Manipulation of Domain Structure in {100} Tetragonal $Pb(Zr, Ti)O_3$ Nanorods by Charge Screening

T. Yamada[1,2*], D. Ito[1], T. Sluka[3], N. Setter[3], O. Sakata[4, 5], T. Namazu[6],
H. Funakubo[5], M. Yoshino[1] and T. Nagasaki[1]
[1]Department of Materials, Physics and Energy Engineering, Nagoya, University, Nagoya 464-8603, Japan
[2]PRESTO, Japan Science and Technology Agency, Kawaguchi 332-0012, Japan
[3]Ceramics Laboratory, EPFL - Swiss Federal Institute of Technology, Lausanne CH-1015, Switzerland
[4]Synchrotron X-ray Station at SPring-8 and Synchrotron X-ray Group, National Institute for Materials Science, Sayo 679-5148, Japan
[5]School of Materials and Chemical Technology, Tokyo Institute of Technology, Yokohama 226-8503, Japan
[6]Department of Mechanical Engineering, Aichi Institute of Technology, Toyota 470-0392, Japan
*Tomoaki Yamada: t-yamada@nucl.nagoya-u.ac.jp

Manipulation of domain structure in nanoscale ferroelectric materials has been widely considered invaluable for improving dielectric, ferroelectric, and piezoelectric responses, and as a result device performance. Despite the significant need to control the domain structure of ferroelectrics, approaches for this are limited. In the case of thin films, the most common approaches are to change the orientation and strain of the films, both of which can be achieved by the selection of an appropriate substrate. However, it has also been reported that the imperfect charge screening at the interface and/or surface[1], resulting in "depolarizing field", can affect the domain structure of a film. This influence becomes larger for smaller structures.

In this presentation, we focus on such an influence on the domain structure in ferroelectric nanorods, the dimensionality of which is different from that of thin films. We fabricated {100} tetragonal $Pb(Zr_{0.35}Ti_{0.65})O_3$ (PZT) nanorods by partly etching a film grown on Nb-doped $SrTiO_3$ (Nb-STO) and Si substrates using a focused ion beam. We found that the *a*-domain fraction in the PZT nanorods drastically decreased with decreasing rod width and an exclusively *c*-domain structure was formed in nanorods of width ≤1 μm on Nb-STO [2]. The preferred formation of the *c*-domain in these nanorods can be rationalized in terms of the large depolarizing field in the *a*-domain. Indeed, the *a*-domain fraction could be increased by weakening the depolarizing field by coating these nanorods with Pt metal layers. The obtained results were in good agreement with the phase field simulation taking into account the effect of charge screening.

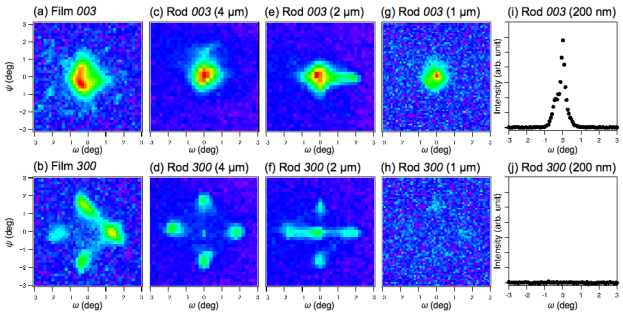

Fig. 1 Synchrotron micro-XRD ω-ψ maps for PZT *003* and *300* (corresponding to *c*- and *a*-domain, respectively) in PZT film on Nb-STO [(a) and (b)] and nanorods of 4 μm [(c) and (d)], 2 μm [(e) and (f)], and 1 μm [(g) and (h)] widths on Nb-STO; ω-scans at ψ = 0° are also shown for the nanorod of 200 nm width [(i) and (j)].

References:

[1] Catalan et al., *Rev. Mod. Phys.* **84**, 119 (2012).
[2] Yamada et al., *Jpn. J. Appl. Phys.* **54**, 10NA07 (2015).