Research Article

Optical Properties of Erbium Zinc Tellurite Glass System

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Er³⁺-doped tellurite glasses with molar compositions of $x\text{Er}_2\text{O}_3\text{-}20\text{ZnO-(}80-x\text{)TeO}_2$ ($x = 0, 1, 2, 3$, and 4 mole%) (EZT) have been successfully synthesized by the melt-quenching method. Density and molar volume have been measured. UV-VIS absorption spectra in the wavelength range of 400–800 nm at room temperature has been measured. The band gap for every composition has been calculated. Photoluminescence spectroscopy in the wavelength range of 400–650 nm and at room temperature has been evaluated.

1. Introduction

Recently, tellurite glass has been used for lasing materials and amorphous silicon solar cells [1, 2]. The properties of the host material are very important to study before being doped with any rare-earth elements. Some of the fundamental aspects of tellurite glasses such as glass structure, physical, thermal, optical, and other spectroscopy properties have been extensively studied [3–16]. Most of the research that is emphasized particularly on tellurite glass doped with rare-earth element has been carried out. Erbium doped tellurite glasses considerable literature has recently emerged concerning the structure, optical, mechanical, thermal, and electrical properties. The optical properties of glasses have been an important topic of continuing interest. For instance, the excellent optical properties of Er³⁺-doped gallium tellurite glasses that promising laser and amplifier material was studied [17].

The aim of this study is to synthesis and characterization of the $\text{Er}_2\text{O}_3\text{-ZnO-TeO}_2$ (EZT) glass system. Density, molar volume of glass, X-ray diffraction (XRD), and the chemical composition of the glass samples will be measured. Absorption and emission spectra through UV-Vis-NIR and photoluminescence spectroscopy, respectively, will be measured.

2. Experimental Work

Glass samples were prepared by using tellurium dioxide (purity $\geq 99\%$), zinc oxide, ZnO (purity $> 97\%$), and erbium (III) oxide (purity 99.9%). The powder chemicals were weighed using an electronic digital weighting machine with an error of $\pm 0.01\text{g}$. Each batch was then melted at 700–900°C in the melting furnace. The melt was held at this temperature for 30 minutes until a bubble-free liquid was formed. The melt was stirred to achieve desirable homogeneity. The homogeneous melt was quenched by pouring it onto a preheated stainless steel mold to avoid excess thermal shocks. The glasses were annealed for 1 hour at 10°C higher than the glass transition temperature to release the mechanical strains. The glass samples with molar compositions of $x\text{Er}_2\text{O}_3\text{-}20\text{ZnO-(}80-x\text{)Te}$ ($x = 0, 1, 2, 3$, and 4 mole%) (known as EZT) were successfully synthesized by the melt-quenching method. The samples were cut into pieces having appropriate dimensions for absorption and emission optical and density measurement [18].

The amorphous nature of each glass sample was confirmed by using X-ray diffraction (XRD) and the chemical composition of the glass samples was analyzed by using energy dispersive X-ray fluorescence (EDXRF). The bulk

TABLE 1: Composition (mol%), molar mass, molar volume, and density of $x\text{Er}_2\text{O}_3$ -20ZnO-(80 - x)TeO₂ glasses.

$x\text{Er}_2\text{O}_3$ (mol%)	ZnO (mol%)	(80 - x) TeO ₂ (mol%)	Molar mass (g/mole)	Molar volume (cm ³ /mole)	Density (g/cm ³)	Optical band gap E_{opt} (eV)
0	20	80	139.62	33.08	4.22	3.04
1	20	79	141.68	33.05	4.28	3.10
2	20	78	143.36	32.86	4.36	3.12
3	20	77	144.28	32.75	4.44	3.13
4	20	76	146.26	32.66	4.47	3.14

FIGURE 1: The erbium doped $x\text{Er}_2\text{O}_3$ -20ZnO-(80 - x)TeO₂ ($x = 0, 1, 2, 3$, and 4 mol%) (EZT) glass samples.

density of glass samples was measured using the Archimedes principle at room temperature and the molar volumes were estimated quantitatively. All the glass samples were measured using XRD measurement system in the powder form. The EDX analysis was performed by using the fluorescence X-ray spectrometer EDX-720/800HS/900HS/. UV-Vis spectrophotometer (Lambda 35, Perkin Elmer) system has been used with sample thickness 1.88 to 2.04 mm have been used.

3. Results and Discussion

Five of EZT glasses have been successfully prepared where all glass samples are transparent, bubble-free, and homogeneous. The glass color changes to be more growing pink with increasing of erbium content as shown in Figure 1. Figure 2 represents the XRD measurement EZT glass. Figure 2 shows a broad halo characteristic, which confirms the amorphous structure.

Figure 3 shows that the density of EZT glass is increased with the addition of Er_2O_3 content. The increasing in density of the glasses is due to the heavier erbium atomic mass as compared to the other element in the glass samples. The atomic mass of erbium is 167.259 which is heavier compared to tellurium (127.60) and zinc (65.409). The molar volume (V_m) of the glass samples has been calculated according to

$$V_m = \frac{M_{\text{glass}}}{\rho_{\text{glass}}} \quad (\text{cm}^3) \quad (1)$$

$$M_{\text{glass}} = \frac{\{(80 - x) M_{\text{TeO}_2} + 20M_{\text{ZnO}} + (x) M_{\text{Er}_2\text{O}_3}\}}{(100)}, \quad (2)$$

where M_{glass} and ρ_{glass} are the mass and density of the glass sample, respectively. Molar volume of tellurite glass samples has been plotted in Figure 3. As the Er_2O_3 content in the EZT glasses increased, the density is also increased, hence

FIGURE 2: The XRD pattern of the EZT glasses.

FIGURE 3: The variation of density and molar volume of EZT glass system.

resulting in the decrease of V_m . Based on the result obtained, the density and the molar volume of the EZT show an opposite trend. The increasing in density of the glasses is due to the heavier Er_2O_3 molecular mass compared to the other element in the glass system as shown in Table 1.

The UV-Vis-NIR absorption spectra for glass system ranging from 400 to 800 nm of wavelength are shown in Figure 4. It is found that optical absorption edge is not sharply defined in the present glasses, which clearly indicates their

FIGURE 4: Graph of quantity $(\alpha\hbar\omega)^{1/2}$ against photon energy $(\hbar\omega)$ for $(80-x)\text{TeO}_2-20\text{ZnO}-x\text{Er}_2\text{O}_3$ glasses.

FIGURE 5: The nonlinear energy gap E_{opt} variation in various Er_2O_3 content.

glassy nature. The optical band gap E_{opt} values of the glasses can be calculated using the relation (proposed by Davis and Mott) between the absorption coefficient $\alpha(\omega)$ and photon energy $\hbar\omega$ of the incident radiation and are given below [19, 20]:

$$\alpha(\omega) = \frac{A(\hbar\omega - E_{opt})^n}{(\hbar\omega)}, \quad (3)$$

where E_{opt} is the optical band gap energy in eV, A is a constant, and the exponent n takes different values depending on the mechanism of interband transitions [19]. The variation of the optical energy band gap (E_{opt}) versus mol% of Er_2O_3 is shown in Figure 5 where the optical band gap is gradually increased from 3.04 to 3.14 eV as the Er_2O_3 content is added into the ZnO-TeO₂ glass system.

It should be noted however that the E_{opt} is found to be higher than in a system with single doped Er_2O_3 (2.43–2.71 eV) [5] and lower than the pure TeO₂ (3.97 eV). The observed increase of the optical band gap E_{opt} is attributed to the substitution of TeO₂ by Er_2O_3 . The addition of small amount of rare-earth is capable of disturbing the disorder and consequently increases the optical band gap energy as shown in Table 1. Also, Figure 4 shows that several significant absorption peaks are observed which are contributed by the excited state of Er^{3+} ions.

The upconversion luminescence spectra in the range of 400 nm–650 nm at the excitation of 520 nm have been observed as shown in Figure 6. Some emission peak can be observed where the emission band center is around 555 nm to 557 nm. It was clear that the higher mol% of erbium doped into the glass gives the decrease of intensity. Usually, when the concentration is high, the nonradiative decay process will increase, while radiation relaxing decreases the intensity of luminescence decrease [21]. It was found that the higher mole% of erbium doped into the glass resulted in the decrease of the intensity due to the concentration of Er^{3+} that affected

FIGURE 6: A luminescence spectrum of EZT glasses.

the intensity of upconversion luminescence [22]. The present data will be gathered with previous data on tellurite glass in order to study the structure of these glasses [23, 24].

4. Conclusion

New tellurite glasses in the form xEr_2O_3 -20ZnO-(80 - x)TeO₂ ($x = 0, 1, 2, 3$, and 4 mole%) (EZT) have been synthesized. The glasses have the following feature due to the increase of Er_2O_3 mol%:

- (1) density increased from 4.22 to 4.47 g/cm³,
- (2) molar volume decreased from 33.08 to 32.66 cm³,
- (3) optical energy gap increased from 3.04 to 3.14 eV,
- (4) upconversion luminescence spectra showed peaks at 555 to 557 nm.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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