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***RESEARCH ARTICLE***

## STUDY OF PHYSICAL AND PHOTOLUMINESCENCE PROPERTIES OF ERBIUM IONS DOPED BARIUM-TELLURITE GLASSES

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***Abstract***

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Tellurite base glass doped with Erbium ions have been synthesized by melting-quenching method. X-ray diffractogam is used to verification of the glassynature of samples. Differential scanning calorimetry determine the glass transition temperature. Density (ρ) of specimens was calculated by Archimedes's principle. Other physical parameters as oxygen packing density (OPD), Erbium ion concentration ($C_L$) in the specimen, molar volume (Vm), intermolecular distance Ri, Polaron radius Rp, erbium ion concentration and Molar index of refraction Rm, were computed. In order to study the optical characteristics of the specimens, for instance, coefficient of absorption, forbidden energy gap (Eg), refractive index, and Urbach Energy (E), UV-visible absorption characterizations of Ba-Te glasses was performed in the range of 340-1000 nm. PL characterization has performed for photoluminescence study.



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## Introduction:-

Given that we are now living in the Glass Era, tellurite glasses are some clever materials. Due to its exceptional physical characteristics, tellurite glasses made from tellurium dioxide (TeO2) are of technological importance [1-4]. Due to their advantages over crystalline materials easily synthesized, inexpensive, capable of producing the required shape and size, and requiring less time for synthesis Rear Earth (RE) ions doped glasses are receiving a lot of attention for photonic applications [5]. Tellurite glasses are among the oxide glasses that exhibit a number of benefits because of characteristics including a low refractive index, good thermal and mechanical stabilities, high gain density, high transparency, and a comparatively low melting temperature [6,7gfa,]. The most significant RE ion in terms of photoluminescence characteristics and its emission transition of 4I13/2 4I15/2 is erbium (Er3+). Moreover, the Er3+ ion exhibits emissions at green and red wavelengths that can be attributed to the transitions 2H11/2 + 4S3/2 4I15/2 and 4F9/2 4I15/2, respectively [8]. A broad near-infrared (NIR) emission band's full width at half maximum (FWHM) implies a wealth of potential uses in optical amplifiers and waveguides, as well as the ability to support concurrent traffic on numerous communication channels [9]. For a long time, Er3+-doped fibre amplifiers (EDFA) operating in the C-band region have been essential for optical communication (1530–1565 nm). Additionally, Er3+ ions are generally co-doped with other Ln3+ ions, such as Yb3+, Tm3+, Nd3+, and Pr3+ in order to expand the region of EDFAs in the specified region [10–11]. Broadband transmission is currently limited since commercial EDFA manufactures glass fibres using silicate glasses, which have a 40 nm bandwidth. For ultrabroadband EDFA applications, it is important to investigate an appropriate glass composition [12]. In comparison to other glasses, tellurite glasses are the best option since they can easily have their chemical endurance

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increased by adding heavy metal ions, specifically Ba2+ for applications like high gain and ultra-broadband EDFA. In the current work, (80-x)% [TeO2]-20% Er3+ [BaO] –x% We looked into [Er2O3] glasses from the standpoint of high gain and broadband optical amplification. By including BaO2, the tellurite network's mechanical strength can be increased. Evaluations were made of physical characteristics like density, polaron radius, interior distance, rear earth ion concentration, and molar refractive index. The absorption spectrum was used to quantify the optical characteristics of the glasses, including their optical band gap, Urbach energy, and refractive index. Emission spectra are used to analyse the photoluminescent characteristics of Er3+.

**Glass Preparation**

In the current study, the glasses are prepared using the aforementioned composition together with the measure of AR (analytical grade reagents) of TeO2, BaO, and Er2O3 with 99.9% purity. By using the traditional melt quench process, the molar composition of (80-x)%TeO2-20%BaO-x%Er2O3 (x=0.5, 1.0, and 1.5mol%) is created. Table 1 lists the glass compositions and accompanying reagent codes. By using a mortar and pestle, the proper weighed quantity of chemicals is thoroughly mixed to create a fine homogenous mixture. The alumina crucible will be filled with a fine powder mixture, which will then be heated for about 30 minutes in a furnace that has been preheated to 700°C. Physical stirring will then be done to create an uniform melt, and the temperature will then be increased to 950°C. These melts were placed into a stainless steel pellet-shaped mold that was kept at 200°C, annealed (cooled) at roughly 300°C for 1.5 hours, and then gradually cooled to room temperature. With this method of cooling samples, the thermal stress and structural stability may be anticipated. These annealed glass samples, known as TBE1, TBE2, and TBE3, are 2 mm thick, very transparent, and pinkish.

## Results and Discussions:-

**Physical parameters**

Using 99.99% pure distilled water as a buoyant liquid, the traditional Archimedes' method can determine the glasses' density with a precision of 0.001 gram/cm3. Different physical parameters, such as Vm (molar volume), ni (Er3+ ion concentration), rp (polaron radius), ri (inter-ionic distance), fi (field strength), and molar refractance, are calculated for the prepared Er3+ doped TBE glass samples using standard formulae [7,13], which are derived from density and index of refraction values and listed in Table 1. Figure 1 displays the fluctuation in density (ρ), molar volume (Vm), and Er3+ ion concentration.

**Table 1:-** Physiacal parameters of $Er^{3+}$ ions doped Barium Tellurite glass systems.

| S.No. | Physical Properties | TBE1 | TBE2 | TBE3 |
|---|---|---|---|---|
| 1 | Density (d) ($g/cm^3$) | 5.082 | 5.137 | 5.193 |
| 2 | Mol. Mass(mole) | 159.45 | 160.89 | 162.01 |
| 3 | Mol. volume($cm^3$/mol) | 31.375 | 31.319 | 31.196 |
| 4 | Lanthanide ionconcentration($c_L$) ($c_L \times 10^{20}$)(ions/$cm^3$) | 1.91965 | 3.85619 | 5.8071 |
| 5 | Polaron radius ($p_r$)(Å) | 4.84375 | 3.83828 | 3.34865 |
| 6 | Inter ionic distance ($I_r$)(Å) | 17.3351 | 13.7387 | 11.9842 |
| 7 | Field strength ($F_L \times 10^{13}$) ($cm^2$ ) | 9.983 | 15.8938 | 2.0881 |
| 9 | Oxygen Packing Density (OPD) (g-atom/l) | 57.52907 | 58.35893 | 58.56646 |

Variation of density and molar volume with Er3+ ion concentration is shown in plot shown in fig.1.

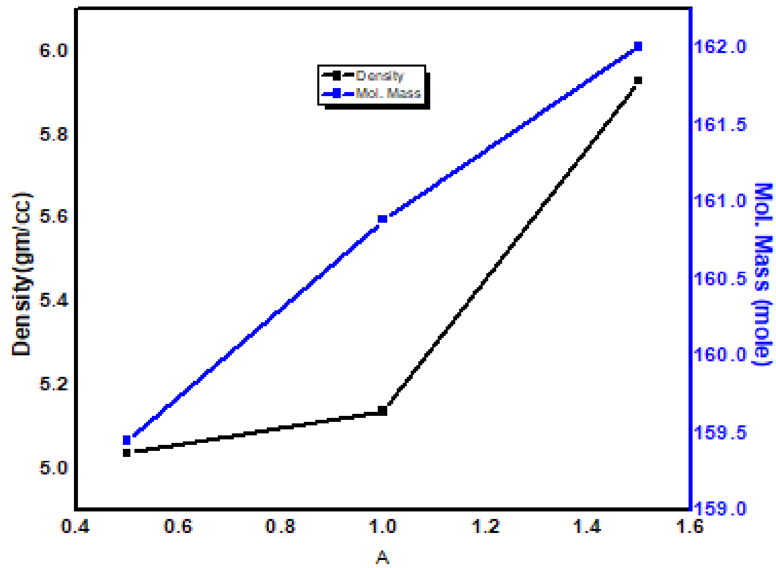


**Fig.1:-** Variation of density and molar mass with concentration of $Er^{3+}$ ions.

**XRD (X-Ray Diffraction) Analysis**

Using a Bruker Model No. D2 Phaser 2nd Gen., the XRD pattern of the currently manufactured TBE glass sample matrix was seen in the range of 20 - 80o (2), as shown in Fig. 2. According to Fig. 2, the Bragg peak is absent from the spectrum, leaving only a broad plentiful hump in the 30 area. This demonstrates the non-crystalline nature of the created glasses.

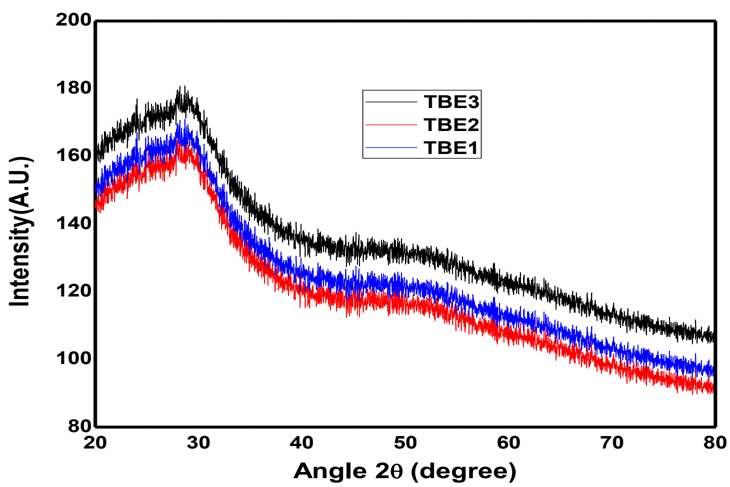


**Fig. 2:-** Powder X-Ray diffraction pattern of TBE glasses.

**DSC (Differential Scanning Calorimerty)**

Figure 3 displays the DSC plot of a batch of TBE glasses with the following composition: (79.5%)%TeO2-20%BaO-0.5%Er2O3. TA Instruments, USA, is the company utilized for DSC, which is examined in the temperature range of 50°C to 450°C. The scan clearly shows that the fabricated glass has a moderate glass transition temperature of 350°C.

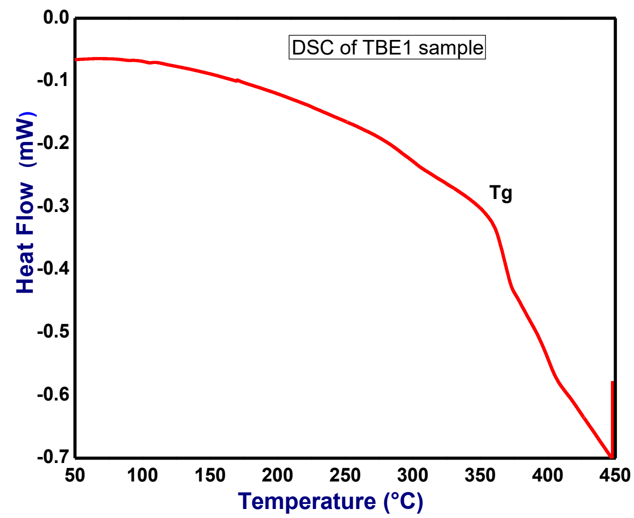


**Fig.3:-** Representative DSC plot of TBE1 glass.

**Optical Properties**

**Gap Energy (Eg)**

The absorption effects in the glass materials are reported by the analysis of Eg values. The analysis of the optical transition positions and electronic band structure in both crystalline and amorphous materials can be done in this way by studying the optical edge in the ultraviolet range. We must determine the optical gap (Eg) values for the current glasses based on the absorption edge investigations by plotting the Tauc plot for (hν)1/2 and (hν)2 as a function of photon energy hν using the equation:

$\alpha(\nu)h\nu = A(h\nu\text{-}E_g)^{\gamma}$ (1)

Thus, "A" stands for constant, and the index () provides values in the glass matrix of γ =1/2 (indirect transitions) and γ=2 (direct transitions) [14]. By extrapolating the linear portion of the curve to the horizontal axis (hν) from the plot of [(hν)]2 and [α(hν)]1/2 vs. photon energy (hν), shown in Figs. 4 and 5, optical gaps (Eg) are calculated using Eq. (1).

The Tauc's plots for $[\alpha(h\nu)]^2$ vs photon energy (hν) and $[\alpha(h\nu)]^{1/2}$ versus photon energy (hν), respectively, are shown in Figs. 4 and 5. Table 2 lists the Eg values of TBE glasses, which are revealed to be between 3.09 and 3.15 eV for direct transitions and 2.96 to 3.01 eV for indirect transitions.

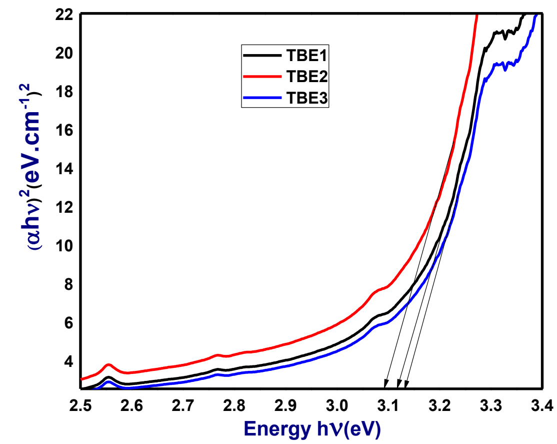


**Fig. 4:-** $(\alpha h\upsilon)^2$ vs (hυ) plotof TBE glassesfor direct energy band gap.

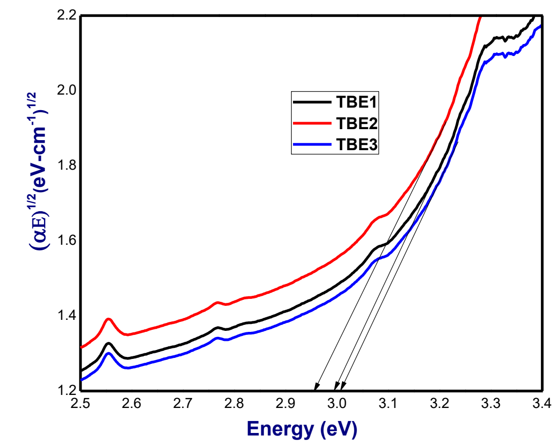


**Fig.5:-** $(\alpha h\upsilon)^{1/2}$ vs (hυ) plot of TBE glasses for indirect energy band gap.

Figure 6 depicts the ln (α)vs. hν plot, which defines the Urbach energy (Eu) as the reciprocal of the slant of the linear portion of the curve in the lower hν (photon energy) area. The glass matrix's elemental disorder is represented by the parameter Eu [15]. For all concentrations, the Eu values for the currently constructed glasses vary from 0.416 to 0.416 eV. (table 2).

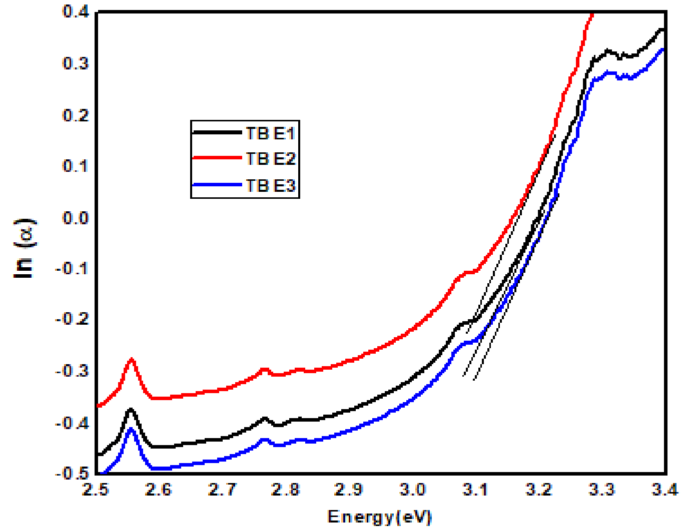


**Fig. 5:-** Representative of Urbach's plot of TBE glasses.

Calculation of Refractive index of synthesized glasses were calculated done by the relation[16]

$(n2 - 1)/ (n2 + 1) = 1 - \sqrt{(Eg/20)}$ (2)

Calculated value of n in the range of 2.0158 to 2.0219 and highest for 1% mol concentration of Er2O3 in glass composition, listed in table 2.

**Table 2:-** Optical properties of of $Er^{3+}$ ions doped Barium Tellurite glass systems.

| S.No. | Physical Properties | TBE1 | TBE2 | TBE3 |
|---|---|---|---|---|
| | Direct forbidden energy gap(Eop)(eV) | 3.11 | 3.09 | 3.12 |
| | Indirect forbidden energy gap(Eop)(eV) | 3.0 | 2.97 | 3.01 |
| | Refractiveindex(RI) | 2.0178 | 2.0219 | 2.0158 |
| | Urbatch's Energy Eu (eV) | 0.417 | 0.416 | 0.418 |

**Absorption spectrum**

In order to study the UV, VIS, and IR absorption spectra of the Er3+ ion-doped TBE samples, a Research India absorption spectrometer with model number RI2SA was used. The results are depicted in Figure 6. As seen in Fig. 6, the spectrum exhibits multiple excitation bands that are represented by the shifts from ground state 4I15/2 to 2G9/2(408nm), $^4G_{3/2}$(444nm), $^4G_{5/2}$(454nm), $^4G_{7/2}$(488nm), $^2H_{11/2}$(520nm), $^4S_{3/2}$(545), $^4F_{9/2}$(650), $^4I_{9/2}$(800nm) and $^4I_{11/2}$(980nm) absorption bands. This peak of Er3+ doped TBE glasses and the band at 520 nm (4I15/2 to 2H11/2) are discovered to have substantially higher intensities than other transitions.

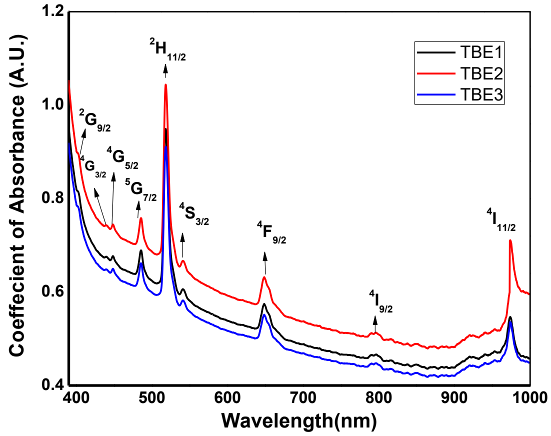


**Fig.6:-** Representative Absorption of TBE glasses.

**Visible Photoluminescence**

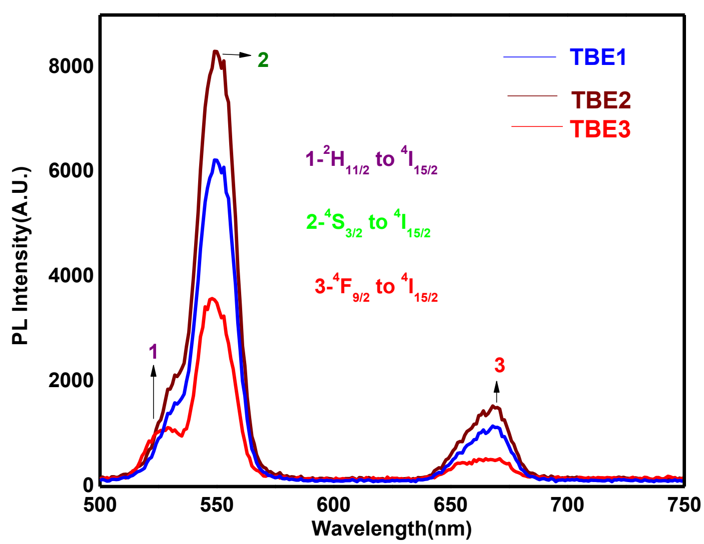


**Fig.7:-** Representative Photoluminescence of TBE glasses.

Using "Fluorolog -3 of Horriba, Jobin Vyon," Fig. 7 displays up-conversion PL spectra of Er3+ ion-doped TBE glasses carried at 980 nm excitation in the spectral region of 500-750 nm. For all of the examined glasses, the peak locations of all detected emission bands essentially remained the same. At 520 nm (2H11/2 4I15/2), 550 nm (4S3/2 4I15/2), and 667 nm (4F9/2 4I15/2) [17] glasses, the bright green and red emission peaks of Er3+ ions are seen. The intensity of PL marginally increases when the concentration of Er2O3 rises from 0.5 mol% to 1.0 mol%; however, it gradually falls at 1.5 mol% due to concentration quenching among Er3+ ions. Energy migration among the Er3+ ions may be the cause of an increase in up-conversion PL intensity with an increase in Er2O3 concentration up to 0.5 mol%.

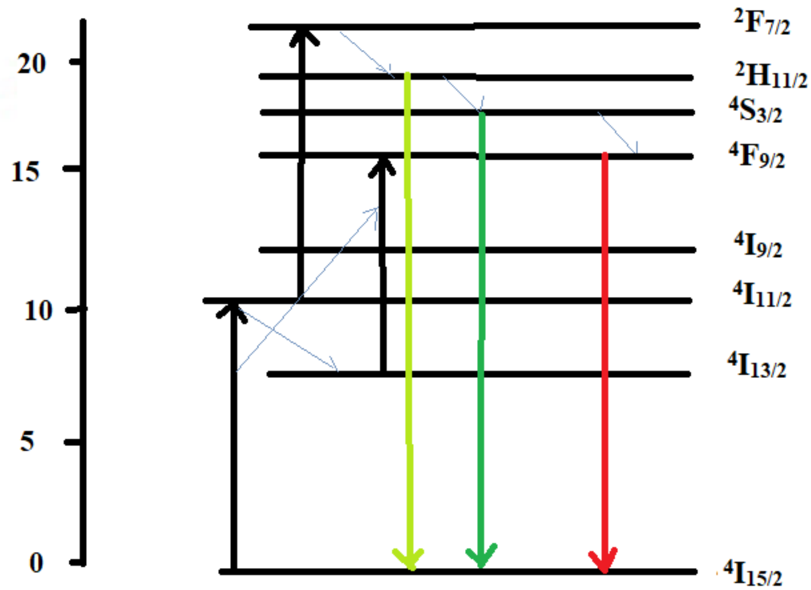


**Figure 8:-** Process of energy transfer by 980nm excitation in TBE glasses codoped with $Er^{3+}$

## Conclusions:-

In conclusion, various Er2O3 doped TBE glasses are produced using the traditional melt-quench method and are identified using various spectroscopic techniques. All of the produced glasses are non-crystalline, according to the XRD investigation.

The glass transition temperature of the glass system is revealed by the DSC analysis. Studying the produced glasses' absorption spectra allows for the evaluation of Eg and Eu values. For the TBE glasses, the Eg values are seen to be smaller in both the direct and indirect optical gap phenomena. Moreover, Eg values vary as Er2O3 concentrations fluctuate. Two strong emission peaks can be seen in the photoluminescence spectrum, one at 550 nm for green light emission at the 4S3/2 4I15/2 transition, which corresponds to the use of green light in the title glasses, and the other at 667 nm for red light emission caused by 980 nm excitation. The highest luminescence intensity in the green and red region is found in 1.0 mol% Er2O3 doped TBE glass, which is why the glass sample TBE2 is appropriate for a variety of optical devices.

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