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Synthesis, structural and dielectric properties of Magnesium calcium titanate (1-x)$MgTiO_3$-x$CaTiO_3$ (x=0, 0.1, 0.2 and 0.3)

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Abstract

Magnesium Titanate-based ceramics is one of the popular microwave dielectric materials. These are widely used as dielectrics in resonators and filters for communication, capacitors and radar systems operating at microwave frequencies. The pure and Calcium doped Magnesium Titanate ceramic materials are synthesised by conventional Solid-state route diffusion method. High purity chemicals of MgO, TiO_2 and CaO which are taken in according to their compositions for the preparation of $Mg_{1-x}Ca_xTiO_3$ (x=0,0.1,0.2 and 0.3) ceramics . They are grounded well for 12h in a Ball Mill. Then the powders are calcined at 1175°C to 1200°C for 36h and are pressed into pellets. These pellets are sintered at 1270°C to 1300°C for 6h. The dielectric constant from room temperature to 350^0C is calculated using HIOKI 3532-50 LCR HiTESTER in the frequency range of 100Hz-5MHz . The dielectric constant at room temperature at a frequency of 0.1KHz for pure Magnesium Titanate is found to be 14.13 and as the concentration of Calcium increases dielectric constant increases. The AC conductivity and Dielectric loss of the samples are measured. XRD studies revealed that the compound exhibits major phase of $MgTiO_3$ with Hexagonal structure and space group 148 : R-3.

Keywords: Ceramics; Dielectric Constant; AC conductivity; XRD.

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1. Introduction

Now a days, there is an increase in development of dielectric resonators and antennas which find many applications in various fields such as in cellular phone, satellite communication systems, global positioning system(GPS) and radar [1-2]. It has many applications such as in dew sensors, pigments and in the electrical and electronic industries [3]. Magnesium Titanate is a low loss dielectric material and Calcium Titanate is high permittivity linear dielectric material. MT-CT system has a temperature stability of permittivity [4]. An MgTiO3 ceramic exhibit ilmenite structure with rhombohedral crystal system and belongs to R-3 group [5]. $MgTiO_3$ can also be used for optical communication in planar light-wave circuits (PLC) as a buffer layer for sapphire and $LiNbO_3$ [6]. It is a positive temperature coefficient of the dielectric constant. It can be combined with negative temperature coefficients to make the coefficient to make to zero. Small amount CaO is one such an additive [7]. The magnesium titanates are usually synthesized at high temperatures of 1400^0 C by solid state reaction between MgO and TiO_2. The solid state reaction by grinding in mill is often used method due to its simplicity, inexpensiveness, applicability. The dielectric constant of (1-x)$MgTiO_3$-x$CaTiO_3$ (x=0,0.1,0.2 and 0.3) ceramics is investigated.

2. Experimental Procedure

(1-x)$MgTiO_3$-x$CaTiO_3$ (x=0,0.1, 0.2 and 0.3) ceramics were synthesized by conventional solid-state reaction technique. Reagent grade MgO, CaO and TiO_2 were used as starting materials. The powders were mixed well by Ball Milling for 12h for homogenous mixing. The mixed powders were calcined in a furnace at 1170^0C to 1200^0C for 36h. The Calcined samples were ball milled for 10h and were mixed with an organic binder (PVA). These powders were pressed into disc-shaped pellets at an isostatic pressure of 8 tons. The pellets were sintered at temperature of 1300^0C for 12h. For determination of dielectric properties, on both surfaces of the sintered samples, silver paste was applied. The pellets were characterised by XRD diffractometer for crystal structure analysis. The crystalline phases were by means of X-ray powder diffraction method using Cuk_α radiation from 10^0 to 80^0 in 2θ. The scanning rate was 4^0 / min. The dielectric properties were measured using HIOKI LCR HITESTER-3532-50 meter from 1 KHz -5 MHz from room temperature to 350^0C. The AC parameters such as capacitance(C) and dielectric loss of the samples were measured in the frequency range 1KHz to 5MHz using LCR meter. The variation of dielectric constant ε_r was calculated using

$$\varepsilon_r = \frac{C * d}{\varepsilon_o * A} \quad (1)$$

Where C is capacitance of the pellet, d is thickness of the pellet; A is the area of the cross section of the pellet and ε_0 is the permittivity of free space.

The AC conductivity of the samples was estimated from dielectric parameters. The AC conductivity (σ_{AC}) was calculated using the relation

$$\sigma_{AC} = \omega\varepsilon\varepsilon_0\tan\delta \quad (2)$$

where ε_0 is the permittivity of the free space, ω is the angular frequency and tanδ is the loss tangent.

3. Results and Discussions

XRD studies of the sintered (1-x)$MgTiO_3$ –x$CaTiO_3$ (x= 0, 0.1, 0.2 and 0.3) samples are shown in Fig. 1. $MgTiO_3$-$CaTiO_3$ ceramics is an eutectic composite containing crystals of $CaTiO_3$: orthorhombic and $MgTiO_3$: Hexagonal. Secondary phase $MgTi_2O_5$ is usually formed as an intermediate phase during crystal growth and it is difficult to eliminate from the sampled prepared by conventional solid state method because it requires a high sintering temperature of about 1450°C. . The lattice parameters of $MgTiO_3$ are a=5.05A°, b=5.05A° and c=13.88A° and α=90°,β=90° and γ=120°. The intensity and the sharpness of the peak indicate that all the compounds are crystalline. As the concentration of CaO increases, small amounts of $CaTiO_3$ were formed.