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Investigation on Physical Properties of Borosilicate Glasses Containing Barium

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Abstract

Borosilicate glasses have been synthesized with a BaO concentration of 0.0 to 10.0 mol%. The glasses are characterized for their physical properties. The density and refractive index of these glasses were found in the range 2.8057 to 3.1746 g/cm³ and 1.581 to 1.607, respectively. It was observed that the density and refractive index of these glasses is increased with increasing the concentration of BaO. The molar volume of the glasses was decreased where BaO is 0.0 to 2.0 mol% then the values of these glasses were increased with the increasing of BaO concentration 4.0 to 10.0 mol%. The absorption spectra were measured in the wavelength ranging from 200 to 1,100 nm. This research is useful for the development of glass science without the lead content.

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1. Introduction

From ancient time to the present day, the various transparencies and colors of glass have remained perhaps its most attractive physical properties. In general, the change of glass color is achieved by changing the glass composition, such as doping different types of ions. For changing the glass composition, it can be get the physical properties varies with ions doped.

Borosilicate glasses, resulting from the additional small amounts of alkali added to silica and boron oxide, make a family of glasses with a large number of applications particularly due to their low thermal expansion coefficient ($\sim 3\text{-}6 \times 10^{-6} \text{ K}^{-1}$) and to a high resistance to chemical attack. Some borosilicate glasses in a powdered form have aroused considerable interest, either for their use in the production of sintered glass with controlled

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porosity or for their application in the manufacture of composite materials [1]. This glass is very popular in the manufacture of scientific instruments, and it was once widely used to make glass for kitchens as well. In nuclear industry it is mainly used as matrix for immobilizing the radioactive ions present in the waste generated from the nuclear reactors [2-6].

The aim of this study was to investigate the physical properties of borosilicate glass by gradual increasing of barium oxide (BaO) content.

2. Experimental

2.1 Sample Preparation

A series of borosilicate glasses samples with the chemical compositions of B₂O₃: Na₂O: CaO: ZrO₂: Bi₂O₃: TiO₂: Al₂O₃ (10: 25: 8: 5: 1: 0.5: 0.5), SiO₂ content ranging from 40 to 50 mol% and doped with BaO from 0.0 to 10.0 mol% were used in the present study. All chemical composition was finely powder (about 30 g). They were thoroughly mixed by hand milling in whole of composite in a high purity alumina crucible for 30 min and then melted at 1,500 °C by an electrical muffle furnace for 3 hours. After complete melting, the melts were quickly poured into a preheated stainless steel mould and annealed at 500 °C for 3 hours before being cooled down to room temperature. Finally, the as-prepared glass samples were cut and then fine polished to a dimension of 1.0 × 1.5 × 0.3 cm³.

2.2 Density and Molar Volume Measurements

The densities of glass samples were measured with xylene as an immersion liquid. The density (ρ) was calculated by applying Archimedes principle [7],

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

where w_a and w_b are the weight of glass in air and xylene, respectively, and ρ_b is the density of xylene ($\rho_b = 0.863 \text{ g/cm}^3$). All weight measurements used a sensitive microbalance. The corresponding molar volume (V_M) were calculated with the relation [7],

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

where M_T is the total molecular weight of the multicomponent glass system given by

$$M_T = x_{SiO_2} Z_{SiO_2} + x_{B_2O_3} Z_{B_2O_3} + x_{Na_2O} Z_{Na_2O} + x_{CaO} Z_{CaO} + x_{ZrO_2} Z_{ZrO_2} + x_{Bi_2O_3} Z_{Bi_2O_3} + x_{TiO_2} Z_{TiO_2} + x_{Al_2O_3} Z_{Al_2O_3} + x_{BaO} Z_{BaO} \quad (3)$$

where x_{SiO_2} , $x_{B_2O_3}$, x_{Na_2O} , x_{CaO} , x_{ZrO_2} , $x_{Bi_2O_3}$, x_{TiO_2} , $x_{Al_2O_3}$ and x_{BaO} are the mole fractions of the constituent oxides, and Z_{SiO_2} , $Z_{B_2O_3}$, Z_{Na_2O} , Z_{CaO} , Z_{ZrO_2} , $Z_{Bi_2O_3}$, Z_{TiO_2} , $Z_{Al_2O_3}$ and Z_{BaO} are the molecular weight of the different oxides.

2.3 Refractive index

The refractive index (n) were measured on an Abbe refractometer (ATAGO) with a sodium vapor lamp as the light source emitting wavelength, λ , of 589.3 nm (D line) and using mono-bromonaphthalene as the adhesive coating between the glass sample and prism of the refractometer.

2.4 Optical absorption Measurement

The optical absorption spectra were recorded at room temperature using a UV–Vis spectrophotometer (Varian, Cary 50), in the wavelength of 200–1,100 nm at room temperature.

3. Results and discussions

The measured density, refractive index and molar volume of barium borosilicate glass samples for different BaO concentrations are shown in Table 1. The variation of the density, refractive index, density and refractive index, and molar volume with BaO concentration is shown in Fig. 1-4, respectively. From Fig. 1, the density increases with additional content of BaO into the network. This indicates that replacing SiO₂ by addition of a small amount of BaO results in the increase in the average molecular weight of oxide ions in the glasses BaO has a higher relative molecular mass than that of SiO₂.

Table 1. Physical properties of barium borosilicate glasses

Physical property	Concentration of BaO (mol%)					
	0.0	2.0	4.0	6.0	8.0	10.0
Average molecular weight, M (g/mol)	68.7150	70.5799	72.4447	74.3096	76.1744	78.0392
Density, ρ (g/cm ³)	2.8507	2.9342	3.0086	3.0706	3.1234	3.1746
Thickness of the glass, d (cm)	0.3500	0.3500	0.3500	0.3500	0.3500	0.3500
Refractive index	1.5814	1.5872	1.5943	1.5995	1.6045	1.6074
Molar volume, V _M (cm ³ /mol)	24.1050	24.0545	24.0789	24.2000	24.3885	24.5825

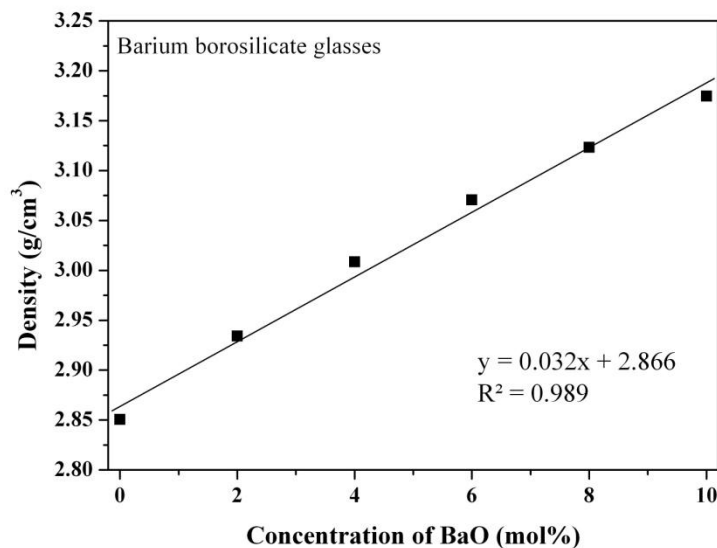


Fig. 1. The density of barium borosilicate glasses

Figure 2 shows the variation of the refractive index and BaO concentration. It can be seen that the refractive index is increased with the increasing BaO concentration and the value is in range 1.581 to 1.607. Refractive

indices of homogenous material have remarkable dependence on polarizing power and atomic weight of constituent ions [8]. From Fig. 3, it was observed that the refractive index of glasses studied was increased when the density increased with variation of BaO concentration.

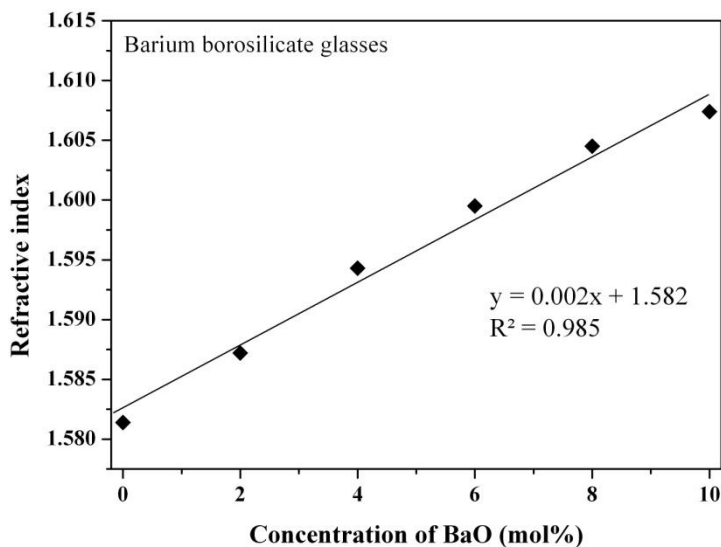


Fig. 2. The refractive index of barium borosilicate glasses

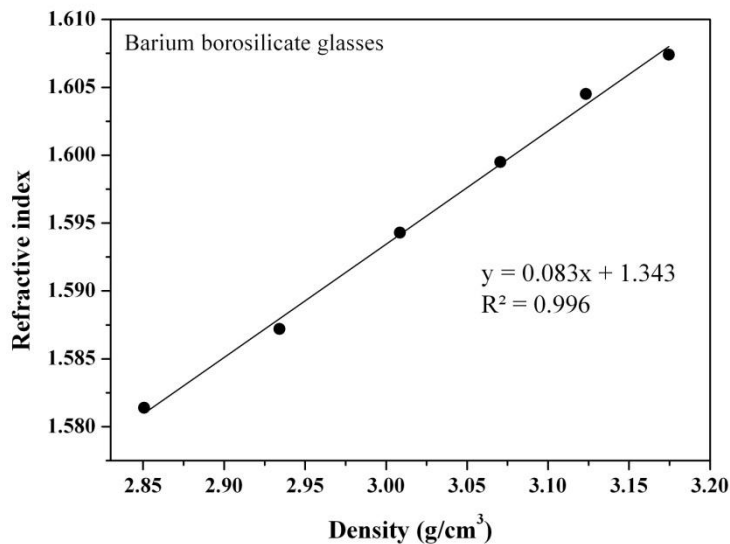


Fig. 3. The relation between density and refractive of barium borosilicate glass

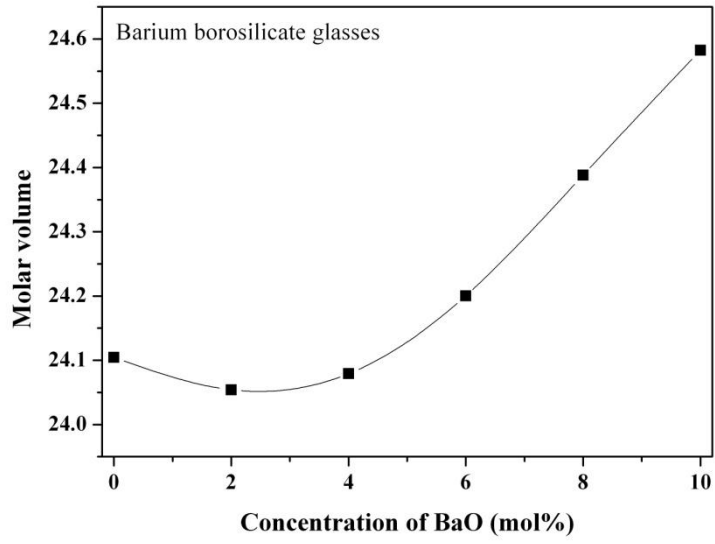


Fig. 4. The molar volume of barium borosilicate glasses

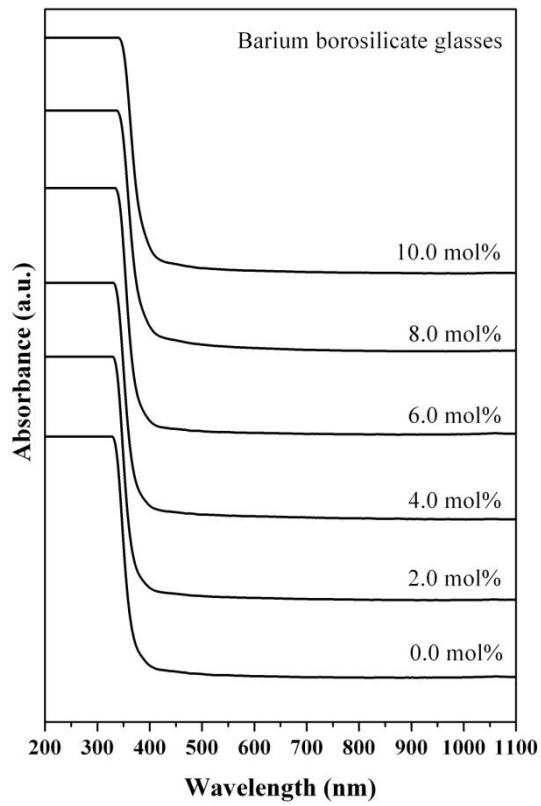


Fig. 5. The absorption spectra of barium borosilicate glasses

From Fig. 4, the molar volume of glasses study is decreased where BaO 0.0 to 2.0 mol% then the values of these glasses was increased with the increasing of BaO concentration 2.0 to 10.0 mol%. The molar volume depends on both the rates of change of density and molecular weight as seen in Table 1. However, when the BaO concentration is increased the increasing rate of molecular weight is greater than that of density. It may be assumed that the increase in BaO concentration at the expense of SiO₂ causes the opened glass network structure [9]. The molar volumes of glass samples are between 24.1046–24.5824 cm³/mol.

The absorption spectra of undoped and different BaO doped borosilicate glasses in wavelength range 200 – 1,100 nm are shown in Fig. 5. The absorption edge occurred at a wavelength of around 330 nm for all BaO concentration. It can be observed that the absorption edge was slightly shifted to the longer wavelength with increasing of BaO concentration.

4. Conclusion

The barium borosilicate glasses were prepared at various doping concentration of BaO and characterized for their physical properties. The density and refractive index increased with the increasing in concentration of BaO. The increase in molar volume with BaO content indicates the extension of glass network due to increase in the number of non-bridging oxygen. The absorption edge of barium borosilicate glass was found to slightly shift around 320 nm. This research is useful for development glass science without the lead content.

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