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Structure and morphology of yttrium doped barium titanate ceramics for multi-layer capacitor applications

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ABSTRACT

Multilayer ceramic capacitors (MLCCs) are essential components in pulsed power systems (PPS) with high charging and discharging capacity for energy storage applications. Yttrium oxide (Y_2O_3)–doped barium titanate ($BaTiO_3$) (BTY) ceramics with a chemical formula of 60 BaO + (40-x) TiO_2 + x Y_2O_3 (x = 2, 8 and 15) have been synthesized by usual solid state reaction process. These ceramics are analyzed by XRD, FTIR and SEM techniques. The crystalline nature of the undoped $BaTiO_3$ (BT) and Y_2O_3 doped ceramics were confirmed by XRD analysis. In addition, a doublet peak at 30.2° has been shifted to lower angles as the concentration of Y^{3+} ions increases. The functional groups of these BT and BTY2 ceramics were investigated using FTIR analysis. Morphological studies were performed through scanning electron microscopy (SEM), revealing the average particle size of BT 331 nm and BTY2 136 nm from Image-J software.

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1. Introduction

In these modern years, especially in pulsed power systems (PPS), dielectric capacitors have been widely developed due to their high energy density and extremely fast charging and discharging. High performance capacitors with high energy density, good thermal capacity stability and high charge efficiency have been reduced the volume and weight of PPS [1]. Multilayer ceramic capacitors (MLCC) have been effectively used to increase the volumetric efficiency of capacitive components [2]. With dielectric layers of small thicknesses arranged in parallel, higher capacitance levels can be achieved along with miniaturization of the electronic circuitry. The electronic devices, which we are using every day, such as smartphones, computers and LED TVs contain more than 1000 of MLCCs. For electric vehicles, more than 10,000 MLCCs are needed due to their electronic control and automation system [3]. Barium titanate ($BaTiO_3$) with a perovskite structure is suitable for MLCC applications due to (BT) high-dielectric constant. Moreover, It can be used as a capacitor with small in size and high-capacitance due to large relative permittivity of 1,000 to 20,000. The $BaTiO_3$ MLCC have been found in the electronics industry for transducers, actuators and high dielectrics applications [4].

Rare earth (RE^{3+}) ions such as Dy^{3+}, Ho^{3+}, Sm^{3+}, La^{3+}, Yb^{3+}, or Y^{3+} have been envisioned to replace Ba and Ti cations in the $BaTiO_3$ structure, but Dy^{3+}, Ho^{3+}, and Y^{3+} also unveil amphoteric behavior and pronounced as being supportive in extending the lifetime of the MLCCs [5]. Y_2O_3 is generally considered as a dopant in the commercial formulation of powders for the fabrication of MLCCs at an industrial scale. Moreover, it results in similar properties compared to adding other RE^{3+} ions.

This present work aims to discuss the structural and morphological studies of Y_2O_3 doped $BaTiO_3$ ceramics for MLCC applications. In the stoichiometric ratio, the powders were prepared by conventional solid state method. The calcined and sintered fine powder samples were investigated through XRD, FTIR and SEM analyses.

2. Experimental

The following raw materials were used to prepare the Y_2O_3 doped $BaTiO_3$ powders: Barium carbonate ($BaCO_3$) with 99%, and titanium dioxide (TiO_2) with 99.9% and Y_2O_3 (99.99%, Aldrich). A batch of 15 g of Y_2O_3 doped $BaTiO_3$ powder was prepared using the composition 60 BaO + (40-x) TiO_2 + x Y_2O_3 (BTY) (where x = 2,

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