Far-From-Equilibrium Processing of $PbZr_xTi_{1-x}O_3$ Thin Films on Glass and Polymeric Substrates

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Ferroelectric oxides' large dielectric, pyroelectric and piezoelectric responses find a wide range of applications in sensor, actuator and transducer devices, multilayer capacitors, non-volatile memories as well as energy harvesting units. The trend towards miniaturization of electronic devices has led to a renewed interest in such multifunctional thin films. However, high quality ferroelectric oxide films typically require an annealing step at approximately 600 to 700 °C. Such high temperatures are incompatible with CMOS fabrication, which usually requires processing temperatures lower than 400 °C. This temperature incompatibility is a major challenge to the integration of ferroelectric thin films in miniaturized devices.

In this work, we discuss application of Xenon pulse thermal processing (PTP) to annealing of $PbZr_{1-x}Ti_xO_3$ thin films on polymeric and glass substrates. PTP is a far-from-equilibrium processing method that uses high-density infrared plasma arc heating to deliver high intensity, uniform energy in pulse waveforms. The heating rates of PTP can be as high as 600,000 °C/sec, enabling a highly localized thermal energy delivery, concentrated on the surface of the sample. Due to the high heating rates, temperature difference between top and bottom surface of the sample can be very large (up to 300 °C). The temperature at the sample surface is controlled through variation of the parameters controlling the heat waveforms, including pre-annealing plasma exposure, number of pulses, pulse duration and intensity. PZT at $x \sim 0.48$ is selected, based on the high dielectric and piezoelectric response expected at this composition, which is in proximity of the morphotropic phase boundary. An in-house prepared chemical solution precursor of the PZT is deposited onto platinized glass or polymeric substrates through spin coating. Pyrolized, 180 nm thick and 1 μm thick PZT thin films are annealed under varying pulse intensity, number of pulses and pulse durations, in order to optimize the crystallization conditions. X-ray diffraction (XRD) measurements are performed on each sample to identify the crystallographic structure, and piezoresponse force microscopy measurements are performed to study the local electromechanical response of the same. XRD data are consistent with the presence of partially oriented perovskite phase, at least on the glass substrates. For samples deposited on glass substrates, the degree of {100} crystallographic orientation mostly increases with increasing thermal energy delivery as measured by improves with increasing number of pulses.