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Original Article

STUDY OF PHYSICAL PROPERTIES OF LITHIUMBOROPHOSPHATE GLASSES

M.D.Thombare

Department of physics, Jagdamba Mahavidyalaya, Achalpur City, India
Email of the corresponding author: meghaveer29386@gmail.com

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Abstract

Glass samples of the Lithium borophosphate 42.5Li2O- (57.5-x) B2O3-xP2O5, x=0-57.5 in the step of 5.75, were prepared by conventional melt-quench technique. The density and molar volume of some phosphate glasses were determined in order to study their structure. Molar volume increases linearly as mole % of P2O5 increases The physical parameters like Oxygen packing density, Ionic concentration, Inter ionic distance, Polaron radius, Dielectric constant, Reflection loss, Band energy gap, Refractive index, Molar refractivity, Molar polarizability, Metallization, Electronic polarizability and Conductivity are studied. Oxygen packing density is increasing with increasing the concentration of B2O3. Ionic concentration decreases, where as inter ionic distance, polaron radius, dielectric constant & reflection loss increases with increases the mole % of P2O5, respectively. Band energy gap and refractive index are exactly apposite to each other. Band gap were in the range from 1.22-1.64 eV.

Dielectric constant, Refractive index; Molar refractivity, Molar polarizability varies alike with increasing mole % of P2O5 respectively The maximum of these parameters are found to be at B2O3=40.25 mole % and B2O3=17.25 mole %. The increase in electronic polarizability (α_e) & density (ρ) is due to higher molecular weight of P2O5 compared to that of B2O3. Dielectric constant and metallization are exactly apposite to each other. Metallization criterion is within the range of 0.1746-0.1993. The study of electronic polarizability and that of oxygen packing density shows a very excellent co-ordination in them; for 87.621 cm³/mole and 82.322 cm³/mole values of oxygen packing densities the maximum value of electronic polarizability are 0.0339x10⁻²⁴ mole/cm³ and 0.0327x10⁻²⁴ mole/cm³ at 17.25 mole % of P2O5 and at 40.25 mole % of P2O5 at constant 42.5 mole % of Li2O. The trend of Molar refractivity & the Molar polarizability, Metallization & Polarizability per unit volume, Reflection loss & electronic polarizability , and Mole % of P2O5 & Molar volume is liner. Their slopes, intercepts, and R² values are also calculated. The densities and refractive indices of these glasses were found to be in the range 2.0-2.67 g/cm³ and 1.644–1.731 respectively. Where as maximum conductivity is 3.39x10⁻⁷ at 42.5 mole % of P2O5.

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Keywords: Density, Molar volume, Oxygen packing density, Dielectric constant, Refractive index, Molar refractivity, Molar polarizability; Metallization, Electronic polarizability, Molar refractivity, Molar polarizability, Polarizability per unit volume, glass composition, mixed glass former effect.

1. INTRODUCTION

Oxide glasses are classically described as a network composed by building entities such as SiO2, B2O3, P2O5, TeO2 and modifiers such as alkaline oxides: Li2O, Na2O, K2O, Ag2O or alkaline earth oxides: CaO, MgO, SrO [1, 2]. In such glasses, the oxygen from the metal oxide becomes part of the covalent glass network, creating new structural units. The cations of the modifier oxide are generally present in the neighborhood of the non-bridging oxygen (NBO) in the glass structure. The extent of the network modification obviously depends on the concentration of the modifier oxide present in the glass. A glass network affects various physical properties such as density, molar volume, glass transition temperature, polarization, etc.

The mixed glass former (MGF) and mixed glass former effect (MGFE) is defined as a nonlinear and non-additive change in the ionic conductivity with changing glass former composition at constant modifier composition. Lithium borophosphate glasses are characterized by an interesting structure on account of the presence of two glass-forming components.

Density of solids is mostly the simplest physical property that can be measured. However, it would be a highly informative property if the structure of material could be
well defined. Density can be used for finding out the structure of different types of glasses. The density of the glass is additive and can thus be calculated on the basis of the glass composition [3,4,5,6]. Several formulas have been derived to correlate the glass density to the glass composition [7, 8, 9, 10, 11]. The glass structure can be explained in terms of molar volume rather than density, as the former deals the spatial distribution of the ions forming that structure. The change in the molar volume with the molar composition of an oxide indicates the preceding structural changes through a formation or modification process in the glass network [12, 13].

The density, molar volume and packing fraction [14, 15, 16] could be directly related to the short range structure of alkali oxide modified borate glasses. The densities prove changes in both short range order and co-ordination as the modification, while the molar volume is sensible in terms of size and packing. The packing of the borate based glasses with ions having volume smaller than the oxygen is considered to be covalent, controlled by oxygen covalent network, and heavily dependent on the glass former. Physical properties such as refractive index, dielectric constant are well known parameters. Optical power loss caused by a refractive-index difference, across propagation media, interfaces encountered by an electromagnetic wave. At an interface of two media with different refractive indices, i.e., with a refractive-index contrast, the loss that occurs because, a fraction of the incident optical power is reflected back toward the light source. At normal incidence, i.e., perpendicular incidence, the fraction of reflected power is expressed by the relation \[ R = \frac{n_1 - n_2}{n_1 + n_2} \] where \( R \) is the refraction loss [17]. For an air-glass interface \( n_2 = 1 \)

The molar refractivity \[ R_i \] \[ \text{is the refraction loss} \] [17]. For an air-glass interface \( n_2 = 1 \) \[ R = \frac{W_a \rho_b - W_b \rho_a}{W_a - W_b} \]

Where \( W_a \) is the weight of glass sample in air, \( W_b \) is the weight of glass sample in buoyant liquid, \( W_a - W_b \) is the buoyancy, \( \rho_b \) is density of buoyant. All the measurements were made using a digital balance.

2.2. DENSITY MEASUREMENTS
Density of all glass samples are measured at room temperature using toluene as the immersion liquid. Density is generally measured by the fluid displacement method depending on Archimedes principle. According the Archimedes principle, the buoyancy equals the weight of the displaced fluid. Archimedes Principle using toluene as the buoyant medium evaluated the density of the glass samples. The density was obtained by employing the relation:

\[ \rho = \frac{W_a \rho_b}{W_a - W_b} \]

2.3. MOLAR WEIGHT CALCULATIONS

**Step I – Calculation of wt/mol**

Weight/mole = molar weight of the constituents * mol% / 100

**Step II – Calculation of molecular weight of sample (M)**
The molecular weight of the sample (M) is nothing but the summations of Wt/mol of its constituents.

**Step III – Calculation of Molar volume (V_m)**
Using molecular weight and density calculated as from above, the molar volume of the glass samples can be calculated from following expression:

\[ V_m = \frac{M}{\rho} \]

Here, \( V_m \) is molar volume, \( \rho \) is the density of the sample and \( M \) is the molecular weight of the sample.

2.4. OXYGEN PACKING DENSITY (O)
The oxygen packing density of the glass samples were calculated using the following relation [24]

\[ O = \frac{\rho M}{n} \]

where \( \rho \), the density of desired glass samples, \( M \), molecular weight of the sample and \( n \), the number of oxygen atoms in the composition.
2.5 THE IONIC CONCENTRATIONS (N)
The ionic concentrations of the glass samples are determined using the following relation,
\[ N = \frac{6.023 \times 10^{23} \text{mol}^{-1} \times \text{mol\% of cation} \times \text{valency of cation}}{V_m} \]
2.6 INTER-IONIC DISTANCE (R)
Inter ionic distance (R) of the glass samples is given as,
\[ R = \frac{1}{N} \]
Where \( N \) = ionic concentrations.

Average molecular weight, Density, Molar volume, Oxygen packing density, Ionic concentrations and Inter-ionic distance, Parameters values of lithium borophosphate glasses are depicted in Table 2.2.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Name of samples</th>
<th>Composition in mol %</th>
<th>( \sigma ) (SCm(^{-1}))</th>
<th>( T_g ) °C</th>
<th>( E_a ) (eV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>LBP 1</td>
<td>42.5 57.5 0</td>
<td>4.27 x 10(^{-5})</td>
<td>463.1</td>
<td>0.755</td>
</tr>
<tr>
<td>2</td>
<td>LBP 2</td>
<td>42.5 51.75 5.75</td>
<td>7.24 x 10(^{-5})</td>
<td>465.7</td>
<td>0.75</td>
</tr>
<tr>
<td>3</td>
<td>LBP 3</td>
<td>42.5 46 11.5</td>
<td>7.59 x 10(^{-5})</td>
<td>473.7</td>
<td>0.72</td>
</tr>
<tr>
<td>4</td>
<td>LBP 4</td>
<td>42.5 40.25 17.25</td>
<td>1.91 x 10(^{-4})</td>
<td>517.2</td>
<td>0.58</td>
</tr>
<tr>
<td>5</td>
<td>LBP 5</td>
<td>42.5 34.5 23</td>
<td>8.51 x 10(^{-5})</td>
<td>408.0</td>
<td>0.66</td>
</tr>
<tr>
<td>6</td>
<td>LBP 6</td>
<td>42.5 28.75 28.75</td>
<td>7.59 x 10(^{-5})</td>
<td>414.8</td>
<td>0.64</td>
</tr>
<tr>
<td>7</td>
<td>LBP 7</td>
<td>42.5 23 34.5</td>
<td>1.35 x 10(^{-5})</td>
<td>400.8</td>
<td>0.67</td>
</tr>
<tr>
<td>8</td>
<td>LBP 8</td>
<td>42.5 17.25 40.25</td>
<td>3.39 x 10(^{-4})</td>
<td>482.2</td>
<td>0.61</td>
</tr>
<tr>
<td>9</td>
<td>LBP 9</td>
<td>42.5 11.5 46</td>
<td>3.16 x 10(^{-5})</td>
<td>514.0</td>
<td>0.82</td>
</tr>
<tr>
<td>10</td>
<td>LBP 10</td>
<td>42.5 5.75 51.75</td>
<td>3.02 x 10(^{-5})</td>
<td>365.4</td>
<td>0.79</td>
</tr>
<tr>
<td>11</td>
<td>LBP 11</td>
<td>42.5 0 57.5</td>
<td>4.79 x 10(^{-5})</td>
<td>303.0</td>
<td>0.795</td>
</tr>
</tbody>
</table>

From Table 2.2 (Figures 2.1, 2.2, and 2.3) increasing the mol% of P2O5 at the cost of B2O3 by keeping modifier Li2O constant, the molar volume, inter ionic distance, polaron radius increasing; while oxygen packing density, ionic concentration decreases, which suggests the increased free space within the glass structure, [25, 26], it means that the glass structure becomes loosely packed [27]. The polaron comprises the electron plus its surrounding lattice deformation. (Polarons can also be formed from holes in the valence band.) Due to the increasing values of polaron radius the deformation extends over many lattice sites, and the lattice can be treated as a continuum.

Molar volume increases linearly as mol% of P2O5 increases gives the slope equal to 0.327, intersect at 23.12 molar volumes and R2 is equal to 0.999.

Transformation of BO3 triangle units to BO4 tetrahedral units can be expected to increase the network linkage of the glass which is reflected in the monotonically increasing density.

Figure 2.1. Variation of Ionic concentration, Molar volume with respective to mol% of P2O5.

Figure 2.2. Variation of Ionic concentration, Inter ionic distance with respective to mol% of P2O5.

Figure 2.3. Variation of Oxygen packing density, Molar volume with respective to mol% of P2O5.
Table 2.2 Average molecular weight, Density, Molar volume, Oxygen packing density Ionic concentrations and Inter-ionic distance for Li$_2$O-B$_2$O$_3$-P$_2$O$_5$ glass system.

<table>
<thead>
<tr>
<th>Name of Sample</th>
<th>Average molecular weight M (gm/mol)</th>
<th>Density $\rho$ (gm/cm$^3$)</th>
<th>Molar volume $V_m$ (cm$^3$/mol)</th>
<th>Oxygen packing density $O$ (cm$^3$/mol)</th>
<th>Ionic concentrations N (10$^{22}$/cm$^3$)</th>
<th>Inter-ionic distance $r_i$(Å)</th>
<th>Polaron radius $r_p$(Å)</th>
<th>E$_g$(eV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LBP 1</td>
<td>52.733</td>
<td>2.26</td>
<td>23.33</td>
<td>92.14</td>
<td>10.972</td>
<td>0.9056</td>
<td>0.328</td>
<td>1.51</td>
</tr>
<tr>
<td>LBP 2</td>
<td>56.889</td>
<td>2.27</td>
<td>25.06</td>
<td>90.377</td>
<td>10.213</td>
<td>0.9387</td>
<td>0.339</td>
<td>1.5</td>
</tr>
<tr>
<td>LBP 3</td>
<td>61.048</td>
<td>2.28</td>
<td>26.834</td>
<td>88.691</td>
<td>9.541</td>
<td>0.9712</td>
<td>0.351</td>
<td>1.44</td>
</tr>
<tr>
<td>LBP 4</td>
<td>65.207</td>
<td>2.29</td>
<td>28.474</td>
<td>87.621</td>
<td>8.898</td>
<td>1.0005</td>
<td>0.362</td>
<td>1.16</td>
</tr>
<tr>
<td>LBP 5</td>
<td>69.365</td>
<td>2.26</td>
<td>30.692</td>
<td>85.036</td>
<td>8.341</td>
<td>1.0387</td>
<td>0.376</td>
<td>1.32</td>
</tr>
<tr>
<td>LBP 6</td>
<td>73.524</td>
<td>2.25</td>
<td>32.677</td>
<td>83.390</td>
<td>7.833</td>
<td>1.0718</td>
<td>0.388</td>
<td>1.28</td>
</tr>
<tr>
<td>LBP 7</td>
<td>77.683</td>
<td>2.26</td>
<td>34.297</td>
<td>82.805</td>
<td>7.465</td>
<td>1.098</td>
<td>0.397</td>
<td>1.34</td>
</tr>
<tr>
<td>LBP 8</td>
<td>81.841</td>
<td>2.23</td>
<td>35.895</td>
<td>82.322</td>
<td>7.172</td>
<td>1.1201</td>
<td>0.413</td>
<td>1.22</td>
</tr>
<tr>
<td>LBP 9</td>
<td>86.000</td>
<td>2.24</td>
<td>38.393</td>
<td>79.962</td>
<td>6.667</td>
<td>1.1617</td>
<td>0.419</td>
<td>1.62</td>
</tr>
<tr>
<td>LBP 10</td>
<td>90.159</td>
<td>2.25</td>
<td>40.070</td>
<td>79.484</td>
<td>6.388</td>
<td>1.1869</td>
<td>0.429</td>
<td>1.58</td>
</tr>
<tr>
<td>LBP 11</td>
<td>94.317</td>
<td>2.24</td>
<td>42.106</td>
<td>68.279</td>
<td>6.079</td>
<td>1.2167</td>
<td>0.439</td>
<td>1.59</td>
</tr>
</tbody>
</table>

Table 2.3 Refractive index, Dielectric constant, Reflection loss, Molar refractivity, Electronic polarizability, Metallization, Molar polarizability and Polarizability per unit volume.

<table>
<thead>
<tr>
<th>Refractive index (n)</th>
<th>Dielectric constant (C)</th>
<th>Reflection loss R</th>
<th>Molar Refractivity R$_m$(cm$^3$)</th>
<th>Electronic polarizability ($\alpha_e$)</th>
<th>Metallization M</th>
<th>Molar polarizability $\alpha_m$</th>
<th>Polarizability per unit volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.667</td>
<td>13.446</td>
<td>0.326</td>
<td>18.798</td>
<td>0.0319</td>
<td>0.1942</td>
<td>7.460</td>
<td>0.8058</td>
</tr>
<tr>
<td>3.674</td>
<td>13.498</td>
<td>0.327</td>
<td>20.211</td>
<td>0.0319</td>
<td>0.1936</td>
<td>8.021</td>
<td>0.8064</td>
</tr>
<tr>
<td>3.717</td>
<td>13.816</td>
<td>0.331</td>
<td>21.741</td>
<td>0.0321</td>
<td>0.1897</td>
<td>8.627</td>
<td>0.8103</td>
</tr>
<tr>
<td>5.008</td>
<td>25.081</td>
<td>0.445</td>
<td>25.321</td>
<td>0.0352</td>
<td>0.1108</td>
<td>10.047</td>
<td>0.8892</td>
</tr>
<tr>
<td>3.811</td>
<td>14.523</td>
<td>0.341</td>
<td>25.118</td>
<td>0.0324</td>
<td>0.1816</td>
<td>9.966</td>
<td>0.8184</td>
</tr>
<tr>
<td>3.844</td>
<td>14.776</td>
<td>0.344</td>
<td>26.834</td>
<td>0.0325</td>
<td>0.1788</td>
<td>10.648</td>
<td>0.8212</td>
</tr>
<tr>
<td>3.794</td>
<td>14.394</td>
<td>0.339</td>
<td>28.015</td>
<td>0.0323</td>
<td>0.1831</td>
<td>11.117</td>
<td>0.8171</td>
</tr>
<tr>
<td>3.896</td>
<td>15.178</td>
<td>0.349</td>
<td>29.457</td>
<td>0.0327</td>
<td>0.1746</td>
<td>11.689</td>
<td>0.8254</td>
</tr>
<tr>
<td>3.581</td>
<td>12.823</td>
<td>0.317</td>
<td>30.621</td>
<td>0.0316</td>
<td>0.2024</td>
<td>12.151</td>
<td>0.7976</td>
</tr>
<tr>
<td>3.619</td>
<td>13.097</td>
<td>0.321</td>
<td>32.108</td>
<td>0.0317</td>
<td>0.1987</td>
<td>12.741</td>
<td>0.8013</td>
</tr>
<tr>
<td>3.613</td>
<td>13.053</td>
<td>0.321</td>
<td>33.714</td>
<td>0.0317</td>
<td>0.1993</td>
<td>13.378</td>
<td>0.8007</td>
</tr>
</tbody>
</table>

Table 2.4 Parameters along with their slopes intercepts and $R^2$ values.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Slope</th>
<th>Intercept</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mol %P$_2$O$_5$ v/s V$_m$</td>
<td>0.327</td>
<td>23.12</td>
<td>0.999</td>
</tr>
<tr>
<td>$R_m$ v/s $\alpha_m$</td>
<td>0.936</td>
<td>0.022</td>
<td>0.996</td>
</tr>
<tr>
<td>R v/s $\alpha_e$</td>
<td>0.028</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>$\alpha_e$ v/s $R_m$/V$_m$</td>
<td>25.23</td>
<td>2.00E-05</td>
<td>1</td>
</tr>
<tr>
<td>$\alpha_e$ v/s M</td>
<td>-25.23</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>M v/s $R_m$/V$_m$</td>
<td>-1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

2.7 PHYSICAL PROPERTIES
RESULTS AND DISCUSSION

The mean atomic volume (VM) of each glass was obtained from the values of densities ($p$) and mean atomic weights. The calculated values are given in Table 2.3. Other physical parameters such as, Refractive index (n) of samples was calculated by using the following relation [28].

$$\frac{n^2 - 1}{n^2 + 2} = 1 - \sqrt{\frac{E_g}{20}}$$

Where, $E_g$ is the energy gap. The dielectric constant (C) was calculated from the refractive index of the glass using[29].

$$C = \frac{n^2}{2}$$

The reflection loss (R) from the glass surface was computed from the refractive index by using the Fresnel’s formula as [30].

$$R = \left(\frac{n-1}{n+1}\right)^2$$

The Lorentz-Lorenz equation [31, 32, 33, 34] relates molar refraction $R_m$ to refractive index n and molar volume $V_m$ of the substance by,
where $V_m$ is equal to the molar volume.

This equation gives the average molar refraction of isotropic substances, i.e., for liquids, glasses and cubic crystals. The Lorentz-Lorenz equation presents the polarizability, i.e., the magnitude of the response of the electrons to an electromagnetic field.

On the other hand, Duffy [35] has obtained an empirical formula that relates energy gap $E_g$ to molar refraction $R_m$.

$$R_m = V_m \left(1 - \sqrt{\frac{E_g}{20}}\right)$$

The ratio $\frac{R_m}{V_m}$ is called polarizability per unit volume.

According to the Herzfeld theory of metallization, if $\frac{R_m}{V_m} > 1$ and $\frac{R_m}{V_m} < 1$ [36], if $>1$ and $<1$ samples are molar RV $mm$

predicting metallic or insulating. From Table 2.3 it is clear that present glass samples behave as non-metal.

The difference $M = 1 - \frac{R_m}{V_m}$ is so-called metallization criterion [37].

Materials with large $M$ close to 1 are typical insulators. The small value of $M$ close to zero means that the width of both valence and conduction bands become large, resulting in a narrow band gap and increased the metallicity of the solid.

The molar refraction $R_m$, can be expressed as a function of molar polarizability $\alpha_m$ as

$$R_m = \frac{4\pi \alpha_m A_v}{3}$$

Where $A_v$ is Avogadro’s number introduced, with $\alpha_m$ in ($Å^3$) this equation can be transformed to,

$$R_m = 2.52 \alpha_m$$

Hence molar polarizability $\alpha_m$ can be calculated.

The electronic polarizability ($\alpha_e$) was calculated using the formula [38],

$$\alpha_e = \frac{3(n^2 - 1)}{4\pi A_v (n^2 + 2)}$$

Where, $A_v$ is the Avogadro number. The measured and calculated values of densities, molar volumes and polarizability of oxide ions of P2O5 doped lithium-borate glasses are listed in the Table 2.3.

Variation of band energy gap and refractive index with increasing mol% of P2O5, are exactly apposite to each other Figure (2.4). This indicates that is due to break down of borate bonds to create non-bridging oxygen atoms; which also supports from the decreasing of oxygen packing density as well as decreasing the values of ionic concentrations of the atoms (Table 2.2). This is due to the glass structure becomes loosely packed.

The trend of dielectric constant and reflection loss, with increasing mol% of P2O5 in LBP glasses are similar to each other (Figure 2.5). The maximum variation of reflection loss and dielectric constant, are founds at P2O5=17.25 mol% and at P2O5=40.25 mol%. While molar polarizability and molar refractivity are uniformly increasing with maximum at P2O5=17.25 mol% indicates that higher values are due modification the glass structure

Figure 2.4: Variation of band energy gap and refractive index with mol% of P2O5.

Figure 2.5: Dielectric constant, reflection loss molar refractivity, molar polarizability against mol % of P2O5.

Figure 2.6: Comparative study of Electronic polarizability and Density

Figure 2.7: Dielectric constant and Metallization verses P2O5 mol %.
by BO3 units with non-bridging oxygen atoms in the network.

Comparative study of electronic polarizability and density (Figure 2.6) shows, the maximum values at P2O5=17.25 mol%, and at P2O5=40.25 mol% due to higher molecular weight of P2O5 compared to that of B2O3, and the formation of BO4 & PO4 which modify the glass structure by creating NBOs in the network. Where as, at 28.75 mol% of P2O5 electronic polarizability is exactly apposite to that of density. This is due to break down of borate & phosphate bonds to create non-bridging oxygen atoms.

The behavior of dielectric constant and metallization are exactly apposite to each other (Figure 2.7), which is also due to break down of borate & phosphate bonds to create non-bridging oxygen atoms at 17.25 mol% and at 46 mol% of P2O5 with constant 42.5 mol% of Li2O. The maximum values of dielectric constant and metallization are 0.25x102 and 0.111 respectively.

The study of electronic polarizability and that of oxygen packing density also shows a very excellent co-ordination in them, for each value of oxygen packing density there is maximum value of electronic polarizability 0.0339x1024mol/cm3 and oxygen packing density 87.621cm3/mol at 17.25 mol% of P2O5 and 0.0327x1024mol/cm3 & 82.322 cm3/mol at 40.25 mol% P2O5 at constant 42.5 mol% of Li2O. The maximum values of dielectric constant and metallization are 0.25x102 and 0.111 respectively.

The formation of BO4 and PO4 which will modify the glass structure by creating NBOs in the network.

The maximum value of conductivity 3.39x10-4 & 1.91x10-4 S/cm-1 is at 40.25 mol% & 17.25 mol% of P2O5, at Tg 514 oC & 517.2 oC. Hence it is clear that the conductivity is maximum at higher Tg, at 42.5 constant mol% of Li2O due to the formation of BO3 and BO4 which will modify the glass structure by creating NBOs in the network. (Figure 2.9). Hence mixed glass former effect (MGFE) gives a nonlinear and non-additive change with changing glass former composition at constant modifier composition is due to the mixed glass former effect (MGFE).

Increasing the mol percentage of phosphate, ionic concentration decreases, inter ionic distance & polaron radius increasing, supports to the glass structure becomes loosely packed. Oxygen packing density, ionic concentration decreases, because the polaron comprises the electron plus its surrounding lattice deformation. Hence, the deformation extends over many lattice sites and the lattice can be treated as a continuum. Transformation of BO3 triangle units to BO4 tetrahedral units can be expected to increase the network linkage of the glass which is reflected in the monotonically increasing density.

Increasing the mol% of P2O5 with respective to the B2O3 by keeping modifier Li2O constant, the molar volume, inter ionic distance, polaron radius increasing, suggest the increased free space within the glass structure, it means that the glass structure becomes loosely packed. Oxygen packing density, ionic concentration decreases, because the polaron comprises the electron plus its surrounding lattice deformation. Hence, the deformation extends over many lattice sites and the lattice can be treated as a continuum.

CONCLUSIONS

The behavior of dielectric constant and metallization are exactly apposite to each other (Figure 2.7), which is also due to break down of borate & phosphate bonds to create non-bridging oxygen atoms. The study of electronic polarizability and that of oxygen packing density gives a very excellent co-ordination in them, for each value of oxygen packing density there is maximum value of electronic polarizability. A nonlinear and non-additive change with changing glass former composition at constant modifier composition is due to the mixed glass former effect (MGFE). Increasing the mol percentage of phosphate, ionic concentration decreases, inter ionic distance & polaron radius increases respectively, because the polaron comprises the electron plus its surrounding lattice deformation. The deformation extends over many lattice sites and the lattice can be treated as a continuum. Polarizability per unit volume predicts present glass samples are non-metals.

The formation of BO4 and PO4 which will modify the glass structure by creating NBOs in the network gives parallel variation in Dielectric constant, Refractive index, Molar refractivity and Molar polarizability. Liner trends are found in Molar refractivity & the Molar polarizability, Metallization & Polarizability per unit volume, Reflection loss & electronic polarizability, and in between Mol % of P2O5 & Molar volume (Vm).

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