Studies on dielectric response of $Ca_2Bi_3LaTi_5O_{18}$ ceramics

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ABSTRACT

Dielectric materials are increasingly used in various electronic circuits / equipments especially in tunable transducer, actuators memory devices, capacitors etc. $Ca_2Bi_3LaTi_5O_{18}$ ceramic has been synthesized by high temperature solid-state reaction between the corresponding oxides and carbonates. Phase identification and structural analysis have been done by XRD. Electrical and dielectric properties have been measured in the frequency range 42Hz – 5MHz in the temperature region 27-450 °C. The results seem to indicate that these materials are good for high temperature application.

Keywords: Bismuth titanates, Impedance, Dielectric constant, X–ray diffraction.

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INTRODUCTION:

Dielectric oxides constitute a large proportion of material which is having large scale technological applications. There is an increasing demand on dielectric material to suppress their present abilities to be of use in the fast changing world of electronic devices .at the root of all devices lie the bulk materials , on whose basic properties future progress may be made . hence , search for new materials with unusual properties is of great importance among a large number of ferroelectric oxide of different structural families (e.g. pervskite , tungsten – bronze , layers etc)available now a day's some compounds of tungsten bronze family such as ,$Ba_2NaNb_5O_{15}$ (1), $Ba_2Na_3RNa_{10}O_{30}$ where R = rare earth (2) , $Ba_{6-x}La_xNb_{10}O_{30+\delta}$ (3), $Pb_2Bi_3NdTi_5O_{18}$ (4)etc have been found attractive because of their promising physical properties suitable for the fabrication of various electronic devices for industrial application. Recently, fatigue free properties against the polarization switching have been found in $SrBi_2Ta_2O_9$ and $Bi_{3.25}La_{0.75}Ti_3O_{12}$flims as the materials of ferroelectric random access memory with platinum electrode (5,6). More ever some numbers of this family are potential candidate for piezoelectric applications at high temperature up to $400^{O}C$ because of their high curie temperature (7,8). Bismuth titanates are compounds of great technological interest because of their application as ferroelectric memories (9) and high temperature piezoelectric materials.(10,11).the present work we aim to determine the crystalline structure of the $Ca_2Bi_3 LaTi_5O_{18}$ compound and to the measure of their dielectric and electronic properties.

EXPERIMENTAL

Polycrystalline Sample of $Ca_2Bi_3 LaTi_5O_{18}$ were prepared by a high temperature solid state reaction technique using pure carbonates and oxides, AR grade (>99.9 % pure) chemical ($CaCO_3$, La_2O_3 , Bi_2O_3 and TiO_2) in suitable stoichiometric ratio . The constituent compounds were mixed thoroughly using agate mortar and pestal for 1 h. The mixed material was then calcined in a platinum crucible at 1000^oC for 5 h. Requisite amount (5%) of polyvinyl alcohol was added as a binder before making it to final stage of pellets.The process of grinding and calcinations was repeated till a homogeneous fine powder of the desired compound was obtained .The calcined fine powder was pressed in to a cylindrical pellet using a hydraulic press at pressure of 3 tons/cm^2 to form pellets of diameter 1.31 cm^2 and thickness 0.21cm .The pellet were sintered in air atmospheric at 1000^oC for 10 h .The formation of single phase compound was checked by XRD.

The X-ray diffraction of the compound were recorded at room temperature using X –ray diffractometer (Rigaku , minifiex) with Cu K α radiation ($\lambda = 1.54$ A^O) in wide range of Bragg angle 2θ ($20^o < 2\theta < 90^o$) at a scanning rate of 0.02 ^{o} / sec. The XRD pattern was indexed using a program called TEROR from the CRYSFIRE. To measure the electrical properties of compounds, air drying silver paint was applied on both the large aces of the samples to serve as electrodes. Electrical and dielectric studies as Dielectric constant (ε) , tangent loss (δ) and conductivity (σ) were measured as a function of frequency (42 Hz - 5 MHz) at different temperatures (27-450 ^OC.) using a HIOKI- LCR Bridge (model no. 3532 -50) Hi-Tester, Japan.

RESULT AND DISCUSSION

X-Ray study

The XRD pattern of $Ca_2Bi_3 LaTi_5O_{18}$ ceramic obtained using Cu Kα radiation as shown in fig (1). A good agreement between the observed and calculated interspacing (d_{OBS} and d_{CAL}) is seen .The sharp and single diffraction peak of each compound which are quite different from those of ingredient oxide and carbonate confirm the formation of single phase compound. All the peaks of XRD pattern were indexed and cell parameter were determine with a standard computer programmed crysfire using these experimental (d) value in different crystal structure and unit cell configuration .Unit cell of tetragonal system was selected. Using the value of 12 strong peaks of $Ca_2Bi_3LaTi_5O_{18}$ ceramic as shown in Table (1).

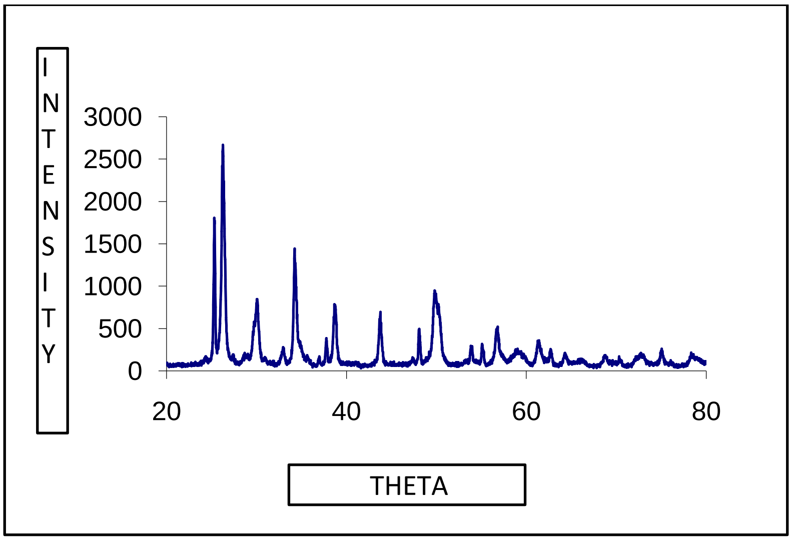

Fig (1) X- ray powder diffraction pattern of $Ca_2Bi_3LaTi_5O_{18}$ at room temperature

Table (1):-Indexed powder diffraction data of $Ca_2Bi_3LaTi_5O_{18}$ ceramic

hkl	d (observed)	d (calculated)	$Intensity_{100}$
411	3.5092	3.9627	67
002	2.9627	2.9646	29
112	2.7090	2.7113	10
402	2.6153	2.6123	51
910	2.3191	2.3190	27
712	2.0661	2.0657	26
902	1.8902	1.8912	16
912	1.8261	1.8264	34
532	1.6973	1.6973	11
1102	1.6627	1.6634	9
1112	1.6196	1.6187	20
1131	1.4772	1.4772	6

Dielectric Studies

Figure 2(a) and (b) show the variation of dielectric constant (ε) and tangent loss (tan δ) of the sample as a function of frequency at room temperature. A decrease in dielectric constant (ε) with frequency is observed which a typical characteristic of normal dielectrics.

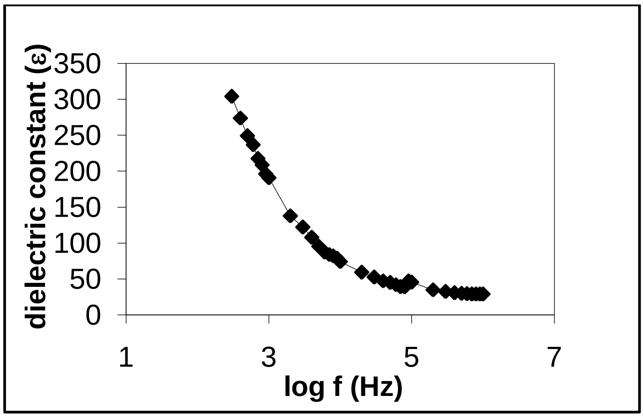

Fig. 2(a): Variation of dielectric constant (ϵ) of $Ca_2Bi_3LaTi_5O_{18}$ ceramic as a function of Frequency at room temperature

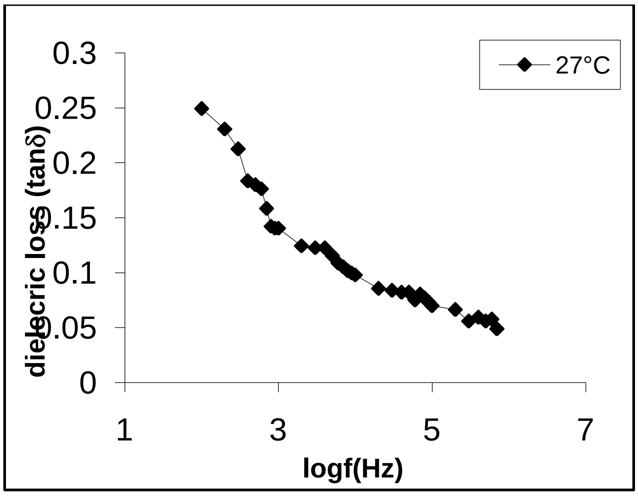

Fig. 2 (b) Variation of tangent loss (tan δ) of $Ca_2Bi_3LaTi_5O_{18}$ ceramic as a function of frequency at room temperature

The higher value of dielectric constant (ε) at lower frequency is due to the presence of various types of polarizations (i. e. electronic, dipolar, interfacial, orientational etc.) in compound at room temperature. As the frequency is increased, some of the polarization becomes ineffective, the electronic polarization dominates and thus the value of ϵ decreases. [12] The loss tangent (tanδ) also decreases with increasing frequency. This trend could be due to parallel conduction (tan δ) = 1/ ω C R, where ω is angular frequency, c is the capacitance and R is the resistance) probably due to connected porosity. It is observed that at higher frequency these parameters become almost frequency independent.

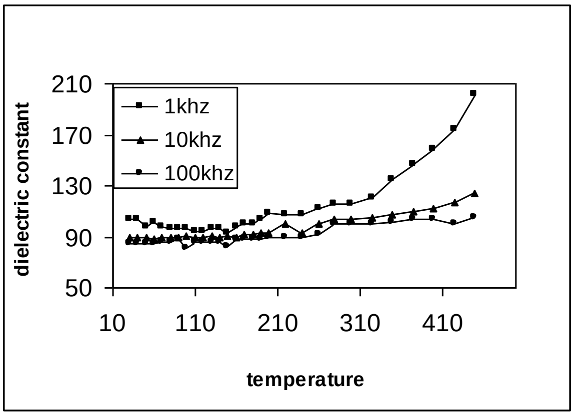

Fig .(3a): Variation of dielectric constant (ϵ) of $Ca_2Bi_3LaTi_5O_{18}$ Ceramic as a function of temperature at different frequencies

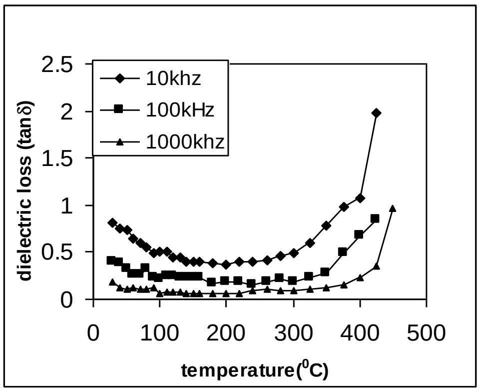

Fig.3(b): Variation of dielectric loss of Ca_2Bi_3 La Ti $_5O_{18}$ Ceramic as a function of temperature at different frequency

Figure (3a) **.and (b) shows** The variation of dielectric constant (ε) and dielectric loss (tan) with temperature at different frequency for **$Ca_2Bi_3LaTi_5O_{18}$** ceramic For Ca_2Bi_3 $LaTi_5O_{18}$, no dielectric anomaly was found and temperature dependence plots of the dielectric constant were rather flat within the investigated temperature range. Curie temperature above $600^{O}C$ are usually found in Ca- Contaning members , such as $CaBi_2Ta_9O_9$, $CaBi_4Ti_4O_{15}$ and $CaBi_8Ti_7O_{27}$(12,13,14).However , from the temperature dependence plots in fig(3a), It is difficult to say whether Ca_2Bi_3 $LaTi_5O_{18}$ is ferroelectric.

Conductivity analysis

Figure 4 shows the variation of ac conductivity as a function of frequency at different temperature (RT to 400^0C) respectively for Ca_2Bi_3 $LaTi_5O_{18}$ ceramic.

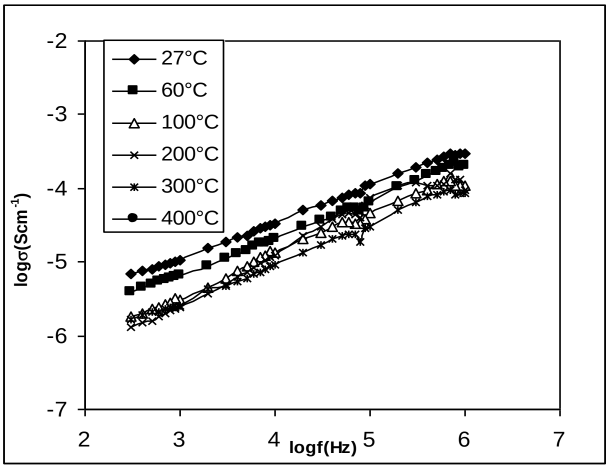

Fig. 4.(a): Variation of ac conductivity (σ_{ac}) by ($\sigma_{(\omega)} = \omega\varepsilon_0\varepsilon'\tan\delta$) of $Ca_2Bi_3LaTi_5O_{18}$ Ceramic as a function of frequency at different temperatures

It is observed in figure 4 that conductivity increases with increasing frequency and temperature (using by relation $\sigma(\omega) = \omega\varepsilon_0\varepsilon'\tan\delta$). The nature of conductivity spectrum shows some typical feature: i.e. There is a very slight dispersion at lower temperature while pronounced dispersion has been observed throughout the frequency side but in lower frequency region (i.e.100Hz - 10kHz).The frequency dependent conductivity in suppose to obey Janscher universal power lawonductivity depends on frequency according to the “Universal dynamic response” or ionic conductor.

CONCLUSION

TB structure compounds **$Ca_2Bi_3LaTi_5O_{18}$** were successfully prepared with a solid state reaction process. It is concluded that **$Ca_2Bi_3LaTi_5O_{18}$** has been tetragonal structure at room temperature. The dielectric constant of this ceramic was temperature stable within the investigated temperature. Curie temperature of **$Ca_2Bi_3LaTi_5O_{18}$** should be higher than 800^{O}C. **$Ca_2Bi_3LaTi_5O_{18}$** has low dielectric constant, low loss, and low conductivity.

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REFERENCES

1. Keitsiro A ; J. Phys. Soc.Jpn. 41 (1976) 880.
2. Singh K.S. , Sati R. and Choudhary R.N.P. ; J.mater.sci.lett. 11 (1992) 788.
3. Hawng Y.K. and KwonY.U.;Mater.Res Bull.32 (1997) 1495.

4. Suman C.K., Prasad K. and Choudhary R.N.P.; J. Mater. Chem. Phys. 82 (2003) 140.
5. Araijo C.A., Cuchlaro J.D., Mecmillan L.D., Scou M.C. and Scott. J.F.; Nature 374 (1995)627.
6. Park B.H., Kang B.S, Bu. S. D.,Noh T.W., Lee J.and Jo. W.;Nature 401 (2004) 682.
7. Tuner R.C.,Fuierer P.A., Newnham R.M. and Shrout T. R. ; Appl.Acoust 41(1994)299.
8. Damjanovic D.; Curr .Opm . Solid State Mater.Sci.3 (1998) 469.
9. Desu,S.B.,Joshi , P.C. Zhang, X.and Ryu. S. O. Appl. Phys. Lett. 71(1997)1041.
10. Tuner,R.C.,Fuierer,P.A., Newnham,R.E.and Srout,T.R.;Appl.Acoustics, 41(1994)299.
11. Villegans,M.,Moure,C.,Duran, P. And Fernandez,J.F. ;Bol.Soc.Esp.Cream.Vidr., 36(1997)179.
12. Shimakawa,Y.,Kubo,Y.,Nakagawa,Y.GotoS.,Kamiyama,Asano,H.,and Izumi,F.Phys.Rev B 61(2000) 6559.
13. Hou R.Z.and X.M.Chen J. Matter.Ceram. Soc.(in press).
14. Maalal,R. ,Manier M. and Mercurie; J.Eur.Ceram.Soc.15(1995)1135.