

Physical and FTIR Studies of $\text{PbO-PbF}_2\text{-Bi}_2\text{O}_3\text{-B}_2\text{O}_3\text{-Y}_2\text{O}_3\text{:Er}_2\text{O}_3$ Glasses

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Abstract

The combination of prepared glasses of $\text{PbO-PbF}_2\text{-Bi}_2\text{O}_3\text{-B}_2\text{O}_3\text{-Y}_2\text{O}_3\text{:Er}_2\text{O}_3$ glasses standard meltquenching technique. The measured physical parameters standard formula. Density values are observed increasing manner and also observed remaining values increasing manner except ion concentration and field strength. IR spectra with increase in the concentration of Y_2O_3 clearly suggest the decreasing presence of the concentration of Y-O-B linkages in the glass network. In other words, IR spectral analyses suggest that there is an increase in the degree of disorder in the glass network with increase in the concentration of Y_2O_3 .

Key words: Erbium ions, Physical parameters, FTIR studies

1.Introduction

Lot of attention has been paid to the investigation on lead fluorine introduced bismuth borate glasses due to their potential applications in various fields such as optical switches, reflecting windows, fiber amplifiers electro-optic & magneto-optical devices, thermal sensing materials etc [1]. In addition to these, borate glasses found to exhibit high physical and chemical stability, low melting temperature, long infrared cut off and high infrared transparency. In general, heavy metal oxide based glasses possess large non-linear optical susceptibility coefficient that makes them suitable for predominant applications in non-linear optical devices (such as ultrafast optical switches and power limiters), broad band optical amplifiers and solid state ionic devices [2]. When bismuth borate glasses mixed with rare earth metal oxides like erbium and yttrium, then these glasses would become prominent materials for bulk lasers, optical waveguides etc [3]. It is also noteworthy to mention that these glasses highly suitable host materials for variety of rare earth metal ions. Many researchers are working on rare earth metal doped borate glasses across the globe. But, the luminescence studies on Er^{3+} ions in Y_2O_3 mixed lead oxyfluoro borate glasses are very limited. Some of the recent studies of this ion in other glass systems have been briefly reviewed below. H O Tekin et al explained capacity in nuclear radiation shielding.

The direct effect of Er_2O_3 on bismuth barium telluro borate glasses for nuclear security applications [5]. S. L. Meena and Beena Bhatia explained The large value of metallization criterion indicates that the glass materials are insulators, Polarizability and Optical Basicity of Er^{3+} Ions Doped Zinc Lithium Bismuth Borate Glasses [6]. J.M.Park et al discussed Luminescence Property of Rare-Earth Doped Bismuth-Borate Glasses, Moreover, Bi-glass scintillators with high light yield with good radiation hardness and low cost can be applied in high energy and nuclear physics, medical imaging, homeland security and radiation detection[7].

Nimitha S. Prabhu explained Linear behaviour obtained through the dose response of the glass (5kGy–50kGy) proved their suitability for dosimetric application in the food irradiation zones and in red LEDs (<50kGy) [8]. M. Mariyappan et al discussed Luminescence properties of Er^{3+} ions doped bismuth borate glasses for 1.53 μm broadband optical amplifiers [9]. A.L.Martins et al explained Influence of BaX_2 (X = Cl, F) and Er_2O_3 concentration on the physical and optical properties of barium borate glasses [10]. G.Chandrashekaraiiah et al Role of Er^{3+} and Bi^{3+} ions on thermal and optical properties of $\text{Li}_2\text{B}_4\text{O}_7$ glasses: Structural correlation[11]. Effendy et al Characterization and optical properties of erbium oxide doped ZnO-SLS glass for potential optical and optoelectronic materials [12].

N.Luewarasirikul, et al Erbium-doped calcium barium phosphate glasses for 1.54 μm broadband optical amplifier [13].
Nimitha S.Prabhu et al Investigations on the physical, structural, optical and photoluminescence behavior of Er^{3+} ions in lithium zinc fluoroborate glass system [14].

II.Experimental Methods

The glasses used for the present study are prepared by the melting and quenching techniques [15-17]. The starting materials used for the preparation of the present glasses were analytical grade reagents of PbO , PbF_2 , H_3BO_3 , Bi_2O_3 , Y_2O_3 and Er_2O_3 (METALL, China, 3N pure). The compounds of required compositions were thoroughly mixed in an agate mortar and melted in a platinum crucible. The furnace used was a Proportional + Integral + Derivative (PID) temperature controlled furnace.

The glasses were melted at about 900–1000 $^{\circ}\text{C}$ for a 1/2 h till a bubble free liquid was formed. The resultant melt was then poured in a brass mould (containing smooth polished inner surface) and subsequently annealed from 300 $^{\circ}\text{C}$ with a cooling rate of 1 $^{\circ}\text{C}/\text{min}$. The glasses were then ground and optically polished. The approximate final dimensions of the glasses used for characterizing and studying the physical parameters and optical properties are 1 cm x 1 cm x 0.2 cm.

The density (d) of the glasses was determined by the standard principle of Archimedes' using O-xylene (99.99 % pure) as the buoyant liquid. The mass of the samples was measured to an accuracy of 0.1 mg using Ohaus digital balance Model AR2140. The density of the samples was determined by weighing the bulk glasses in the liquid and in air. From the measured values of density d and calculated average molecular weight $\bar{M}$, various physical parameters such as rare earth ion concentration N_i , mean ion separation R_i , which are useful for understanding the physical properties of these glasses were evaluated using standard formulae [18, 19].

The refractive index (n_d) of the glasses was measured (at $\lambda = 589.3 \text{ nm}$) at room temperature using Abbe refractometer (Fig. 2.2) with monobromo naphthalene as the contact layer between the glass and the refractometer prism.

Infrared transmission spectra were recorded on a (Fig. 2.5) with a resolution of 0.1 cm^{-1} in the spectral range 400–2000 cm^{-1} using potassium bromide pellets (300 mg) containing pulverized sample (1.5 mg). These pellets were pressed in a vacuum die at $\sim 680 \text{ MPa}$. The spectra were recorded on JASCO-FT/IR-5300 spectrophotometer.

III.Results and Discussions

1 .Physical Parameters

Various physical parameters such as erbium ion concentration N_i , mean Er^{3+} ion separation r_i , polaron radius r_p , molar volume, molar refractivity, specific refractivity, molar electronic polarizability, oxygen molar volume, oxygen packing density and metallization criterion of these glasses are evaluated using the conventional formulae [20] and the measured values of density and refractive index. The physical parameters are presented in Table 1.

Table1. Summary of the data on various physical parameters of $\text{PbF}_2\text{--PbO--Bi}_2\text{O}_3\text{--B}_2\text{O}_3\text{:Er}_2\text{O}_3$ glasses mixed with different concentrations of Y_2O_3 .

Property	EY ₂	EY ₄	EY ₆	EY ₈	EY ₁₀
Density ρ (g/cm ³)	5.650	5.714	5.778	5.842	5.905
Er^{3+} ion conc. N_i (10^{22} ions/ cm ³)	2.252	2.231	2.211	2.192	2.174
Inter ionic distance of Er^{3+} ion R_i (Å)	3.541	3.552	3.563	3.573	3.583
Polaron radius R_p (Å)	1.427	1.431	1.435	1.440	1.444

Field strength F_i ($10^{16}/\text{cm}^2$)	1.433	1.465	1.456	1.447	1.439
Molar Volume V_m ($\text{cm}^3 \text{mol}^{-1}$)	26.745	26.992	27.234	27.471	27.703
Refractive index (n)	1.769	1.773	1.779	1.782	1.791
Molar refractivity R_m ($\text{cm}^3 \text{mol}^{-1}$)	11.103	11.249	11.415	11.548	11.744
Molar electronic polarizability α_m ($10^{-24} \times \text{cm}^3$)	4.303	4.461	4.527	4.579	4.657
Oxygen molar volume V_o ($\text{cm}^3 \text{mol}^{-1}$)	11.167	11.270	11.371	11.470	11.567
Oxygen packing density (mol/lit)	89.550	88.729	87.940	87.182	86.452

2. Infrared spectra

In a process of having some pre-structural variations due to the introduction of sesquioxide in the titled glass we have studied the infrared transmission spectra. The spectra exhibited two main groups of bands in the regions $1300\text{--}1400 \text{ cm}^{-1}$ and $1100\text{--}1200 \text{ cm}^{-1}$ attributed, respectively, due to the vibrations of BO_3 and BO_4 structural units. Another band at about 710 cm^{-1} identified as being due to the bending vibrations of B–O–B linkages is also located in these spectra [21] and also referred [22]. vibrations of BO_3 and BO_4 structural units are observed this paper[23]. In the region of vibrations of BO_4 structural units a band due to octahedral distorted PbO_2F_4 vibrational groups is also expected [24]. Vibrational band due to PbO_4 structural units is also observed in the spectra of all the glasses at about 470 cm^{-1} [25]. With the introduction of Y_2O_3 into the glass matrix, the intensity of second group of bands (band due to the vibrations of BO_4 units) is observed to decrease, whereas the intensity of the first group of bands (bands due to the BO_3 structural units) is observed to increase. As the concentration of Y_2O_3 is increased, the intensity of band due to BO_4 structural units observed to increase, whereas that of the bands due to BO_3 structural units is decreased. In other words, the octahedral occupancy of yttrium ions decreases gradually with increase in the concentration of Y_2O_3 in the glass network and are responsible for the decrease of vibrational band due to BO_3 structural borate groups.

Two of the oxygen ions associated with each tetrahedron is assumed to be non-bridging ions forming ionic bonds with the trivalent yttrium ions. Here, Y^{3+} ions in the borate tetrahedra must be moved more outward since the ionic radius of this ion is larger. Hence, the octahedron of yttrium ion linked in triangle with BO_4 structural units is more distorted. The highest disorder in the network of high Y_2O_3 mixed glasses is also evident from IR spectra. The lowest intensity of band due to BO_4 structural units is seen in EY_{10} among all the glass samples indicates this inference. The increasing intensity of the band due to BO_3 structural units at the expense of BO_4 structural units in the IR spectra with increase in the concentration of Y_2O_3 clearly suggests the decreasing presence of the concentration of Y–O–B linkages in the glass network. In other words, IR spectral analyses suggest that there is an increase in the degree of disorder in the glass network with increase in the concentration of Y_2O_3 .

Table .2 Summary of band positions in the IR Spectra of $\text{PbF}_2\text{--PbO--Bi}_2\text{O}_3\text{--B}_2\text{O}_3\text{:Er}_2\text{O}_3$ glasses mixed with different concentrations of Y_2O_3 . (Band positions were measured to an accuracy of $(\pm 1.0 \text{ cm}^{-1})$)

Glass	Borate groups (cm^{-1})			YO_6/PbO_4 Units
	BO_3	BO_4	B–O–B Linkages/Y–O–B Units	
EY_2	1338	1042	727	473
EY_4	1334	1045	723	472
EY_6	1329	1048	719	472
EY_8	1326	1051	714	472
EY_{10}	1321	1053	710	471

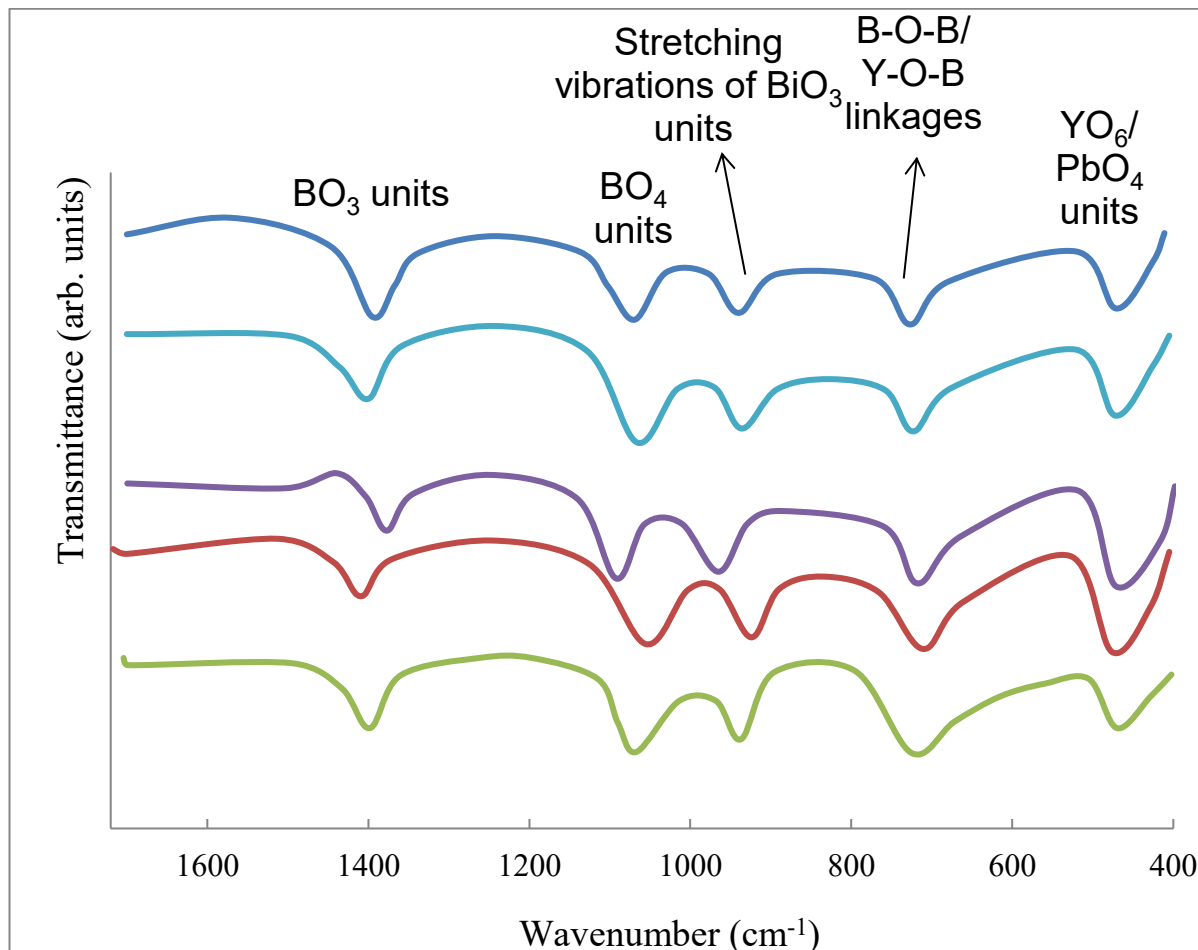


Fig. 1 Comparison plot of IR transmittance spectra of B_2O_3 - PbO - PbF_2 - Er_2O_3 glasses doped with different concentrations of Y_2O_3 recorded at room temperature.

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