Converse magnetoelectric effect in Co-based Heusler alloy/PMN-PT(011) multiferroic heterostructures

1. CSRN, Osaka Univ., 2. Grad. Sch. Eng. Sci., Osaka Univ., 3. Dept. Mat. Sci. Eng., Tokyo Tech. 4. Grad. Sch. Sci., Univ. of Tokyo, 5. Grad. Sch. Eng., Osaka Univ.

Takamasa Usami[1], Shumpei Fujii[2], Amran Mahfudh Yatmeidhy[3], Yoshihiro Gohda[3,1], Jun Okabayashi[4], Shinya Yamada[1,2], Takeshi Kanashima[2], Yu Shiratsuchi[5,1], Ryoichi Nakatani[5,1], Kohei Hamaya[1,2]

E-mail: usami.takamasa.es@osaka-u.ac.jp

In the previous reports, we demonstrated a giant converse magnetoelectric (CME) effect in the multiferroic heterostructures of Heusler alloy Co_2FeSi on ferroelectric $Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$ (PMN-PT) substrate [1,2]. However, the origin of the giant CME effect has not been clarified yet. In this study, we conduct a comprehensive study of multiferroic heterostructures using several Heusler alloys on PMN-PT.

30-nm-thick Co-based Heusler-alloy thin films (Co_2FeSi, $Co_2FeAl_{0.5}Si_{0.5}$, $Co_2Fe_{0.4}Mn_{0.6}Si$, and Co_2MnSi) were grown on PMN-PT(011) substrates with the insertion of a 0.3-nm-thick Fe layer by molecular beam epitaxy. As a reference, ferromagnetic Fe_3Si (Fe_2FeSi) was also grown on PMN-PT(011). X-ray diffraction measurements exhibit that all Co-based Heusler films are grown in polycrystalline, and the $L2_1$-ordered structure is confirmed by the {111} diffraction peaks (not shown here).

The CME effect was characterized by in-plane magneto-optical Kerr-ellipticity (η) measurements and conventional magnetization measurements at room temperature. Prior to the η measurements, we firstly applied an electric field (E) of +8 kV/cm, then released to zero-electric field for all heterostructures to prepare the same remanent polarization state of the PMN-PT(011). Figure 1 shows the in-plane magnetic-field (H) dependence of η for various Co-based Heusler alloys and Fe_3Si on PMN-PT at E of 0 and -8 kV/cm. We found that all multiferroic heterostructures using the Co-based Heusler alloys provide the 90° changes from a hard axis to an easy axis by applying E within the in-plane magnetic anisotropy. For the Fe_3Si case, on the other hand, a small variation in η-H curves can be seen where the magnetic easy axis observed at the zero-electric field is weakened at E of -8kV/cm. We will discuss the difference in such behavior between Co-based Heusler alloys and Fe_3Si multiferroic heterostructures in detail to consider the origin of the giant CME effect in Co_2FeSi/PMN-PT [1,2].

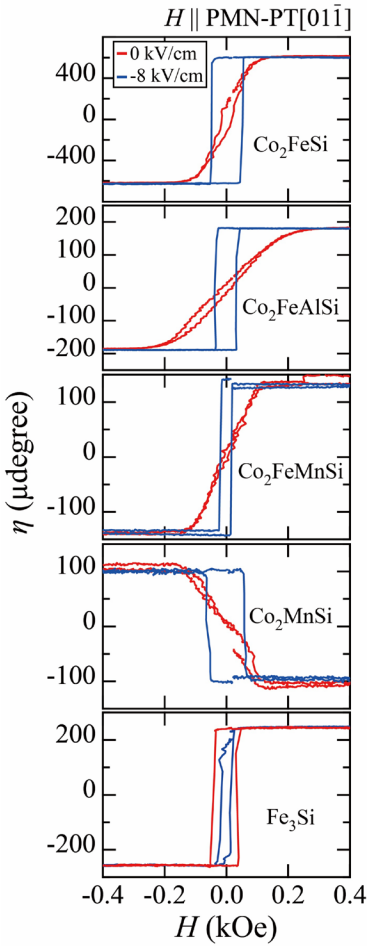

Fig. 1. In-plane magnetic field dependence of the Kerr ellipticity (η) for various Heusler-alloy/PMN-PT multiferroic heterostructures at E of 0 and -8 kV/cm at room temperature.

This work was partly supported by JST CREST Grant No. JPMJCR18J1 and JSPS KAKENHI Grant No. JP21K14196.

[1] T. Usami *et al.*, Appl. Phys. Lett. **118**, 142402 (2021).
[2] S. Fujii, T. Usami *et al.*, submitted.