Ceramics International 47 (2021) 121–129

Contents lists available at ScienceDirect

Ceramics International

journal homepage: www.elsevier.com/locate/ceramint

$NaTaO_3$ microwave dielectric ceramic a with high relative permittivity and as an excellent compensator for the temperature coefficient of resonant frequency

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ARTICLE INFO

Keywords:
$NaTaO_3$
High relative permittivity
Adjusting temperature coefficient of resonance frequency

ABSTRACT

$NaTaO_3$ ferroelectric ceramics sintered at 1550 °C exhibit high relative permittivity and outstanding microwave dielectric properties of ε_r = 113.76, $Q \times f$ = 8824 GHz, and τ_f = +645 ppm/°C in the low-frequency band (3.5195 GHz). The high relative permittivity is advantageous for the miniaturization of modern wireless communication devices. A near zero temperature coefficient of the resonance frequency (τ_f = +1.05 ppm/°C) and good microwave dielectric properties ($Q \times f$ = 54,680 GHz, ε_r = 19.42) were obtained for $0.92MgTiO_3$-$0.08NaTaO_3$ ceramics. Moreover, the sintering temperature of $MgTiO_3$ could be decreased from 1350 °C to 1200 °C. Hence, $NaTaO_3$ is a high-potential microwave dielectric material for adjusting systems with a negative temperature coefficient of resonance frequency.

1. Introduction

The introduction of 5G communication technology has facilitated a development boom in various industries, including the field of microwave communication equipment. There has been a strong demand in the development of materials with different permittivity values, high $Q \times f$ value and a near zero temperature coefficient of the resonant frequency [1,2]. $NaTaO_3$ is an incipient ferroelectric, which belongs to the orthorhombic perovskites structure and exhibits a crystal structure equivalent to that of $CaTiO_3$ [3,4]. To date, many ceramics with perovskite structures have been found to possess excellent microwave dielectric properties, such as $LnAlO_3$ [5,6], $LnGaO_3$ [7] (where Ln = La, Nd, and Sm), $CaTiO_3$ [8], and $SrTiO_3$ [9]. Axelsson et al. [10] reported that the $KTaO_3$ ceramics sintered at 1340 °C demonstrated good microwave dielectric properties of ε_r = 177, $Q \times f$ = 2900 GHz, and τ_f = −450 ppm/°C. However, the excessively large negative τ_f value makes this type of ceramics unsuitable for application. Although the $Q \times f$ values of $CaTiO_3$ and $SrTiO_3$ are not very high, these materials are still used as a very important stabilizers of the temperature coefficient of resonance frequency due to their high relative permittivity and positive temperature coefficient of resonance frequency. However, the selection of the stabilizer material is incomplete. Hence, it is necessary to find and develop new, resonant frequency temperature-stable materials.

$MgTiO_3$ ceramic has been widely used in microwave dielectric ceramic resonators and filters because of its low cost and good microwave dielectric properties with a $Q \times f$ = 160,000 GHz, ε_r = 17, and τ_f = −64 ppm/°C [11,12]. However, the rigorous sintering temperature (1400 °C) and large deviation from zero of the τ_f value restrict their further applications in devices [13–16]. MCT95 ($0.95MgTiO_3$-$0.05CaTiO_3$ ceramics) has been widely used in the practical production of resonators and filters, especially in the commercial processing 5G smart devices, due to its excellent microwave dielectric properties [17,18]. In our recent work, we found that $Mg_{(1-x)}Ca_xTiO_3$ ceramics prepared by a one-stage sintering process were more reasonable and beneficial for decreasing production costs [19].

In this work, $NaTaO_3$ ceramics with a high relative permittivity were synthesized by a solid powder sintering process. In order to study the role of $NaTaO_3$ in performance optimization for other systems, $MgTiO_3$ was selected as the matrix, then the microwave dielectric properties were studied after adding a certain range of $NaTaO_3$.

2. Experimental procedure

The experimental processes for $NaTaO_3$ and (1-x) $MgTiO_3$-$x NaTaO_3$ (x = 0, 0.05, 0.07, 0.08, 0.09, 0.11.) ceramics are described in the

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https://doi.org/10.1016/j.ceramint.2020.08.114
Received 19 July 2020; Received in revised form 14 August 2020; Accepted 14 August 2020
Available online 20 August 2020