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Electric Field Effect on Exchange Interaction in Pt/Co Thin Film

M. Ishibashi[1], K. T. Yamada[1], F. Ando[1], T. Koyama[2], H. Kakizakai[1], H. Mizuno[1], K. Miwa[3], S. Ono[3], T. Moriyama[1], D. Chiba[2], and T. Ono[1]

[1]Institute for Chemical Research, Kyoto University
Uji, Kyoto 611-0011, Japan
[2]Department of Applied Physics, The University of Tokyo
Bunkyo, Tokyo 113-8656, Japan
[3]Central Research Institute of Electric Power Industry
Yokosuka, Kanagawa 240-0196, Japan

Abstract

The electric field effect on the exchange interaction in an ultra-thin Co film is investigated. Temperature dependence of the saturation magnetization is measured using superconducting quantum interference device magnetometer under an electric field, from which the electric field dependent exchange constant is estimated.

1. Introduction

The electric field (EF) control of magnetism was intensively investigated because of its potential importance for the reduction of power consumption in magnetic storage devices. For the realization of EF-assisted or -induced magnetization switching, the modulation of magnetic anisotropy (MA) is of great importance. Not only the MA modulation but also a change in the Curie temperature T_C was reported in a metallic Pt/Co system [1, 2] as well as in ferromagnetic semiconductors [3]. Using ab initio calculation, the T_C change due to EF application to a Pt/Co system was suggested to be explained by the modulation of the Heisenberg exchange parameter [4]. Recently, the EF modulation of the exchange stiffness A in a Co ultra-thin film investigated by characterizing the domain size was reported [5, 6]. However, the measurement opportunity of the domain size was limited only in the vicinity of the Curie temperature and it prevents from further determining the exchange constant J. In the present work, we conduct another measurement in which we characterize the temperature dependence of the saturation magnetization for estimating the exchange constant J.

2. Experimental and results

The Pt/Co sample was deposited on the GaAs (100) substrate using RF sputtering. The layer structure was as follows: Ta (3.3 nm)/Pt (2.0 nm)/Co (0.25 nm)/MgO (2.0 nm) from the substrate side. The film had perpendicular magnetic anisotropy and showed a square hysteresis curve.

An electric-double-layer capacitor structure (shown in Fig.1) were prepared consisting of an electrode of the Ta (3.3 nm)/Pt (2.0 nm)/Co (0.25 nm)/MgO (2.0 nm) film, Ti/Au side gate electrodes, and ionic liquids. In our definition, the positive gate voltage V_G increases the electron density at the MgO/Co interface.

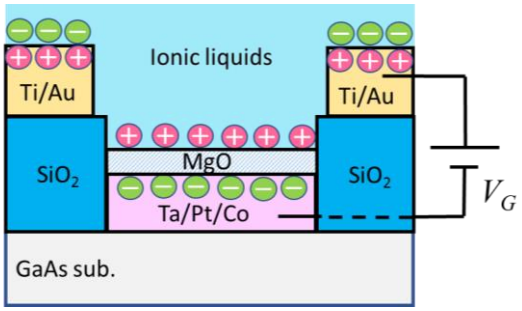

Fig. 1 Cross-sectional schematic image of device consisting of an electrode of Ta (3.3 nm)/Pt (2.0 nm)/Co (0.25 nm)/MgO (2.0 nm) film, Ti/Au side gate electrodes, and ionic liquids.

We measured the temperature dependence of the saturation magnetization $M(T)$ using superconducting quantum interference device magnetometer while applying V_G. Figure 2 shows the temperature dependence of the saturation magnetization and a clear difference between V_G = +2.5 V and V_G = -1.5 V is observed, suggesting that J is modified by the application of the electric field. The temperature dependence of the saturation magnetization is found to be proportional to $T^{3/2}$, indicating that the reduction of the saturation magnetization with temperature can be attributed to the spin wave excitation. Thus, J can be determined to be J (+2.5V) = 3.41×10^{-22} J and J (-1.5V) = 3.22×10^{-22} J from the slope.

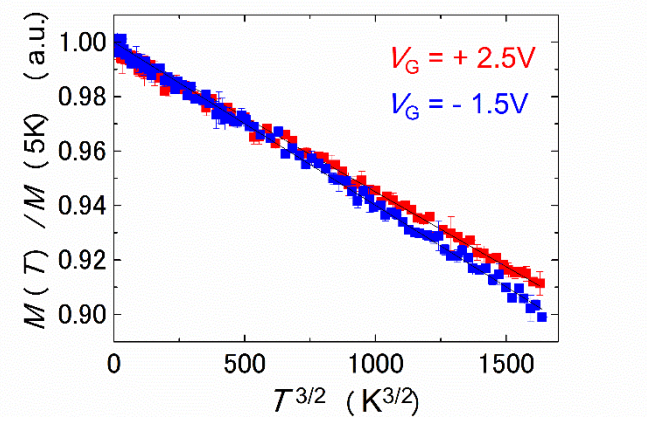

Fig. 2 Temperature dependence of the saturation magnetization $M(T)$ normalized by the saturation magnetization at 5 K for the gate voltages V_G = +2.5 and -1.5 V.

3. Conclusions

We have investigated the electric field effect on the exchange constant in an ultra-thin Co film by measuring the temperature dependence of the saturation magnetization using superconducting quantum interference device magnetometer under an electric field. The modulation of the exchange constant by the electric field was observed.

Acknowledgements

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