Physical and optical study of TeO_2 and Sb_2O_3 based Phosphate glasses

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Abstract

The physical and optical properties of 10BaO: $5Al_2O_3$: $15Sb_2O_3$: $10Gd_2O_3$: $60P_2O_5$ and 10BaO: $5Al_2O_3$: $15TeO_2$: $10Gd_2O_3$: $60P_2O_5$ composition was study systematically. In this studied the samples were prepared by conventional melt quenching technique and characterized by XRD, density, refractive index, molar volume, dielectric constant (ε), optical dielectric constant (P∂t/∂P), molar refractivity, and refraction lose. The XRD analysis shows the amorphous nature of so prepared samples. The composition with TeO_2 and Sb_2O_3 has density 3.185303 g/cm^3 and 3.367803 g/cm^3 respectively. Refractive index for TeO_2 composition is 1.6514 which is greater than 1.6328 for the Sb_2O_3 composition.

Keywords: amorphous, dielectric constant, melt quenching, optical properties

1. Introduction

Phosphate glasses have advantages over its counterparts because of its properties like these glasses generally hold high thermal expansion coefficient (α), low melting temperature, low glass transition temperature (Tg) and high electric conductivity (Yajun et al., 2014: 414-418). Therefore an increasing interest is drawn in phosphate glasses for many low temperature applications (Sahar et al., 2015: 18-23). But unfortunately, the phosphate glasses have some problems like comparatively low chemical durability which makes phosphate glasses in general inappropriate for practical applications (Shih et al., 2001: 1811-1813). It was suggested that the crosslink density and bonding strength of the glass network can be increased by nitridation and addition of proper modifiers, which lead to a good enhancement in the chemical durability of the modified phosphate glasses (Shih et al., 2001: 1811–1813), in view of the fact that Tg increases with increasing bonding strength of the glass structure (Shih et al., 2001: 1811–1813). Therefore improving chemical durability by with addition of different modifiers is frequently accompanied by an increase in Tg. Therefore, it is not easy to prepare a phosphate glass possessing a low Tg and excellent chemical durability simultaneously. Among all the additives made to phosphate glasses to improve their durability, PbO is the only one which reduces the dissolution rate and *T*g simultaneously (Shih et al., 2001: 1811–1813).

Lead based low-melting point glasses are used in a number of commercial areas like adhesives for glass, sealing or coating frits for electronic components, conductive or resistive pastes. Science lead is harmful to human health and environment. Therefore, the research for development of lead-free low-melting point glasses with good properties, has involved a great interest (Yajun et al., 2014: 414-418).

Amongst different metal oxides, the use of Al_2O_3 in to phosphate glass network is likely to boost the chemical durability of these glasses since Al_2O_3 penetrate into the glass network with AlO4 structural units. Incidentally, the vibrational frequency of Al–O stretching in AlO_4 and the band due to P–O–P stretching vibrations of PO_4 groups are found to be around 700 cm^{-1} (Prasad et al., 2006: 2478–2488). As an outcome, it is quite probable that tetrahedral Al ions to cross-link with the adjacent phosphor chains by the formation of $AlPO_4$ species that strengthen the glass network. The presence of such linkages improves the aqueous durability, increases the glass transition temperature and reduces the thermal expansion coefficient of these glasses. Rare earth (RE) glasses are famous for their better physical and chemical properties, such as enhanced hardness, thermal characterization and elastic modulus, and particularly, higher chemical durability, due to higher field strength than traditional network modifier cations (Liang et al., 2014: 135–140)

The Sn contain phosphate glass attract extensive investigation because these glasses have low melting point and good water durability (Bing et al., 2008: 1948–1954). So these types of glasses can be good candidate for replacing lead containing glasses. But tin based glass have to major problems one is the fluctuation of T_g due to the +2 and +4 valiancy of cannot be completely eliminated and the other problem is the cost. So as such there is a need of tin free low melting point glass for practical application (Bing et al., 2008: 1948–1954). The Sb_2O_3 is much cheaper then tin and antimony contains glass with lower Tg show much improved stability against moisture under ambient conditions (Bing et al., 2008: 1948–1954).

As amongst the various oxide glasses that have been explored, those with P_2O_5 as a glass former are unique because of their ease in preparation, low melting point and ease of glass-forming while TeO_2 based glasses are less hygroscopic and, in view of their high dielectric constant and high refractive index, they find applications for optical and semiconducting materials (Chowdari et al., 1996: 31-40).

Thus, P_2O_5 and TeO_2 have different physical and structural characteristics. In order to overcome some of the above referenced disadvantages and to take advantage of positive attributes of each of them, we incorporate TeO_2 in one of our composition.

2. Experimental procedure

The raw materials that are used for the preparation of 10BaO : $5Al_2O_3$: $15Sb_2O_3$: $10Gd_2O_3$: $60P_2O_5$ (BAGS) and 10BaO : $5Al_2O_3$: $15TeO_2$: $10Gd_2O_3$: $60P_2O_5$ (BAGT) were of high purity. The 20 gram batch will mix and put in furnace. Initially the materials were heated at 400 °C to avoid the P_2O_5

evaporation on high temperature and remove the moisture present in composition. Then melt on 1200 °C for 4 hrs and the homogeneous melt was poured on free heated mold to quench. After quenching the samples were put another furnace on 200 °C for annealing for 2 hrs and then slowly cool down to room temperature. After preparation, the samples were cute in proper dimension and then polished. The prepare samples are shown in the Fig. 1.

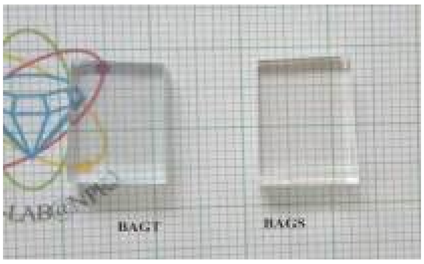

Fig 1. Picture of prepared glass samples.

3. Result and Discussions

3.1 XRD

The XRD pattern of prepared glass samples are show in Fig. 2A and 2B. It was observed that glass samples have amorphous nature because this figure shows the broad hump instead of sharp peaks, which is a sign of amorphous nature of these samples.

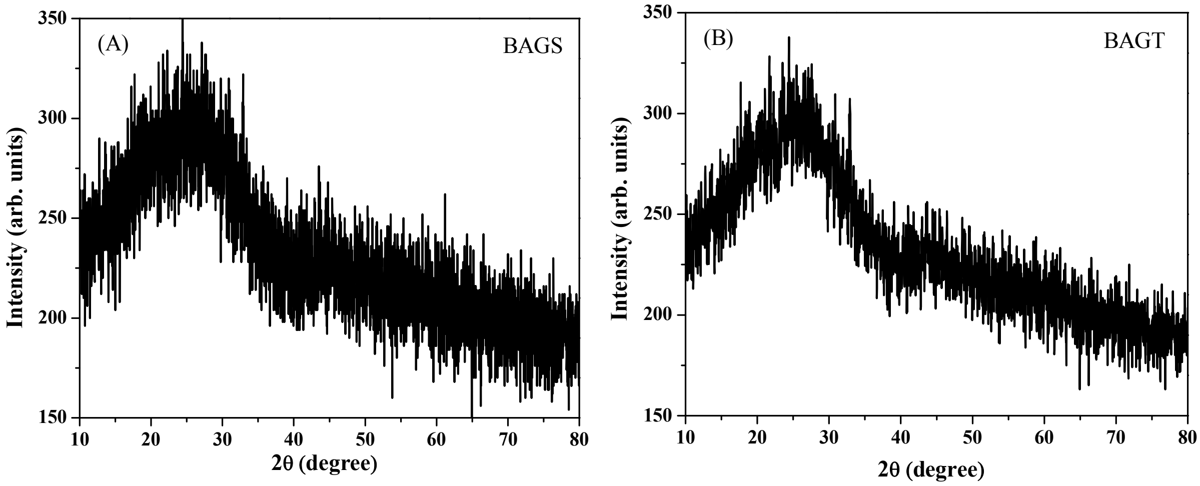

Fig. 2. XRD of glass samples (A) BAGS and (B) BAGT.

3.2 Density and Molar volume

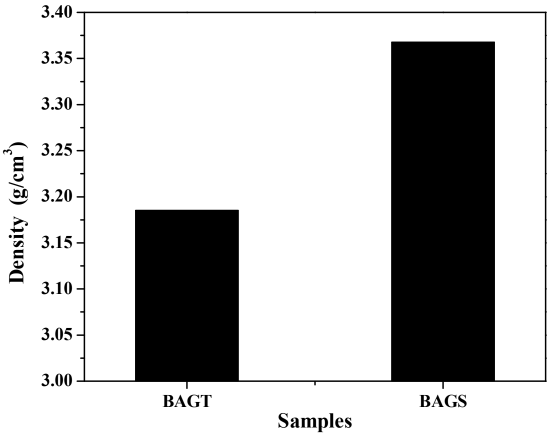

Fig. 3. Density of glass samples.

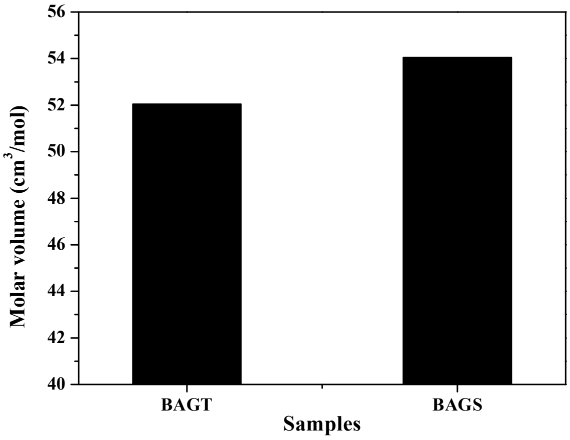

Fig. 4. Molar volume of glass samples.

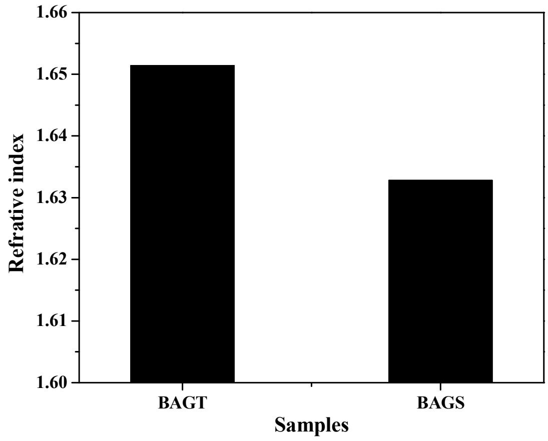

Fig. 5. Refractive index of glass samples.

Table 1. Physical and optical properties.

Quantity	BATG	BAGS
Average molecular weight, M (g/mol)	165.78	182
Thickness, d (cm)	0.3	0.3
Dielectric constant (ε)	2.72	2.66
Optical dielectric constant (P∂t/∂P)	1.72	1.66
Molar refractivity, Rm (cm^3/mol)	52.04	54.04
Refraction losses, R (%)	6.03	5.77

Densities of two glasses are measured at room temperature using water as the immersion liquid. Density is generally measured by the fluid displacement method depending on Archimedes principle. The density is obtained by using the following (Bhatia et al., 2015: 44-52)

$$\rho = \frac{w_a}{w_a - w_b} \times \rho_b \qquad (1)$$

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, ρ_b is density of buoyant. All the measurements were made using a digital balance. The density of the BAGS is higher than the BAGT as shown in Fig. 3.

The molar volume of the so prepared samples are calculated from following equation (Bhatia et al., 2015: 44-52)

$$V_m = \frac{M_T}{\rho} \quad (2)$$

where V_m is molar volume, ρ is the density of the sample and M_T is the molecular weight of the sample. It was found that molar volume of BAGS has higher value than BAGT as shown in Fig. 4.

3.3 Optical properties

Refractive index is an important property to be measured with respect to the optical properties of glasses. So, a huge number of researchers have carried out studies to ascertain the relation between refractive index and glass composition. The value of refractive index in our study is given in the Table 1 and plat in comparison with one and other in Fig. 5. The refractive index of BAGT is higher than the BAGS it is obvious because by adding the TeO_2 increase the electron density as compare with Sb_2O_3. So when the electron density increases the refractive index increase as will.

With the help of Fresnel's formula the refraction loss is calculated from the glass surface using the refractive (Bhatia et al., 2015: 44-52)

$$R_l = \left[\frac{(n-1)}{(n+1)}\right]^2 \quad (3)$$

where *n* is the refractive index.

The values for refraction lose are 6.035 and 5.776 % for BATG and BAGS respectively. The dielectric constant and optical dielectric constant are calculated as will. The dielectric constant (ε) was calculated from the refractive index of the glass using (Thombare, 2014: 9-15)

$$\varepsilon = n^2 \quad (4)$$

The values of dielectric constant for BATG and BAGS are 2.727 and 2.666, respectively and the optical dielectric constant for BAGT and BAGS is 1.727 and 1.666, respectively.

3.4 Micro hardness

Micro hardness was measure for our glass using the HVS-1000 Digital-micro Vickers hardness tester machine, the recorded values for BAGS and BAGT are 419.7982 and 364.828, respectively. The previous study suggests that an increase in the hardness number of different oxides is credited to the decrease in the flow mechanism in a glass containing oxides (Nabhan et al., 2016: 145-151).

4. Conclusion

The study of physical and optical properties was carried out for the Sb_2O_3 and TeO_2 containing phosphate glass composition. The result shows that the BAGS show good physical properties as compare to the BAGT glass. The refractive index of BAGS is lease then the BAGT glass. The hardness of the BAGS is higher than BAGT which show that the BAGS have more viscosity than BAGT.

5. Reference

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