

Supplementary Information

Size effect of precursor particles in W⁶⁺-doped CaBi₂Nb₂O₉ high-temperature piezoelectric ceramics

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Fig. S1. SEM images and particle size distribution of as-received microscale Nb₂O₅ powders and the sieved Nb₂O₅ powders after ball-milling for 10 h.

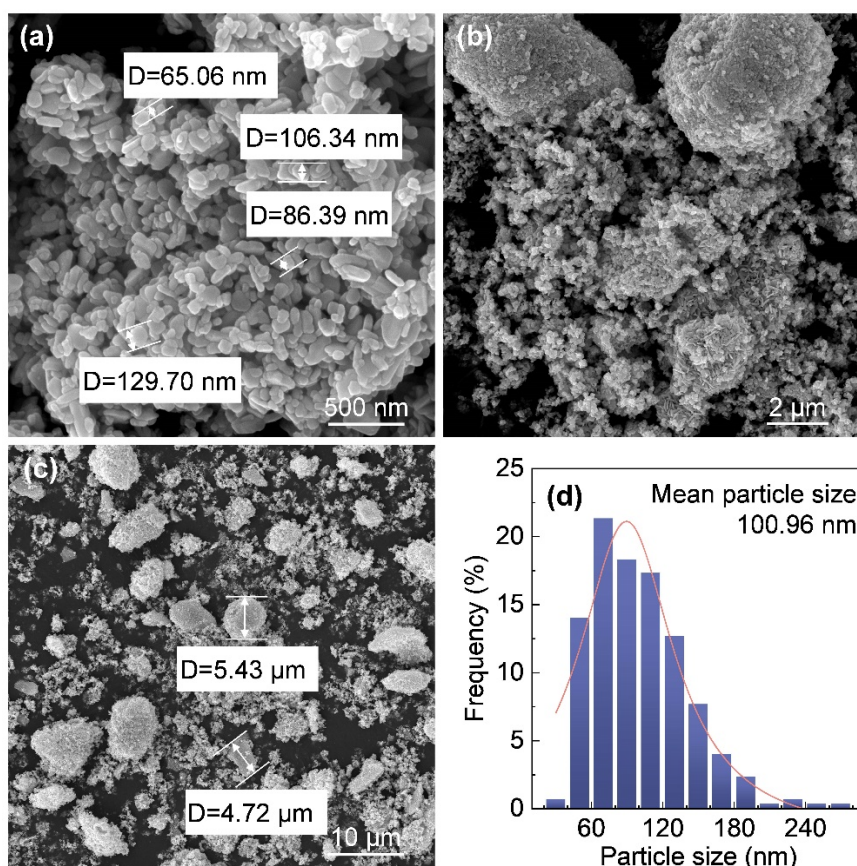


Fig. S2. (a-c) Microscopic morphology of as-received nanoscale WO₃ powders under different magnifications. (d) Particle size distribution collected by using the Nano Measurer software with over 300 particles in panel (a).

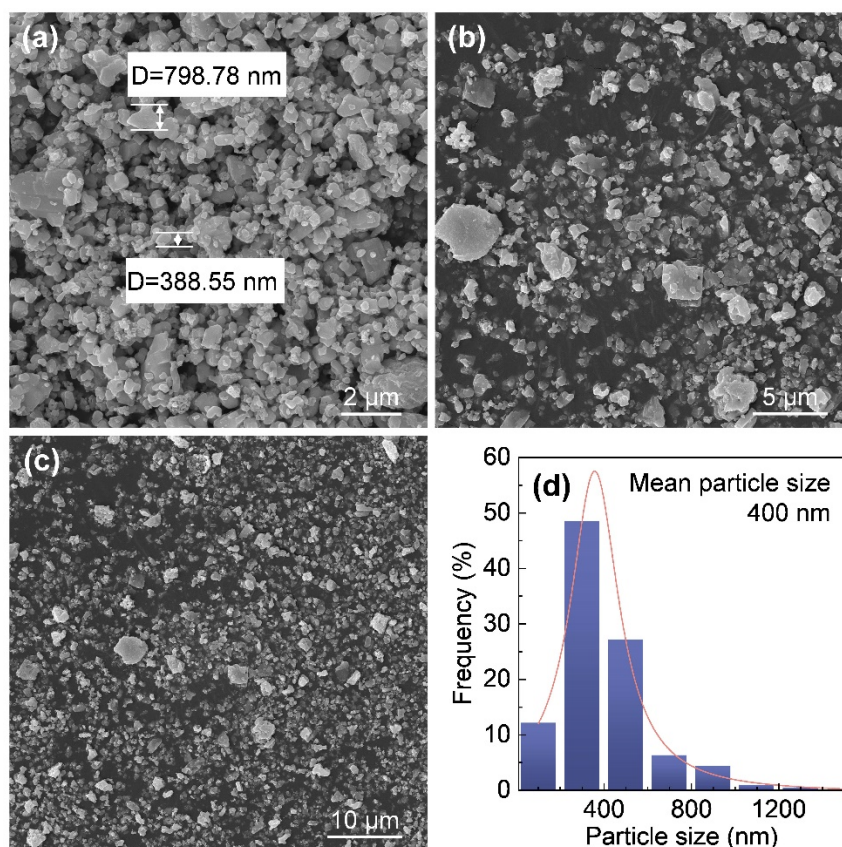


Fig. S3. (a-c) Microscopic morphology of as-received nanoscale Nb_2O_5 powders under different magnifications. (d) Particle size distribution collected by using the Nano Measurer software with over 300 particles in panel (a).

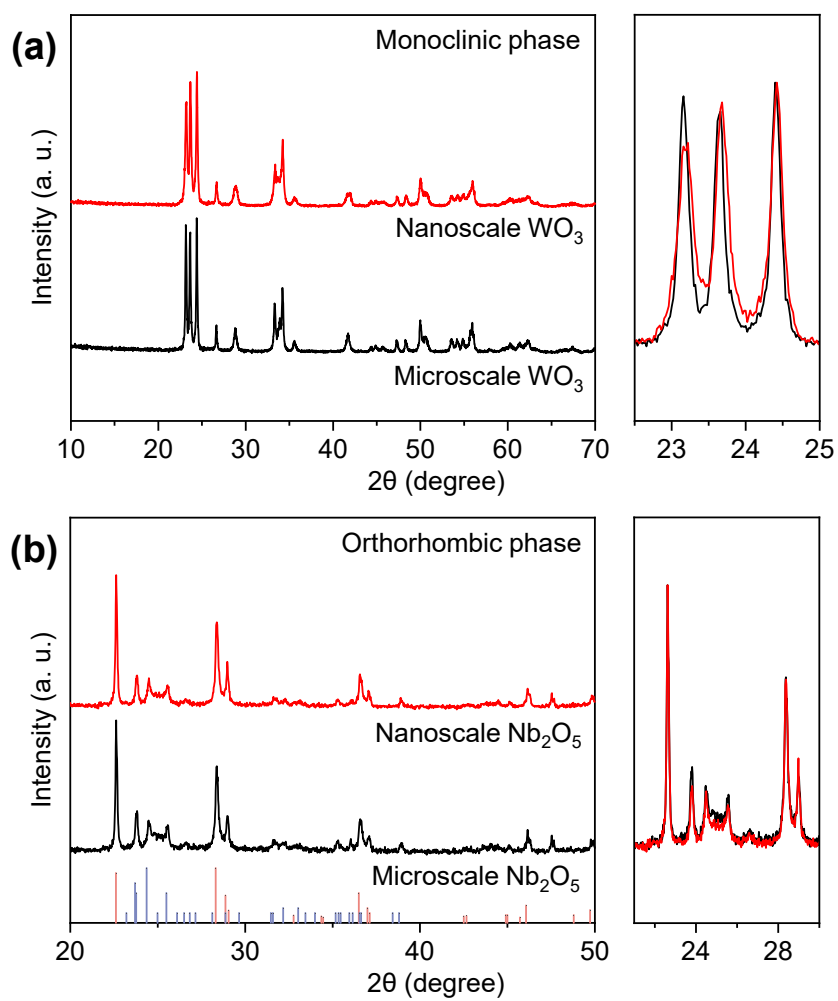


Fig. S4. XRD patterns of (a) WO_3 and (b) Nb_2O_5 precursors.

Fig. S5. Statistical analysis of grain aspect ratio. (a) Schematic illustration of aspect ratio measurement for anisotropic grains. Corresponding statistical grain aspect ratio distribution histograms for (b) undoped CBN, (c) mWmNb, (d) nWmNb, (e) mWnNb, and (f) nWnNb ceramics.

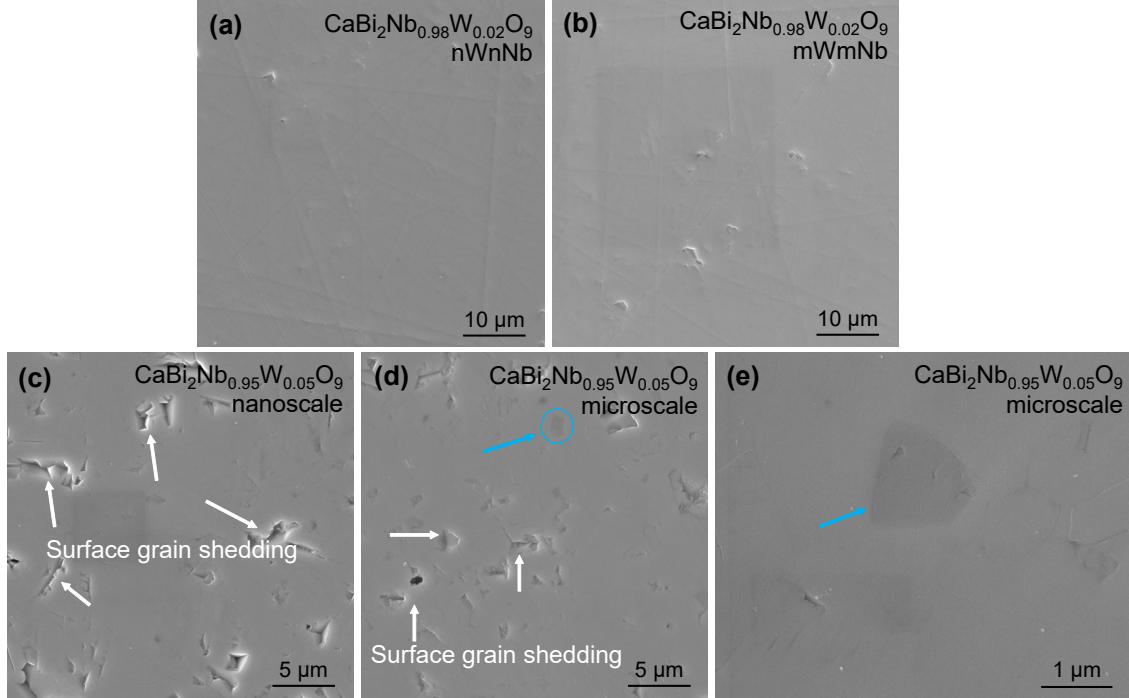


Fig. S6. Secondary electron images of (a) nWnNb, (b) mWmNb, (c) $\text{CaBi}_2\text{Nb}_{0.95}\text{W}_{0.05}\text{O}_9$ -nanoscale prepared from nanoscale $\text{WO}_3/\text{Nb}_2\text{O}_5$ precursors, and (d-e) $\text{CaBi}_2\text{Nb}_{0.95}\text{W}_{0.05}\text{O}_9$ -microscale prepared from microscale $\text{WO}_3/\text{Nb}_2\text{O}_5$ precursors. Surface grain shedding shown in the polished surface of $\text{CaBi}_2\text{Nb}_{0.95}\text{W}_{0.05}\text{O}_9$ ceramics (c-d).

Fig. S7. Rietveld refinement results of XRD patterns for (a) undoped CBN, (b) mWmNb, (c) nWmNb, (d) mWnNb, and (e) nWnNb ceramic powders. (f) The crystal structure with cation site occupancy.

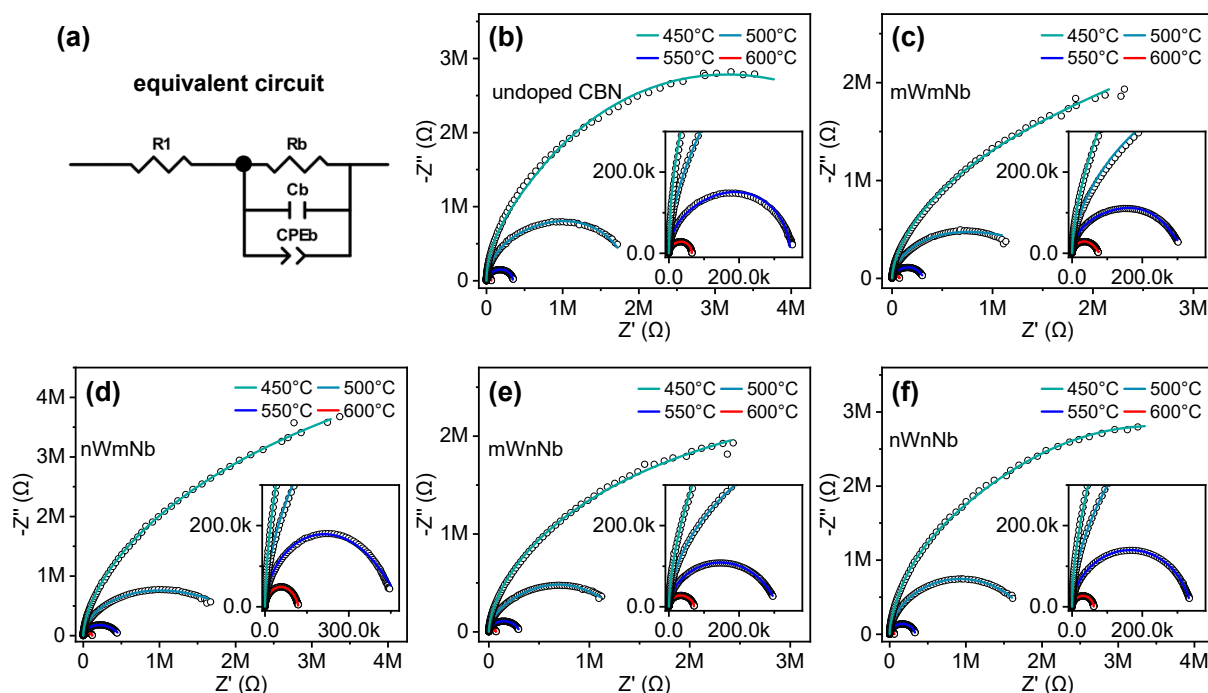


Fig. S8. (a) Schematic of the equivalent circuit used for fitting the impedance spectra. Nyquist plots with corresponding fitting curves for (b) undoped CBN, (c) mWmNb, (d) nWmNb, (e) mWnNb and (f) nWnNb ceramics.

Fig. S9. Combined $Z''/Z''_{\max}$ and $M''/M''_{\max}$ spectroscopic plots for (a) undoped CBN, (b) mWmNb, (c) nWmNb, (d) mWnNb, and (e) nWnNb ceramics.