Sonderforschungsbereich 595

Elektrische Ermüdung
in Funktionswerkstoffen

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**SFB 595 Kolloquium**

**28. Juni 2007, 16.15H**

**Gebäude der Materialwissenschaften**

**Raum 77**

Datum: 28. Juni 2007

# Ferroelectric $PbTiO_3/SrTiO_3$ Superlattices with Tailored Properties

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The physical properties of ferroelectric $PbTiO_3$ films have been investigated using x-ray diffraction, atomic force microscopy and x-ray photoelectron diffraction and I will summarize our findings on ultrathin single layer films. With this experience, we have studied ferroelectric / paraelectric superlattices of $PbTiO_3$ / $SrTiO_3$ prepared using off-axis RF magnetron sputtering on conducting 0.5% Nb doped (001) $SrTiO_3$ substrates. X-ray and cross-sectional TEM investigations reveal coherent growth with the $PbTiO_3$ c-axis (and polarization) parallel to the growth direction and the artificial layering of the samples. Because of the large electrostatic cost of having different polarizations in the $PbTiO_3$ and $SrTiO_3$ layers, the properties of the two materials are coupled and this electrostatic energy turns out to be an interesting tuning parameter allowing the properties of the overall system to be tailored. It is shown that the polarization, critical temperature and tetragonality can be controlled by selecting the $PbTiO_3$ volume fraction x (defined as $x=l_p/(l_s+l_p)$ where $l_p$ and $l_s$ are the $PbTiO_3$ and $SrTiO_3$ thicknesses respectively). It is observed that, reducing x from close to 1 (where strong ferroelectricity is observed), the system progressively approaches the paraelectric phase until x reaches approximately 0.5. However, a striking recovery of ferroelectricity is found for smaller x, at very small $PbTiO_3$ layer thicknesses (one and two unit cells). The recovery of ferroelectricity is confirmed using atomic force microscopy, direct electrical measurements of the polarization and measurements of the Curie critical temperature. This anomalous and still unexplained behavior may reveal a new type of coupling between $SrTiO_3$ and $PbTiO_3$ at atomic layer thicknesses.