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Next Generation Electrocaloric and Pyroelectric Materials for Solid State Electrothermal Interconversion

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ABSTRACT:

The electrothermal (electrocaloric and pyroelectric) properties of ferroelectric thin films have many applications in active solid-state cooling and infrared sensing devices. The electrocaloric and pyroelectric responses describe converse effects, wherein an adiabatic change in temperature occurs in response to an applied electric field, or a change in the electric polarization occurs in response to a change in temperature. It has been demonstrated that some thin film ferroelectrics can produce much larger electrothermal responses than their bulk counterparts. For on-chip applications, thin film ferroelectrics must be deposited on IC compatible substrates. The growth of ferroelectric films typically employs sputtering or metal-organic solution deposition techniques and the resultant ferroelectric film is usually polycrystalline. For such films, in-plane strains arise from thermal stresses due to the thermal expansion mismatch between the film and the substrate, and also from the self-strain of the paraelectric-ferroelectric phase transformation. Here, we use a nonlinear thermodynamic model based on Landau-Ginzburg-Devonshire formalism to analyze the electrothermal properties of perovskite ferroelectric materials such as $BaTiO_3$, $PbTiO_3$, and the incipient ferroelectric $SrTiO_3$ under different electrical and mechanical boundary conditions. The results show how these boundary conditions alter the electrothermal properties for a given material composition. It is further demonstrated that thermal stresses that develop during processing can have a significant influence on the electrothermal properties of polycrystalline ferroelectric films on IC-friendly substrates. Therefore, appropriate choices of the ferroelectric material, substrate, growth or annealing temperature, and electrode configuration can be used to optimize the electrothermal properties.

BIOGRAPHY:

S. Pamir Alpay received his PhD in Materials Science and Engineering in 1999 from the University of Maryland. He was a post-doctoral research associate at the Materials Research Center at the University of Maryland until 2001. Alpay then joined the Department of Materials Science and Engineering (MSE) of the University of Connecticut (UConn) in 2001 as an Assistant Professor. Prof. Alpay is currently serving as the Department Head of MSE at UConn. His research focuses on materials for electromagnetic applications and materials modeling. Alpay received the NSF-CAREER Award in 2001 and the UConn School of Engineering Outstanding Junior Faculty Award in 2004. He is a Fellow of the American Physical Society, an elected member of the Connecticut Academy of Science and Engineering (CASE), and an Editor for the Journal of Materials Science. Alpay is the author of >130 publications in peer-reviewed journals, 20 peer-reviewed conference proceedings, four invited book chapters, and an invited book on compositionally graded ferroelectric materials. He delivered >70 invited talks/seminars in international meetings and at academic institutions, national laboratories, and industry.