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Research Papers

Enhanced energy storage performance in oxygen-deficient $Ca_{0.28}Ba_{0.72}Nb_2O_6$-based tungsten bronze ceramics

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ABSTRACT

The development of high-power technology and modern electronic devices imposes stringent demands on the energy storage performance of capacitors. Achieving an optimal balance between polarization and dielectric breakdown strength is essential for improving energy storage density. This study proposes a strategy to enhance polarization without compromising dielectric breakdown strength by deliberately introducing defects. In this context, a series of non-stoichiometric $Ca_{0.7}Ba_{1.5}La_{0.2}Nb_{5-x}Fe_xO_{15-\delta}$ ceramics were prepared. Investigations into the structure and electrical behavior suggested that defects did not stabilize ferroelectricity, rather, they served as sources of random fields and incommensurate modulation structure that enhanced the relaxor behavior. Nevertheless, defects introduced additional polarization, and contributed to the asymmetry of the *P-E* loops and the fluctuation of the polarization response at high temperature/frequency. Furthermore, the maintenance of high BDS is attributed to the trapping of carriers by defects and the improvement of electrical homogeneity, which is confirmed by defect analysis and complex impedance spectroscopy. As a result, a releasable energy density of 3.42 J/cm^3 and an efficiency of 86.23 % are obtained in defect-rich $Ca_{0.7}Ba_{1.5}La_{0.2}Nb_{4.875}Fe_{0.125}O_{15-\delta}$ ceramics. Meanwhile, a discharge energy density of 2.24 J/cm^3 and a power density of 171.97 MW/cm^3 are achieved, which also shows excellent stability to the use environment. This work provides valuable insights into the improvement of the energy storage performance of relaxors and other weakly polar dielectrics.

1. Introduction

As a key device in pulse power systems, pulse power capacitors play an important role in their miniaturization, high integration and light weight. Ceramic capacitors are capable of discharging a substantial amount of energy in a brief period, enabling the output of large currents, as this discharge process relies solely on the electrostatic field [1]. However, their energy density remains considerably lower compared to other energy storage systems, such as supercapacitors. The energy release process of the dielectrics can be described by the external electric

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