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Preparation, Characterization, and Microwave Dielectric Properties of $Sr_2La_3Nb_{1-x}Ta_xTi_4O_{17}$ ($0 \leq x \leq 1$) Ceramics

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$Sr_2La_3Nb_{1-x}Ta_xTi_4O_{17}$ ($0 \leq x \leq 1$) ceramics were processed via a solid-state mixed oxide route. $Sr_2La_3Nb_{1-x}Ta_xTi_4O_{17}$ ($0 \leq x \leq 1$) solid solutions were single phase in the whole range of x values within the x-ray diffraction (XRD) detection limit. The microstructure comprised elongated and needle-shaped grains. The ceramics exhibit relative permittivity (ε_r) of 73 to 68.6, product of unloaded quality factor and resonant frequency (Q_uf_0) of 7100 GHz to 9500 GHz, and temperature coefficient of resonant frequency (τ_f) of 78.6 ppm/°C to 56.6 ppm/°C.

Key words: SEM, microwave, materials, ceramics

INTRODUCTION

Recent technological developments in wireless telecommunication systems utilizing microwave dielectric ceramics as resonators, filters, and other components have increased interest in designing and engineering new materials for better performance and miniaturization of microwave components. Materials for commercial applications as dielectric resonators (DRs) require high relative permittivity ($\varepsilon_r > 24$), near-zero temperature coefficient of resonant frequency ($\tau_f \approx 0$ ppm/°C), and a high unloaded quality factor Q_u, generally reported as a product with the frequency f_0 at which it is measured ($Q_uf_0 \approx 30{,}000$ GHz). For certain applications, e.g., antennas, the values of τ_f and Q_uf_0 can be compromised to ±10 ppm/°C and >10,000 GHz, respectively; however, ε_r must be high, as this leads to a reduction in device size. Several materials have been employed as DRs in mobile phone handsets and base stations, but the search for materials with ultralow losses (high Q_uf_0), $\tau_f \approx 0$, and $\varepsilon_r > 50$[1–3] continues.

Dielectric ceramics with general formula $A_nB_nO_{3n+2}$ have been investigated for practical applications as DRs exhibiting high ε_r; e.g., Jawahar et al.[4] found the microwave dielectric properties of $CaLa_4Ti_5O_{17}$ ceramics sintered at 1625°C to be $\varepsilon_r \approx 53$, $\tau_f \approx -20$ ppm/°C, and $Q_uf_0 \approx 17{,}359$ GHz. The microwave dielectric properties of $CaLa_4Ti_5O_{17}$ ceramics were improved by substituting Ca^{2+} ions for Zn^{2+} ions.[5] Addition of 0.5 wt.% CuO to $Ca_{0.99}Zn_{0.01}La_4Ti_5O_{17}$ ceramics resulted in $\varepsilon_r \approx 57$, $Q_uf_0 \approx 15{,}000$ GHz, and $\tau_f \approx -8.16$ ppm/°C after sintering at 1450°C for 4 h.[6] Recently, Manan et al.[7] investigated the dielectric properties of $Sr_{5-x}Ca_xNb_4TiO_{17}$ (x = 0 to 5) ceramics, and $Sr_2Ca_3Nb_4TiO_{17}$ was reported to exhibit good properties with $\varepsilon_r \approx 53$ and $\tau_f \approx -6.5$ ppm/°C, although Q_uf_0 (~1166 GHz) was too low. More recently, the authors have investigated the microwave dielectric properties of $SrLa_4Ti_5O_{17}$ in the $Sr_{5-x}La_xNb_{4-x}Ti_{1+x}O_{17}$ (x = 4) series and reported $\varepsilon_r \approx 60.8$, $Q_uf_0 \approx 9969$ GHz, and $\tau_f \approx 117$ ppm/°C.[8,9] The high positive τ_f precluded its use as a DR. τ_f of $SrLa_4Ti_5O_{17}$ was tuned to zero by suitable dopants at the A-site of the perovskite structure but at the cost of decreasing ε_r and Q_uf_0 value.[10] However, to get materials with $\varepsilon_r > 50$, $Q_uf_0 > 10{,}000$ GHz, and near-zero τ_f, the microwave dielectric properties of some new $Sr_2La_3Nb_{1-x}Ta_xTi_4O_{17}$ ($0 \leq x \leq 1$) ceramics were investigated in this work.

EXPERIMENTAL PROCEDURES

$Sr_2La_3Nb_{1-x}Ta_xTi_4O_{17}$ ($0 \leq x \leq 1$) ceramics were fabricated using a solid-state mixed oxide route.

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