cover both the channel and gate electrode.

To evaluate the SOI in Ta thin film, we focused on quantum correction of the conductance, i.e. weak antilocalization.

3. Results

Gate voltage dependence of *I*-*V* characteristics is shown on Fig 1. This figure indicates the resistance was systematically changed against each gate voltage and this should be the evidence that the carrier density in Ta thin film was tuned by gate voltage.

Figure. 2 shows the results of quantum magneto conductance against each gate voltage. From this figure, the shape of quantum magneto conductance curve has been changed depending on gate voltages and it suggests that SOI parameter has been controlled. Further analysis including quantitative evaluation of spin relaxation length is undergoing.

[1] M. Johnson, Science **260**, 320 (1993).

[2]D. Chiba *et al.*, Nat. Mater. **10**, 853 (2011).

[3]S. Shimizu *et al.*, Phys. Rev. Lett. **111**, 216803 (2013).

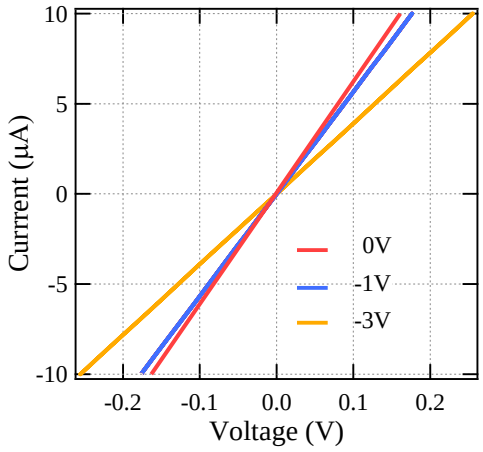

Fig. 1, *I*-*V* characteristics of different gate voltages, 0V, -1V and -3V at T = 10 K.

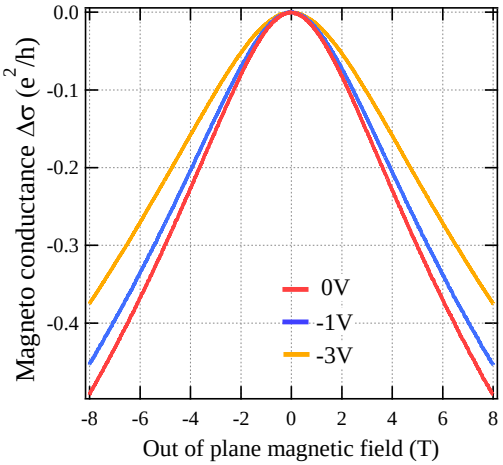

Fig. 2, Magneto conductance of different gate voltages, 0V, -1V and -3V at T = 10 K.