

Supplementary Materials

Tailoring the microstructure of lead-free KNN piezoelectric ceramics for force-sensitive smart windows

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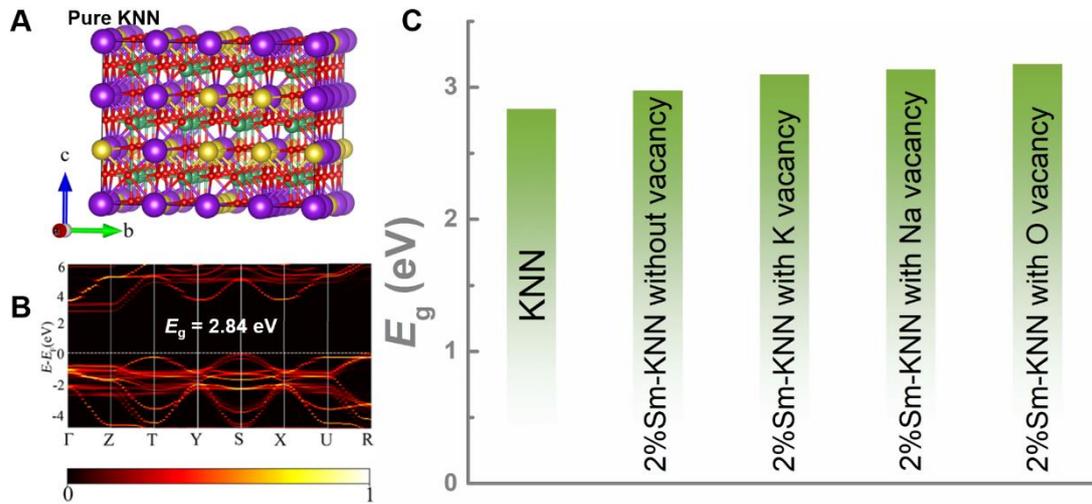


Figure 1. (A) The SQS structure of the KNN $4 \times 4 \times 3$ supercell including 240 atoms. (B) The unfolding plots of band structures for KNN. (C) The calculated shGGA-1/2 bandgap for the KNN and 2% Sm-doped KNN with different defect types.

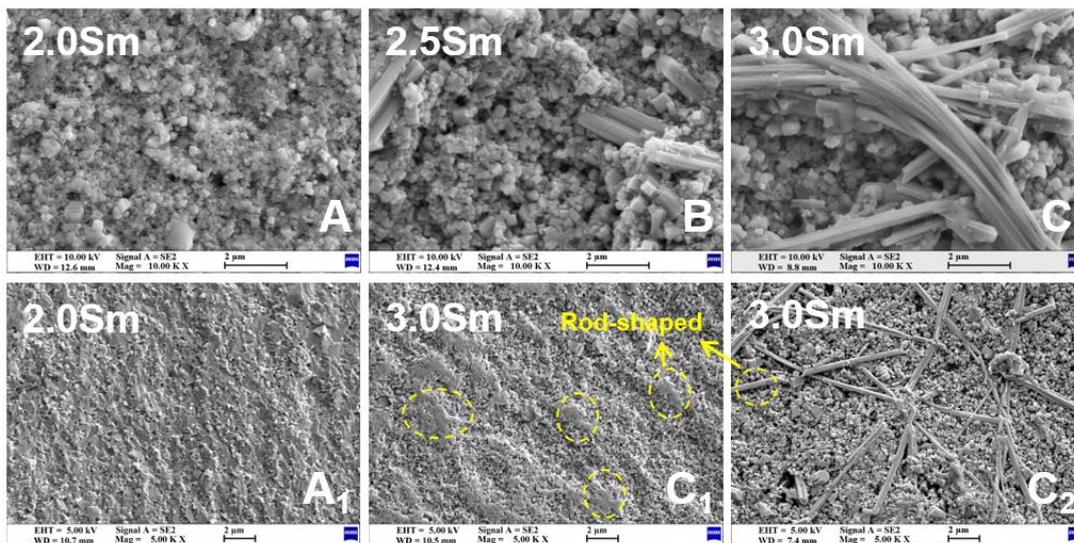


Figure 2. The free and fracture surface of the x Sm transparent ceramics.

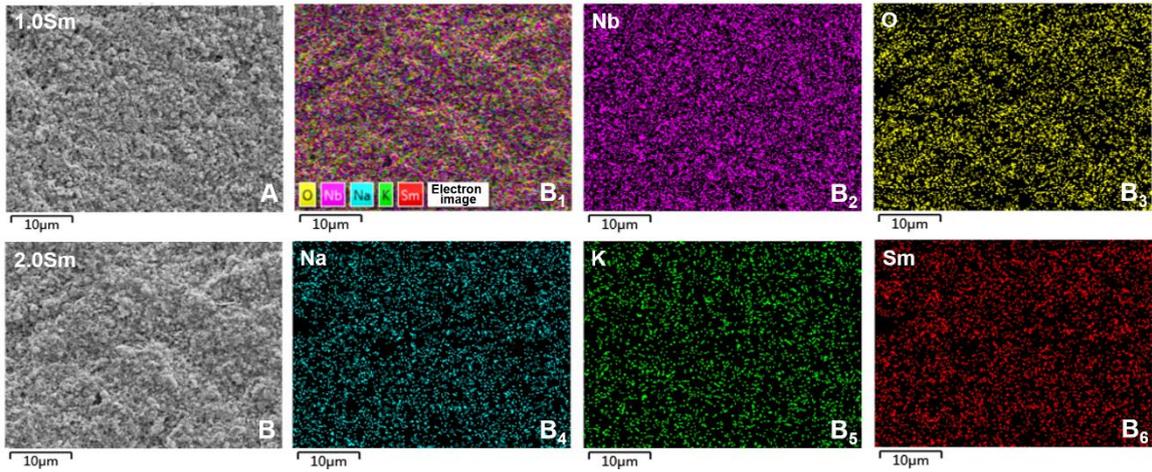


Figure 3. EDS analysis based on the SEM of the 1.0Sm and 2.0Sm transparent ceramics.

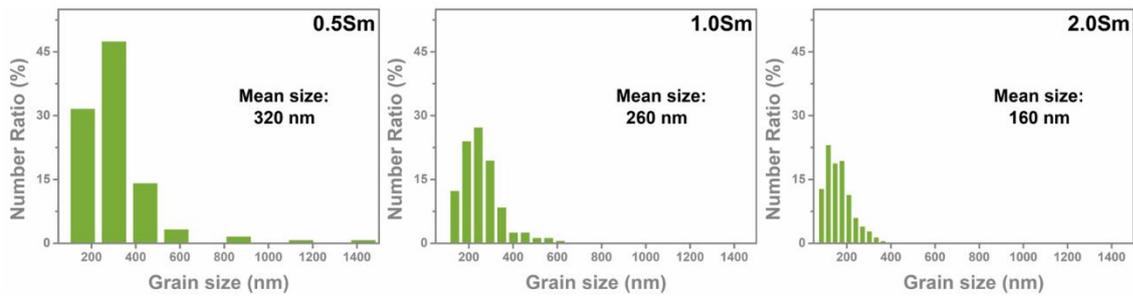


Figure 4. Distributions of grain size for the x Sm ceramics from the SEM data.

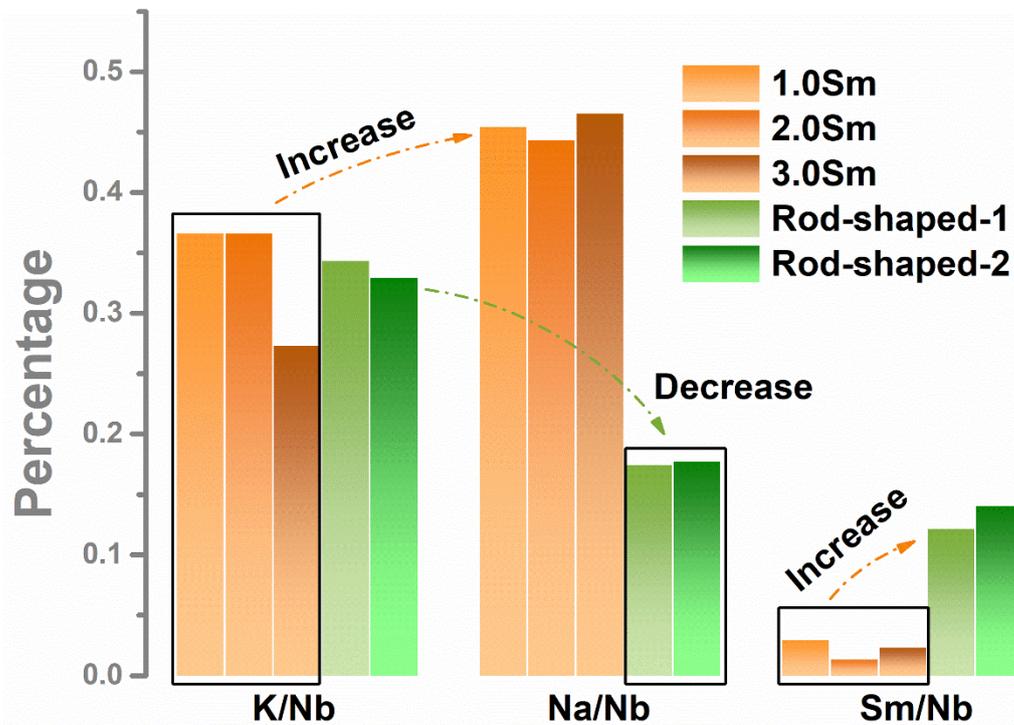


Figure 5. The comparison of K/Nb, Na/Nb and Sm/Nb ratios from EDS analysis between x Sm ceramic matrix and second phase.

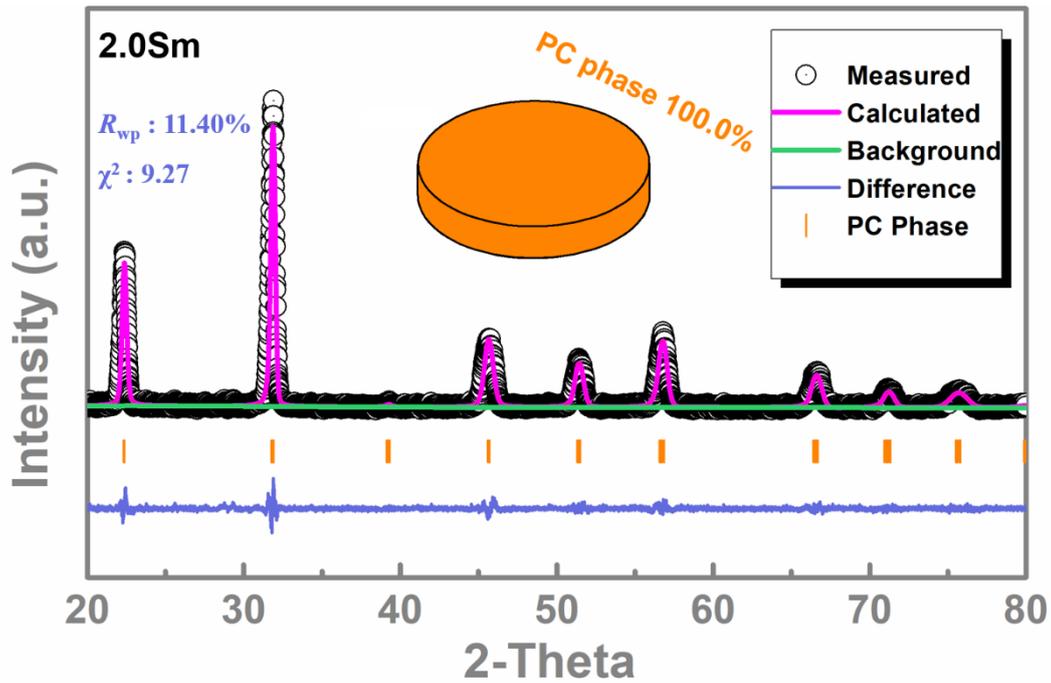


Figure 6. Rietveld refinements for XRD pattern with the 2.0Sm ceramic.

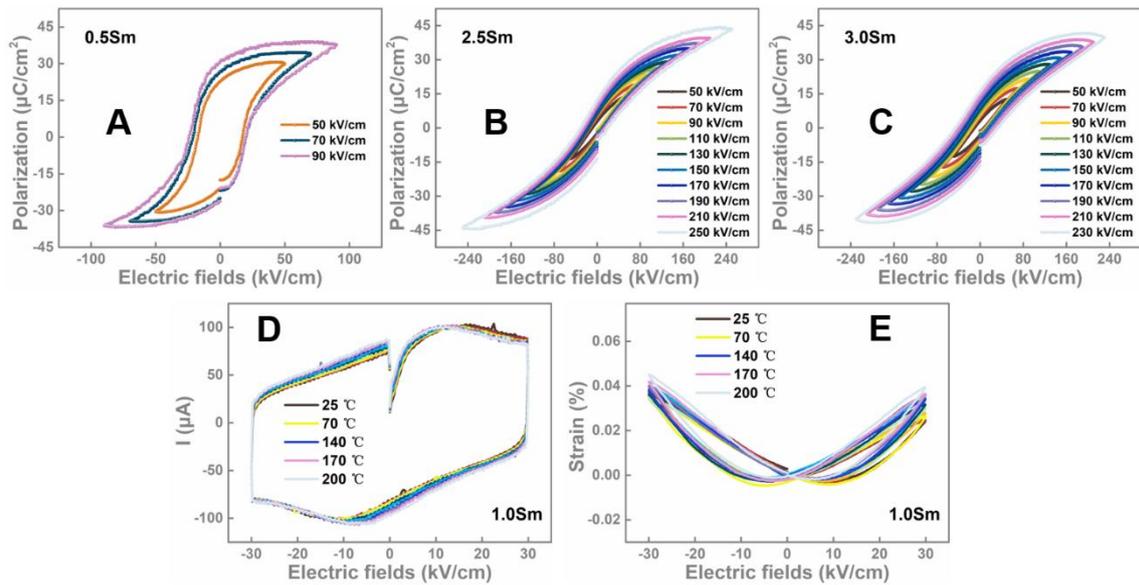


Figure 7. (A-C) *P-E* hysteresis loops under different electric fields at 10 Hz of the *xSm* ceramics with a thickness of ~ 0.25 mm. (D) *I-E* curves and (E) bipolar electrical field-induced strain under different temperatures at 10 Hz of the 1.0Sm ceramic with a thickness of ~ 0.3 mm.

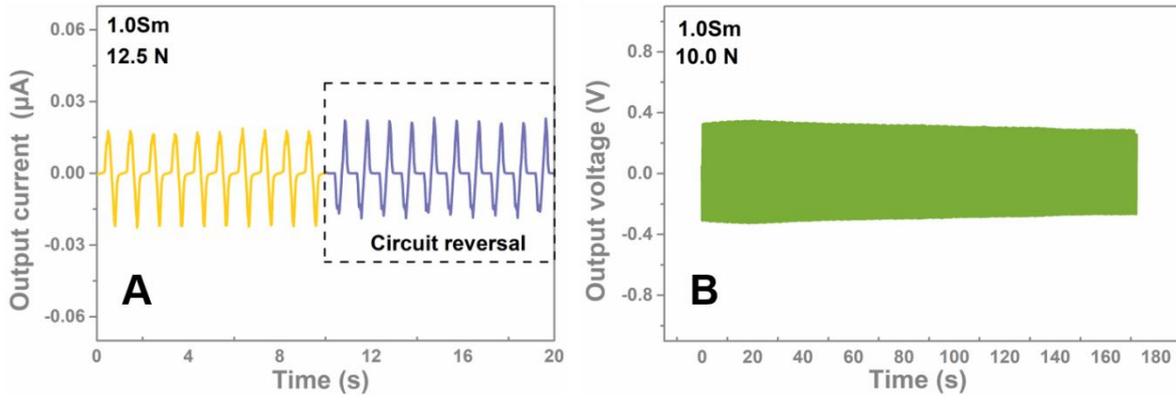


Figure 8. (A) The forward and reverse output current curves of the 1.0Sm transparent ceramic under 1 Hz and 12.5 N. (B) The output voltage curves under 1 Hz and 10.0 N for the 1.0Sm transparent ceramic.

Table 1 Theory density (TD), actual density (AD) and relative densities (RD) of the x Sm ceramics.

Samples	TD (g/cm ³)	AD (g/cm ³)	RD
$x = 0.5$	4.518	4.396	97.3%
$x = 1$	4.541	4.450	98.0%
$x = 2$	4.573	4.465	97.6%
$x = 3$	4.606	4.492	97.5%