Multiferroic ε-Fe_2O_3 Thin Films for Highly Efficient Visible Light Photoelectrochemical Water Splitting

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α-Fe_2O_3 was one of the most studied photoanode oxide materials for photoelectrochemical (PEC) water splitting, which is an effective process for producing sustainable energy carrier using solar energy [1]. However, α-Fe_2O_3 still hinders the PEC activity due to its low absorption coefficient, a very short excited-state lifetime, a short hole diffusion length, and poor electrical conductivity [2]. Multiferroic ε-Fe_2O_3 is considered to be a promising photoanode material because photoexcited electron–hole pairs could be further separated by the internal electric field induced by the ferroelectric polarization.

Herein, single-phase ε-Fe_2O_3 thin film was grown on $SrTiO_3$ (111) substrate through a pulsed laser deposition technique, with a growth temperature and an oxygen pressure of 700°C and 11 Pa, respectively. The X-ray diffraction $2\theta/\omega$ pattern for the ε-Fe_2O_3 film is shown in Fig.1. The ε-Fe_2O_3 thin film was highly oriented along the (004) direction. The epitaxial growth was confirmed using reciprocal space mapping of the (20$\underline{1}$0) reflection of the ε-Fe_2O_3 film and the (313) reflection of $SrTiO_3$ substrate. The in-plane epitaxial relationship ε-Fe_2O_3 (200)//$SrTiO_3$ (1–21) was also revealed. The three-electrode j-V measurement was conducted under visible light and UV light illumination condition, as shown in Fig. 2. We applied Pt as a counter electrode, 3M NaCl saturated Ag/AgCl as a reference electrode, and the photoelectrode samples as working electrode. The bandgap of ε-Fe_2O_3 was evaluated to be 2.1 eV using the Tauc plot. It could be observed that ε-Fe_2O_3 can produce photogenerated charge carriers without an external bias (0 V). The incident photon-to-current efficiency (IPCE) can reach 76.4% at the wavelength of 390 nm. This research might contribute to the water splitting application by providing a room-temperature multiferroic candidate.

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[1] M. Kim, B. Lee, et al. Adv. Mater. 2019, 31, 1903316.

[2] J. Song, T. Kim, et al. Nano Res. 2018, 11(2): 642-655.

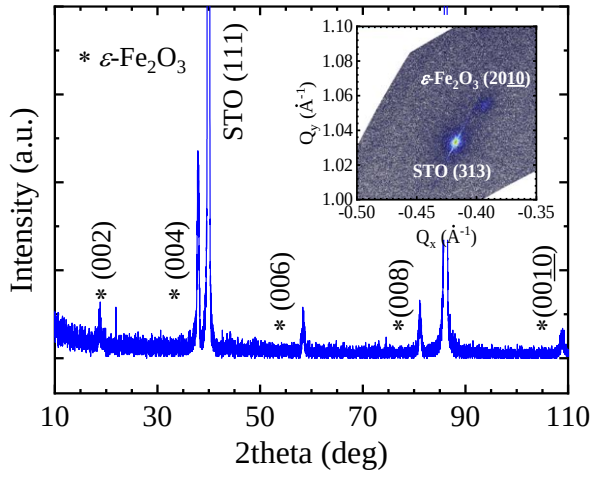

Fig. 1. XRD $2\theta/\omega$ patterns of as-grown (004)-oriented ε-Fe_2O_3 films.

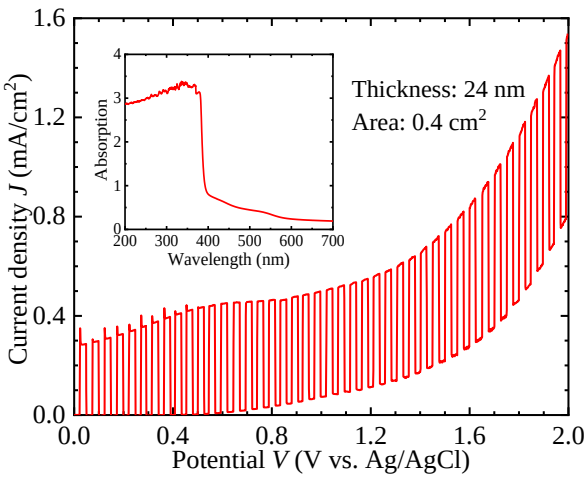

Fig. 2. Three-electrode j-V plot of ε-Fe_2O_3 under UV illumination and Absorption coefficient measured in absorption spectra.