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DIELECTRIC PROPERTIES OF LI_2O-B_2O_3-AL_2O_3 GLASS SYSTEM

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ABSTRACT

The ion conducting glasses $35Li_2O$: (65-X) B_2O_3: X Al_2O_3 have been prepared with various compositions (where X = 0,5,10,15,20) by using melt quenching technique. The electrical conductivity and dielectric parameters of glasses were analyzed by LCR impedance analyzed in the frequency range (100Hz-1MHz) at different temperatures (323K-623K). It has been observed that the electrical conductivity of glass increases with increase in mole percent of aluminum oxide. The dielectric constants and dielectric modulus are reported and described dielectric relaxation mechanism.

KEYWORDS: Electrical Conductivity, Dielectric Constant, Dielectric Relaxation Mechanism

INTRODUCTION

Electrical properties of glasses have been studied extensively for a number of years due to their use in solid state devices and batteries. The introduction of metal oxide or alkali ions into glass exhibit high conductivity as like semiconductor, and can be used as solid electrolytes high energy density batteries [1]. In the literature, it has been reported that Bi_2O_3 occupy both network forming and network modifier. Therefore, physical properties, and dielectric properties of these glasses exhibit discontinuous changes due to role of structural cations changes [2-3]. The dielectric properties of lithium borate doped with nickel and lead have been studied by Seema Dalal et al. It is reported that it shows significant changes in the dielectric properties of glasses with change in composition and temperature [4-5]. The electrical conductivity of lithium borate glasses has been investigated and special attention has been devoted to describing dielectric relaxation on the basis of dielectric parameters [6-9]. The aim of the present work is to study the dielectric properties of lithium alumna borate glasses.

PREPARATION OF MATERIAL AND EXPERIMENTAL

The starting material, lithium carbonate, boric acid and aluminum oxide of AR grade purchased from Merc laboratory were used. The aluminum lithium borate glasses of composition were prepared by melting quenching technique. A homogeneous mixture of different composition has melted in a ceramic crucible by keeping it into Muffle furnace equipped with digital temperature controller. The materials were melted at1150^0C for two hours with heating rate 30^0C/min and molted material is quenched in aluminum molds at room temperature (27^0C). The samples were annealed at 200^0C for 2Hrs in hot air oven. The sample was in circular disc shapes and then polished by using sandpaper. These samples were stored in desiccators and taken only at the time of measurement. The structure of the sample was confirmed by the measurements of XRD using XPERT PRO DIFFRACTOMETER. The capacitance (Cp) and conductance (G) of all samples were measured from LCR impedance analyzed in the frequency range 10Hz-1MHz at a temperature range 323K-623K and determined dielectric parameters

RESULT AND DISCUSSIONS

AC Conductivity

The frequency dependence of AC conductivity of all investigated samples (LB5A) at different temperature is depicted in the Figure. 1. and Figure.2. . All the curve obey Jonscher's law [10]. . At low frequency conductivity shows a flat response which corresponds to Dec part of the conductivity and at higher frequency conductivity show dispersion.In this series value of the s component varies from 0 to 1and values of s decreases with an increase in the temperature, it may be attributed due to conduction and dielectric loss. The conductivity of glass samples increases with introducing Al_2O_3 in Li_2O:B_2O_3 glass network. Addition of Li_2O into B_2O_3 base glass form BO_4^- tetrahedra where Li^+ is weakly bonded. The Li^+ conduction is consequence of Li^+ hopping between BO_4^- tetrahedra. When Al_2O_3 is added as a minor component in borate glass, it can act as former in the unit of AlO_4^- tetrahedra. In this case Li^+ conduction will occur by hopping of Li^+ ions between non bridging in AlO_4^- tetrahedra.The distance of Al-O ions are more loosely bound to AlO_4 and can migrate easily. Therefore an enhancement in conductivity at a constant Li2O concentration can be attributed to an increase in Li^+ ion mobility by substitution of Al_2O_3 into B_2O_3. The improvement in conductivity was attributed to the mixed former effect between Al_2O_3 and B_2O_3 [11].

The high conductivity was observed in LB_5A sample, $6.57x10^{-7}$S/cm at temperature 323K and $3.013x10^{-6}$S/cm at frequency 1 KHz. The relation between log σ and 1/T shows the linear relationship and it indicates conductivity increases with increase in temperature, enhancement in conductivity related to increasing mobility of charge carriers at the high temperature region in which Li^+ ion contributes to conduction [12].

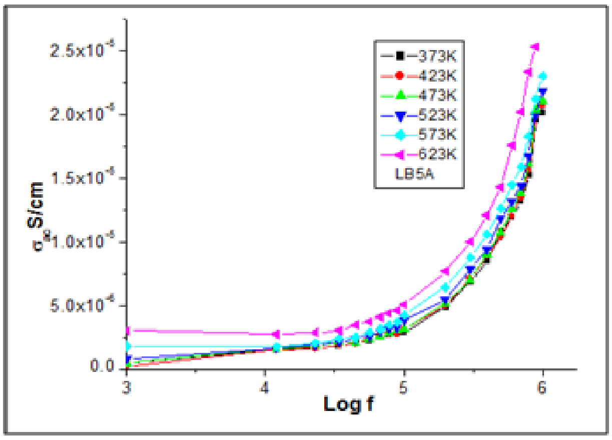

Figure 1: Conductivity of Glass at Different Temp

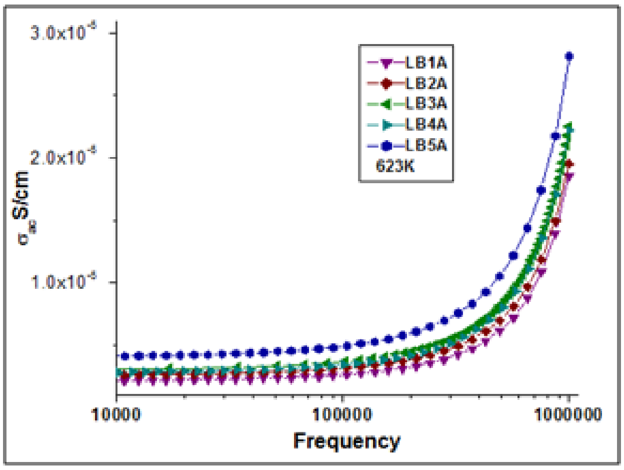

Figure 2:Conductivity of Glasses with Variation of Frequency

Dielectric Constants (ε', ε")

The dielectric response of these classes has been examined by measuring both real and imaginary parts of the dielectric constant (ε', ε") and dielectric modulus (M' and M"). The variation of dielectric constant (ε') and imaginary dielectric constant (ε") with the frequency of these glass samples at different temperature are shown in Figure.3 & Figure.4. It is observed that dielectric constant (ε') and imaginary dielectric constant (ε") decreases with increase in frequency and increases with increase in temperature. The abrupt decrease in ε' and ε" in the low frequency region, which may be due to interfacial effect such as space charge polarization and also shows that on the low frequency side dielectric constant has a power law dependence [13]**.** The increase in dielectric constant (ε') is associated with a decrease in bond energy. The electrode polarization is significant at high temperature and masks the bulk response of glass in the low frequency regime. When the temperature increases, the dielectric dispersion shifts towards higher frequencies. All the plots merge in the high frequency regime (above 10 KHz) this electrode independent behavior at high frequency is attributed to the intrinsic dielectric response of the glasses. The imaginary dielectric constant (ε") at higher frequency are much lower than those occurring at low frequency at a specific temperature (above 473K). This kind of dependence of dielectric loss (ε") upon frequency is associated with loss of conduction.

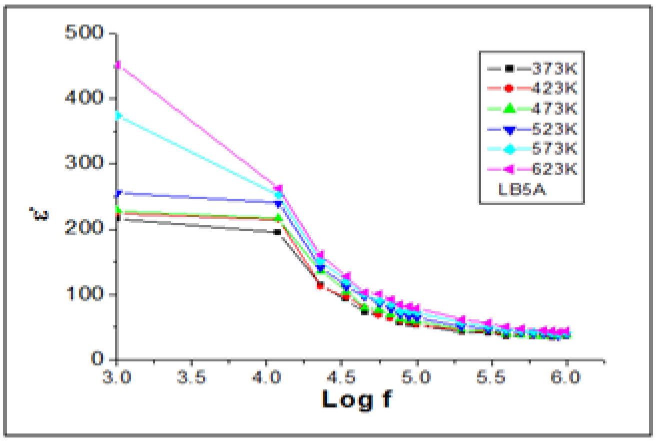

Figure 3: Variation of Dielectric Constant

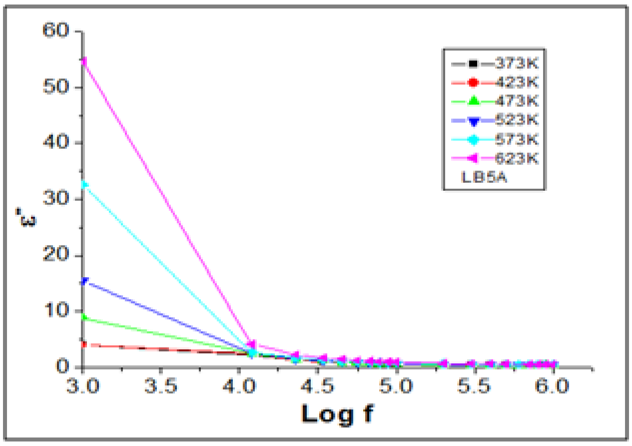

Figure 4: Variation of Imaginary Dielectric Constant

Dielectric Modulus (M' and M'')

It is observed that at low frequencies M` approaches to 0 at all temperatures under study suggesting the suppression of the electrode polarization. The dielectric modulus M` reaches maximum values corresponding to M $_{(}= (\varepsilon_{\infty})^{-1}$ due to the relaxation process. The imaginary part of dielectric modular M" is indicative laws under the electric field. The M" peak shift to higher frequencies which increase in temperature and also observed that magnitude of M" decreases with increase in temperature which is attributed with losses by conductions. The nature of the graph is found to be same for all investigated samples. It is observed from scaling data (Figure.6) that the spectra of M" at different temperature do not merge into a single curve. This indicates the relaxation process is temperature dependent.

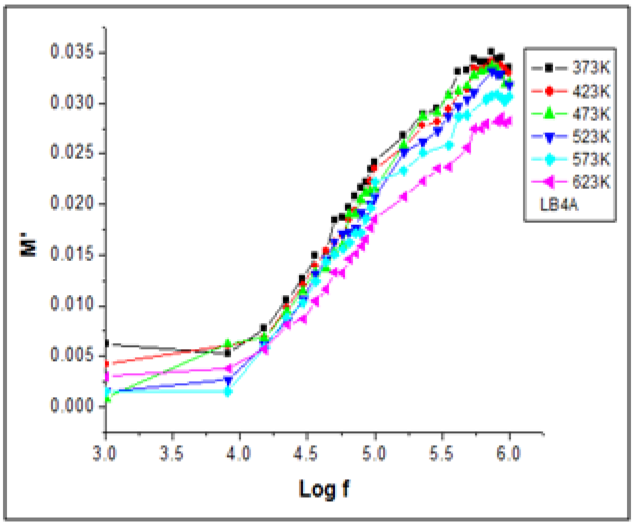

Figure 5: Variability of M', with temperature

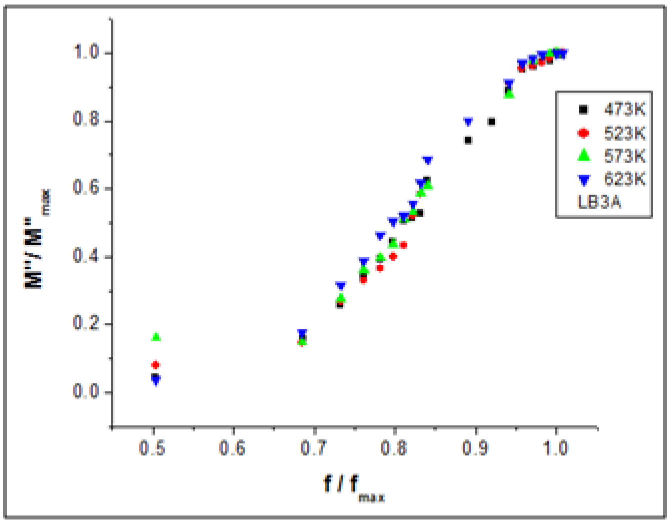

Figure 6: Scaling of data with M"

CONCLUSIONS

The effect of compositional changes by addition of second former Al_2O_3 into Li_2O:B_2O_3 glass on electrical conductivity and dielectric properties have been investigated. It was observed that DC conductivity decreases with the addition of Al2O3, which is attributed to structural modification and formation of Al-O-B linkage, resulting in hindrance to the migration of Li+ ions. The maximum conductivity was observed for Al_2O_3 free glass and it indicates that the mixed former effect does not exist in these compositions. The frequency and temperature dependence of the dielectric properties of Li2O:B2O3:Al2O3 glasses have been investigated in the frequency range 10Hz – 1MHz. The dielectric relaxation, peak was observed in the frequency dependent dielectric loss plots, whose magnitude was composition dependent. The dielectric constant (ε', ε'') increases with increase in temperature. The electrical properties were investigated and found obeying Jonscher's law and observed that the value of the power exponent (s) changes in composition.

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