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 $V_G$.