In-Situ X-Ray Diffraction Studies On Piezoelectric Thin Films

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Within the last decade, the properties of ferroelectrics have been extensively studied. Several important devices, such as Ferroelectric Random Access Memories (FeRAMs) and Dynamic Random Access Memory (DRAM), are manufactured based on ferroelectric thin films [1, 2]. With the crescent and continuous demand for portability in consumer electronics, the understanding of the effects of miniaturization on the properties of ferroelectric thin films becomes increasingly important. Although continuous improvements in conventional semiconductor designs are implemented, the basic physics of the size effects is, however, poorly understood. It is well known that the crystallite size plays an important role in tailoring ferroelectric properties.

The piezoelectric properties of $Pb(Zr_{1-x}Ti_x)O_3$ (PZT) and $Pb_{1-y}La_y(Zr_{1-x}Ti_x)O_3$ (PLZT) thin films of different compositions consisting of few tens of nanometer sized grains were studied by *in-situ* local probe X-ray diffraction at the DiffAbs beamline at Synchrotron SOLEIL [3]. For this purpose, gold electrodes of 0.3 mm in diameter were deposited on top of the thin film of which one was contacted electrically with a thin wire. A Pt layer was used as back electrode. Constant electric fields as well as alternating ones with frequencies ranging from 0.01 Hz to 31 kHz were applied. The diffraction signal from an area beneath the electrically contacted electrode was monitored as a function of the applied electric field. From the shift of the position of the Bragg peak induced by the applied potential, the piezoelectrically generated strain was determined revealing "butterfly loops" [4] which are a clear signature of the piezoelectric hysteresis. Asymmetric butterfly loops found for PZT thin films with $x = 0.5$ indicate the presence of a self-polarization which tends to disappear for PZT thin films with $x = 0.47$ [5]. These findings are supported by piezoelectric force measurements revealing an asymmetry of the hysteresis loops towards positive electric fields which are a clear signature of a macroscopic self-polarization effect in the studied PZT films. For PLZT thin films the piezoelectric coefficient was found to be increased with a maximum for films with 3% La. For both PZT and PLZT films the butterfly loops are less pronounced for AC frequencies > 1 Hz and the piezoelectric response was found to be smaller than for DC electric fields. In addition, a linear behavior of the piezoelectrically induced strain as a function of the applied electric field was found for PLZT thin films instead of butterfly loops.

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