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Piezoresponse force microscopy and electron backscattering diffraction of 90° ferroelectric twins in $BaTiO_3$ positive temperature coefficient (PTC) thermistors

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Barium titanate ($BaTiO_3$) with positive temperature coefficient (PTC) of resistivity is widely used in surge protection devices, self-regulating heaters and temperature sensing applications. $BaTiO_3$ is a ferroelectric insulator at room temperature; however, the materials can become a ferroelectric semiconductor by suitable doping with ions La^{+3}, Sm^{+3}, Ho^{+3}, or Nb^{+5}. The resistivity of donor doped $BaTiO_3$ can increase by several orders of magnitude near the phase transition temperature 'T_C' for the ferroelectric tetragonal to the paraelectric cubic phase transformation. It is believed that the huge resistivity change at T_C in donor doped barium titanate ($BaTiO_3$) is a grain boundary effect [1,2]. In this study, we combine two surface analysis tools, electron backscatter diffraction (EBSD) and piezoresponse force microscopy (PFM) to investigate the role of crystallographic orientation, topography and intergranular polarization in polycrystalline PTC $BaTiO_3$ ceramic that leads to PTC effect. EBSD of $BaTiO_3$ reveals individual grains of $BaTiO_3$ possess a preferred orientation. Ferroelectric domains and twinning is evident in both electron back scattered images and PFM images. In individual grains, the domains mostly appear in a single twin pair set rather than random pairs of all available phase variants. While the EBSD on these thermally etched samples showed 90° domains it could not discern the type between *a-a* and *a-c* domains. PFM on the other hand clearly distinguishes *a-a* and *a-c* type domains using vertical and lateral piezoresponse. The work reported here will contribute to grain boundary control of PTC effect in semiconducting ferroelectric barium titanate ceramics.

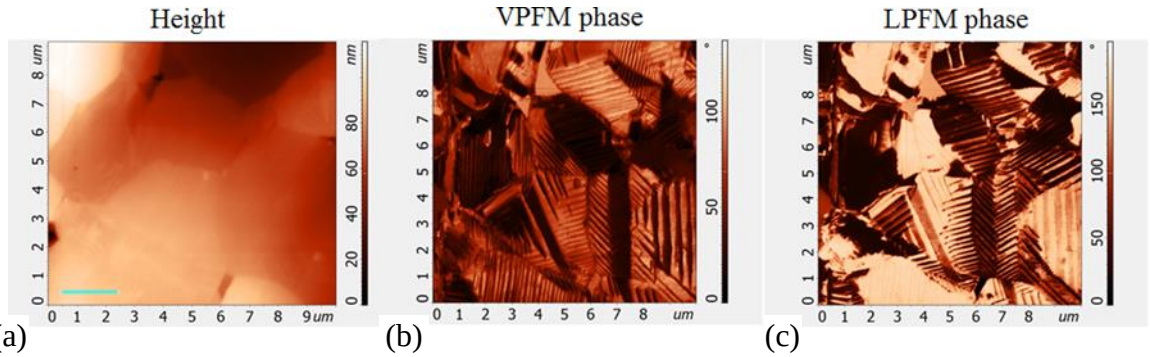

Figure 1. PFM images of $BaTiO_3$ showing (a) height, (b) vertical piezoresponse VPFM (phase) and (c) lateral piezoresponse LPFM (phase) of the same area. A clear herringbone pattern is evident on most of the grains (b, c), indicating that the domains are ferroelectric in nature. The scale bar indicated in (a) is 2 μm.

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