High-Entropy Dielectric Relaxors: A New Frontier in Energy Storage Technology

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Dielectric capacitors, fundamental to high/pulsed power electronic devices, find extensive applications in fields like hybrid electric vehicles, microwave communications, and distributed power systems. Their popularity stems from their high-power density and ultra-fast charge/discharge rates[1]. Unlike batteries and solid oxide fuel cells that store energy through chemical reactions, dielectric capacitors store energy by displacing bound charged elements. The design of high-performance, lead-free energy storage capacitors holds significant promise in the global market, particularly with the growing emphasis on environmental protection. These capacitors are essential for advanced electronic and electrical power systems[2], [3]. However, their relatively low energy storage capability compared to electrochemical devices like batteries poses a challenge, hindering advanced devices' miniaturization, integration, and cost-effectiveness. Significant efforts have been directed towards developing high-energy-density, high-efficiency, and reliable dielectrics. Nonlinear ferroelectric dielectrics with substantial spontaneous polarization, such as $Pb(ZrTi)O_3$, $BiTiO_3$, and $Bi_4Ti_3O_{12}$, have been used to achieve a high maximum polarization (Pm)[4]. To achieve a low remnant polarization (Pr), researchers have explored element doping, solid solutions, and fabrication parameter modifications to disrupt long-range ferroelectric domains, lower polarization switching barriers, and reduce polarization hysteresis. Also, nanostructure modification, thickness optimization, grain refinement, and defect engineering have enhanced the breakdown strength (Eb). By strategically combining these methods to optimize dielectric parameters, energy densities (Ue) of up to approximately 150 J cm^{-3} have been recently achieved.

Recently, high-entropy materials, where multiple elements occupy equivalent lattice sites, have been shown to significantly enhance various functionalities, such as thermos-electrics, batteries, and catalysts [5]. This improvement is attributed to entropy-dominated phase stabilization, an atomic disorder with lattice distortion, sluggish diffusion kinetics, and the synergistic properties of multiple components. The high-entropy concept offers a promising strategy for enhancing dielectric energy performance.

Design of high-entropy stabilized $Bi_4Ti_3O_{12}$ based dielectric ceramics and thin film

We will design high-entropy dielectrics relaxors starting from the ferroelectric $Bi_4Ti_3O_{12}$ by introducing equimolar-ratio Zr, Ho and Sn elements into the Ti sites, and Sr into the Bi sites with the nominal composition of $(Bi_{4-x}Sr_x)(Ti_{3-3y}Zr_yHo_ySn_y)O_{12}$ (x=(0-2,Δ=0.5),y=(0-1, Δ=0.5). We investigate the electronic structure, dielectric properties, and energy storage capacities of these high-entropy dielectric relaxors.

Reference

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