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The effect of transformation twins on the seismic-frequency mechanical properties of polycrystalline $Ca_{1-x}Sr_xTiO_3$ perovskite

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ABSTRACT

The low-frequency mechanical properties of polycrystalline $Ca_{1-x}Sr_xTiO_3$ ($0.5 \leq x \leq 0.9$) have been investigated as a function of temperature and bulk composition using the technique of dynamical mechanical analysis in three-point bend geometry. $Ca_{1-x}Sr_xTiO_3$ forms a cubic solid solution at high temperatures. At lower temperatures it undergoes successive displacive transitions to tetragonal and orthorhombic phases on cooling and increasing $CaTiO_3$ content. The low-frequency mechanical response of the tetragonal phase is dominated by thermally activated displacements of transformation twin domain walls, causing almost a twofold decrease in storage modulus relative to the twin-free cubic phase on cooling through the phase transition (superelastic softening). Below 140 °C the mobility of domain walls decreases and the storage modulus returns to a value close to that of the cubic phase. For $x > 0.85$, the cubic to tetragonal transition temperature is below 140 °C and domain walls are immobile immediately on formation, greatly reducing the magnitude of mechanical softening. The frequency dependence of the storage modulus is accurately described by a modified Burgers model of anelastic relaxation. Activation energies of 103 and 96 kJ/mol were obtained for samples with $x = 0.7$ and 0.74, respectively, suggesting that domain walls are strongly pinned by vacancies at the O positions. Superelastic softening is not observed below T_c for the tetragonal to orthorhombic phase transition in samples with $x = 0.5$, 0.55, and 0.6. This is explained by the small value of the spontaneous strain in orthorhombic samples with intermediate compositions, which are distorted from cubic symmetry by less than 1‰. With such small strain contrast between differently oriented twin domains, the effective force on the domain walls due to the external stress is less than the critical unpinning force, preventing displacement of the walls and suppressing superelastic softening.