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Preparation, characterization and dielectric properties of $Ba_{3-x}Sr_xM_4Ti_4O_{21}$ (M = Nb, Ta and $0 \le x \le 3$) ceramics

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Abstract

$Ba_{3-x}Sr_xM_4Ti_4O_{21}$ (M = Nb, Ta and $0 \le x \le 3$) ceramics have been prepared through solid state ceramic route. The structure and microstructure of the compositions have been studied using powder X-ray diffraction and Scanning Electron Microscopic studies. In the present study, both $Ba_3Nb_4Ti_4O_{21}$ and $Ba_3Ta_4Ti_4O_{21}$ are obtained as single phase compositions whereas strontium rich compositions exhibit multiphase in nature. Energy dispersive X-ray analysis has been performed to identify the nature of additional phases present in the strontium rich compositions. The dielectric constant, dielectric loss and temperature variation of dielectric constant of the well sintered ceramic specimens have been studied in the low frequency region (<13 MHz) using an impedance analyzer. The present study reveals that high dielectric compositions can be realized by Sr-substitution in the $BaO–TiO_2–Nb_2O_5/Ta_2O_5$ ternary systems.

Keywords: Oxides; Ceramics; Dielectric resonators; Niobates; Tantalates

1. Introduction

The unprecedented growth of cellular mobile, satellite communication, military radars etc. have led to the use of compact, lightweight and inexpensive components in the microwave band of frequencies. To satisfy the demands of microwave circuit design, materials having high dielectric constant (ε_r), high quality factor (Qu) and near zero temperature coefficient of resonant frequency (τ_r) are preferred [1–3]. In the last few decades a number of materials have been developed as dielectric resonators. Among them, $Ba_2Ti_9O_{20}$, $(Zr,Sn)TiO_4$, $Ba_5Nb_4O_{15}$, complex perovskites, $BaO–Ln_2O_3–TiO_2$ (Ln = rare earths) etc. have gained wide recognition and put into use frequency determining components in many microwave systems [4–9].

Since the relative wavelength in ceramic compact decreases in proportion to the square root of the dielectric constant, often-high permittivity materials are required for lower bands of microwave frequencies. Although many high permittivity materials have been realized in the $BaO–Ln_2O_3–TiO_2$ systems, recently it have been reported that materials in the $BaO–TiO_2–Nb_2O_5/Ta_2O_5$ also possess excellent microwave dielectric properties. A number of materials in the $BaO–TiO_2–Nb_2O_5/Ta_2O_5$ ternary system have been reported by Sebastian [10] and Millet et al. [11]. Roberts et al. report the low frequency dielectric properties of $Ba_3Ti_4Nb_{4-x}Ta_xO_{21}$ Ceramics [12]. The high frequency dielectric properties of $BaTi_3Nb_4O_{17}$ and $Ba_6Ti_4Nb_2O_{39}$ are studied by Ratheesh et al. [13].

Most of the excellent dielectric resonators have been developed through research on the B-site substitution effect because A-site substitution often causes an increase in the dielectric loss. Although the dielectric constant and the dielectric loss of $Ba_3Ta_4Ti_4O_{21}$ and $Ba_3Nb_4Ti_4O_{21}$ are good, the temperature variation of dielectric constant is comparatively higher. In the present work, an attempt has been made to study the effect of A-site substitution with an objective to tune the temperature coefficient of dielectric constant of these materials.

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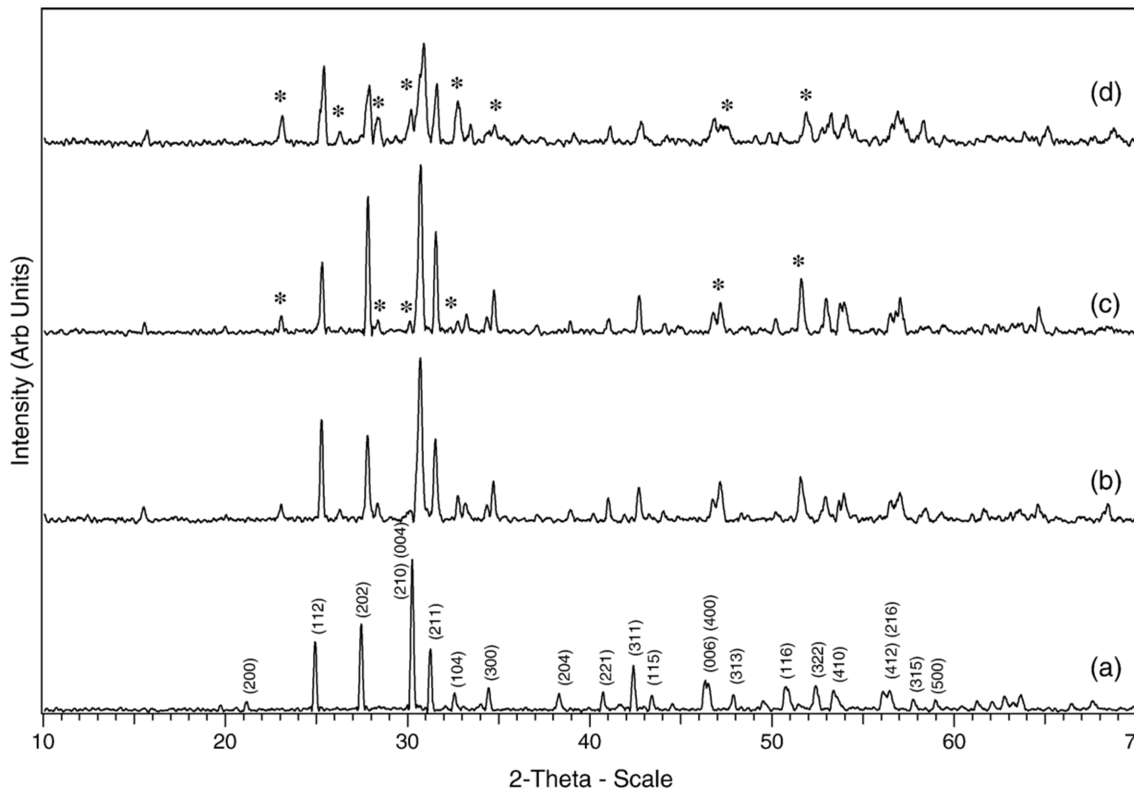

Fig. 1. Powder X-ray diffraction patterns of (a) B3N4 (b) B2SN4 (c) BS2N4 and (d) S3N4 ceramics.

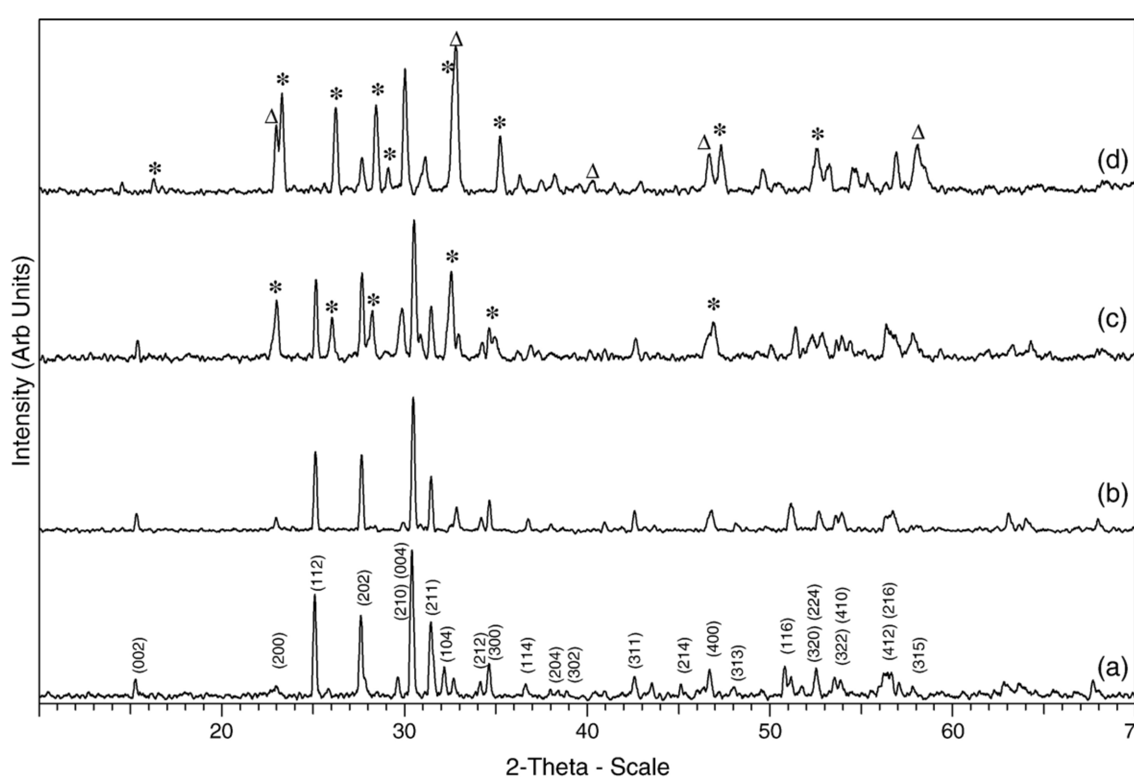

Fig. 2. Powder X-ray diffraction patterns of (a) B3T4 (b) B2ST4 (c) BS2T4 and (d) S3T4 ceramics.