Structure-Processing Relations in $PbZr_xTi_{1-x}O_3$ Films Processed Far From Equilibrium on Glass and Polymer Substrates

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Pulsed thermal processing (PTP) involves chemical solution deposition of a material and annealing by Xe-plasma arc lamp irradiation on a micro- to millisecond time scale. Under appropriate conditions, this can result in crystallization in a far from equilibrium regime with minimal heat transferred to the substrate, allowing for the use of heat sensitive substrate materials such as glass and polymers that are unsuitable for conventional annealing procedures. Materials such as polymers can be mechanically flexible thus, when used as substrates, they can lead to novel device applications such as wearable electronics. However, as with any novel processing procedure, significant challenges remain in ensuring optimal film growth, hence detailed structural characterization is of paramount importance.

Thin films of $PbZr_xTi_{1-x}O_3$ (PZT) have been successfully fabricated by PTP on glass and polymer substrates by the team at Georgia Tech. Here we explore the link between the thin film structure and processing conditions. We explore the impact of the pulse voltage and number of pulses on the film microstructure and develop strategies to further optimize the annealing conditions. We assess the quality of the films by both polarized optical and scanning electron microscopies, allowing for rapid assessment of the overall film quality. We identify and assess heterogeneities throughout the thickness of PTP PZT films as well as the uniformity of the latter by a combination of focused ion beam (FIB) milling and (scanning) transmission electron microscopy analysis. We further discuss FIB preparation strategies for inorganic films atop polymer substrates since this is a particularly challenging aspect due to the radiation sensitive nature of organic materials. These studies reveal large variations in film microstructure and functional properties – as revealed by piezoresponse force microscopy – due to the far from equilibrium nature of the crystallization process.

The detailed characterization presented here significantly augments the understanding of the impact of PTP growth conditions on the final film structure. These results will therefore facilitate targeted optimization of this novel fabrication process on both glass and polymer substrates by exploring the kinetics of crystallization and their impact on microstructure and functional properties.