Three-Dimensional Observation of Nano-scale Ferroelectric Domain using Scanning Nonlinear Dielectric Microscopy with Electric Field Correction by Kelvin Probe Force Microscopy

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Recently, we have developed the two types (needle-type and cantilever-type) of Scanning Nonlinear Dielectric Microscopy (SNDM) for measuring polarization distribution. In needle-type SNDM, a wide-scale polarization distribution can be measured with micrometer order resolution, whereas in cantilever type SNDM, we can measure the polarization distribution with sub-nanometer resolution. Originally, SNDM was developed to measure the polarization component perpendicular (out-plane) to the surface. However, today, the polarization component parallel (in-plane) to the surface can also be measured by applying an parallel electric field to the sample surface[1]. In this lateral measurement, to know the precise domain direction, it is quite important to apply the field exactly parallel to the surface without the normal component. Therefore, we reported a new system that makes more exact measurement of the in-plane polarization in needle-type SNDM by detecting displacement current distribution and canceling a normal component of the electric field to obtain the exactly parallel field. However, for the nano-scale three-dimensional measurement using cantilever-type SNDM, a new technique has been required.

In this paper, we have developed the cantilever-type SNDM for the in-plane measurement with the function of the electric field correction using Kelvin Force Microscopy.

Figure 2 shows experimental results for the domain structure of a multi-domain $LiTaO_3$ using this newly developed SNDM, as shown in Fig. 1. The image obtained through the out-plane measurement on the top surface (z-plane) is shown in Fig. 2(a), where the c-c domain structure was confirmed. Subsequently, the in-plane measurement on the cross-sectional surface (x-plane) was carried out. Figure 2 (b) and (c) show the phase and amplitude image, respectively. It was confirmed that the domains do not penetrate along the z-axis contrary to an usual expectation. Moreover, it was found that there is a large response area at the charged domain boundary (A) in Fig. 2(c), which is expected to be an electric field distribution due to an electric charge in the charged boundary.

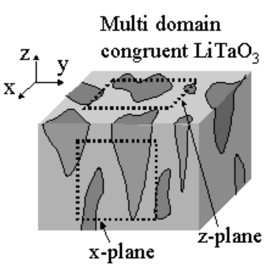

Figure 1 Domain structure of multi domain $LiTaO_3$.

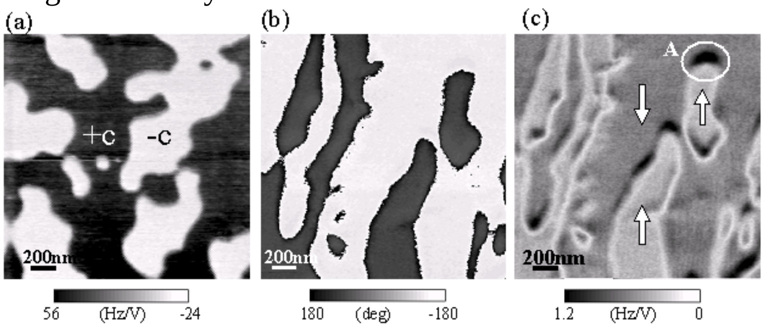

Figure 2 (a) Acosθ signal in z-plane of multi domain $LiTaO_3$ obtained by out-plane measurement. (b) Phase and (c) amplitude signals in x-plane obtained by in-plane measurement.

[1] H. Odagawa and Y. Cho, Appl.Phys.Lett., **80** (2002)2159