Electronic Supplementary Material

Realizing enhanced energy storage and hardness performances in $0.90NaNbO_3$–$0.10Bi(Zn_{0.5}Sn_{0.5})O_3$ ceramics

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1 Experimental procedure

Based on stoichiometric proportions, the $(1-x)NaNbO_3$–$xBi(Zn_{0.5}Sn_{0.5})O_3$ (in brief as $(1-x)$NN–xBZS, x = 0.05, 0.10, 0.15, and 0.20) ceramics were composited by a traditional solid-state reaction technique. Na_2CO_3 (≥ 99%), Nb_2O_5 (≥ 99%), Bi_2O_3 (≥ 99%), ZnO (≥ 99%), and SnO_2 (≥ 99.5%) were chosen as original materials. These natural materials were weighed and wet-milled in alcohol and ZrO_2 for 4 h. Then, the resulting slurry fluid was dried and calcined at 800 ℃ for 4 h in air. After calcining, the powders were wet-milled for 4 h, and then pressed into pellets with 8 mm in diameter and 1 mm in thickness using 5 wt% polyvinyl alcohol (PVA) as the binder. Finally, the pellets were sintered at 1200–1300 ℃ for 2 h after removing PVA.

The phase structures were tested by an X-ray diffractometer (XRD) (Cu Kα1, 1.54059 Å, Model X'Pert PRO, PANalytical, the Netherlands). Free surface of the samples was analyzed by a field emission scanning electron microscope (SEM) (FE–

SEM, Model S4800, Hitachi, Japan) equipped with an energy-dispersive X-ray spectroscope (EDS). The selected area electron diffraction (SAED) and high-resolution transmission electron microscopy (HRTEM) imaging were acquired by JEM-2100F. The temperature-dependence of ε_r and tanδ for xBZS ceramics was measured at a frequency of 10 kHz by a precision impedance analyzer (4294A, Hewlett–Packard, Palo Alto, USA). Ferroelectric hysteresis (P–E) loops were measured with the ferroelectric analyzer (RT66, Radiant Technologies, USA), and the thickness and electrode area of all the test samples were 0.10–0.12 mm and 0.0314 cm^2, respectively. Unipolar hysteresis loops were carried out based on the half-period triangular waveform. PFM amplitude and phase images were obtained by a piezoresponse force microscope (PFM, MFP-3D, USA), which was using Pt/Ir-coated conductive tips (Nanosensors, Neuchatel, Switzerland) with an AC tip voltage of 3 V and out-of-plane mode. The charge and discharge characteristics of ceramics were examined using a dielectric charge and discharge test system (CFD-003, TG Technology, Shanghai, China). The nanoindentation testing system (iNano, KLA, USA) conducted by a Berkovich indenter and a Vickers diamond indenter (HMV-G31DT, Shimadzu, Japan) was used to measure the hardness of ceramics with a polished surface. The indentation load was 4.903 N, together with a holding time of 15 s. The corresponding 3D morphologies were detected via the Bruker Countor GT K 3D.

2 Results and discussion

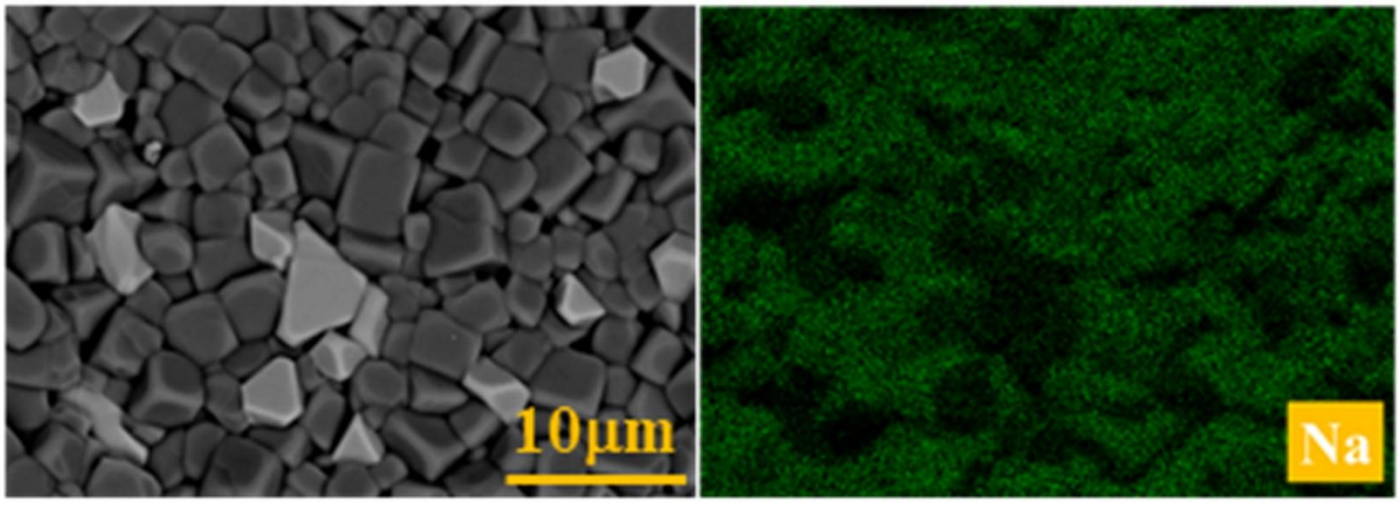

Fig. S1 Elemental mapping of 0.20BZS ceramics.

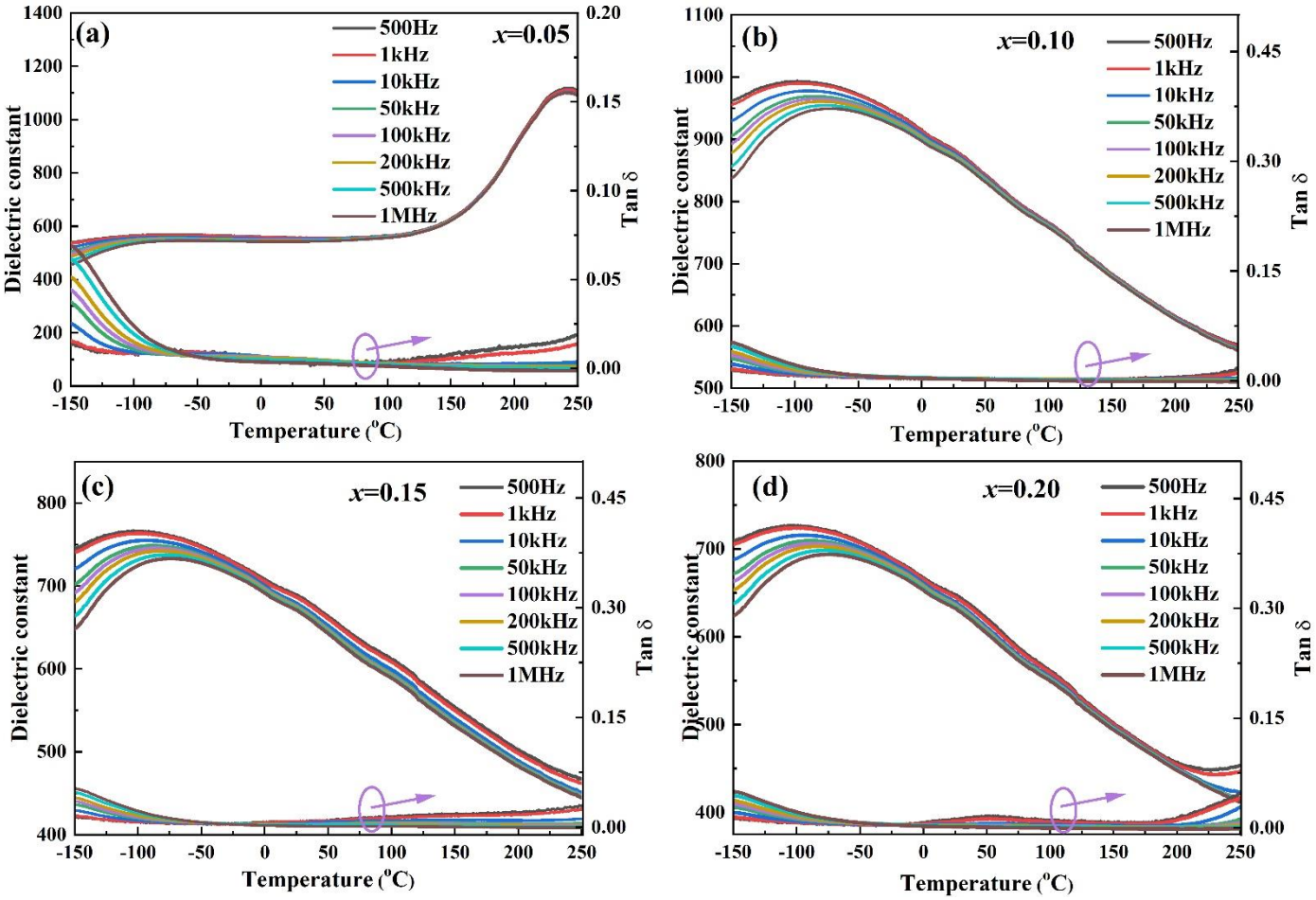

Fig. S2 Temperature dependences of dielectric constant and dielectric loss for (1−*x*)NN–*x*BZS ceramics.

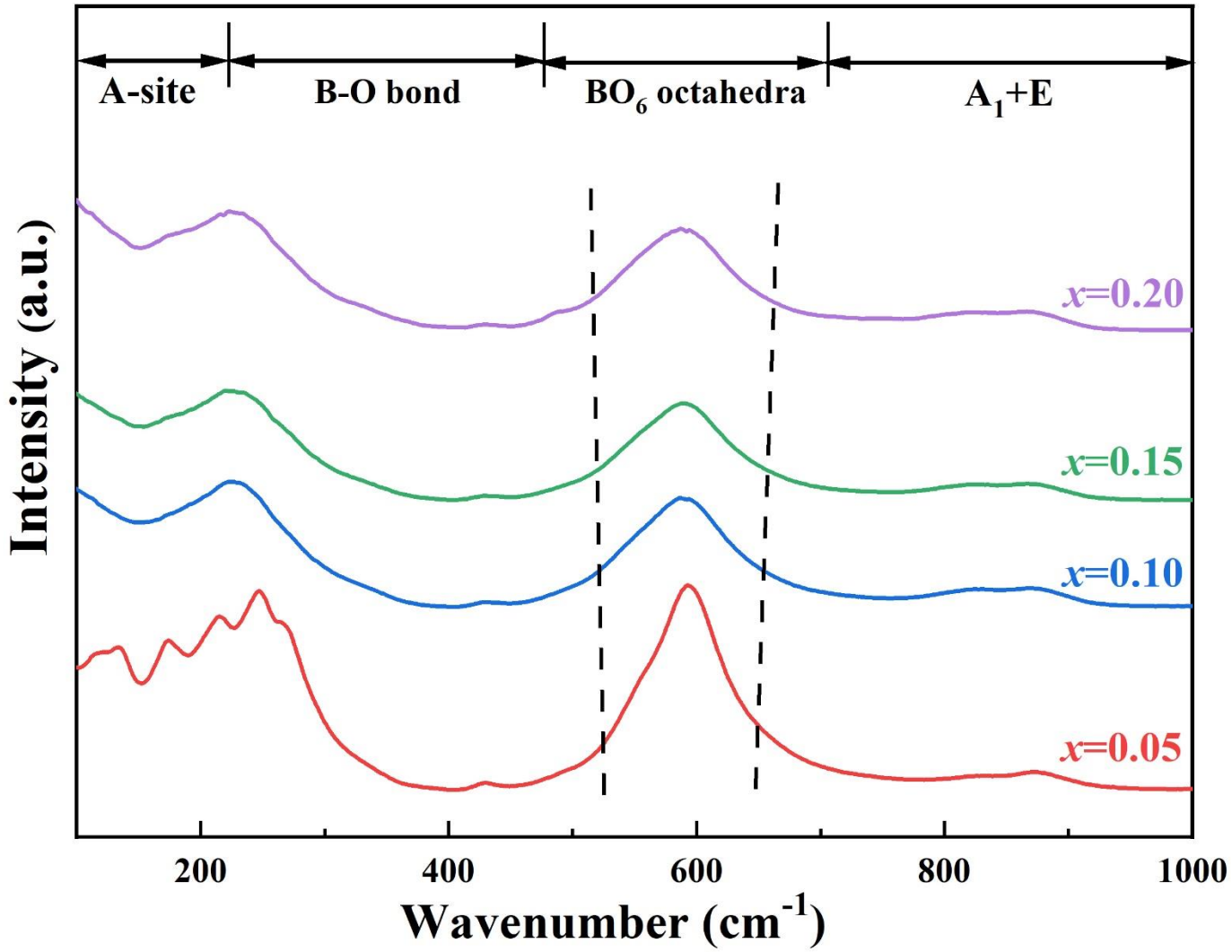

Fig. S3 Raman spectra of *x*BZS ceramics at room temperature.

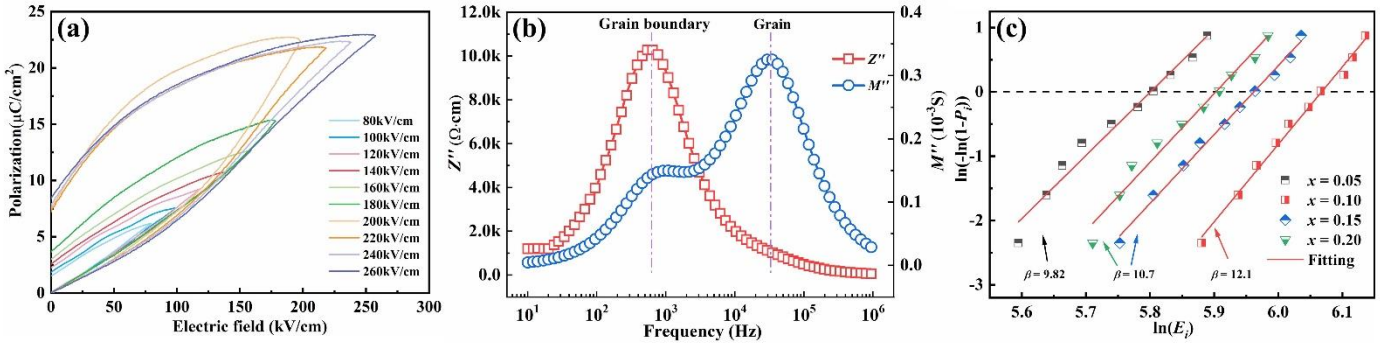

Fig. S4 (a) Unipolar *P*–*E* loops at various electrical fields of 0.05BZS ceramics. (b) Imaginary part of impedance (*Z*″) and modulus (*M*″) in 0.10BZS ceramics as a function of frequency measured in 500 ℃. (c) Weibull distribution function of dielectric breakdown strength for *x*BZS ceramics.

Table S1 Mechanical properties of *x*BZS ceramics (x = 0.00 and 0.10) derived from Vickers indentation test.

Component	P_m (N)	d (μm)	H (GPa)
0.00	4.903	44.10	4.68
0.10	4.903	40.68	5.49