Synthesis and Characterization of Boro-Aluminotellurite Glass System

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ABSTRACT

Boroalumino tellurite 50 B₂O₃-(40-x)ZnO-10Al₂O₃-xTeO₂ (x=0,5,10,15, 20&25) glasses have been prepared by using conventional melt quenching method. Some fundamental physical parameter such as density and molar volume were measured. The amorphous nature of the glass has been characterized using X-ray Diffraction (XRD) and all glasses are found to be amorphous in nature. The FTIR spectra were recorded at room temperature in the frequency range from 500 to 2000 cm⁻¹. From the IR results, the absorption bands were found to be in the range 600-650 cm⁻¹, 662-674 cm⁻¹, 1190-1204 cm⁻¹ which correspond to the stretching and bending vibrations mode. The optical band gaps were calculated from the absorption spectra measured between 300 nm to 900 nm at room temperature.

Keywords: Boroalumino tellurite, Diffraction (XRD), FTIR spectra, IR results.

1. INTRODUCTION

In recent years, great interests have been focused on the physical, optical and structural properties of tellurite glasses¹ due to their easy fabrication, high refraction index, and excellent infrared transmittance. It has been widely accepted that tellurite glasses are promising nonlinear optical materials². Tellurite based glasses are of scientific and technical interest due to their unique properties such as relatively low phonon energy, good infrared transmittivity, low glass transition and melting temperatures and good thermal and chemical stabilities³. The TeO₂ is not a typical glass former. It does not form a glass by itself, but it requires the presence of other components to form a glass⁴⁵. It is interesting to study the effect of TeO₂ on the fraction of tetrahedral boron’s in the glass network. Borotellurite glasses have potential
application especially in micro-electronics and opto-acoustics owing to their favorable optical and electrical properties.

2. MATERIALS AND METHODS

In the present study, the glass samples of composition $50 \text{B}_2\text{O}_3-(40-x)\text{ZnO}-10\text{Al}_2\text{O}_3-x\text{TeO}_2$ ($x=0,5,10,15,20,25$) have been prepared by the melt quench technique. High purity (99.99%) zinc oxide (ZnO), tellurium oxide (TeO$_2$), orthoboric acid (H$_3$BO$_3$), aluminum nitrate (Al(NO$_3$)$_3$ 9H$_2$O) were used as starting materials. A batch of 20 g of the above high purity chemicals in powder form was weighed, well mixed and melted in a alumina crucible in the temperature range 1100–1200 °C for 2 Hrs.

3. RESULT AND DISCUSSION

3.1 Density and Molar Volume

Figure 1 shows the composition dependence of the density and calculated molar volumes for the series of $50 \text{B}_2\text{O}_3-(40-X)\text{ZnO}-10\text{Al}_2\text{O}_3-X\text{TeO}_2$ ($X=0,5,10,15,20,25$) glasses studied in this work. While the density values increases from 1.415 to 1.518 g/cm$^3$ and volume increases from 54.70 to 63.86 cc/mol with increase ZnO content, shows the mixed glass former effect (MGFE). This suggests that since the density can often be dominated by short range atomic packing of constituent atoms (ions) in the glass, the lack of a strong MGFE in the molar volume may indicate that the short range order, the first co-ordination sphere around each atom (ion) in the glass, is not strongly affected by mixing the glass formers. This is to be expected since both end members are oxide materials and hence mixing of these two glass former (B$_2$O$_3$ and Al$_2$O$_3$) would to the first approximation suggest that changes would not occur to the first coordination sphere around each glass forming cation.

![Fig.1. Variation of density and molar volume with mol% TeO$_2$.](image-url)
Table 1. Variation of Density and Molar Volume of Boroalumino tellurite Glass System

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Glass Code</th>
<th>Glass Composition (mol %)</th>
<th>Molar Mass (gm)</th>
<th>Density (g/cm³)</th>
<th>Molar Volume (cc/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>BZA-0</td>
<td>B₂O₃ 50 ZnO 40 Al₂O₃ 10 TeO₂ -</td>
<td>77.41</td>
<td>1.415</td>
<td>54.7</td>
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<tr>
<td>2.</td>
<td>BZAT-1</td>
<td>B₂O₃ 50 ZnO 35 Al₂O₃ 10 05 TeO₂ -</td>
<td>81.31</td>
<td>1.493</td>
<td>54.66</td>
</tr>
<tr>
<td>3.</td>
<td>BZAT-2</td>
<td>B₂O₃ 50 ZnO 30 Al₂O₃ 10 10 TeO₂ -</td>
<td>85.22</td>
<td>1.498</td>
<td>56.88</td>
</tr>
<tr>
<td>4.</td>
<td>BZAT-3</td>
<td>B₂O₃ 50 ZnO 25 Al₂O₃ 10 15 TeO₂ -</td>
<td>89.13</td>
<td>1.502</td>
<td>59.34</td>
</tr>
<tr>
<td>5.</td>
<td>BZAT-4</td>
<td>B₂O₃ 50 ZnO 20 Al₂O₃ 10 20 TeO₂ -</td>
<td>93.04</td>
<td>1.511</td>
<td>61.57</td>
</tr>
<tr>
<td>6.</td>
<td>BZAT-5</td>
<td>B₂O₃ 50 ZnO 15 Al₂O₃ 10 25 TeO₂ -</td>
<td>96.95</td>
<td>1.518</td>
<td>63.86</td>
</tr>
</tbody>
</table>

3.2 XRD Analysis

X-ray diffraction (XRD) studies were performed on powdered samples in the 2 theta range of 10°-80°. The glass samples of Borosalumino tellurite were identified by XRD, the investigated glass samples as shown in fig. The X-ray diffraction pattern shows no sharp peaks indicating the absence of crystalline nature, and observed broad humps in the glass samples, characteristic of the amorphous phase at diffraction angles (2h) to be fully amorphous indicating that these glass samples are composed of glassy phase.

3.3 FT-IR Spectroscopy

The FTIR absorption spectra of the glasses in the range 500 – 2000 cm⁻¹ spectral range were obtained with an Equinox 55 Bruker spectrometer. The measurements were done using the KBr pellet technique. The samples were crushed in an agate mortar to obtain particles of micrometer size to avoid structural modifications due to ambient moisture. The existence of intense absorption bands was centered at 645 cm⁻¹, 1223 cm⁻¹, and 1331 cm⁻¹. The transmission band of the local structure of pure TeO₂ glass was centered at 624.74 cm⁻¹. Tellurite oxide containing glass possesses two types of structural arrangement which are trigonal pyramidal TeO₃ and trigonal bipyramid (TeO₄). The first group of band (TeO₄) is
located in the range 600-650 cm\(^{-1}\) which correlates to the trigonal bipyramidal structural unit. Meanwhile second group of band is located in the region 650-700 cm\(^{-1}\) which corresponds to the triagonal pyramidal, TeO\(_3\) structural unit.

![FTIR Spectra of 50 B\(_2\)O\(_3\)-(40-X) ZnO-10Al\(_2\)O\(_3\)-XTeO\(_2\) glass system](image)

3.4 UV Spectroscopy:

![FTIR Spectra of 50 B\(_2\)O\(_3\)-(40-X) ZnO-10Al\(_2\)O\(_3\)-XTeO\(_2\) glass system](image)

Table 2. Optical properties of Boroalumino tellurite glass system

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Sample Code</th>
<th>Composition X mole %</th>
<th>% T</th>
<th>UV cut off (nm)</th>
<th>Band Gap in eV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BZAT-1</td>
<td>05</td>
<td>17.90</td>
<td>359</td>
<td>3.5</td>
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<tr>
<td>2</td>
<td>BZAT-2</td>
<td>10</td>
<td>15.31</td>
<td>361.47</td>
<td>3.4</td>
</tr>
<tr>
<td>3</td>
<td>BZAT-3</td>
<td>15</td>
<td>21.90</td>
<td>355.96</td>
<td>3.5</td>
</tr>
<tr>
<td>4</td>
<td>BZAT-4</td>
<td>20</td>
<td>19.33</td>
<td>366.63</td>
<td>3.3</td>
</tr>
<tr>
<td>5</td>
<td>BZAT-5</td>
<td>25</td>
<td>20.60</td>
<td>369.18</td>
<td>3.0</td>
</tr>
</tbody>
</table>
Optical absorption spectra of Borotellurite glasses were measured at room temperature on Shimadzu 1601 double beam UV–visible spectrophotometer in a wavelength range of 300–800 nm. The optical band gap $E_g$ of glasses was determined from $\lambda_o$. The variation of the obtained values of $E_{opt}$ with composition are shown in Fig. It is noted that $E_{opt}$ decreases from 3.5 to 3.0 eV with the gradual decrease in the ZnO Mol % content.

4. CONCLUSION

A series of of 50 B$_2$O$_3$-(40-x) ZnO-10Al$_2$O$_3$-xTeO$_2$ (x=0, 5, 10, 15, 20&25) has been successfully prepared. The XRD, density and molar volume of the glasses were discussed.

The absorption band at 600 –700 cm$^{-1}$ represents the stretching vibration of Te-O bonds in the trigonal bipyramid (TeO$_4$) and trigonal pyramid (TeO$_3$). The stretching vibration of TeO$_3$ group is between 650 –700 cm$^{-1}$ while the stretching vibration of TeO$_4$ is in between 600 –650 cm$^{-1}$. Optical band gap decreases from 3.5 to 3.0 eV.

REFERENCES