Nanoscale Piezoelectric Response and Domain Relaxation of (K,Na)NbO_3-Based Lead-Free Perovskite with Abnormal Grain Growth

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Piezoelectric materials have been extensively studied and commercially used for many different applications. However, PZT and other lead-based piezoceramics are considered as toxic materials since lead can cause severe environmental and health problems. As the reason, there is an increasing number of concern over the usage of these hazardous materials

$CaZrO_3$-doped (K,Na)NbO_3 (KNN) piezoceramic is considered as a potential alternative for lead-based piezoceramics due to its promising performance. However, abnormal grain growth behavior has been discovered in the composition, where large grains over 10 μm and small grains less than 1 μm coexist. It is well known that the grain size plays an important role in polycrystalline piezoceramics, yet the relationship between macroscopic piezoelectric property and grain size is hard to be confirmed. Because some other material parameters, which associated with grain size, could also contribute to the change of macroscopic piezoelectricity, e.g. density, compositional deviation, etc. On the contrast, by using piezoresponse force microscopy (PFM), all the aforementioned factors, which are convoluted with the grain size effect, could be neglected; thus, an in-depth comprehension of the grain size effect on nanoscale piezoelectric response in polycrystalline ceramics could be achieved.

In the present study, Piezoresponse force microscopy (PFM) was utilized to determine the grain size effect on local piezoelectric response as well as domain relaxation behavior in one single bulk ceramic pellet. The results have verified that the nanoscale piezoelectric performance is highly enhanced at the grain boundary region. Thus, it is indicated that the macroscopic piezoelectric constant d_{33} could be largely increased in polycrystalline KNN-based perovskite, if dense bulk samples with homogenously distributed small grains could be obtained.