Preparation and study of non-Pb piezoelectric ceramic system

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\text{Ba(Ti}_{0.75}\text{Zr}_{0.15})\text{O}_3 - (\text{Ba}_{0.77}\text{Ca}_{0.23})\text{TiO}_3
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Lead has recently been expelled from many commercial applications and materials (for example, from solder, glass and pottery glaze) owing to concerns regarding its toxicity. Lead zirconium titanate (PZT) ceramics are high-performance piezoelectric materials, which are widely used in sensors, actuators and other electronic devices; they contain more than 60 weight per cent lead. Although there has been a concerted effort to develop lead-free piezoelectric ceramics, no effective alternative to PZT has yet been found [1]. The basic approach to achieving high piezoelectricity is to place the composition of the material to the proximity of a composition-induced phase transition between two ferroelectric phases. Such a transition has been known as the morphotropic phase boundary (MPB) in the phase diagram [2]. In this work, we present a study and characterization of the non-Pb piezoelectric system \((1-x)\text{Ba(Ti}_{0.85}\text{Zr}_{0.15})\text{O}_3 - x(\text{Ba}_{0.77}\text{Ca}_{0.23})\text{TiO}_3\).

The studied materials were prepared through the conventional ceramic method, starting from high-purity precursor powders of \(\text{BaCO}_3\) (99 %), \(\text{TiO}_2\) (99 %), \(\text{ZrO}_2\) (99 %) and \(\text{CaCO}_3\) (99 %). These raw materials were mixed in stoichiometric proportions according to the nominal formulations:

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\begin{align*}
(0.77) \text{BaO} + (0.23) \text{CaO} + \text{TiO}_2 & \rightarrow (\text{Ba}_{0.77}\text{Ca}_{0.23})\text{TiO}_3 \\
\text{BaO} + (0.85) \text{TiO}_2 + (0.15) \text{ZrO}_2 & \rightarrow \text{Ba(Ti}_{0.85}\text{Zr}_{0.15})\text{O}_3
\end{align*}
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after homogenization for 4h, the mixtures were calcined at 1200 °C for 2h. We designed a system \(\text{Ba(Ti}_{0.85}\text{Zr}_{0.15})\text{O}_3 - x(\text{Ba}_{0.77}\text{Ca}_{0.23})\text{TiO}_3\), or \(\text{BZT-xBCT}\), were x is the molar percent of BCT \((x=0, 0.25, 0.50, 0.75, 1.0)\). The powders were then, ball-milled for 4h into fine powders, compacted into disk-shaped samples and then sintered at 1500 °C for 2h. The final density of each sintered specimen was determined by the Archimedes method, showing values above 95 % of the BaTiO\textsubscript{3} density in all cases. On the other hand, both \(\text{BZT-xBCT}\)-modified phase and microstructure developments were followed by X-ray diffraction (XRD) using a Rigaku Geigerflex diffractometer (with a monochromatic CuK\textsubscript{α} radiation, \(\lambda = 1.5406 \text{ Å}\)) and scanning electron microscopy (SEM) using a Zeiss DSM-960 equipment, respectively. Grain size of the ceramics was evaluated by the intercept method on the SEM images. Electrical measurements were carried out with a Solartron SI 1260 impedance/gain-phase analyzer over a wide temperature range from −100 to 150 °C. Our studies are in progress to optimize the sample microstructure, electrical and piezoelectric properties. Keywords: Ceramics, morphotropic phase boundary, piezoelectric.

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