Chemical Degradation Study of Sodium Borophosphate Glasses

Amit L. Patil, Umakant B. Chansheti and Pravin S. Bhalet

Department of Chemistry, Arts, Science & Commerce College, Naldurg, Tq-Tuljapur Dist.- Osmanabad- 413602, MS, INDIA

Available online at: www.isca.in, www.isca.me

Received 28th December 2013, revised 18th January 2014, accepted 9th February 2014

Abstract

Sodium borophosphate glasses of the series of 30Na$_2$O – (70-x) B$_2$O$_3$ – xP$_2$O$_5$ (x=15, 20, 25, 30, 35,..) have been prepared by melt-quench technique. The glass samples were characterized using X-ray diffraction (XRD) and chemical degradation (corrosion) techniques. The X-ray diffraction pattern confirms the amorphous nature of the glass samples. Chemical degradation studies of the glass samples were carried out in 10% HCl and 10% NaOH. The dissolution rate was seen to be higher in acidic medium as compared to alkaline medium.

Keywords: Sodium borophosphate glasses, XRD, chemical degradation, glass composition, glass former.

Introduction

In the material science literature, there is a wealth of information on glass degradation. Boron oxide (B$_2$O$_3$) usually occurs in the glassy form which is virtually in capable of direct crystallization. Pure boron trioxide (B$_2$O$_3$) is a very good glass former, covalently bonded with interesting physico chemical properties. It exhibit unique structural features and attracts because of it simple composition which consists of planar BO$_3$ triangle. Glasses having P$_2$O$_5$ as one of the major component are called phosphate glasses. Phosphorous pentaoxide is used as a glass former. Pure P$_2$O$_5$ has a melting point of 560°C and a boiling point of 605°C. Phosphate glasses have poor durability which often limits their practical applications, that is generally overcome by adding certain oxides to the phosphate glasses, such as PbO, Al$_2$O$_3$ and Fe$_2$O$_3$. In phosphate network the addition of alkali ions depolymerizes the phosphate network and decreases the connectivity. A similar increase was observed in Na$_2$O, SiO$_2$ glasses with the addition of Al$_2$O$_3$. The pure phosphate glasses are highly hygroscopic. However, the alkali oxides and other additives modified phosphate glasses were reported to stable and durable.

The non linear optical properties of semiconductor doped glasses, in which the semiconductor microcrystal from quantum dots has been a topic of recent theoretical and practical interest. Phosphate glasses have high IR transmission nearly up to 8 mm, because of low thermo-optical coefficients and large emission they are more suitable for high power lasers. Phosphate glasses have many applications in optics and other areas. Researchers have studied wide variety of phosphate glass compositions. P$_2$O$_5$ is main glass former gives with (Na$_2$O) sodium oxide modifier gives phosphate glasses with good physical properties and high UV transmission. Alkali borophosphate glasses are of interest for fast ion conducting applications.

Material and Methods

Glass preparation: The Sodium borophosphate glasses of various compositions were prepared by melt quench technique. The chemicals were use NaNO$_3$, H$_3$BO$_3$ and (NH$_4$)$_2$HPO$_4$ of analytical grade. These chemicals were thoroughly mixed and ground for 30-40 min in a mortar past and then the charge 30g was melted in alumina crucible using muffle furnace for 4-5 hrs at temperature ranging from 900-1100°C depending on composition. Glasses with compositions 30Na$_2$O – (70-x) B$_2$O$_3$ – xP$_2$O$_5$ (x=15, 20, 25, 30, 35,...)

XRD- Analysis: Prepared glasses were characterized by X-ray diffraction technique to check amorphous nature of glasses, using X-ray diffractometer with Cu-K$_\alpha$ radiation. The XRD patterns were recorded in the 2θ range 20-80 degree with scanning rate 1/10mint.

Chemical Degradation: The result of the corrosion test for the polished samples of sodium borophosphate glasses were carried out in 10% NaOH and 10% HCl solutions at room temperature for 1hrs to 6hrs of exposure are monitored.

Results and Discussion

XRD Analysis: Prepared glasses were characterized by X-ray diffraction technique. Figure 1 shows the XRD pattern of the samples of sodium borophosphate glasses indicate that the broad peaks, characteristic of glass structure. This is the clear indication of amorphous nature within the resolution limit of XRD instrument.

Chemical Degradation: The result of the corrosion test for the polished samples of sodium borophosphate glasses were carried out in 10% NaOH and 10% HCl solutions at room temperature for 1hrs to 6 hrs of exposure are shown in table 1 and table 2.
The dissolution rate was seen to be higher in acidic medium as compared to alkaline medium. In 10% HCl solution, the rate of dissolution of for glass II-3 i.e. $30\text{Na}_2\text{O}-45\text{B}_2\text{O}_3-25\text{P}_2\text{O}_5$ is maximum and for glass II-1 i.e. $30\text{Na}_2\text{O}-55\text{B}_2\text{O}_3-15\text{P}_2\text{O}_5$ is less in all the studied glass samples of sodium borophosphate glasses.

In 10% NaOH solution, the dissolution rate is very slow, for II-1 glass than the II-2 and II-3. From the studies of chemical degradation it came to notice that the rate of dissolution of II-1 glass in both i.e. in 10% HCl and in 10% NaOH is low in comparison to other investigated sodium borophosphate glasses.

In 10% HCl solution, the rate of dissolution of for glass II-3 i.e. $30\text{Na}_2\text{O}-45\text{B}_2\text{O}_3-25\text{P}_2\text{O}_5$ is maximum and for glass II-1 i.e. $30\text{Na}_2\text{O}-55\text{B}_2\text{O}_3-15\text{P}_2\text{O}_5$ is less in all the studied glass samples of sodium borophosphate glasses.

The investigated glasses contain group I (Periodic Table) fluxes i.e. Na and glass former $\text{B}_2\text{O}_3$, which help to improve the chemical resistance hence the rate of dissolution in NaOH solution is slower than in HCl. Plot of weight loss versus $\text{P}_2\text{O}_5$ content at various time of exposure in 10% HCl is shown in figure 2 and the Plot of weight loss versus $\text{P}_2\text{O}_5$ content at various time of exposure in 10% NaOH is shown in figure 3.

![Figure-1](image-url)

**X-ray diffraction patterns for typical sample II-3 (X=25%)**

### Table-1

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Glass Code</th>
<th>Composition X mole% of $\text{P}_2\text{O}_5$</th>
<th>Wt. loss in 10% HCl g/cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 hrs</td>
</tr>
<tr>
<td>1</td>
<td>II-1</td>
<td>15</td>
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</tr>
<tr>
<td>2</td>
<td>II-2</td>
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<td>0.40</td>
</tr>
<tr>
<td>3</td>
<td>II-3</td>
<td>25</td>
<td>0.38</td>
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### Table-2

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Glass Code</th>
<th>Composition X mole% of $\text{P}_2\text{O}_5$</th>
<th>Wt. loss in 10% NaOH g/cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 hrs</td>
</tr>
<tr>
<td>1</td>
<td>II-1</td>
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<tr>
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<td>3</td>
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<td>25</td>
<td>0.014</td>
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</table>
Conclusion

The XRD pattern of various Sodium borophosphate glasses confirms the amorphous nature of glasses. The investigated glasses contain Na and glass former B$_2$O$_3$, which help to improve the chemical resistance hence dissolution rate was seen to be higher in acidic medium as compared to alkaline medium at room temperature. In alkaline medium percentage of P$_2$O$_5$ increases dissolution rate also goes on increases.

References


2. Shashidhar B., Role of Bi$_2$O$_3$ content on physical, optical and vibrational studies in Bi$_2$O$_3$–ZnO–B$_2$O$_3$ glasses, *J. of Alloys and Compounds*, **460**, 699-703 *(2008)*


