Macro- and microstructure of binary system piezoelectric relaxor-$PbTiO_3$ single crystals by AC poling

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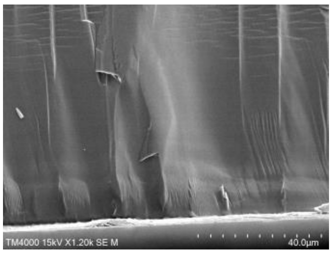
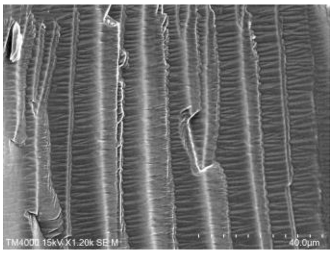
Piezoelectric materials and devices that perform electromechanical conversion are commonly polarized by applying a direct current (DC) electric field to obtain piezoelectric properties. In 2014, Yamashita et al. reported that enhanced dielectric and piezoelectric properties could be obtained for $Pb(Mg_{1/3}Nb_{2/3})O_3$ (PMN)-$PbTiO_3$ (PT) binary single crystal (SC)s and $Pb(In_{1/2}Nb_{1/2})O_3$ (PIN)-PMN-PT ternary SCs by a novel AC polarization (ACP).[1-2)] Based on these reports, the relationship between domain structures and electrical properties of DCP and ACP piezoelectric SCs has been widely studied.[3)] In addition, piezoelectric SCs are also characterized by poling intensity, and piezoelectric SCs are known to be divided into four stages: non-polarized, under-polarized, optimum-polarized, and over-polarized. Most of the previous reports on microstructural observation of DCP and ACP piezoelectric SCs have used piezoresponse force microscopy (PFM) to study areas smaller than $10 \times 10\ \mu m^2$.
We investigated the relationship between the macro- and microstructures and piezoelectric properties of ACP binary 0.72PMN-0.28PT [001]c SC materials produced by conventional Bridgeman method and other materials by examining the differences in domain structures observed by scanning electron microscopy (SEM), which is suitable for wide area observation, to determine the relationship. Fig. 1 show SEM photographs of center and bottom sections of a 0.3-mm-thick ACP SC subjected to 10 cycles of AC triangular wave with an intensity of 1.5 kVrms/cm and a frequency of 0.1 Hz at 80 ºC. The field of view of the photographs was approximately $80 \times 100\ \mu m^2$ square. Center part was typical stripe-like fine domain of ACP SC. Different domain morphologies were observed at the bottom of the ACP SC. The dielectric constant and piezoelectric constant d_{33} of the triangle ACP SCs were 8230 and 1970 pC/N, respectively. And the ACP sample caused small spurious vibration mode in the impedance spectra.



(a) Near electrode part.



(b) Center part.

Fig. 1. Microstructures of two parts of ACP SC. The arrow is poling direction.

(1) Yamamoto *et al.*, U.S. patent application publication 2014/0062261 A1 (2014).
(2) Yamashita *et al.*, U.S. patent application publication 2015/0372219 A1 (2015).
(3) H-P. Kim, H.T. Wan, C. Luo, Y. Yamashita, Y. Sun, T. Karaki, H-Y. Lee, and X. Jiang, IEEE, TUFFC, **69**(11): 3037-3047 (2022).