Strain Effect on the Electrocaloric Properties of $PbTiO_3$ Nanocylinders with the Consideration of Surface Polarization Effect

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1. Abstract

The refrigeration technology of electronic devices has faced severe challenges with the trend of miniaturization and higher working frequency, and the research on the electrocaloric effect (ECE) of ferroelectric nanomaterials has made it possible to solve such problems. Due to the symmetry breaking on surfaces of a ferroelectric crystal, the polarizations on surfaces are different from those inside the crystal, which can further affect the electrocaloric properties of the material. In addition, when considering the nanostructure grown on the substrate, the mismatch strain induced by the substrate also has an important influence on the ECE of the material. In this paper, the extrapolation length is incorporated in the phase-field method based on the time-dependent Ginzurg-Landau equation to investigate the effects of different strain and surface polarization on the ECE of $PbTiO_3$ nanocylinders. The alternating electric field and different axial strain are applied to the nanocylinders with different extrapolation lengths. The strain—adiabatic temperature change ($\triangle T$) graphs with different extrapolation lengths are plotted by simulation results, which reveal that the extrapolation length and the strain effect can significantly affect the polarization switching behavior of the $PbTiO_3$ nanocylinders. The results of this paper can provide theoretical guidance for the design of the nanoscale solid-state cooling devices.

2. Figures

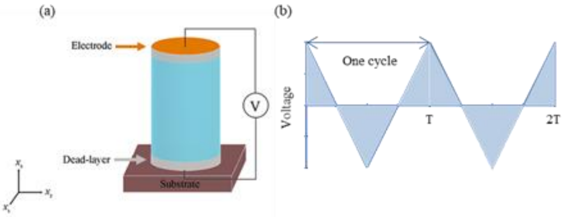

Fig.1. Schematic diagram of (a) the $PbTiO_3$ nanocylinder grown on a substrate with the dead-layers at the top and bottom surfaces, and (b) the applied triangular electric field.

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