Voltage-controlled Bistable Thermal Conductivity in Suspended Ferroelectric Thin-film Membranes

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Ferroelastic domain walls in ferroelectric materials possess two properties that are known to affect phonon transport: a change in crystallographic orientation and a lattice strain. Changing populations and spacing of nanoscale-spaced ferroelastic domain walls lead to the manipulation of phonon-scattering rates, enabling the control of thermal conduction at ambient temperatures. In the present work, lead zirconate titanate (PZT) thin-film membrane structures were fabricated to reduce mechanical clamping to the substrate and enable a subsequent increase in the ferroelastic domain wall mobility. Under application of an electric field, the thermal conductivity of PZT increases abruptly at similar to 100 kV/cm by similar to 13% owing to a reduction in the number of phonon-scattering domain walls in the thermal conduction path. The thermal conductivity modulation is rapid, repeatable, and discrete, resulting in a bistable state or a "digital" modulation scheme. The modulation of thermal conductivity due to changes in domain wall configuration is supported by polarization-field, mechanical stiffness, and in situ microdiffraction experiments. This work opens a path toward a new means to control phonons and phonon-mediated energy in a digital manner at room temperature using only an electric field.

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