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Giant Enhancement of Ferroelectricity in Strained $BaTiO_3$ Thin Films

K. J. Choi[1]*, C. B. Eom[1], M. Biegalski[2], Y. L. Li[2], A. Sharan[2], L.-Q. Chen[2], V. Gopalan[2], D. G. Schlom[2], J. Schubert[3], R. Uecker[4], and P. Reiche[4]

[1]Department of Materials Science and Engineering, UW-Madison, USA
[2]Department of Materials Science and Engineering, Penn State University, USA
[3]Institut für Schichten und Grenzflächen ISG1-IT, Germany
[4]Institute of Crystal Growth, Germany
*Present Address: Materials Science and Technology Division, KIST, Korea

Epitaxial ferroelectric thin films have different properties from the bulk single crystals due to epitaxial and thermal strain and it offers an opportunity to modify the various ferroelectric properties. We deposited fully commensurate $BaTiO_3$ (a = 3.992 Å) ferroelectric thin films on novel substrates including (110) $DyScO_3$ (a = 3.944 Å) and (110) $GdScO_3$ (a = 3.97 Å) by pulsed laser deposition (PLD) and molecular beam epitaxy (MBE) and observed ferroelectric transition using temperature dependent (room temperature to 900 °C) four-circle x-ray diffraction and second harmonic generation measurements. Biaxial compressive strain dramatically enhanced the ferroelectric properties—both the ferroelectric transition temperature (T_c) and remanent polarization (P_r)—of $BaTiO_3$ thin films. This strain, imposed by commensurate epitaxy, can result in a T_c nearly 500 K higher and a P_r at least 170% higher than $BaTiO_3$ single crystals. This is the largest increase in T_c ever reported for a ferroelectric. These giant property enhancements are consistent with thermodynamic predictions. This work demonstrates a route to a lead-free ferroelectric with the high T_c and high P_r needed for ferroelectric memories, and also a general means for achieving extraordinary physical properties in thin films through strain engineering.