RESEARCH ARTICLE

THE STUDY ON MICROWAVE DIELECTRIC MATERIAL OF THE TIN MODIFIED ZIRCONIUM TITANATE IN WIRELESS COMMUNICATION TECHNOLOGY

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ABSTRACT

Zirconium titinate solid solution with tin has a variety of applications ranging from wireless communications to effective acid–base bifunctional catalysts and as high temperature pigments in chemical industry. The ZrTiO$_3$ with tin modified has excellent microwave dielectric property such as dielectric constant $\varepsilon_r = 42$, quality factor $Q_f = 28000$GHz and temperature coefficient of resonant frequency $\tau_f = 56$ ppm/C which is very much useful for practical wireless communication system. Annealing ZrTiO$_3$ increases the order parameter and improves the dielectric quality factor. Many investigations showed as ZrTiO$_3$ as a useful temperature-stable dielectric ceramic device. In the variation of dielectric constant with temperature, zirconium titinate containing tin show a peak at 1190 °C (= 90) and by increasing Sn content in the mother compound, its quality factor also increases with a little effect on dielectric constant. One of the advantages of ZrTiO$_3$ with Sn is that by varying the Sn content, one can control temperature coefficient of resonant frequency $\tau_f$ without drastically affecting the other properties. This is important for applications because $\tau_f$ of precisely zero is not always required. A non-zero $\tau_f$ is often preferable to compensate for frequency variation due to the effect of temperature change on the resonator housing and dielectric support structure. Zirconium titinate is an important dielectric material with excellent properties useful for applications in wireless communication.

INTRODUCTION

Microwave dielectric materials play a key role in global society with a wide range of applications from terrestrial and satellite communication including software radio, GPS, and DBS TV to environmental monitoring via satellites. In order to meet the specifications of the current and future systems, improved or new microwave components based on dedicated dielectric materials and new designs are required. The recent progress in microwave telecommunication, satellite broadcasting and intelligent transport systems (ITS) has resulted in an increasing demand for dielectric resonators (DRs), which are low loss ceramic pucks used mainly in wireless communication devices(Cohen, 1968). With the recent revolution in mobile phone and satellite communication systems using microwaves as the carrier, the research and development in the field of device miniaturization has been one of the biggest challenges in contemporary materials Science. This revolution is apparent on a daily basis in the ever increasing number of cell phone users. The recent advances in materials development has led to these revolutionary changes in wireless communication technology. Dielectric oxide ceramics have revolutionized the microwave wireless communication industry by reducing the size and cost of filter, oscillator and antenna components in applications ranging from cellular phones to global positioning systems. Wireless communication technology demands materials which have their own specialized requirements and functions.

The importance of miniaturization cannot be overemphasized in any hand-held communication application and can be seen in the dramatic decrease in the size and weight of devices such as cell phones in recent years. This constant need for miniaturization provides a continuing driving force for the discovery and development of increasingly sophisticated materials to perform the same or improved function with decreased size and weight (Wakino et al., 1975). A DR is an electromagnetic component that exhibits resonance with useful properties for a narrow range of frequencies. Dielectric Resonators (DR) are dielectric bodies of high permittivity and high Q-factor that can be used as energy storage devices. Ceramic DRs are usually prepared in the form of cylindrical or rectangular pucks by the sintering process. They are much smaller in size compared to its metallic counterpart. The three important characteristics of an ideal DR are high relative permittivity or dielectric constant ($\varepsilon_r$) for resonator applications and low $\gamma$, for millimeter wave applications, low dielectric loss tan $\delta$ and low coefficient of temperature variation of the resonant frequency $\tau_f$(Schliche, 1953).

Dielectric Constant, Dielectric loss, Quality factor and Temperature Coefficient of Resonant Frequency: The dielectric constant is measured as a function of frequency to obtain the true static dielectric constant. The dielectric constant measured in the frequency independent region is taken as static or low frequency dielectric constant $\varepsilon_r$ (sometimes referred to as infrared dielectric constant $\varepsilon_{ir}$). As the frequency is increased further, the value remains...
The polarization due to δ (maximum energy stored per cycle) is a measure of the average power loss in ε = 42, quality factor ε. The study on microwave 2- inside direct sunlight and preferably the most of the sample (using ετ) is identified with the measured dielectric constant ε and ε is a measure of the average power loss in the system. The loss is expressed in terms of the phase angle δ as
\[ \tan \delta = \frac{\varepsilon}{\varepsilon} \]

The term “quality factor” is more commonly associated with microwave resonators. Quality factor, or Q, is a measure of the power loss of a microwave system. The name quality factor is used for the reciprocal of the tan δ. One should carefully distinguish this quantity from the Q-factor of a resonator which is defined as
\[ Q = 2 \pi \left( \frac{\text{maximum energy stored per cycle}}{\text{Average energy dissipated per cycle}} \right) \]

The temperature coefficient of resonant frequency τ_f is the parameter which indicates the thermal stability of the resonator. The τ_f indicates how much the resonant frequency drifts with changing temperature. The electronic device with microwave resonators requires τ_f values as close to zero as possible. Microwave circuits will normally have some low characteristics τ_f, so the resonator components which go into them are required to compensate for the inherent drift. For this reason, the τ_f values of resonators required are typically non-zero but with some low finite value. The origin of τ_f is related to linear expansion coefficient α_e which affects the resonator dimensions and its dielectric constant variation with temperature. Mathematically the relationship is (Whelss et al., 1985)
\[ \tau_f = - \alpha_e \cdot \tau_\varepsilon \]

where τ_ε is the temperature coefficient of the permittivity and α_e is the linear thermal expansion coefficient of the dielectric material which is usually positive.

**Experimental**

The chemical was grinded into the fine powder in an agate mortar, avoiding direct sunlight and preferably the most of the sample preparation was done at night. The pellets were prepared with compression machine (Flexrual Testing Machine CAT No.AIM-313, S.No.91070 AIMIL Associated, India), having pressure range 0-10 tonne wt/cm². A suitable die was used having rectangular Cross-Sectional area of the piston =2.33cm². The polishing of the pellets has been done to obtain smooth parallel surface to be used for electrode formation polishing of the crystal introduces electrical charges inside the material. These charges and strains are to be removed, which we did by the process of annealing of the sample. In this process the pellets were kept in a suitable furnace at nearly 2/3 of their melting points for sufficient times (generally 8-10 hours). The most of the irreproducibility was removed by annealing and therefore this process was necessarily done. The electrodes were formed using colloidal silver paints (Dubey et al., 2021). The sample holder loaded with pellet is kept into the furnace such that it lies very near to the middle part of the furnace. A good quality thermometer, precisely calibrated is used to record the temperature. This thermometer is adjusted with the help of stand in such a way that it touches the metallic part of sample holder to record the exact temperature of sample. Wang (Wang et al., 1997) prepared ZrTiO₄ ceramics with additives such as ZnO, CuO and Y₂O₃ and reported that the microstructure and microwave dielectric properties are sensitive to the presence of additives and processing conditions. Yamamoto (Yamamoto et al., 1991) prepared single crystals of ZrTiO₄ by heating a mixture of ZrTiO₄, Li₂MoO₄ and MoO₃ in the molar ratio 1:2:5 at 1300°C for 5 hours and slowly cooled to 800 °C at a rate of 3 °C/h and then quenched. Macias (Macias et al., 1992) obtained crystalline ZrTiO₄ powders by heating reactive amorphous precursors. Several authors studied the effect of high energy ball milling on the formation of zirconium titanate. Single phase ZrTiO₄ was formed on annealing the milled powders and the grain size increased with prolonged annealing (Houivet et al., 1997).

**RESULTS AND DISCUSSION**

The ZrTiO₄ with tin modified has excellent microwave dielectric property such as dielectric constant ε = 42, quality factor Qf = 28000GHz and temperature coefficient of resonant frequency τ_f = 56 ppm/C which is very much useful for practical wireless communication system (Stubicar et al., 2001). In the variation of dielectric constant with temperature, zirconium titanate containing tin show a peak at 1190 °C (= 90) as shown in Fig 1.
Fig. 2 shows the variation of $\tau_f$ as a function of Sn content $z$. By increasing Sn content in the mother compound, its quality factor also increases with a little effect on dielectric constant. One of the advantages of $\text{ZrTiO}_4$ with Sn is that by varying the Sn content, one can control temperature coefficient of resonant frequency $\tau_f$ without drastically affecting the other properties. A non-zero $\tau_f$ is often preferable to compensate for frequency variation due to the effect of temperature change on the resonator housing and dielectric support structure.

Fig. 3 shows the variation of quality factor as a function of Sn content $z$. In $\text{ZrTiO}_4$, improvement in ordering increases the quality factor. Kudesia (Kudesia et al., 1994) noted that although the $Q_f$ appears to increase with larger grains produced by longer sintering times, it is not the grain size itself that is controlling the $Q_f$. The effect of annealing the $\text{ZrTiO}_4$ ceramics on the dielectric properties was found that slow-cooled ceramic has a much higher quality factor as compared to rapidly cooled ceramic. Rapid cooling from the sintering temperature yielded a disordered structure having a low $Q_f$ value. Zirconium titanate is an important dielectric material with excellent properties useful for applications in wireless communication. The raw materials required for its commercial production are inexpensive (Christefferson et al., 1992).

**REFERENCES**


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