

# Designing Piezoelectric Films for Micro Electromechanical Systems

Author(s): S. Trolier-McKinstry<sup>1,2</sup>, F. Griggio<sup>1,2</sup>, C. Yaeger, <sup>1,2</sup>, P. Jousse<sup>1,2</sup>, D.L. Zhao<sup>1,2</sup>, S.S.N. Bharadwaja<sup>1,2</sup>, T.N. Jackson<sup>1,2</sup>, S. Jesse<sup>3,4</sup>, S.V. Kalinin<sup>3,4</sup>, and K. Wasa<sup>5</sup>

**Source:** IEEE TRANSACTIONS ON ULTRASONICS FERROELECTRICS AND FREQUENCY CONTROL Volume: 58 Issue: 9 Pages: 1782-1792 DOI: 10.1109/TUFFC.2011.2015 Published: SEP 2011

**Abstract:** Piezoelectric thin films are of increasing interest in low-voltage micro electromechanical systems for sensing, actuation, and energy harvesting. They also serve as model systems to study fundamental behavior in piezoelectrics. Next-generation technologies such as ultrasound pill cameras, flexible ultrasound arrays, and energy harvesting systems for unattended wireless sensors will all benefit from improvements in the piezoelectric properties of the films. This paper describes tailoring the composition, microstructure, orientation of thin films, and substrate choice to optimize the response. It is shown that increases in the grain size of lead-based perovskite films from 75 to 300 nm results in 40 and 20% increases in the permittivity and piezoelectric coefficients, respectively. This is accompanied by an increase in the nonlinearity in the response. Band excitation piezoresponse force microscopy was used to interrogate the nonlinearity locally. It was found that chemical solution-derived  $\text{PbZr}_{0.52}\text{Ti}_{0.48}\text{O}_3$  thin films show clusters of larger nonlinear response embedded in a more weakly nonlinear matrix. The scale of the clusters significantly exceeds that of the grain size, suggesting that collective motion of many domain walls contributes to the observed Rayleigh behavior in these films. Finally, it is shown that it is possible to increase the energy-harvesting figure of merit through appropriate materials choice, strong imprint, and composite connectivity patterns.

## Addresses:

1. Penn State Univ, Dept Mat Sci & Engr, University Pk, PA 16802 USA
2. Mat Res Inst, University Pk, PA USA
3. Oak Ridge Natl Lab, Ctr Nanophase Mat Sci, Oak Ridge, TN USA
4. Oak Ridge Natl Lab, Div Mat Sci & Technol, Oak Ridge, TN USA
5. Kyoto Univ, Grad Sch Engr, Microengn Div, Sakyo Ku, Kyoto, Japan

**E-mail Address:** [STMckinstry@psu.edu](mailto:STMckinstry@psu.edu)