Scientific Suprises in Electroceramic Materials when Undergoing New Non-Equilibrium Processes.

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In general, we consider non-equilibrium thermodynamic processes to be those that describe a material undergoing change and not existing in a stable state. In this presentation, we will describe three far-from-equilibrium concepts within this general framework, outlining new approaches of relevance in electroceramic materials.

The first example introduces a new model to understand transient densification under isothermal conditions. Here, we consider the time evolution with a double relaxation process. This provides a comprehensive methodology with different temperature and pressure dependencies that permits the energetics to be determined and accurately predicts the strain and strain rates as the material undergoes densification. Through a modified Kingery model, we are also able to demonstrate that the process is consistent with a dissolution mechanism. Through a Fourier transform, the densification can be represented in the frequency domain, and the data, when presented with a modulus formalism, is consistent with a two-relaxation process, exhibiting both slow and fast components, analogous to impedance spectroscopy methods.

The second case revisits the electrical poling of ferroelectric materials to create piezoelectric materials. Poling is a process that orients the domain structures. Traditionally, this has been performed by applying a DC field at room temperature or an elevated temperature. More recently, in single crystals, an AC poling strategy has emerged as a method whereby higher properties have been observed. In this study, we have considered pulse poling as a novel method to control the nucleation and domain growth processes. This is accomplished with different magnitudes of pulses and at different temperatures in relaxor ferroelectric textured ceramics and single crystals. Significantly higher piezoelectric properties are obtained with this approach compared to DC and AC poling. The nature of this pulse-poled ferroelectric is fundamentally different; under pulse poling, the material exhibits strongly first-order behavior, and there are very different phenomena arising, such as, in acceptor-doped materials, a new positive aging process driven by an unequilibrated depolarization field.

Thirdly, we will revisit the electrical degradation of multilayer ceramic capacitors and piezoelectric actuators under the framework of non-equilibrium thermodynamics and consider the use of fluctuations in the leakage noise as a means of early detection of failure trends, thereby providing advantages for faster manufacturing and screening of electrical components.