Supplementary Material

$BaTiO_3$-$NaNbO_3$ energy storage ceramics with an ultrafast charge-discharge rate and temperature-stable power density

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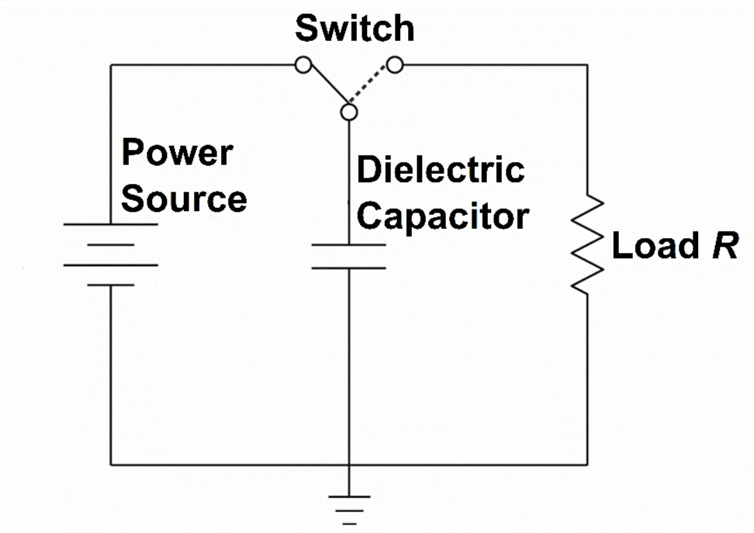

Figure S1. Schematic diagram of the resistor-capacitance circuit measurement system.

The dielectric capacitor as shown in Figure S1 is the (1-*x*)BT-*x*NN ceramics with gold electrodes, which is charged by the power source before measurement. After charging, the dielectric capacitor discharges to the load resistor (R). For overdamped discharge measurement, the R should meet the condition: $R^2 \gg {}^{4L}/_{C}$, where the L is the circuit inductance and the C is the capacitance of the dielectric capacitor (here $R = 100\ \Omega$). For underdamped discharge measurement, the R should be small enough to be ignored ($R^2 \ll {}^{4L}/_{C}$). Here, the dielectric capacitor discharges to the wire of the circuit.

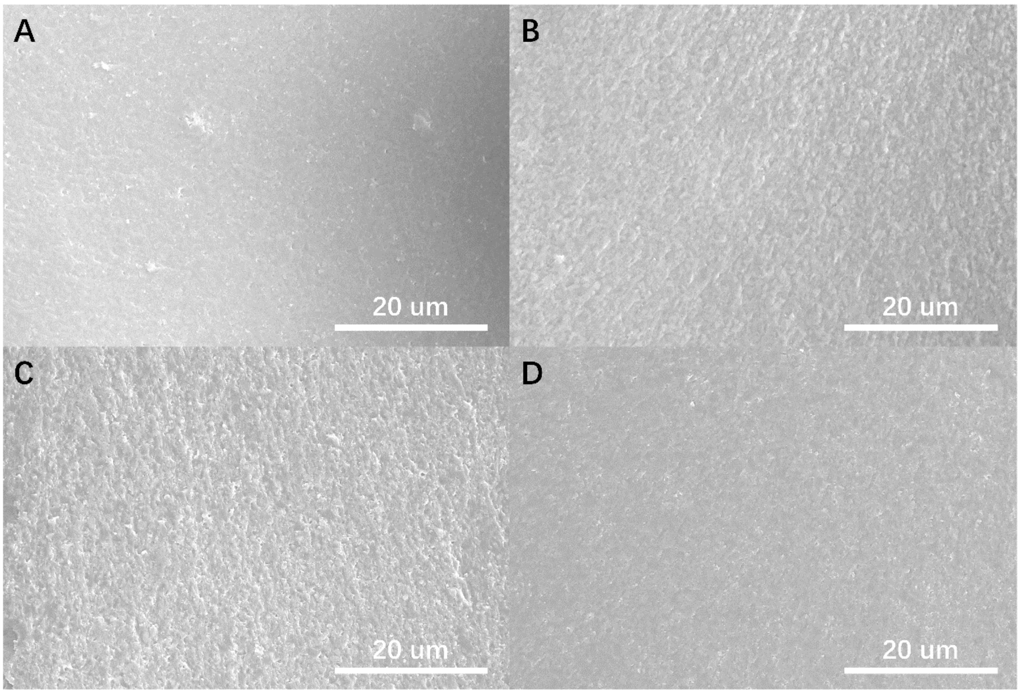

Figure S2. The cross-section SEM images of the (1-*x*)BT-*x*NN ceramics: (A) 0.65BT-0.35NN, (B) 0.60BT-0.40NN, (C) 0.55BT-0.45NN, and (D) 0.50BT-0.50NN.

There are no obvious pores in the cross-section of (1-*x*)BT-*x*NN ceramics, suggesting that the ceramics possess high relative density.

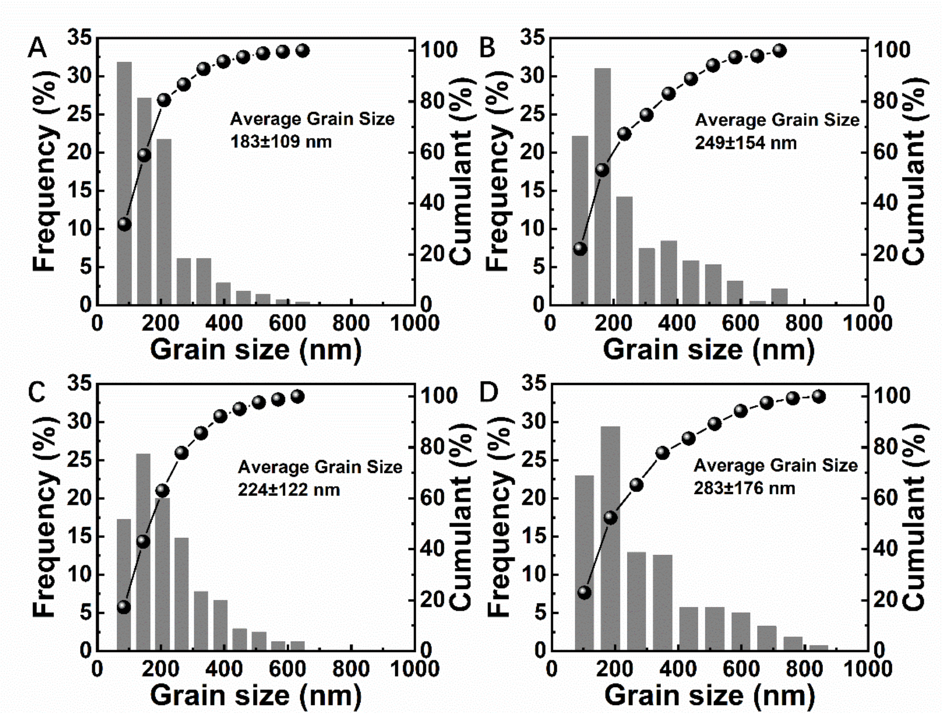

Figure S3. The grain size distributions of all samples: (A) 0.65BT-0.35NN, (B) 0.60BT-0.40NN, (C) 0.55BT-0.45NN, and (D) 0.50BT-0.50NN.

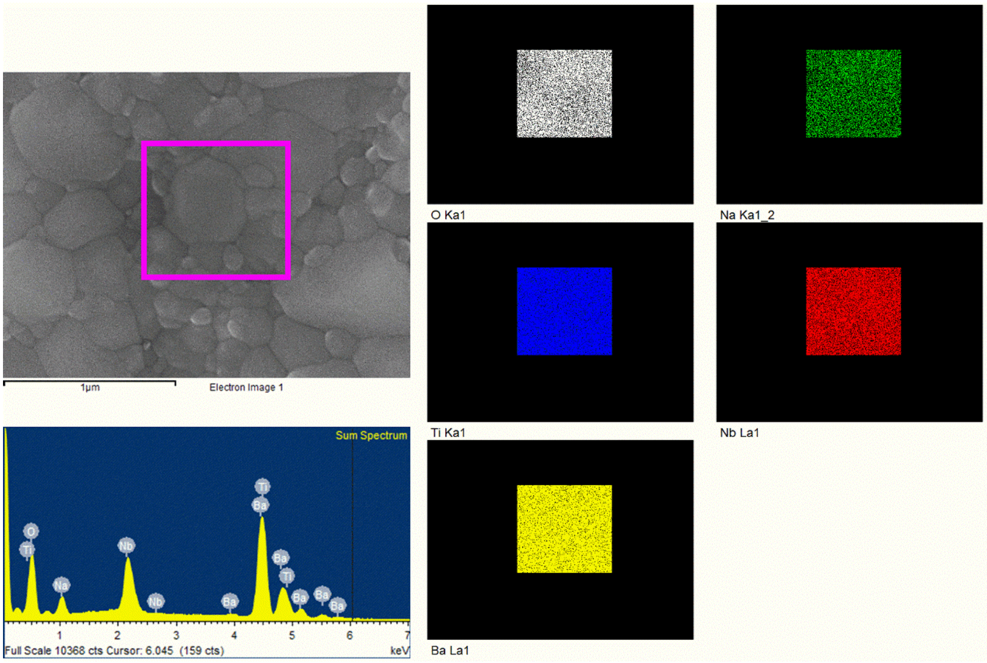

Figure S4. The elements (O, Na, Ti, Nb, and Ba) distribution in the 0.60BT-0.40NN ceramics.

All elements (O, Na, Ti, Nb, and Ba) are uniformly distributed in the 0.60BT-0.40NN ceramics.

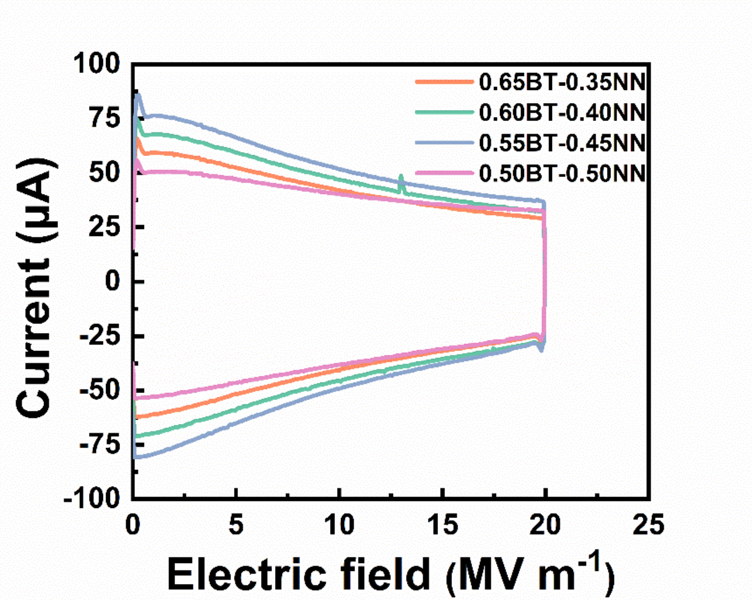

Figure S5. The current-field (*J*-*E*) curves of (1-*x*)BT-*x*NN ceramics.

Table S1. The amount of the secondary phase ($Ba_6Ti_7Nb_9O_{42}$).

Composition	The ratios of the main peak intensities	The amounts of the $Ba_6Ti_7Nb_9O_{42}$
0.65BT-0.35NN	0.012	4.31%
0.60BT-0.40NN	0.006	2.20%
0.55BT-0.45NN	0.013	4.66%
0.50BT-0.50NN	0.006	2.20%

The ratios of the two main peak intensities (the main peak intensities of the secondary phases $Ba_6Ti_7Nb_9O_{42}$ and the main peak intensities of BT-NN ceramics) are about 0.012, 0.006, 0.013, and 0.006 for x=0.35, 0.40, 0.45, and 0.50 respectively. The reference intensity ratio (RIR) of $Ba_6Ti_7Nb_9O_{42}$ is 2.22[1]. The RIRs of BT-NN ceramics are unknown, and here we choose the RIR of BT (8.34) for calculation. The amounts of the $Ba_6Ti_7Nb_9O_{42}$ can be calculated by the following equations:

$$W_1 = \frac{I_1}{I_1 + \frac{I_2}{K}}$$

$$K = \frac{RIR_2}{RIR_1}$$

$$W_2 = 1 - W_1$$

where the W is the amount, 1 and 2 are the BT-NN phases and $Ba_6Ti_7Nb_9O_{42}$ phases respectively. The W_2s for (1-x)BT-xNN ceramics are about 4.31%, 2.20%, 4.66%, and 2.20% for x=0.35, 0.40, 0.45, and 0.50 respectively (Supplementary Table 1). The amounts of $Ba_6Ti_7Nb_9O_{42}$ phases in various ceramics are irregular. The dielectric constants of all BT-NN ceramics at room temperature are about 1000~1200, and the $Ba_6Ti_7Nb_9O_{42}$ phases are considered to have paraelectric characteristics[2]. Hence, the $Ba_6Ti_7Nb_9O_{42}$ phases may not greatly affect the dielectric characteristics of the ceramics.

Table S2. The cell parameters of the (1-x)BT-xNN ceramics.

Composition	Cell parameters
0.65BT-0.35NN	a=b=c=3.9938(4) Å, α=β=γ=90°
0.60BT-0.40NN	a=b=c=3.9916(5) Å, α=β=γ=90°
0.55BT-0.45NN	a=b=c=3.9854(6) Å, α=β=γ=90°
0.50BT-0.50NN	a=b=c=3.9833(2) Å, α=β=γ=90°

Reference

1. Fang L. Synthesis and X-ray powder study of a new compound: $Ba_6Ti_7Nb_9O_{42}$. *Journal of Wuhan University of Technology(materials science)* 1998;4:42-4.

2. Kim M, Lee J, Kim J, Lee H, Cho S. Microstructure evolution and electrical properties of $Ba_2NaNb_5O_{15}$ and $BaTiO_3$ composites. *Ceramics- Silikaty* 2005;49:13-8.