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Effect of sintering temperature on dielectric properties of $Ba_{0.6}Sr_{0.4}TiO_3$–MgO composite ceramics prepared from fine constituent powders

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ABSTRACT

Composite ceramics of $Ba_{0.6}Sr_{0.4}TiO_3$ + 60 wt.% MgO were prepared from fine constituent powders by sintering at 1200–1280 °C. The composite specimens sintered at the relatively low temperatures showed satisfactory densification due to fine morphology of the constituent powders. The elevation of sintering temperature promoted the incorporation of Mg^{2+} into the lattice of the $Ba_{0.6}Sr_{0.4}TiO_3$ phase and grain growth of the two constituent phases. The dependence of the dielectric properties on sintering temperature was explained in relation to the structural evolution. Controlling the sintering temperature of the composite was found to be important to achieve the desired nonlinear dielectric properties. Sintering at 1230 °C was determined to be preferred for the composite in terms of the nonlinear dielectric properties. The specimen sintered at the temperature attained a tunability of 17.3% and a figure of merit of 127 at 10 kHz and 20 kV/cm.

1. Introduction

Barium strontium titanate ($Ba_{1-x}Sr_xTiO_3$, BST) has been considered to be a leading candidate material for tunable microwave dielectric devices by the virtue of strong dielectric nonlinearity under bias electric fields and linearly variable Curie temperature with the content of strontium [1,2]. It has been well recognized that a moderate dielectric constant, a low dielectric loss and a high tunability are preferred for the application. BST compositions have relatively large dielectric constants, resulting in an impedance matching difficulty for their application in the tunable microwave devices. Designing composite systems composed of BST and nonferroelectric constituents has been found to be efficient in overcoming the problem [1]. The basic principle of the composite design is to take advantage of each constituent to achieve the preferred nonlinear dielectric properties. Various nonferroelectric constituents, including MgO [1], Mg_2SiO_4 [3], Mg_2TiO_4 [4], Mg_2AlO_4 [5] and $MgTiO_3$ [6], have been employed to dilute the dielectric constant of BST. From a viewpoint of materials design, magnesium is the crucial element of the nonferroelectric constituents. Thus, BST–MgO emerges as the typical system of the ferroelectric/nonferroelectric composites. In the past decade, BST–MgO composites have been the subject of extensive researches in view of the tunable device application [7–11]. Meanwhile, the system has been adopted as the basis to develop new BST-based composites by doping various oxides [12–14]. Despite these previous works, there have been few researches regarding the influence of sintering temperature on the nonlinear dielectric properties of the composite system with respect to structural evolution. On the other hand, the majority of the prior researches were conducted based on BST–MgO composite ceramics prepared from conventional constituent powders, which were sintered at high temperatures (≥1350 °C). It has been expected that lowering the sintering temperature of BST–MgO composites would leave a larger space for their realization in the tunable microwave devices [10]. We believe that utilizing highly-reactive constituent powders is a viable approach to this aim.

In this work, we prepare $Ba_{0.6}Sr_{0.4}TiO_3$–MgO composite ceramics at relatively low sintering temperatures of 1200–1280 °C by using fine $Ba_{0.6}Sr_{0.4}TiO_3$ and MgO powders. Moreover, the dependence of the dielectric properties on sintering temperature was investigated from the viewpoint of structural change. The purpose of the research is to specify contributing factors to the nonlinear dielectric properties of the composite in the context of low-temperature sintering and offer a clue to the design of new BST-based composites for the tunable device application.

2. Experimental

$Ba_{0.6}Sr_{0.4}TiO_3$ powder was synthesized by a citrate method. Reagent grade $Ba(NiO_3)_2$, $Sr(NiO_3)_2$, tetrabutyl titanate and citric acid

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