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RESEARCH ARTICLE

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

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ABSTRACT

Zirconium titanate 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 $ZrTiO_4$ with tin modified has excellent microwave dielectric property such as dielectric constant $\varepsilon = 42$, quality factor Q_f =28000GHz and temperature coefficient of resonant frequency τ_f = 56 ppm/°C which is very much useful for practical wireless communication system. Annealing $ZrTiO_4$ increases the order parameter and improves the dielectric quality factor. Many investigation showed as $ZrTiO_4$ as a useful temperature-stable dielectric ceramic device. In the variation of dielectric constant with temperature, zirconium titatnate containing tin show a peak at 1190 °C (ε= 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 $ZrTiO_4$ with Sn is that by varying the Sn content, one can control temperature coefficient of resonant frequency τ_f without drastically affecting the other properties. This is important for applications because τ_f of precisely zero is not always required. A non-zero τ_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 tin titanate is an important dielectric material with excellent properties useful for applications in wireless communication.

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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 (ε_r) for resonator applications and low ε_r for millimeter wave applications, low dielectric loss tan δ and low coefficient of temperature variation of the resonant frequency τ_f (Schlicke, 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 ε_s (sometimes referred to as infrared dielectric constant ε_{ir}). As the frequency is increased further, the value remains unaffected till the strong resonance absorption frequency is approached in the infrared region. Beyond the resonant frequency, since the ions cannot follow the field, the polarization due to electronic contribution alone persists. Hence the dielectric constant in this region is termed as high frequency dielectric constant (ε_∞). Under the influence of static field, the dielectric constant is treated as a real number. The system is assumed to get polarized instantaneously on the application of the field. When the dielectric is subjected to alternating field, the displacement cannot follow the field due to inertial effects and spatially oriented defects. The dielectric constant is then treated as a complex quantity $\varepsilon(\omega)$. The variation of real and imaginary parts of the complex dielectric constant with frequency ω is given by the Debye equations (Dekker, 1957)

$$\varepsilon(\omega) = \varepsilon'(\omega) - i\varepsilon''(\omega)$$

where $$\varepsilon'(\omega) = \varepsilon(\infty) + \frac{\varepsilon(s)-\varepsilon(\infty)}{1+\omega^2\tau^2}$$

and $$\varepsilon''(\omega) = \varepsilon(s) - \varepsilon(\infty)\frac{\omega}{1+\omega^2\tau^2}$$

where τ is the relaxation time. ε' 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

$\tan\delta = \varepsilon''/\varepsilon$

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 $\tan\delta$. One should carefully distinguish this quantity from the Q-factor of a resonator which is defined as

Q = 2 π((maximum energy stored per cycle)/(Average energy dissipated per cycle))

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_L which affects the resonator dimensions and its dielectric constant variation with temperature. Mathematically the relationship is(Whelss *et al*., 1985)

$\tau_f = -\alpha_L - \tau_{E/2}$

where τ_E is the temperature coefficient of the permittivity and α_L 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 (Flextural Testing Machine CAT No.AIM-313, S.No.91070 AIMIL Associated, India), having pressure range 0-10 tonne wt/cm^2. A suitable die was used having rectangular Cross-Sectional area of the piston =2.33cm^2. 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 $ZrTiO_4$ ceramics with additives such as ZnO, CuO and Y_2O_3 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 $ZrTiO_4$ by heating a mixture of $ZrTiO_4$, Li_2MoO_4 and MoO_3 in the molar ratio 1:2:5 at 1300ºC for 5 hours and slowly cooled to 800 ºC at a rate of 3 ºC /h and then quenched. Macias(Macias *et al*., 1992) obtained crystalline $ZrTiO_4$ powders by heating reactive amorphous precursors. Several authors studied the effect of high energy ball milling on the formation of zirconium titanate. Single phase $ZrTiO_4$ was formed on annealing the milled powders and the grain size increased with prolonged annealing (Houivet *et al*., 1997).

RESULTS AND DISCUSSION

The $ZrTiO_4$ with tin modified has excellent microwave dielectric property such as dielectric constant ε = 42, quality factor Q_f =28000GHz and temperature coefficient of resonant frequency τ_f = 56 ppm/$^\circ$C which is very much useful for practical wireless communication system (Stubicar *et al*., 2001). In the variation of dielectric constant with temperature, zirconium titatnate containing tin show a peak at 1190 ^{o}C (ε= 90) as shown in Fig.1

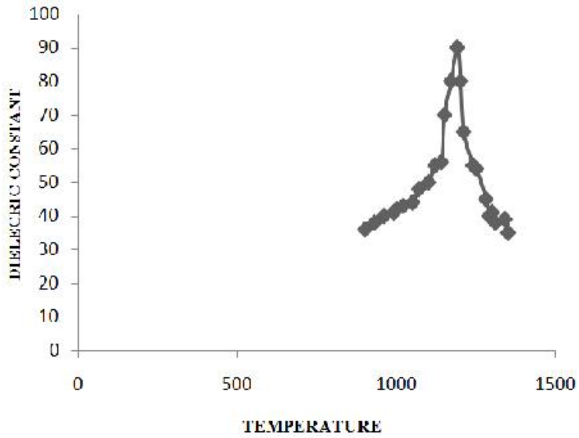

Fig 1. Temperature variation of dielectric constant of $ZrTiO_4$ with tin modified

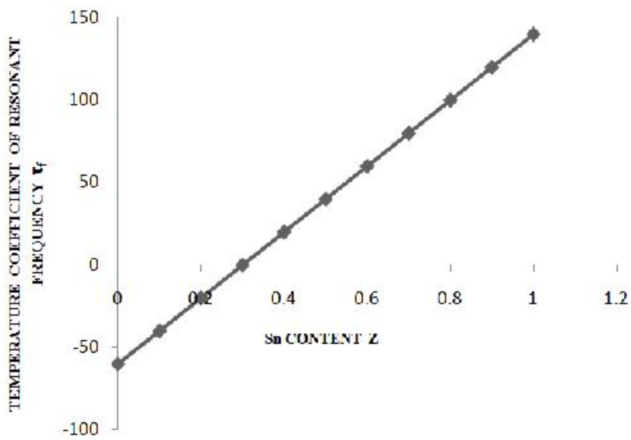

Fig. 2. Variation of temperature coefficient of resonant frequency τ_f with sn content z

Fig. 2 shows the variation of τ_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 $ZrTiO_4$ with Sn is that by varying the Sn content, one can control temperature coefficient of resonant frequency τ_f without drastically affecting the other properties. A non-zero τ_f is often preferable to compensate for frequency variation due to the effect of temperature change on the resonator housing and dielectric support structure.

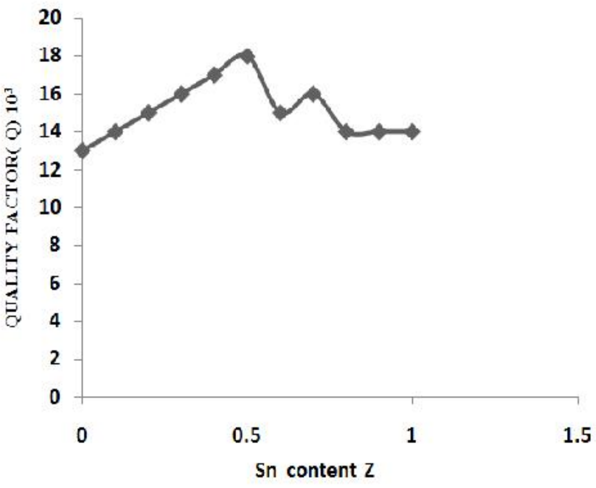

Fig. 3. Variation of quality factor with sn content z

Fig.3 shows the variation of quality factor as a function of Sn content z. In $ZrTiO_4$, 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 $ZrTiO_4$ 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 tin 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 (Christerfferson *et al*., 1992).

REFERENCES

Christerfferson R. and P. K. Davies (1992), Structure of commensurate and incommensurate ordered phase in the system $ZrTiO_4$-$Zr_5Ti_7O_{24}$, *J. Am. Ceram. Soc.*, Vol.75, pp. 563–569.

Cohen, S. B. 1968. Microwave band pass filters containing high Q dielectric resonators, *IEEE Trans. Microw. Theory and Techniques MTT-16*, pp. 1628–1629.

Dekker, A. J. 1957. Solid State Physics, *Prentice-Hall, New York*, pp.211-212.

Dubey S. P. and S. K. Sharma, 2021. International Journal of Multidisciplinary Research and Analysis, Vol.4(6), pp.774-778.

Houivet., D. J. El. Fallah. and J. M. Haussonne 1997. Effect of the grinding process on different characteristics of $(Zr,Sn)TiO_4$ microwave dielectric ceramics, *Key Engineering Materials, Trans-Tech publications Inc, Zurich, Switzerland*, Vol.132-136, pp. 1199–1202.

Kudesia., R. A. E. McHale and R. L. Snyder (1994), Effect of La_2O_3/ZnO additives on microstructure and microwave dielectric properties of $Zr_{0.8}Sn_{0.2}TiO_4$ ceramics., *J. Am. Ceram. Soc.*, Vol.77, pp. 3215-3220.

Macias., M. P. J. Sanchez-Soto and J. A. Navio, 1992. Kinetic study of crystallization in zirconium titanate from an amorphous reactive prepared precursor., *J. Non-Cryst. Solids*, Vol. 147,pp. 262–265.

Schlicke, H. M. 1953. Quasidegenerate Modes in high ε_r Dielectric Cavities, *J. Appl. Phy.*, Vol.24, pp. 187-191.

Stubicar., M. V. Bermance., N. Stubicar, D. Dudrnovski and D. Drumes (2001), Microstructure evolution of an equimolar powder mixture of ZrO_2-TiO_2 during high energy ball milling and post annealing, *J. Alloys Compd*, Vol.316, pp. 316–320.

Wakino., K. T. Nishikawa., S. Tamura and Y. Ishikawa 1975. Microwave band pass filters containing dielectric resonators with improved temperature stability and spurious response, *Pro. IEEE MTT Symposium (New York)*, pp. 63-65.

Wang., C. L. H. Y. Lee., F. Azough and R. Freer, 1997. The microstructure and microwave dielectric properties of zirconium titanate ceramics in the solid solution system., J. Mater. Sci., Vol.32, pp.1693–1701.

Whelss P. and D. Kajfezz, 1985. The use of higher order resonant modes in measuring the dielectric constant of dielectric resonators., *IEEE MTT-S. Symp. Dig. St Louis.*, pp. 473-476.

Yamamoto., A. T. Yamada., H. Ikawa., O. Fukunga., K. Tanaka and I. Marumo 1991. Modulated structure of zirconium titanate, *Acta Crystallogr. C*, Vol.47, pp.1588–1591.

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