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Electric field effect on magnetic moment in Pd with solid-state gating

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Abstract

The electric field effect on the magnetism in a MgO/Pd/Co system, in which a magnetic moment is induced in the Pd layer owing to the ferromagnetic proximity effect, has been investigated using various experimental methods. An electric field was applied to the surface of the Pd layer through a solid-state HfO_2/MgO dielectric bilayer in a back-gating configuration. Changes in the magnetic properties of the system as a result of gate voltage application were detected using magnetization and polar-Kerr effect measurements. A systematic change in the proximity-induced magnetic moment in the Pd by the application of a gate voltage was observed. The magnetic hysteresis loops obtained by the polar-Kerr effect measurement clearly show a reproducible change in the coercivity by the electric field.

1. Introduction

Electric field (EF) effect on magnetic properties in a capacitor structure has been intensively studied. Especially, electric field control of magnetic anisotropy is attracted to attention from the viewpoint of application. Our group have reported that the EF effect on anisotropy in MgO/Pd/Co system, in which the proximity-induced magnetic moment (PIM) exists in Pd. We have also shown that in the similar structure not only the anisotropy but also the magnitude of PIM in the Pd is controllable by the EF using an ionic liquid gating [1]. Although the change in the Pd magnetic moment in the reported study is most likely due to the modulation of the electron density in the Pd, it is difficult to exclude the possibility that the redox reactions affect the magnetic properties of the system as long as the ionic liquid gating is used [2]. Thus, in the present study, we investigate the EF effect on the Pd in all-solid-state system, in which the electron charging/discharging effect is expected to be dominant.

2. Sample preparation and measurement set up

The multilayer structure consisted of Ta(8.3 nm)/Pt(2.0)/HfO_2(50)/MgO(2.0)/Pd(0.9)/Co(0.6)/ Pt(2.0) from the GaAs substrate side was prepared (see Fig. 1). All metal layers and the MgO layer were deposited by rf sputtering. The HfO_2 dielectric layer was deposited using atomic layer deposition (ALD) under 150 °C, which is the appropriate temperature for the process[3].

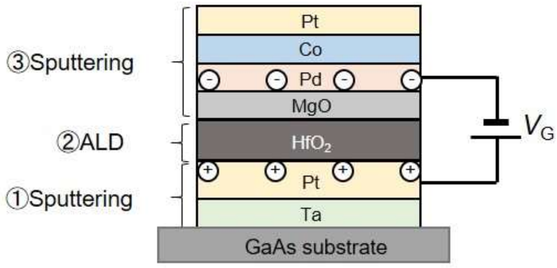

Fig. 1 Sample structure.

A gate EF E_G was applied to the surface of the Pd through the HfO_2/MgO insulating bilayer with the total thickness $t_{ins.}$ of 52 nm. A Polar Kerr effect measurement was conducted under applying gate voltage to obtain the magnetization hysteresis loop and the value of coercivity $\mu_0 H_c$. The perpendicular component of the magnetic moment per unit area $m_\perp/S$ of the sample was measured using a SQUID magnetometer under the application of EF.

3. Result

Figure 2 shows magnetic hysteresis loop under the gate voltage V_G of ±10 V obtained at room temperature. $\mu_0 H_c$ was determined from this loop. As shown in Fig. 2, $\mu_0 H_c$ changes reproducibly by applying gate voltage of ±10 V alternately. Applying positive (negative) gate voltage, that is, an increase (a decrease) of electron density at the surface of Pd, enhances

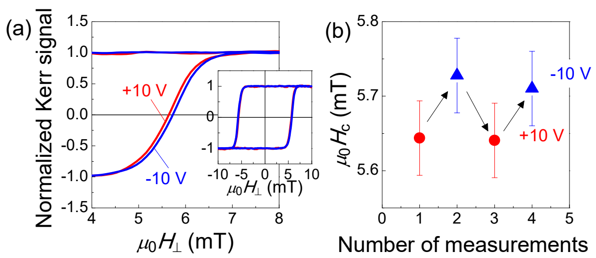

Fig. 2 (a) The magnetic hysteresis loop under applying the gate voltage V_G of ±10 V at room temperature, measured using polar Kerr effect. (b) The values of coercivity $\mu_0 H_c$ in each measurement.

(reduces) $\mu_0 H_c$.

The E_G (= $V_G/t_{ins.}$) dependence of $m_\perp/S$ is shown in Fig. 3. $m_\perp/S$ linearly depends on E_G. Assuming that only the magnetic moment of the Pd monolayer adjacent to MgO layer is changed by EF, the change in the magnetic moment per Pd atom is calculated to be 1.6±0.3μ_B, which is comparable to our previous result obtained in the ionic liquid-gating case [1].

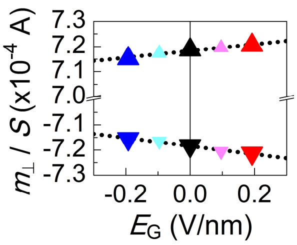

Fig. 3 Gate electric field E_G dependence of magnetic moment per unit area $m_\perp/S$. ▲(▼) symbols correspond to the result for the positively-(negatively-)magnetized state.

4. Conclusions

We investigated the electric field effect on magnetic properties of MgO/Pd/Co structures by solid-state gating. From the measurement using polar-Kerr effect, the coercivity depends on the gate voltage. In addition, the direct magnetization measurement shows that magnetic moment linearly depends on the magnitude of applied electric field. These results is expected to be helpful to understand the electric field effect on the proximity-induced magnetic moment.

Acknowledgements

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References

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