Effect of Feature Size on Dielectric Nonlinearity of Patterned $PbZr_{0.52}Ti_{0.48}O_3$ Films

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Lead zirconate titanate, PZT (52/48), thin films with a $PbTiO_3$ seed layer were patterned into features of different widths, including various sizes of squares and 100 μm, 50 μm, and 10 μm serpentine designs, using argon ion beam milling. Patterns with different surface area/perimeter ratios were used to study the relative importance of damage produced by the patterning. It was found that as the pattern dimensions decreased, the remanent polarization increased, presumably due to the fact that the dipoles near the feature perimeter are not as severely clamped to the substrate. This investigation is in agreement with a model in which clamping produces deep wells, which do not allow some fraction of the spontaneous polarization to switch at high field. The domain wall mobility at modest electric fields was investigated using the Rayleigh law. Both the reversible, ε_{init}, and irreversible, α, Rayleigh coefficients increased with decreasing serpentine line width for de-aged samples. For measurements made immediately after annealing, ε_{init} of 500 μm square patterns was 1510 ± 13; with decreasing serpentine line width, ε_{init} rose from 1520 ± 10 for the 100 μm serpentine to 1568 ± 23 for the 10 μm serpentine. The irreversible parameter, α, for the square patterns was 39.4 ± 3.2 cm/kV and it increased to 44.1 ± 3.2 cm/kV as the lateral dimension is reduced. However, it was found that as the width of the serpentine features decreased, the aging rate rose. These observations are consistent with a model in which sidewall damage produces shallow wells that lower the Rayleigh constants of aged samples at small fields. These shallow wells can be overcome by the large fields used to measure the remanent polarization and the large unipolar electric fields typically used to drive thin film piezoelectric actuators.