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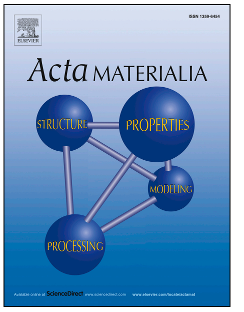

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Relaxation and saturation of electrostriction in 10 mol% Gd-doped ceria ceramics

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Abstract

10 mol% Gd-doped ceria (10GDC) ceramics, with grain size in the single micron range, display electrostrictive behavior under ambient conditions of temperature and pressure. In weak, quasi-static electric fields, i.e. <1 kV/cm, frequency < 1 Hz, the longitudinal strain is measured to be proportional to the square of the applied electric field, albeit with the corresponding electrostrictive strain coefficient (M_{33}) displaying large variability between samples: -(2-20)·10^{-17} (m/V)^2. Nevertheless, $|M_{33}|$ of all samples exceeds the values expected on the basis of the classical (Newnham) electrostriction scaling law by up to two orders of magnitude. A systematic study reveals the functional dependence of M_{33} on frequency: above 10 Hz, $|M_{33}|$ decreases to ≈10^{-18} (m/V)^2, which may be characterized as non-Debye relaxation with non-ideality factor 0.35-1.13. For frequencies ≤ 1.5 Hz, increasing the field strength beyond 1kV/cm results in an exponential decrease in $|M_{33}|$: the longitudinal strain saturates at 1-4 ppm. Dielectric impedance spectra suggest that partitioning of the applied voltage between grain boundaries and grain cores may be a factor contributing both to the large variability in the electrostriction parameters, and to the strong dependence on electric field amplitude. The frequency dependence may have two sources: the slow electric field-driven reorganization of the Ce-containing active complexes in the electrostrictive medium as well as the influence of the grain boundaries. 10GDC ceramics may therefore be added to the list of non-classical electrostrictors which includes reduced and Gd-doped ceria thin films and (Nb,Y)-doped bismuth oxide ceramics.

Keywords: Gd-doped ceria, electrostriction, grain boundaries, impedance spectroscopy

1 Introduction

Electromechanically active materials (electrostrictors and piezoelectrics) are essential components of a large variety of technologies ranging from focusing devices in cellular phone cameras to sonar. Electrostriction is an electromechanical response, proportional to the square of the applied electric field amplitude, which may be displayed by all dielectrics, independent of crystal symmetry. For a uniaxial electric field applied parallel to the z-axis, E_3, the longitudinal (z-directed) strain is described by $u_3 = M_{33} \cdot E_3^2$, where M_{33} ($\mathrm{m^2/V^2}$) is the corresponding electrostriction strain coefficient (M_{33} is Voigt notation for M_{ijkl}, a fourth-rank, symmetric