

# What are the energy storage performance indicators of ferroelectric materials

Why is ferroelectrics a promising energy storage material?

Due to its properties of high energy density, wide operating temperature range  $T$ , quick charge-discharge ability and extended active life  $t$ , ferroelectrics is a kind of prospective and promising energy storage material [7, 8, 9, 10, 11, 12, 13].

Which ferroelectric materials improve the energy storage density?

Taking PZT, which exhibits the most significant improvement among the four ferroelectric materials, as an example, the recoverable energy storage density has a remarkable enhancement with the gradual increase in defect dipole density and the strengthening of in-plane bending strain.

How can flexible ferroelectric thin films improve energy storage properties?

Moreover, the energy storage properties of flexible ferroelectric thin films can be further fine-tuned by adjusting bending angles and defect dipole concentrations, offering a versatile platform for control and performance optimization.

What is the recoverable energy storage density of PZT ferroelectric films?

Through the integration of mechanical bending design and defect dipole engineering, the recoverable energy storage density of freestanding  $\text{PbZr}_{0.52}\text{Ti}_{0.48}\text{O}_3$  (PZT) ferroelectric films has been significantly enhanced to  $349.6 \text{ J cm}^{-3}$  compared to  $99.7 \text{ J cm}^{-3}$  in the strain (defect)-free state, achieving an increase of 251%.

How can energy storage and conversion be realized in ferroelectrics?

Scientific Reports 15, Article number: 7446 (2025) Cite this article The energy storage and conversion in ferroelectrics can be realized through the microstructures of polar domains and domain walls, which resulting in the transformations from macro/microdomains to nanodomains or forming complex polar topologies.

What is a high-efficiency energy storage material?

Scientists and engineers have been working together to develop environment-friendly high-efficiency energy storage materials including relaxor ferroelectrics and anti-ferroelectrics and experimental technology [1, 2, 3, 4, 5, 6].

**5.2 Ferroelectrics.** Regarded as an important topic in materials physics, ferroelectrics have been widely used in various applications, including sensors, energy storage and capacitors [171]. Ferroelectric materials are a subcategory of pyroelectric materials that belong to a subcategory of piezoelectric materials [172, 173] from the crystallographic point of view, ...

Materials science has played a very crucial role in developing new technologies so far that could probably address the challenges of economic and ecological sustainability soon. In the field of advanced materials,

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perovskite oxides stand out to provide a clean environment, ensure enough clean energy, and sanitized water, and provide resources for industrial and growing ...

a, P-E loops in dielectrics with linear, relaxor ferroelectric and high-entropy superparaelectric phases, the recoverable energy density  $U_d$  of which are indicated by the grey, light blue and ...

The results prove that the stability of slope (K) is positively correlated with the stability of energy storage performance of ferroelectric materials, which provides the basis for the evaluation ...

However, some significant drawbacks in current lead-free dielectric materials hinder the energy storage performance of these materials. Based on this, we review herein some new strategies to improve the energy-storage capacity of dielectric materials. ... (Zn  $2/3$  Nb  $1/3$ )O<sub>3</sub> weakly coupled relaxor ferroelectric materials for energy storage. RSC ...

Compared to other dielectric materials like polymers, oxide-based ferroelectric materials typically exhibit higher  $P_{max}$  and  $P_r$  due to their larger spontaneous polarization, promising for energy storage [2], [6], [7]. A classic approach to promote energy storage performance involves combining ferroelectrics with materials of a different structure to reduce ...

In the past years, several efforts have been devoted to improving the energy storage performance of known antiferroelectrics. Polymers and ceramic/polymer composites can present high breakdown fields but store ...

The MLESCC with two dielectric layers (layer thicknesses of 5  $\mu$ m) sintered by a two-step sintering method exhibits excellent energy storage ...

In the past, most researchers analyzed energy storage performance of ferroelectric materials through P-E loops. In this paper, combining P-E loops, I-E curves and Raman spectral fitting we analyse energy storage performance of ferroelectric materials and propose an ...

Ferroelectrics are the materials with switchable spontaneous polarization. Switching of polarization from one state to another by the application of an electric field gives rise to a hysteresis loop, the signature of ferroelectricity. Different modes of operation, ferroelectrics can be used to harvest energy from distinguished sources such as solar, thermal, magnetic, wind, ...

Energy is a key input for almost all ventures; hence, it is imperative for improving the quality of life. To meet our ever-growing energy demand and to ensure its continuous supply, we are compelled to take cognizance of energy and its storage due to its centrality in all spheres, including industry, transport, commerce, telecommunications, agriculture, and domestic.

Ferroelectric materials with higher permittivity have higher energy storage capacity and are more suitable for

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applications such as energy storage devices, capacitors and actuators. View 2 ...

Of the various types of non-volatile memory used in in-memory and in-sensor computing, those based on ferroelectric materials have attracted considerable research interest owing to their low energy consumption, high speed, and strong fatigue resistance [10]. The non-volatile spontaneous polarization state of ferroelectric thin films can be reversed by applying ...

As indicated, clearly all of ferroelectric materials are both piezoelectrics and pyroelectrics, and all pyroelectrics are piezoelectric. With the integration of dielectric, ...

Ferroelectric Materials for Energy Harvesting and Storage is the first book to bring together fundamental mechanisms for harvesting various abundant energy sources using ferroelectric and piezoelectric materials. The authors discuss strategies of designing materials for efficiently harvesting energy sources like solar, wind, wave, temperature ...

The demand for renewable and environmentally friendly energy sources has attracted extensive research on high-performance catalysts. Ferroelectrics, a class of materials with switchable polarization, are unique ...

Materials exhibiting high energy/power density are currently needed to meet the growing demand of portable electronics, electric vehicles and large-scale energy storage devices. The highest energy densities are ...

Accelerating the development of revolutionary high-energy battery technology is essential for strengthening competitiveness in advanced battery innovation and achieving carbon-free electricity. Unfortunately, poor ion ...

In recent years, dielectric capacitors with high energy storage density have been developed. They include linear dielectrics (LD), ferroelectrics (FE), relaxor ferroelectrics (RFE) and antiferroelectrics (AFE), among which RFE and AFE are outstanding candidates for dielectric capacitors due to their high energy storage density [14]. Lead based ferroelectric materials ...

The improvement in energy storage performance of ferroelectric (FE) materials requires both high electric breakdown strength and significant polarization change. The phase-field method can couple ...

The first commercial application of stable high-performance perovskite ferroelectrics was in ultrasound devices. The high piezoelectric constants of these materials mean that their ferroelectric ...

These materials allow for real-time data processing directly within storage elements, significantly enhancing energy efficiency and processing speeds by reducing data transfer between separate processing and memory units. One of the most critical properties of 2D ferroelectric materials, such as a-In<sub>2</sub>Se<sub>3</sub>-based FeFETs, is their non-volatile ...

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BaTiO<sub>3</sub>-BiScO<sub>3</sub> (BT-BS) ceramics are the kind of material first demonstrated in 2009 [23], [24] to be promising in energy-storage applications with an energy density of 6.1 J/cm<sup>3</sup> for a single layer capacitor as a result of the weakly coupling effect of the PNRs. BT-BS ceramic is fancy for energy-storage because it has ultra-slim hysteresis, and small polarization ...

We report the energy-storage performance and electric breakdown field of antiferroelectric PbZrO<sub>3</sub> (PZ) and relaxor ferroelectric Pb<sub>0.9</sub>La<sub>0.1</sub>(Zr<sub>0.52</sub>Ti<sub>0.48</sub>)O<sub>3</sub> (PLZT) single films, as well as PLZT/PZ and PZ/PLZT heterolayered films grown on SrRuO<sub>3</sub>/Ca<sub>2</sub>Nb<sub>3</sub>O<sub>10</sub>-nanosheet/Si substrates using pulsed laser deposition. These films show the highly ...

Ferroelectric materials featured with the noncentrosymmetric crystal structure, exhibit the unique property of spontaneous polarization. This attribute makes ferroelectrics as promising candidates for enhancing the ionic conductivity of solid electrolytes, improving the kinetics of charge transfer, and boosting the lifespan and electrochemical performance of ...

(Bi<sub>0.5</sub>Na<sub>0.5</sub>)TiO<sub>3</sub> (BNT) is a traditional lead-free ferroelectric material and possesses superior P<sub>max</sub>, excellent dielectric and ferroelectric properties [15]. But its large P<sub>r</sub> and coercive force (E<sub>c</sub>) result in the low W<sub>rec</sub> and η. In recent years, to promote its energy storage performance, BNT has been widely used as the matrix of HECs and at the same time, ...

Porous non-polar polymers that exhibit ferroelectric-like behaviour when subjected to a high electric field can be classified as ferroelectret materials [1]. Ferroelectrets are a class of piezoelectrically-active polymer foam whereby a gas, such as air, within a macro-sized pore space (typically > 1 μm) can be subject to electrical breakdown during the application of a high ...

The improvement in energy storage performance of ferroelectric (FE) materials requires both high electric breakdown strength and significant polarization change. The phase-field method can ...

Bismuth (Bi)-based materials have been receiving considerable attention as promising electrode materials in the fields of electrochemical energy stora...

Dielectric materials find wide usages in microelectronics, power electronics, power grids, medical devices, and the military. Due to the vast demand, the development of advanced dielectrics with high energy storage capability has received extensive attention [1], [2], [3], [4]. Tantalum and aluminum-based electrolytic capacitors, ceramic capacitors, and film ...

The recoverable energy density (W<sub>rec</sub>) and energy storage efficiency (η) are key indicators for evaluating the performance of thin film energy storage devices. The energy storage mechanism of dielectric thin films is illustrated in Fig. S1, where W<sub>rec</sub> and η can be expressed as [1, 6]: (1) W<sub>rec</sub> = ∫ P<sub>r</sub> P<sub>max</sub> E dP (2) η = W<sub>rec</sub> / W<sub>total</sub>

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/  $(W_{rec} + W_{loss})$  here  $P_{max}$ ,  $P_r$ ,  $P$ , and ...

To deep understand and optimally design the energy storage properties of dielectrics with the ferroelectric nano-to-macro structural transformation and nano vortex ...

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