Adjustable giant negative electrocaloric effect in $\text{Pb}_{1+x}\text{ZrO}_3$ thin films

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Research Article

Keywords: Negative Electrocaloric Effect, Antiferroelectric, Refrigeration, PbZrO_3 thin films

Posted Date: February 19th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-212950/v1>

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Abstract

Electrocaloric effect (ECE) driven by electric field is suitable for implementation of built-in cooling in electronic devices. However, most of the known electrocaloric materials show low adiabatic temperature change (ΔT_{ad}) near room temperature and usually require high electric field. Here, the investigation of ECE in $\text{Pb}_{1+x}\text{ZrO}_3$ ($x=0, 0.1, 0.15$) thin films, which were prepared on $\text{Pt}/\text{Ti}/\text{SiO}_2/\text{Si}$ substrates by sol-gel method, reveals that both the magnitude and the present temperature range of ΔT_{ad} can be controlled by Pb concentration. Through increasing the dosage of PbO , decreased lead vacancies and enhanced interface layer are induced, which postpone the transition from antiferroelectrics to ferroelectrics of PbZrO_3 films under a given electric field (E), which thus controls the appearance temperature range of negative ECE. As a result, large isothermal entropy change (ΔS) and ΔT_{ad} are observed in the temperature range from 260 K to 494 K, depending on the applied electric field and Pb concentration. Giant ECE (ΔT_{ad} , ~ 0.054) at room temperature (303 K) is obtained in $\text{Pb}_{1.1}\text{ZrO}_3$ films under 460 kV/cm. This result provides a convenient method for modulating ECE of PbZrO_3 -based materials and will benefit its applications in cooling devices.

Full Text

Due to technical limitations, full-text HTML conversion of this manuscript could not be completed. However, the manuscript can be downloaded and accessed as a PDF.

Figures

Figure 1

(a) XRD patterns of $\text{Pb}_{1+x}\text{ZrO}_3$ thin films. AFM surface morphology of (b) PbZrO_3 , (c) $\text{Pb}_{1.10}\text{ZrO}_3$, (d) $\text{Pb}_{1.15}\text{ZrO}_3$ thin films.

Figure 2

SEM cross-sectional images of (a) PbZrO₃, (b) Pb_{1.10}ZrO₃, (c) Pb_{1.15}ZrO₃ thin films.

Figure 3

(a)-(c) Pb 4f and (d)-(f) O 1s XPS spectra and their dividing results of Pb_{1+x}ZrO₃ thin films. The inset in (f) represents the x dependent $I_{O[2]}/I_{O[1]}$.

Figure 4

Room-temperature antiferroelectric hysteresis loops (P-E loops) and switching currents of (a) PbZrO₃, (b) Pb_{1.10}ZrO₃, (c) Pb_{1.15}ZrO₃ thin films under 550 kV/cm.

Figure 5

Temperature dependent dielectric constant ϵ_r of (a) PbZrO₃, (b) Pb_{1.10}ZrO₃, (c) Pb_{1.15}ZrO₃ thin films at various frequencies of 102 Hz, 102.5 Hz, 103 Hz, 103.5 Hz, 104 Hz, 104.5 Hz, 105 Hz, 105.5 Hz, 106 Hz. P-E loops of (d) PbZrO₃, (e) Pb_{1.10}ZrO₃, (f) Pb_{1.15}ZrO₃ thin films measured under 460 kV/cm and different temperatures.

Figure 6

Temperature dependent (a)-(c) polarization (P-T curves), (d)-(f) ΔT and (g)-(i) ΔS of $\text{Pb}_{1+x}\text{ZrO}_3$ thin films measured under various electric fields.