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Excellent energy storage density and efficiency in lead-free Sm-doped $BaTiO_3$-$Bi(Mg_{0.5}Ti_{0.5})O_3$ ceramics

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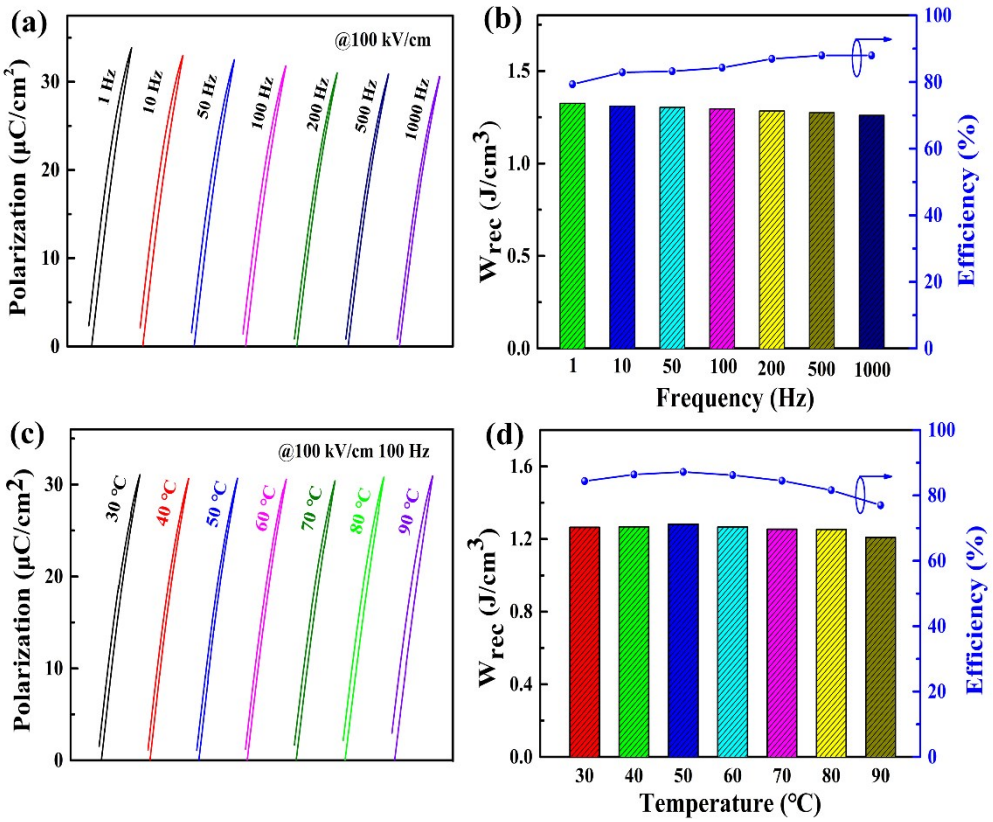

Figure S1: (a) The P-E loops (1 to 1000 Hz at RT with 100 kV cm^{-1}), (b) W_{rec} and efficiency as function of frequency of BT-BMT-0.03Sm ceramics; (c) P-E loops (30 to 90 °C at 100Hz and 100 kV cm^{-1}), (d) W_{rec} and efficiency as functions of temperature of the BT-BMT-0.03Sm ceramics.

The stability of frequency and temperature is a crucial factor to assess the application of energy storage ceramic in complex environments. **Fig. S1(a)** shows the unipolar P-E loops of BT-BMT-0.03Sm ceramics at RT and different frequencies. It can be found that the P-E curves are slim at high frequencies and the W_{rec} and efficiency are calculated and presented in **Fig.S1(b)**. As the increase of frequency, the values of W_{rec} decrease gradually (1.31 J cm^{-3} to 1.26 J cm^{-3}) and the efficiencies keep going up (79.3% to 87.9%). These fluctuations of W_{rec} and efficiency indicate a characteristic of frequency dependence. **Fig. S1(c)** illustrates unipolar P-E loops for BT-BMT-0.03Sm ceramics at 100 Hz and different temperatures and the calculated results are shown in **Fig. S1(d)**. Between the temperature ranges of 30 °C to 80 °C, the values of W_{rec} fluctuate 1.26 J cm^{-3} and the maximum fluctuation value doesn't exceed 0.03 J cm^{-3}. When the tested temperature reaches 90 °C, the P-E loops exhibits a little fat and the energy storage efficiency is below 80%. These results indicate BT-BMT-0.03Sm ceramics present excellent temperature stability at temperature range of 30 °C to 80 °C.

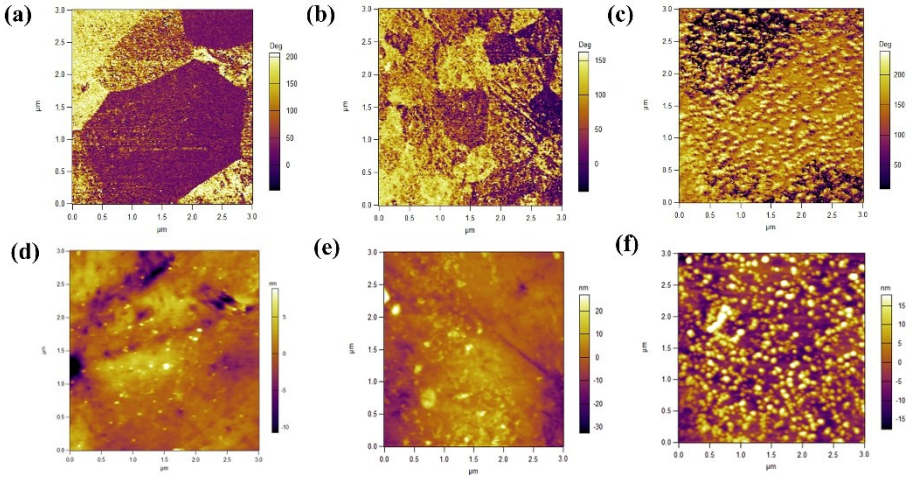

Figure S2: PFM in-plane and topography images of polished surface of BT-BMT-*x*Sm ceramics. (a) and (d) *x*=0.005, (b) and (e) *x*=0.01, (c) and (f) *x*=0.04.

PFM is an effective method to investigate the domain structure. **Fig. S2(a-c)** show the PFM in-plane images of polished surface of BT-BMT-xSm ceramics and PFM topography images are displayed in **Fig. S2(d-f)**. There are no obvious changes in topography images. However, for domain structure, the domain size decreased first and then increased on the whole. The increasing doping contents may induce local microdomains size decrease and many small and irregular microdomains maybe lead to the enhancement of relaxation behaviours.