How Does Cyclic Electrical Loading Influence the Electrocaloric Effect in PMN-Xpt?

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Electric fields several times larger than the coercive field have to be applied on bulk ferroelectric materials in order to induce notable electrocaloric (EC) temperature changes.[1] For example, in Zr modified $BaTiO_3$ the temperature change of 4.5 K is achieved with an electric field of 145 kV/cm.[2] This relatively high electric field can alter the state of the material, leading to fatigue. This phenomenon related to weakening of the material under continuous loads is well-known and studied in electronic ceramics.[3] Nonetheless, to-date no systematic investigation has been conducted on the influence of the fatigue on the EC effect. Since the EC materials have a potential to be used as small-scale coolers in the electronic devices, the study of the fatigue and reliability is an important issue that needs to be addressed and researched prior to the integration of these materials in EC coolers.

Here, we investigated the EC properties in $(1-x)Pb(Mg_{1/3}Nb_{2/3})O_3–xPbTiO_3$ (PMN-xPT) under unipolar cycling using square electrical signals. Our experimental work on the fatigue behavior in PMN-xPT consisted of two steps: i) monitoring of the EC effect using a slow square waveform with a period of 200 s; ii) cycling the sample with a faster square waveform (period 0.5 s), which emulated the excitation as expected in an EC cooler.[4] The steps were repeated until the sample's failure. To precisely study the fatigue mechanisms, throughout the field cycling we additionally measured polarization-electric-field (P-E) loops, leakage current density, dielectric losses and microstructural changes. We built a numerical model to estimate the stresses in the material due to electromechanical effects. With the models we investigated the influence of the electrode size on the stresses in the material and distinguished the areas which are critical from the point of view of the fatigue behavior.

The experimental results showed an increase in Joule heating and asymmetry between the adiabatic depoling and poling developed with increasing number of cycles. The results show that the state of the material is altered with unipolar cycling, significantly affecting the EC effect.

References

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