Electrical control of magnetism in electric double layer capacitors with a Co electrode

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Recently, electric field effect on magnetism has been intensively studied. We have reported the change in Curie temperature by applying gate voltage V_G in solid state or electric double layer (EDL) capacitors with a Co electrode [1,2]. One of main factors for this effect has been considered to be a modification of electron density by an electric field application. Other mechanisms (*e.g.* redox) have been recently suggested and become controversial. In this presentation, the electric field effects on magnetism in EDL capacitors with a Co electrode will be discussed and the results will be compared with intentionally oxidized Co films by an oxygen plasma ashing.

Ta(3 nm)/Pt(3)/Co(1)/MgO(2) structure from the substrate side was deposited on Si or GaAs substrate by rf sputtering. The as-deposited sample showed in-plane magnetic anisotropy (IMA) at 300 K, whereas the sample after oxygen plasma ashing at 150 W for 30 s had perpendicular magnetic anisotropy (PMA). By X-ray photoelectron spectroscopy, ~50% of Co was confirmed to be oxidized by this ashing process.

To form EDL capacitors, a polymer film containing ionic liquid ($TMPA^+$-$TFSI^-$) and having Au top electrode was directly put on the as-deposited sample. The magnetic properties were measured using the anomalous Hall effect or SQUID magnetometer. Figure 1 shows hysteresis curves under applying various V_G observed in the Hall resistances. Each measurement was started 20 min after changing V_G at 300 K. IMA at V_G = 0 V was slightly enhanced by positive V_G application (+2 V), which corresponds to the direction of the increase of the electron density, whereas PMA was observed when negative V_G (-2 V) was applied. The IMA has slightly restored by an additional positive V_G application but not completely come back.

The comparison between ashing and electric field experiments suggests that the Co layer was oxidized by negative V_G and its activation energy is lower than that of the reduction reaction.

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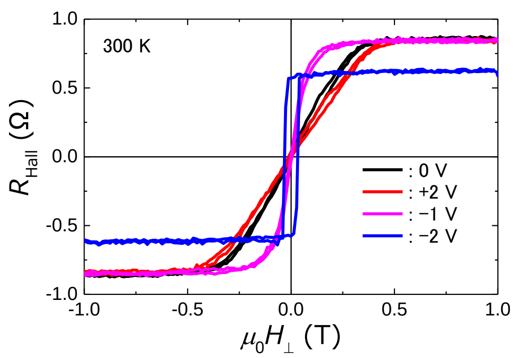

Fig.1 Magnetic hysteresis loops obtained under various V_G.

[1] D. Chiba, *et. al*., Nature Mat. **10**, 853 (2011).
[2] K. Shimamura, *et. al*., Appl. Phys. Lett. **100**, 122402 (2012).