Investigation of ferroelectric ceramic powders using piezoresponse force microscopy

Nejc Suban[1,2*], Silvo Drnovšek[2], Hana Uršič[1,2]

[1] *Electronic Ceramics Department, Jožef Stefan Institute, Slovenia*
[2] *Jožef Stefan International Postgraduate School, Slovenia*
[*] *Corresponding author: nejc.suban@ijs.si*

Piezoresponse force microscopy (PFM) is powerful and widely used technique for probing piezoelectric and ferroelectric properties in ferroelectric single crystals, bulk ceramics, thick and thin films. However, its application to the pristine ceramic powders is limited due to the irregular, non-flat morphology, weak attachment to the substrate, and particle movement during PFM imaging.

In this study, we present a reliable and reproducible procedure for sample preparation and PFM imaging that overcomes these challenges and enables high-quality PFM imaging of ceramic powders. The approach was demonstrated on two ceramic powders; ferroelectric $PbZr_{0.53}Ti_{0.47}O_3$ (PZT) and relaxor-ferroelectric $0.65Pb(Mg_{1/3}Nb_{2/3})O_3–0.35PbTiO_3$ (PMN–35PT). Prior to the PFM measurements, powders were fixed and embedded in polymer resin and polished to ensure flat surface for stable PFM imaging. Out-of-plane PFM amplitude and phase images were recorded in dual AC resonance tracking (DART) mode. An AC voltage with an amplitude of 5 V at frequency of ~280 kHz was applied to the PFM tip in the virtual ground mode. Local PFM hysteresis loops were recorded in PFM switching spectroscopy mode [1].

PFM measurements reveal clear piezoelectricity observed inside the powder particles and localises the ferroelectric domains within them. In some larger powder particles, ferroelectric domains, including wedge-shaped and irregular domains, are visible (Figure 1). In order to investigate the polarization switching within the individual powder particle, local PFM hysteresis loops were measured. The recorded amplitude and phase loops of both investigated powders, indicate the switching of ferroelectric domains in a single particle.

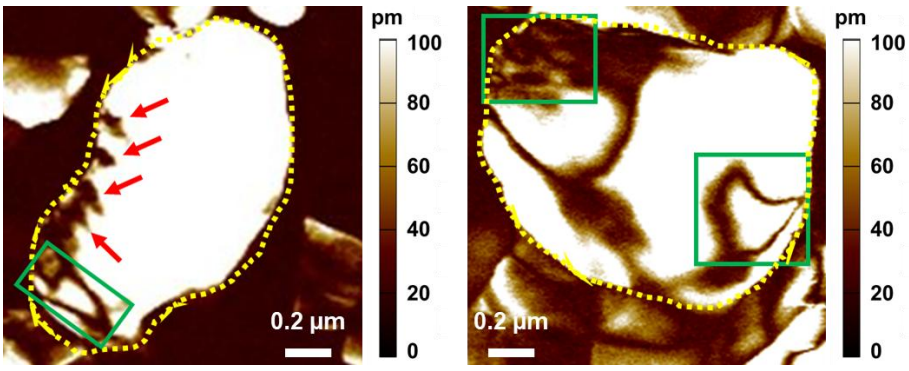

Figure 1. *PFM amplitude images of a single PZT powder particle, showing wedge-shaped and irregular ferroelectric domains inside the particle.*

[1] N. Suban, S. Drnovšek, and H. Uršič, Investigation of ceramic powders using piezoresponse force microscopy, *Mater. Lett.*, vol. 409, pp. 140226, 2026, doi: 10.1016/j.matlet.2026.140226.