Pyroelectric Energy Conversion Cycles Tailored for Antiferroelectrics

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Pyroelectric energy conversion research is accelerating towards realizing efficient, practical systems, which can be credited to two major innovations: electric field and temperature-driven thermodynamic cycles [1], and thin-film active materials able to withstand high electric fields [2]. Antiferroelectrics have been recognized for their potential for energy conversion [3], but there has not been a thermodynamic cycle analysis that takes advantage of the unique features of antiferroelectric polarization-temperature relationships. Specifically, the polarization at low electric fields increases as temperature increases, creating a region of inverse intrinsic pyroelectricity. This region is highlighted in figure 1. We have developed a two-part conversion cycle (figure 2) that takes advantage of this unique region while increasing energy density by over 17% for a given temperature range and enables cascaded heat transfer system designs. As materials with exotic polarizations are realized[4], it will be important to re-examine their energy conversion cycles for specific property relationships.

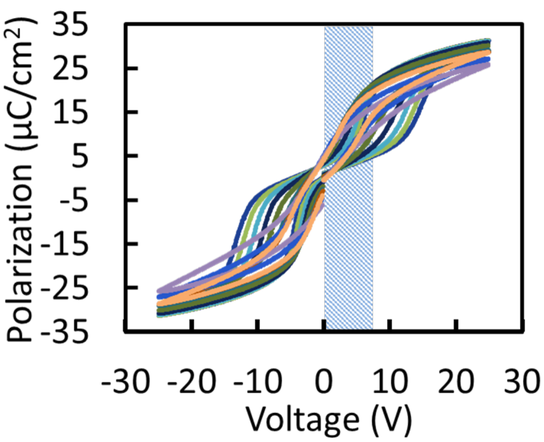

Figure 1. Isothermal hysteresis loops from 300-540K for a 500 nm $(Pb_{0.995}La_{0.05})$ $Zr_{(0.95)}Ti_{(0.05)}O_3$ thin film with Pt bottom and IrO_2 top electrodes.

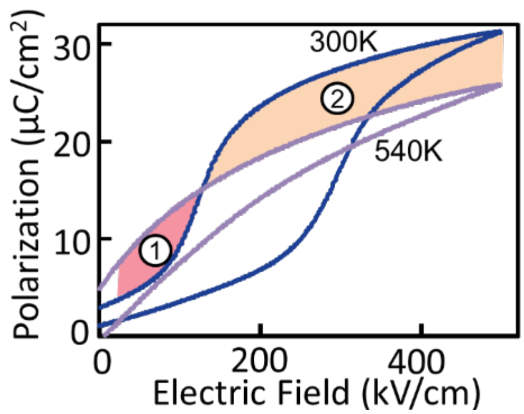

Figure 2. Energy conversion cycles between AFE and PE phases. Cycle 1 consists of heating at a low field while polarizing, charging, iso-polarization cooling, and discharging. Heat is transferred to cycle 2, which is an Olsen cycle [1].

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