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# Ultra-low temperature sintering and microwave dielectric properties of a novel temperature stable $Na_2Mo_2O_7$-$Na_{0.5}Bi_{0.5}MoO_4$ ceramic

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**Abstract**

The novel ultra-low temperature sintering (1-x)$Na_2Mo_2O_7$-x$Na_{0.5}Bi_{0.5}MoO_4$ ceramics have been obtained via solid-state reaction method for passive integration use. The $Na_2Mo_2O_7$ and $Na_{0.5}Bi_{0.5}MoO_4$ crystal phases are found to be compatible with each other from the results of XRD and SEM-EDS. With the x value changing from 0.36 to 1.00, the $\varepsilon_r$ increases from 16.0 to 32.0 and the $\tau_f$ value varies from -58 to 47 ppm/°C. At x = 0.75, the 0.25$Na_2Mo_2O_7$-0.75$Na_{0.5}Bi_{0.5}MoO_4$ ceramic sintered at an ultra-low sintering temperature of 580 °C can be densified (>96%) and possesses good microwave dielectric properties of an $\varepsilon_r$ of 24.0, a Q×f value of 13,000 GHz (at 6.2 GHz), and a $\tau_f$ value of 3 ppm/°C. The theoretical $\varepsilon_r$ and $\tau_f$ of the (1-x)$Na_2Mo_2O_7$-x$Na_{0.5}Bi_{0.5}MoO_4$ composites were calculated using the mixing law and in accordance with the measured values.

***Keywords*** **:** Ceramics; Dielectrics; Microwave dielectric properties; Temperature stable material; Ultra-low temperature sintering.

## 1. Introduction

In recent years, with the development of wearable wireless communication, it requires that microwave dielectric ceramics have a suitable permittivity, low loss, a near zero temperature coefficient of the resonant frequency ($\tau_f$) and an ultra-low sintering temperature to co-fire with semiconductor, polymer and electrode materials, such as the Al paste (550 °C) or the nano particle silver ink [1-4]. However, most of the ultra-low firing microwave ceramics have the negative temperature coefficient of the resonant frequency. Many kinds of ultra-low temperature co-fired ceramic (ULTCC) materials (about 100) have been reported in the literature [4]. However, among the materials with sintering temperatures below 600 °C, there are only two ceramics with temperature stability, namely $BaTe_4O_9$-40wt%$TiTe_3O_8$ ($\varepsilon_r$ = 25.0, Q×f = 19,300 GHz, $\tau_f$ = -3 ppm/°C) and 0.47$BaTe_4O_9$-0.53$TiTe_3O_8$ ($\varepsilon_r$ = 28, Q×f = 12,000 GHz, $\tau_f$ = 4 ppm/°C) [5,6]. However, tellurium oxide is highly toxic. Therefore, the temperature-stable ultra-low firing ceramics especially sintered below 600 °C still need to be studied.

The previous study demonstrates that the ceramics in $A_2O$-$MoO_3$ (A = Na, K, Ag) systems have ultra-low sintering temperatures of 460-660 °C and good microwave dielectric properties ($\varepsilon_r$ = 4.1-14.0, Q×f = 8,500-62,400 GHz and $\tau_f$ = -142~-57 ppm/°C) [7,8]. Among them, the $Na_2Mo_2O_7$ ceramic sintered at 575 °C has the best Q×f value of 62,400 GHz, an $\varepsilon_r$ of 12.9 and a $\tau_f$ of -72 ppm/°C [8]. Among the microwave dielectric materials with ultra-low sintering temperatures and positive $\tau_f$ values, the $Na_{0.5}Bi_{0.5}MoO_4$ ceramic sintered at 690 °C has a high Q×f