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Research Article

Dielectric Properties of Calcium Borophosphate Glasses Doped With Chromium Ion (TMI)

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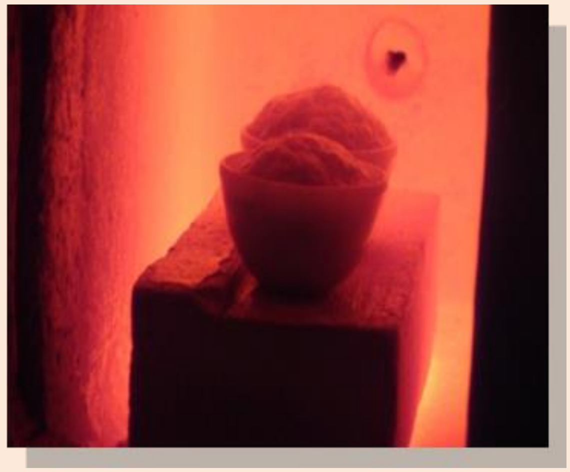
Abstract
Glass samples of a mixed alkali borophosphate glasses doped with TMI have been prepared by the melt quenching technique. The dielectric properties, viz. dielectric constant, loss tan δ and a.c. conductivity over wide ranges and dielectric breakdown strength of mixed alkali doped borophosphate glasses are studied. The analysis of these results, with the aid of the data on optical absorption, IR spectra and elastic properties, indicate that the insulating and mechanical strength of the glasses is high. The glassy state of the samples is characterized using X-ray diffraction. Glass-transition temperatures are measured using differential scanning calorimeter (DSC).



Keywords: Dielectric Properties, Alkali Borate Glasses, Chromium oxide, Nickel oxide, Cobalt Oxide

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Introduction

The study of dielectric properties such as dielectric constant, loss tan δ and a.c. conductivity sac over a wide range of frequency and temperature of the glass materials not only helps in assessing the insulating character and understanding the conduction phenomenon but also gives information on the structural aspects of the glasses to a substantial extent [1-2]. The transition metal ions are very interesting ions to probe in the glass networks because their outer d-electron orbital functions have rather broad radial distributions and their responses to surrounding actions are very sensitive; as a result these ions influence the physical properties of the glasses to a substantial extent. Three series of elements are formed by filling the 3d, 4d and 5d shells of electrons. Together these comprise the d-block elements. They are often called ‘transition elements’ because their position in the periodic table is between s block and p-block elements. Their properties are transitional between the highly reactive metallic elements of the s-block, which typically form ionic compounds and the elements of p-block, which are largely covalent. In s- and p-blocks, electrons are added to the outer shell of the atom where as in d-block they are added to the penultimate shell. Typically transition elements have an incompletely filled d level. In the d-block elements, the penultimate shell of electrons is expanding. Thus they have many physical and chemical properties in common and hence all the transition elements are metals. They are therefore good conductors of electricity and heat have a metallic luster and are hard, strong and ductile. They also form alloys with other metals, [3-5] one of the most striking features of the transition metal elements is that they usually exist in several different oxidation states

Table 1 Different oxidation states of Transition metal elements

Element	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
Electronic Structure	d^1s^2	d^2s^2	d^3s^2	d^5s^1	d^5s^2	d^6s^2	d^7s^2	d^8s^2	$d^{10}s^1$	$d^{10}s^2$

Investigations on dielectric properties of transition metal ion doped glasses help to throw some light on insulating/conducting character of the material. Investigations on the spectroscopic properties such as such as optical absorption and electron spin resonance can be used as probes to identify the valence states and the environments of the dopant ions in the host glass network. Infrared and Raman spectral studies throw light on the structural aspects of the glasses. [6] The study of dielectric properties, such as dielectric constant, dielectric loss tangent and dielectric loss over a wide range of frequency and constant temperature. The current investigation is aimed at an understanding the structural aspects of xLi_2O-(30-x)Na_2O-15CaO(45-y/2)B_2O_3(45 -y/2)P2O510Al2O3-yCr glasses by studying their dielectric properties.

Experimental

Materials and Reagents

Glass Preparation

To study the effect of mixed alkali effect (MAE) and transition metal ion (TMI). The composition of the prepared glass sample was selected via the criteria that they have the following molecular formula

$$xLi_2O\text{-}(30\text{-}x)Na_2O\text{-}15CaO\text{-}(45\text{-}y/2)B_2O_3\text{-}(45\text{-}y/2)P_2O_5\text{-}10Al_2O_3\text{-}yCr$$

1. $20Li_2O$-$10Na_2O$-15CaO-22.25B_2O_3-22.25P_2O_5-10Al_2O_3-0.5Cr
2. $20Li_2O$-$10Na_2O$-15CaO-22 B_2O_3-22P_2O_5-10Al_2O_3-1.0Cr
3. $20Li_2O$-$10Na_2O$-15CaO-21.75B_2O_3-21.75P_2O_5-10Al_2O_3-1.5Cr
4. $20Li_2O$-$10Na_2O$-15CaO-21.50B_2O_3-21.50P_2O_5-10Al_2O_3-2.0Cr
   (x=10, 20. y=0.5, 1.0, 1.5, 2.0)

Chemically pure i.e. analytical grade chemicals are used. Glass was prepared by the conventional melt-quench technique. These chemicals were thoroughly mixed and ground for 30-40 min in a mortar pastel and then the charge (30g) was melted in alumina crucible using muffle furnace for 4-5 hrs at temperature ranging from 800-1100 ºC depending on composition. When the melt was thoroughly homogenized and attained desirable viscosity it was poured either onto metal plate or into graphite moulds. The prepared glass was the annealed at appropriate temperatures (between300 and 400 °C) for 2 hrs and stored in desiccators prior to evaluation.

Results and Discussion

The dielectric properties measured as a function of frequency by using L.C.R.-Q meter in frequency range 100Hz to 5MHz with accuracy 0.001Hz, measurement capacitor and dissipation factor tan δ with varying frequency. Using theses value to calculate dielectric constant (ε'), dielectric loss (ε'') and dielectric loss tangent (tan δ) using following relation [6].

$$\varepsilon' = \frac{C_p d}{\varepsilon_0 A} \qquad (1)$$

$$\varepsilon'' = \varepsilon' \tan\delta \qquad (2)$$

Where d is thickness of glass, A area of glass and ε_0 permittivity of free space, The dielectric properties of glasses arises ionic motion. **Figure 1** shows the frequency dependence of dielectric constant with room temperature of the studied samples. From **Figure 2** all samples show the same behavior is observed. Dielectric constant initially decreases rapidly with increases in frequency up to a certain frequency and beyond this frequency that remains fairly constant the similar behavior is reported by investigations [7]. At certain frequency dielectric constant increases with increases in Cr ion. Dielectric properties are governed by conductions mechanism in glasses at low frequency the dielectric constant is high this behavior can explained on the basis of polarization process.

The study of dielectric properties, such as dielectric constant, dielectric loss tangent and dielectric loss over a wide range of frequency and constant temperature are made. The variation of dielectric loss is studied at room temperature as an applied frequency in the range 100Hz to 5MHz. The figure of dielectric loss with log of frequency is shown in **Figure 3**, it can be seen that dielectric loss in each glass are with same behavior. Figure 3 shows the dielectric loss tangent with frequency of all samples. The dielectric loss tangent decreases with increase in frequency similar behavior is reported by investigations of glass samples. [8, 9]

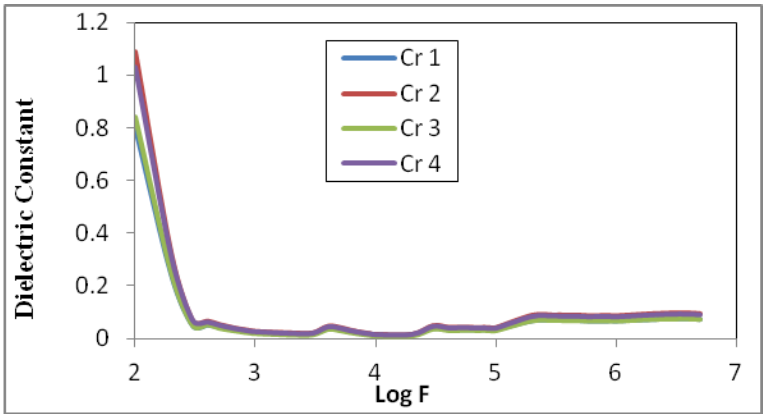

Figure 1 Variation of dielectric constant with different frequencies at constant temperature of glass

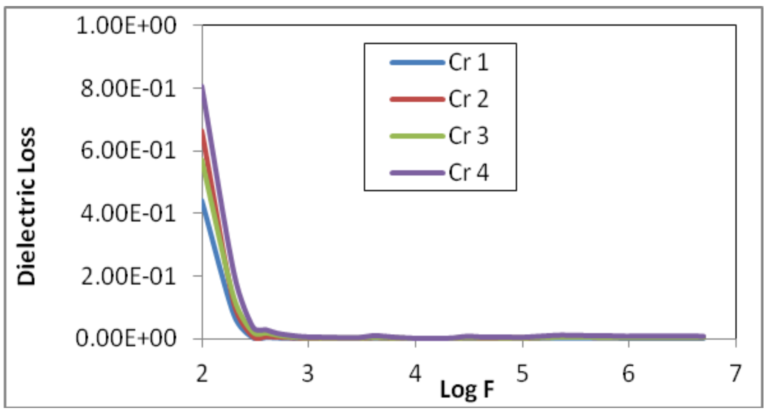

Figure 2 A comparison plot of variation of dielectric loss at room temperature with log f *i.e.* frequency

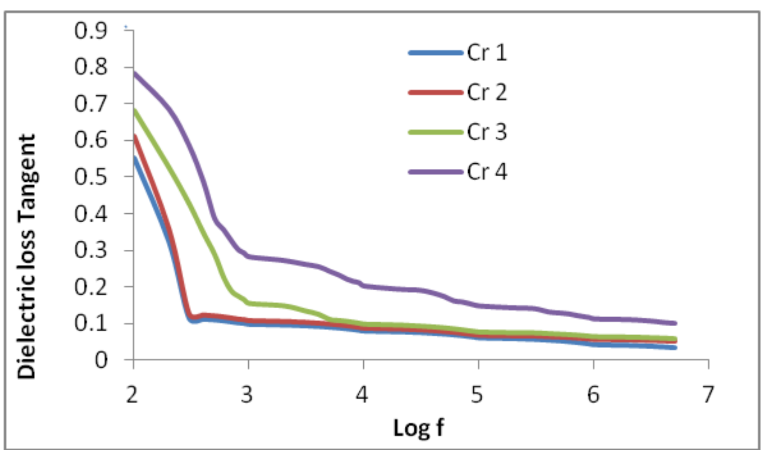

Figure 3 A comparison plot of variation of dielectric loss tan δ at room temperature with log f *i.e.* frequency log

Conclusions

Glass samples of a mixed alkali borophosphate glasses doped with TMI have been prepared by the melt quenching method. The glass transition temperatures have been determined to be sure that the applied temperature still under Tg (in the amorphous range). The dielectric properties of the glass samples have been studied for over a wide range of frequency (42 Hz to 5M Hz) and temperature (303K to 468k). The dielectric constant, dielectric loss both are decreases with increase in applied frequency. The dielectric properties as a function of frequency and temperature have been investigated.

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