Sign reversal of current-induced effective magnetic field in La$_{0.67}$Sr$_{0.33}$MnO$_3$ heterostructures

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Recently, we have reported that the sign of the planar Hall effect (PHE), which originates from the spin-orbit interaction (SOI), for La$_{0.67}$Sr$_{0.33}$MnO$_3$/LaAlO$_3$/SrTiO$_3$ (LSMO/LAO/STO) is opposite to that for LSMO/STO at low temperature [1]. If the current-induced effective magnetic field H_{eff} observed in LSMO [2] is related to the SOI, H_{eff} can be modulated by growing an LSMO layer on an LAO/STO. In this work, we investigated H_{eff} in LSMO/LAO/STO.

LSMO(18)/LAO(6) and LSMO(18) (numbers in parentheses are nominal film thicknesses in unit cells) were grown on STO (001) substrates by pulsed laser deposition. The stacks were processed into a Hall bar structure having a 10-μm wide channel along [100] and two pairs of Hall probes. The magnetic field angle dependence of transverse resistance R_{yx}, which is dominated by the PHE, shows that both of the LSMO/LAO/STO and LSMO/STO have an in-plane biaxial magnetic anisotropy with the easy axes almost along <110>. After aligning magnetization direction along [$\bar{1}$10], R_{yx} was measured under various currents while sweeping magnetic field H in [0$\bar{1}$0]. We calibrated device temperature T_d under large current by monitoring longitudinal resistance. Figure shows normalized R_{yx} for LSMO/LAO/STO and LSMO/STO as a function of μ_0H (where μ_0 is the permeability of a vacuum). A change of normalized R_{yx}, reflecting switching of magnetization direction from [$\bar{1}$10] to [$\bar{1}\bar{1}$0], is observed in both structures. The R_{yx} value for the LSMO/LAO/STO changes from a high level to a low level during the switching, whereas that for the LSMO/STO changes from a low level to a high level. This reversal of the switching direction is consistent with the sign reversal of the PHE coefficient. The switching magnetic field, giving a normalized $R_{yx} = 0$, is larger for negative (positive) current than that for positive (negative) current in LSMO/LAO/STO (LSMO/STO), indicating that the H_{eff} in LSMO/LAO/STO and that in LSMO/STO are opposite. These results suggest the correlation between the observed H_{eff} and the PHE in LSMO.

References

[1] T. Oyamada *et al*., JSAP Autumn Meeting, 18a-131-5 (2018).

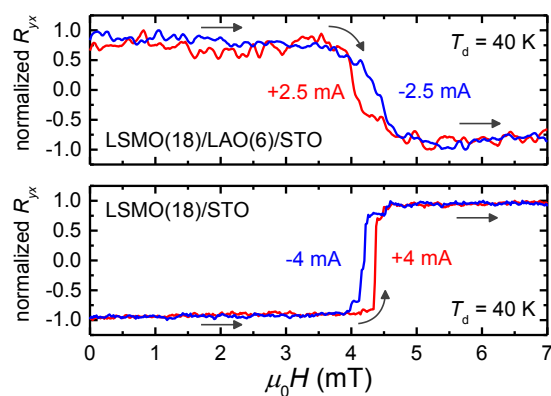[2] M. Yamanouchi *et al*., JSAP Autumn Meeting, 13p-P8-14 (2016).

Figure: μ_0H dependence of normalized R_{yx} for LSMO(18)/LAO(6)/STO and LSMO(18)/STO structures at T_d = 40 K.