Observation of Ferroelectric Domain Structure by Direct Piezoelectric Effect

Takeshi Yoshimura[1*], Kento Kariya[1], and Norifumi Fujimura[1]
[1]Department of Physics and Electronics, Osaka Prefecture University
1-1 Gakuen-cho, Naka-ku, Sakai, Osaka 599-8531, JAPAN
*Takeshi Yoshimura: tyoshi@pe.osakafu-u.ac.jp

[Introduction}

Domain walls and domain structure of ferroelectric films have an important role on the dielectric, ferroelectric, and piezoelectric properties. Piezoelectric force microscopy (PFM) is useful for domain observation of ferroelectric thin films and evaluation of inverse piezoelectric response. However, many discussions have been created in the quantitative evaluation of the converse piezoelectric response in PFM,[1] because the effects of electrostriction and injected charges in the insulator are superimposed on the converse piezoelectric response.[2] Moreover, it was reported that the effective transverse piezoelectric coefficients evaluated from the converse piezoelectric effect were greater than that evaluated from the direct effect.[3] The origin of the difference is explained by the contribution of the extrinsic response caused by not only the non-180° domain motion but also intergranular strain accommodation. Although the direct piezoelectric response is important for sensors and energy harvesters, there is no way to evaluate it microscopically. Therefore, the contribution of the domain walls on the direct piezoelectric response has not been revealed yet. In this study, a novel method to evaluate the direct piezoelectric response microscopically using a scanning probe microscope (SPM) was developed.

[Experiment and Results]

Epitaxially grown (100) $BiFeO_3$ film was used as a sample. A conductive SPM probe was placed on the film, and the film was vibrated using piezoelectric actuators. The current generated by the direct piezoelectric response was measured by a lock-in amplifier. Conventional PFM using converse piezoelectric response was also carried out at same reason. Figure shows (a) surface morphology, and mappings of vertical piezoresponse by (b) converse and (c) direct effects. The image shown in Fig. (c) is similar to that shown in Fig. (b), which indicates that the domain structure was successfully observed using the direct piezoelectric response. $e_{33,f}$ piezoelectric coefficient was calculated from the direct piezoresponse assuming the contact area of the SPM probe. The magnitude of $e_{33,f}$ coefficient is consistent with that estimated from the $e_{31,f}$ coefficient of this sample, which indicates the possibility of quantitative evaluation of this method.

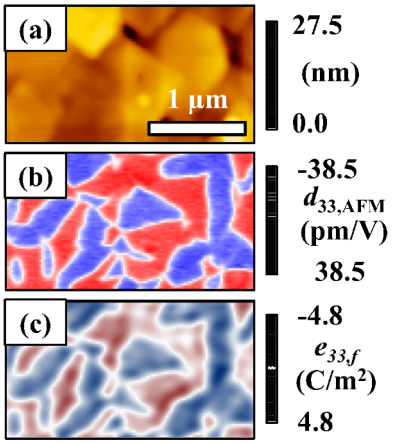

Fig. (a) Surface morphology, and vertical piezoresponse by (b) converse and (c) direct effects.

ACKNOWLEDGEMENT

This work was supported by CREST, JST, and the Industrial Technology Research Grant Program in 2011 from New Energy and Industrial Technology Development Organization (NEDO) of Japan.

Ref.
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