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Improvements in the Sintering Behavior and Microwave Dielectric Properties of Geikielite-Type $MgTiO_3$ Ceramics

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Microwave dielectric ceramics based on geikielite-type $MgTiO_3$ were prepared by an aqueous sol–gel process. The precursor powders and dielectric ceramics were characterized by x-ray diffraction, scanning electron microscopy (SEM), transmission electron microscopy (TEM), and microwave methods. Highly reactive nanosized magnesium titanate powders with particle sizes of 20 nm to 40 nm were successfully obtained at 500°C as precursors. Sintering characteristics and microwave dielectric properties of $MgTiO_3$ ceramics were studied as a function of sintering temperature from 1100°C to 1300°C. With increasing sintering temperature, the density, ε_r, and Qf values increased, saturating at 1200°C with excellent microwave properties of $\varepsilon_r = 17.5$, $Qf = 156{,}300$ GHz, and $\tau_f = -44$ ppm/°C. Correlations between the microstructure and dielectric properties of $MgTiO_3$ ceramics were also investigated.

Key words: $MgTiO_3$, nanopowder synthesis, sol–gel, microwave dielectric properties

INTRODUCTION

Recently, microwave and millimeterwave dielectric materials have been developed for a wide range of applications in mobile and satellite communication systems such as miniaturization for mobile phones, transmitters, and receivers with high performance.[1] Over the years, low-loss dielectric materials have been developed for applications in three directions: mobile phone handsets, base stations, and millimeterwave communication. The third direction with high Q and low ε_r is for devices working in the millimeterwave range, and much research has mainly focused on these systems,[2–6] using materials such as M_2SiO_4 (M = Mg, Zn), Al_2O_3, MAl_2O_4 (M = Mg, Zn), $R_2Ba(Cu_{1-x}A_x)O_5$ (R = Y, Sm, Nd, Yb; A = Mg, Zn), $A_5B_4O_{15}$ (A = Ba, Sr, Mg, Ca, Zn; B = Nb, Ta), etc. Compared with these, Geikielite-type magnesium titanate ($MgTiO_3$; MT), with high quality factor and appropriate dielectric constant, became a well-known kind of dielectric ceramic with promising applications in resonators, filters, and antennas for communication operating at millimeterwave frequencies.[7,8] Therefore, synthesis of pure $MgTiO_3$ phase has been performed by many methods such as solid-state reaction methods,[9–12] thermal decomposition of peroxide precursors,[13] hydrothermal mechanical–chemical complexation routes,[14] and other methods.[15–18] Applying these methods, $MgTi_2O_5$ usually appears in the final product as a metastable phase to a certain extent, especially when using solid-state reactions,[12] and the sample has a sintering temperature of over 1400°C. Even when using the mechanical–chemical complexation method a small amount of $MgTi_2O_5$ also appears in the final product of $MgTiO_3$ ceramic.[14] Obviously, synthesis of pure $MgTiO_3$ phase without $MgTi_2O_5$ phase seems to be difficult using these methods, and additionally the high sintering temperature of these ceramics limits their practical application. In addition, many investigations have described the development of chemical processing or special methods[19–27] as alternatives to the conventional solid-state reaction of mixed oxides. Among such wet chemical techniques,

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