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Role of Er_2O_3 on physical and optical properties of borosilicate glasses

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Abstract

In this work, borosilicate glasses, produced from rice husk ash, doped with different concentration of Er_2O_3 have been prepared by normal melt-quenching technique. The physical and optical properties of present glasses have been performed. The results show that the density and refractive index of glasses increased with additional content of Er_2O_3. Moreover, the absorption spectra and color of all glasses have been studied.

Keywords: borosilicate; physical property; optical property; glasses; Er_2O_3

1. Introduction

Rare earth doped glasses have been investigated for their interesting optical, electrical and magnetic properties. These glasses are useful in various applications in the field of laser, up-conversion, fluorescence, high density optical storage, amplifiers, optical fiber, electro-luminescent devices, memory devices and flat panel display, etc. [1]. Consequently, rare earth doped glasses play an important role in wide of technology. With increasing demand of various applications, further investigations in rare earth dopes glasses are becoming more important. In generally, borosilicate glass is a general term referring to a range of glass containing silica (typically over 60%) and boric acid (5-20%) [2]. It has low thermal expansion coefficients, high soften temperature, and a high resistance to chemical. The borosilicate glass plays an important role in a widely of technically orientated glass application [3].

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The aim of present work is to prepare borosilicate glasses doped with Er_2O_3 and to investigation on the effect of Er_2O_3 on the physical and optical properties of the glasses.

2. Experimental procedure

2.1 Sample preparation

The glass samples of composition $(55\text{-}x)SiO_2 : 20Na_2O : 1Al_2O_3 : 13B_2O_3 : 6.3CaO : 0.2Sb_2O_3 : 4.5BaO : xEr_2O_3$ (with x = 0.0, 1.0, 2.0, 3.0, 4.0, and 5.0 mol%) were prepared by taking required stoichiometric amounts of different constituent oxides of Al_2O_3, CaO, Sb_2O_3, H_3BO_3, BaO, Na_2O with 99.9% purity, while SiO_2 produced from rice husk ash. The glass composition in the present work is listed in Table 1. These constituent oxides in amounts of about 30 g were mixed together in high alumina crucibles and melted at 1100 °C in electrical furnace. The melt was quenched in air using pre-heated stainless steel mould. The quenched glass was then annealed at 500 °C to remove the internal stress. After annealing, each glass was polished and cut into the rectangular shaped for further investigation. The photograph of glasses is shown in Fig.1.

Table 1. Composition for borosilicate glasses doped with Er_2O_3

Sample No.	Glass composition (mol%)
I	$55.0SiO_2 : 20.0Na_2O : 1.0Al_2O_3 : 13.0B_2O_3 : 6.3CaO : 0.2Sb_2O_3 : 4.5BaO : 0.0Er_2O_3$
II	$54.0SiO_2 : 20.0Na_2O : 1.0Al_2O_3 : 13.0B_2O_3 : 6.3CaO : 0.2Sb_2O_3 : 4.5BaO : 1.0Er_2O_3$
III	$53.0SiO_2 : 20.0Na_2O : 1.0Al_2O_3 : 13.0B_2O_3 : 6.3CaO : 0.2Sb_2O_3 : 4.5BaO : 2.0Er_2O_3$
IV	$52.0SiO_2 : 20.0Na_2O : 1.0Al_2O_3 : 13.0B_2O_3 : 6.3CaO : 0.2Sb_2O_3 : 4.5BaO : 3.0Er_2O_3$
V	$51.0SiO_2 : 20.0Na_2O : 1.0Al_2O_3 : 13.0B_2O_3 : 6.3CaO : 0.2Sb_2O_3 : 4.5BaO : 4.0Er_2O_3$
VI	$50.0SiO_2 : 20.0Na_2O : 1.0Al_2O_3 : 13.0B_2O_3 : 6.3CaO : 0.2Sb_2O_3 : 4.5BaO : 5.0Er_2O_3$

2.2 Density

The density (ρ) measurements were carried out directly after preparation, at room temperature by the Archimedes method using 4-digit sensitive microbalance (AND, HR-200) with xylene (density = 0.86 g/cm^3) as working liquid. The obtained values of density were used to calculated molar volume (V_M) by the following relation,

$$V_M = \frac{M_T}{\rho} \quad (1)$$

Where M_T is the molecular weight of the glass expressed as the mole fraction of the constituent oxides multiplied by their molecular weights.

2.3 Refractive index

The refractive index (n) was 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-bromonapthalene as the adhesive coating between the glass sample and prism of the refractometer.

2.4 Optical spectra

The optical spectra of the glasses were performed in absorption mode at room temperature using a dual beam UV-VIS spectrophotometer (Varian, Cary 50) in the wavelength range of 300 - 900 nm.

3. Results and discussion

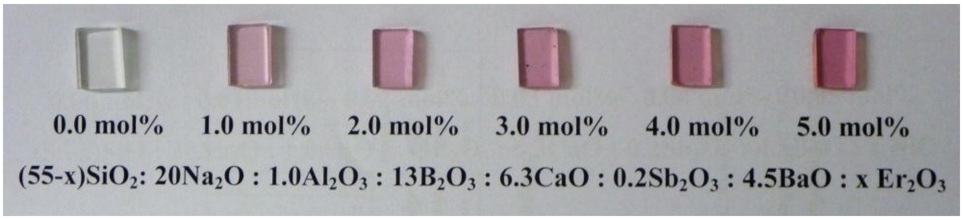

Fig. 1. Glass samples in present work

The photograph of as-prepared glasses in present work is shown in Fig.1. The molecular weight, density, molar volume and refractive index of glasses with different Er_2O_3 concentration are shown in Table 2. The dependence of glass density on the Er_2O_3 content is shown in Fig. 2. In all samples, the density increases linearly with the composition of Er_2O_3 due to the change in atomic mass and atomic volume of the doping Er^{3+} ions. The obtained values of molar volume, depending on both molecular weight and density, are in the range of 23.9671 to 25.3562. The observed change of the molar volume of the glasses may be attributed to the change of interatomic spacing inside the glasses network. The measured refractive index has been found to change linearly with increasing Er_2O_3 concentration. As stated in the Lorenz electron theory, the refractive index depends on both density and on polarizability of the atom in a given materials. Therefore, the refractive result corresponds with density value [4].

Table 2. The molecular weight, density, molar volume and refractive index of the present glasses

Concentration of Er_2O_3 (mol%)	Molecular Weight, M_T (g/mol)	Density, ρ (g/cm^3)	Molar volume, V_M (cm^3/mol)	Refractive index, n
0.0	66.5280	2.7311	24.3594	1.5480
1.0	69.7523	2.9103	23.9671	1.5611
2.0	72.9766	3.0061	24.2765	1.5658
3.0	76.2009	3.1061	24.5329	1.5757
4.0	79.4253	3.2027	24.7997	1.5814
5.0	82.6496	3.2595	25.3562	1.5863

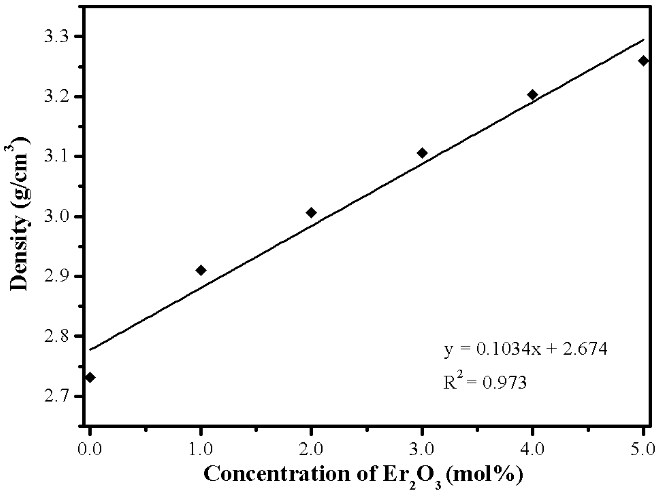

Fig. 2. The variations of density with composition of Er_2O_3

The optical spectra of present glasses performed at room temperature in absorption mode are shown in Fig.3. It can be seen that the nine absorption peaks occurred at 350, 380, 400, 440, 480, 530, 545, 640 and 790 nm for the doped glasses. With increasing in content of Er_2O_3 up to 5 mol%, no detectable changes in position of these bands are observed. However, the intensity of those bands was noticed to increase.

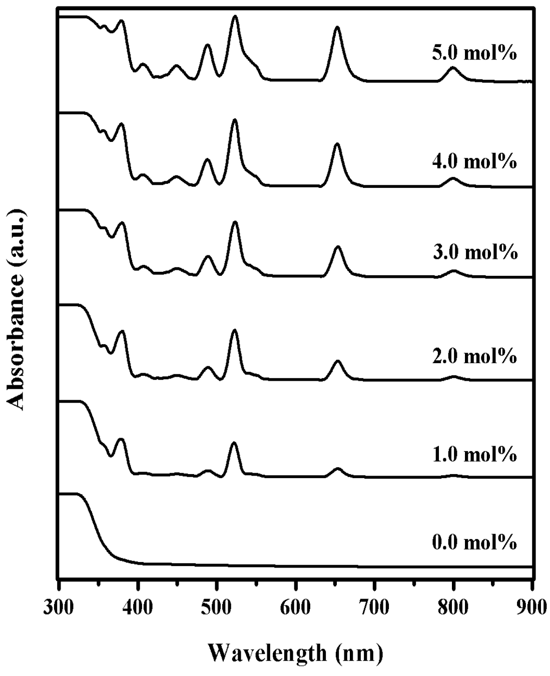

Fig. 3. The absorption spectra of present glasses

For the observed color, the undoped glass sample was colorless while the doped glasses were pink. The brightness, L^* values were increased with the increasing of Er_2O_3 content and also shown in Fig. 4.

Table 3. The color measurement of present glasses in CIE L^* a^* b^*color scale

Concentration of Er_2O_3 (mol%)	Color scale in CIE L^* a^* b^* color scale		
	L^*	b^*	b^*
0.0	87.13	-0.73	0.85
1.0	85.38	12.53	-1.79
2.0	86.77	17.68	-3.66
3.0	78.61	19.39	-3.01
4.0	87.31	24.66	-4.64
5.0	87.36	29.35	-4.94

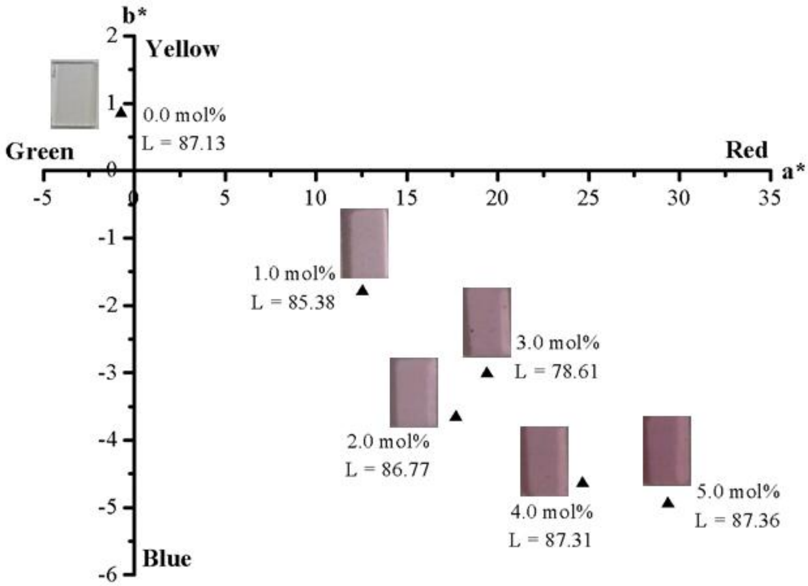

Fig. 4. The color measurement of present glasses in CIE L* a* b* color scale

4. Conclusion

The borosilicate glasses doped with different Er_2O_3 concentration have been prepared in this present work. The density, molar volume, refractive index, optical absorption spectra and color of all glasses have been changed with the concentration of Er_2O_3. The density and refractive index are increased with increasing Er_2O_3 concentration. The variations of the molar volume may be attributed to the change of interatomic spacing inside the glasses network. The absorption peaks have been observed for the doped glasses occurred at 350, 380, 400, 440, 480, 530, 545, 640 and 790 nm, corresponded with pink color of glass samples. The brightness, L* were increased with the increasing of Er_2O_3 content.

Acknowledgements

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