# Fabrication of $EuF_2$ and EuO epitaxial thin films using anion-conducting substrates

°(D)Xin DAI[1], Yuya Komatsu[1], Ryota Shimizu[1,2], Taro Hitosugi[1]
Tokyo Tech[1], JST-PRESTO[2]
E-mail:dai.x.ab@m.titech.ac.jp

**[Introduction]** Divalent europium ($Eu^{2+}$) compounds such as $EuF_2$ (band insulator and possible $F^-$ anion conductor) and EuO (magnetic semiconductor) have attracted wide attention due to their unique magnetic and optical properties originating from in *f*-electron configurations [1-2]. For electronics applications, it is required to fabricate them in an epitaxial thin film form. Although the fabrication of EuO epitaxial thin films has been reported using pulsed laser deposition previously [3], there has been no report on the fabrication of $EuF_2$ epitaxial thin films. Distinct from oxides, the fabrication of fluoride thin films is difficult as following reasons: (1): preparation of fluorite targets is generally difficult, and (2): fluorine gas necessary for the fluorination has toxic and corrosive properties, hindering further studies using fluoride thin films. To overcome these difficulties, here, we introduce an alternative route to use anion conducting substrates as anion sources, respectively, and report the successful fabrication of $EuF_2$ and EuO epitaxial thin films.

**[Experiment]** Thin films of $EuF_2$ and EuO were deposited on $CaF_2$ (111) and yttria-stabilized zirconia (111) substrates respectively, using magnetron sputtering. A Eu metal plate (1 inch) was used as a target, and Ar gases were introduced into a vacuum chamber for the sputtering. During the depositions, the pressure of Ar was fixed at 1.0 Pa with a constant flow rate of 10 SCCM in the growth chamber. The RF power supply at the Eu target was maintained at 20 W. Substrate temperatures ($T_s$) were varied from 500°C to 700°C. A typical film thickness was 90 nm with a growth time of 30 min. The structural properties were characterized using X-ray diffraction (XRD).

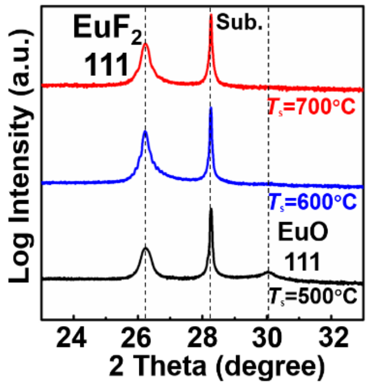


Fig.1. $T_s$ dependence of out-of-plane XRD scan obtained from $EuF_2/CaF_2$ (111) thin films.

**[Results & Discussion]** Figure1 shows XRD patterns on the thin films deposited on $CaF_2$(111) substrates. All the films show clear $EuF_2$ 111 peaks at $2\theta$ = 26.233º. In addition, a EuO 111 peak ($2\theta$ = 30.067º) observed at $T_s$ = 500ºC disappears, as $T_s$ increases up to 700ºC. More $F^-$ anions are diffused from $CaF_2$ substrates into films with the increase of $T_s$, because of high $F^-$ conductivity of $CaF_2$, and preferentially combined with Eu atoms, leading to the disappearance of EuO impurity phase at $T_s$ = 700ºC. The full width at half maximum of the rocking curve of $EuF_2$ 111 is obtained as 0.20º, indicating high crystallinity. We also confirmed epitaxial growth of $EuF_2$ (111) thin films on $CaF_2$(111) substrates (cube on cube) by pole-figure measurement. Figure2 shows XRD patterns of thin films deposited on YSZ (111) at $T_s$ = 500-700ºC. Near the peaks of YSZ 111 ($2\theta$ = 30.084º), EuO 111 diffraction peaks are observed at 2θ = 30.168° for the films deposited at $T_s$ = 600ºC and 700ºC. These results demonstrate that a use of anion-conducting substrates allows us to easily fabricate $EuF_2$(111) and EuO (111) epitaxial thin films.

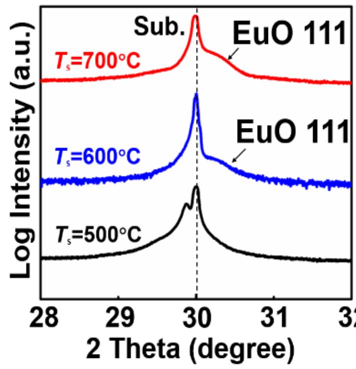


Fig.2. $T_s$ dependence of out-of-plane XRD scan obtained from EuO/YSZ (111) thin films.

**References:**

[1] Schmehl *et al.*, Nat. Mater. **6** 882 (2007).
[2] He *et al.*, Nanoscale **3** 184 (2011).
[3] Yamasaki *et al.*, Appl. Phys. Lett. **98**, 082116 (2011).