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# Improvement in the electrical properties of BCZT Ceramics induced by self-seeds

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**Abstract**
$Ba_{0.85}Ca_{0.15}Zr_{0.10}Ti_{0.90}O_3$ (BCZT)-x seed ceramics were prepared, where BCZT seed ($x$) = 0.0, 1.0, 2.0, 3.0 and 4.0 mol%. The powder was calcined at 1200 °C for 2 h and sintered at 1450 °C for 4 h. Phase formation and surface morphology were analyzed by X-ray diffraction (XRD) and scanning electron microscope (SEM). Dielectric, piezoelectric and ferroelectric properties of the ceramics were investigated. The results indicated that all samples showed pure perovskite phase. Density and grain size values were in the range of 5.54–5.62 g/cm$^3$ and 9.40–10.42 µm, respectively. Electrical properties changed with BCZT seed content. Samples with 3.0 mol% seed had the highest phase transition temperature ($T_c$), piezoelectric coefficient ($d_{33}$) and thickness electromechanical coupling coefficient ($k_t$) with values of 93 °C, 520 pC/N and 48%, respectively. Moreover, dielectric loss (tan $\delta$) at room temperature was lower than 0.014 for all samples (at 1 kHz).

## 1 Introduction

In recent years, researchers have been interested in developing lead-free piezoelectric materials as alternatives to lead-based materials, such as $(K_{0.5}Na_{0.5})NbO_3$ (KNN), $(Na_{0.5}Bi_{0.5})TiO_3$ (NBT), $(BaZr_xTi_{(1-x)}O_3$ (BZT) and $Ba_{(1-x)}Ca_xTiO_3$ (BCT) [1–4]. However, some elements such as K, Na and Bi are volatile during high-temperature processes [5]. In particular, the modified $BaTiO_3$ ceramics modified with metal oxide have been widely reported [6]. The lead-free $(Ba_{1-x}Ca_x)(Zr_yTi_{1-y})O_3$ (BCZT) ceramic is a modified $BaTiO_3$, which has attracted considerable attention because of its notable piezoelectric and dielectric properties, as well as its large tunability. These properties are found, especially, in the $Ba_{0.85}Ca_{0.15}Zr_{0.1}Ti_{0.9}O_3$ ceramic system, and this ceramic can be easily sintered because of its nonvolatile components [5, 7]. However, these ceramics require very high calcining and sintering temperatures of 1300–1350 °C and 1500–1540 °C, respectively, for 4–6 h, to form the pure perovskite phase [5, 7, 8]. The seed-induced method is a new methodology used to stabilize the perovskite phase and lower the fabrication temperature. Addition of seed compound induces formation of the perovskite phase at low temperature as it decreases the energy barrier of phase formation [9]. The use of seed-induced method in sol–gel preparation has been widely reported, and the synthesis of powder ceramics using this technique produced pure perovskite phase at low temperature [9–12]. However, the use of seed-induced technique, whereby seeds are prepared by the molten-salt method, has not been studied previously. In this research, the effect of seeds on the physical and electrical properties, including dielectric, piezoelectric and ferroelectric properties of $Ba_{0.85}Ca_{0.15}Zr_{0.1}Ti_{0.9}$ ceramic systems, was studied.

## 2 Experiment

### 2.1 Synthesis of ceramics

Lead-free $Ba_{0.85}Ca_{0.15}Zr_{0.1}Ti_{0.9}O_3$ ceramic systems were mixed with BCZT seed in the ratio of (1–$x$):$x$, where BCZT

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