

DY³⁺ ION - DOPED ZINC BARIUM NIOBIUM BORO-TELLURITE GLASSES: STRUCTURAL, OPTICAL, AND LUMINESCENCE INSIGHTS FOR WHITE LIGHT APPLICATIONS

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Abstract

Analysis and review of physical, structural, optical, and luminescence properties of dysprosium-doped zinc barium niobium boro-tellurite glass has been carried out. All glass samples were prepared by melting around 1.5 h at 1,150°C and annealing around 3 h at 350°C. Six different concentrations of Dy₂O₃ were used to prepare the glasses, ranging from 0.00 to 1.50 mol%. The samples were prepared, involving both shaping and refining, for density, refractive index, and optical/photoluminescence measurements at room temperature. Structural measurements were obtained using XRD, FTIR, and Raman spectroscopy. The absorption spectra demonstrate that the transition state of Dy³⁺ ion from ⁶H_{15/2} (ground state) to several excited states (⁶P_{7/2}), (⁴F_{7/2}+⁴I_{13/2}), (⁶F_{3/2}), (⁶F_{5/2}), (⁶F_{7/2}), (⁶H_{7/2}+⁶F_{9/2}), (⁶H_{9/2}+⁶F_{11/2}), and (⁶H_{11/2}) at wavelengths of 350, 394, 759, 804, 903, 1,094, 1,276 and 1,681 nm, respectively. The sample was excited with a xenon flashlamp of 453 nm, which produces 3 emission peaks at 482, 574, and 661 nm associated with the transitions ⁴F_{9/2}→⁶H_(11/2, 13/2, and 15/2), in that order. The combination of blue light from energy level ⁴F_{9/2}→⁶H_{15/2} and yellow light from energy level ⁴F_{9/2}→⁶H_{13/2} resulted in white light emission, as corroborated by the CIE 1931 chromaticity diagram. The Lifetime exhibits a diminishing trend as the concentration of Dy₂O₃ increases. According to the Judd Ofelt (JO) intensity values, the trend was $\Omega_2 > \Omega_4 > \Omega_6$ observed. The radiative parameters utilized to assess the suitability of these glasses for laser operation in the visible range were the branching ratios (β_R), transition probabilities (A_R), and stimulated emission cross-sections (σ_e) for the ⁴F_{9/2}→⁶H_{13/2} transition. The current Dy³⁺ ion doped zinc barium niobium borotellurite glasses are thus suggested to be ideal for applications of white light and optical devices.

Keywords: Borotellurite glasses; dysprosium; Judd-Ofelt; luminescence; optical devices

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Introduction

The surge in electronic device production has fueled a relentless pursuit of technological advancements and market dominance. For a pioneering enterprise, strategic investments in recruiting top-tier scientists for research endeavors are imperative. Among the myriad subjects under exploration, glass and crystal have emerged prominently. Beyond their conventional roles as ornamental embellishments, these materials unveil a realm of practical applications, ranging from fluorescent lights and solid-state lasers to optical fibers, amplifiers, and incandescent sensors (Tuyen *et al.*, 2019). At the heart of glass production lies a fascinating interplay of raw ingredients-sand, soda ash, and limestone-transformed into a natural and inert substance through a fusion process in a furnace. Typically associated with decorative creations, glass's malleability extends beyond aesthetics to encompass vital roles in electronics, solid-state lighting, and diverse applications. By infusing additional minerals like silica and barium, the glass undergoes a metamorphosis, allowing for customization of color, toughness, and thickness. The glass-forming landscape features an array of types, including silicate, borosilicate, phosphate, soda-lime, and tellurites, with tellurite glass gaining prominence due to its low phonon energy. The synergy of borate and tellurite oxides produces stable glass, with borotellurite glass standing out for its exceptional thermal, optical, and electrical properties, making it a preferred choice for various devices (Kaur *et al.*, 2014). Optimization of borotellurite glass introduces zinc oxide into the equation. This contributes to improved glass production and reduced crystallization rates (Pandarinath *et al.*, 2016). Meanwhile, barium oxide earns high resistance to extreme radiation, heightened density, and improved optical transparency (Azuraida *et al.*, 2015). niobium pentoxide, renowned for its vacant d-orbital and nonlinear optical sensitivity, further elevates the glass's performance (Pelosi *et al.*, 2021). Delving

into the realm of lanthanides, these substances, often catalysts, find applications in diverse fields, including the production of rocket fuel and nuclear weapons. Lanthanide oxides play a pivotal role in fluorescent lights due to their light-emitting capabilities. Exploring the uncharted territory of dysprosium (Dy³⁺ ion), with its unique emission bands spanning the blue, yellow, and red spectra, unveils its potential as a source for generating white light. The emission properties of Dy³⁺ ions are linked to the local field environment and pumping wavelengths, offering a dynamic interplay that influences the Y/B intensity ratio. The judicious balance of yellow and blue emissions not only traverses the white light region of the CIE color chromaticity diagram but also stimulates the host material's production of white light (Karthikeyan *et al.*, 2017). This report makes a comprehensive investigation to unravel the complexity of zinc oxide-doped borotellurite glass. barium oxide Niobium pentoxide and dysprosium with a laser focus on exploring the physical, structural, optical, and luminescence characteristics of Dy³⁺ ion in borotellurite glass with various concentrations. The goal is to discern their suitability for use in white light applications.

Experiment

Figure 1 shows the preparation process for borotellurite glass, consisting of (30-x)TeO₂ - 30B₂O₃ - 10ZnO - 20BaO - 10Nb₂O₅ - xDy₂O₃ (where x = 0.00, 0.05, 0.10, 0.50, 1.00 and 1.50 mol%). The substances were prepared in crucibles of 20 g and heated for 1.5 h in an electric furnace at 1,150°C. After that, the sample was placed into a heated graphite mold and annealed for three hours at 350 °C. Subsequently, every sample underwent cutting and polishing to achieve uniform dimensions of 1.0×1.5×0.3 cm³. The samples were prepared, and schematic characterization carried out for the

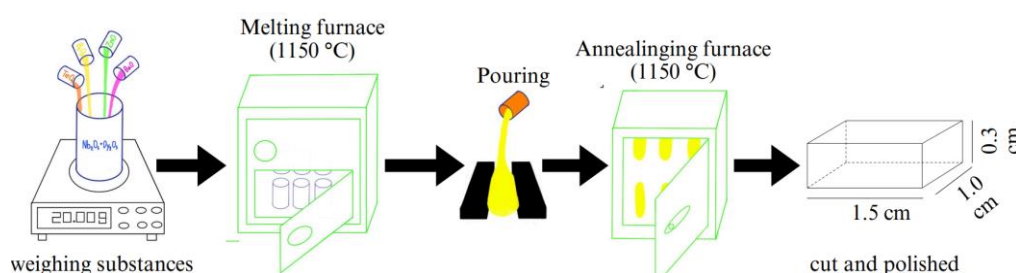


Figure 1. Preparation of samples

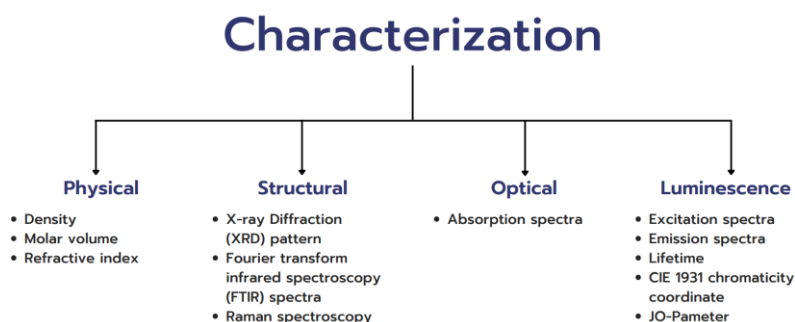


Figure 2. The schematic diagram of the characterization

present work is presented in Figure 2. By weighing the specimens, a densitometer (model AND HR-200) was used to estimate the density (ρ) of the samples. The refractive index (n) was determined using a Presidium Refractive Index Meter II. Using a Rigaku SmartLab X-ray Diffractometer, X-ray diffraction (XRD) examination was used to determine the characteristics of the materials. Utilizing a Nicolet™ iS™5 FTIR spectrophotometer and the Raman spectroscopy, the vibrational states of the boro-tellurite glasses that are currently on the market were examined. A UV-3600 Shimadzu UV-VIS-NIR spectrophotometer was used to detect the UV-Vis-NIR absorption spectra. Moreover, the Agilent Cary Eclipse fluorescence spectrometer was utilized to measure the excitation, emission, and lifetime spectra.

Results and Discussion

Physical Properties

The sample's molar volume, density, and refractive index are listed in Figure 3. In borotellurite glasses doped with Dy^{3+} ion, the density ranges from 3.948 to 4.046 g/cm^3 in the absence of linear association. When the concentration of Dy_2O_3 was increased to 0.05 mol%, it tended to rise first, then drop somewhat at 0.10 mol%, rise at 0.50 mol%, drop slightly at 1.00 mol%, and eventually rise to 4.015 mol% at 1.50 mol%. Glass's molar volume is determined using its density in the calculation formula. Because of the density, the molar volume did not exhibit a linear correlation, encompassing values ranging from 33.180 and 34.210 cm^3/mol . The refractive index of borotellurite glasses, which ranges from 1.801 to 1.780, is nonlinear at varying Dy_2O_3 contents. The refractive index exhibits a decreasing trend from 1.801 to 1.780, as the Dy_2O_3 concentrations vary between 0.00 mol% and 0.50 mol% after that, it increases from 1.790 to 1.796 at

the concentration of Dy_2O_3 1.00 mol% to 1.50 mol%. In general, an increase in refractive index signifies the growth of Bridging Oxygen (BO) in structures, whereas a decrease in index often indicates a rise of Non-Bridging Oxygen (NBO) in structures. That means from the result when Dy_2O_3 was doped in borotellurite glass saturation point, it changed itself from the development of NBO into the development of BO in the structures. The trend of all results is not linear which same literature (Ruamnikhom *et al.*, 2023).

Structural Properties

X-ray Diffraction (XRD) Pattern

Structural measurements were conducted to analyze the composition of the glass samples and verify the characteristics of the glass. The XRD patterns of all the created samples of borotellurite glasses were obtained in the 5-80 degree range of diffraction angle (2θ). The XRD patterns show no sharp peaks with a broad hump, indicating the prepared glasses are amorphous. Lacking distinct sharp peaks and observing a broad hump confirms their amorphous nature (Hegde *et al.*, 2019).

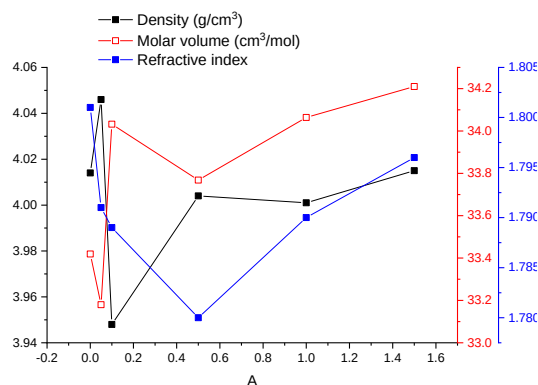


Figure 3. The schematic diagram of the characterization

Fourier transform Infrared (FTIR)

The quaternary glass system (30-x)TeO₂ - 30B₂O₃ - 10ZnO - 20BaO - 10Nb₂O₅ - xDy₂O₃ is shown in Figure 5 along with its FTIR spectra spanning the 650-4,000 cm⁻¹ range. The FTIR bands observed in the glasses and the vibrational modes

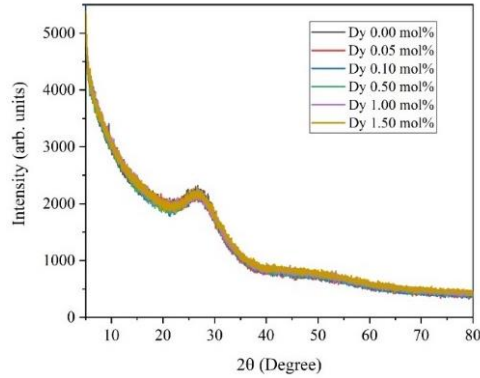


Figure 4. X-ray diffraction (XRD) pattern of borotellurite glass doped with Dy³⁺ ion

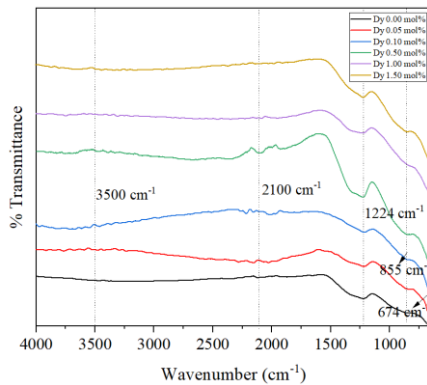


Figure 5. FTIR transmittance spectra of borotellurite glass doped with Dy³⁺ ion

associated with them are shown in Table 1. The Te-O symmetric stretching vibration in TeO₄ tpb units is identified by the significant band at 674 cm⁻¹ (Pelosi *et al.*, 2021) in the FTIR analysis. Additionally, this band indicates the asymmetric stretching vibration of Te-O bonds in TeO₃ tp units. Furthermore, around 822 and 1,221 cm⁻¹ (Kaur *et al.*, 2017), the B-O bond's stretching vibrations are visible. Bridging oxygen (BO) manifests in the glass matrix, as indicated by the band at 822 cm⁻¹, which more precisely exhibits asymmetric stretching vibrations of B-O bonds in tetrahedral BO₄ units. The B-O stretching vibrations of orthoborate and meta-borate chains' BO₃ unit are detected at 1,204-1,226 cm⁻¹ (Kaur *et al.*, 2017), signifying the significant presence of non-bridging oxygen (NBO) at high Dy₂O₃ concentrations. The usage of H₃BO₃ rather than B₂O₃ is responsible for the notable occurrence of the OH group between 2,100 and 3,500 cm⁻¹ (Surekha *et al.*, 2020).

Raman Spectroscopy

In Figure 6, the Raman spectra for all samples are depicted within the 200-2,000 cm⁻¹ range, with baseline subtraction achieved through a polynomial function. Table 2 provides Raman bands along with their assigned vibrational modes. In the 0.0 mol% Dy₂O₃ sample, TeO₂-B₂O₃-ZnO-BaO-Nb₂O₅ glasses exhibit five characteristic bands at approximately 424 cm⁻¹, 671 cm⁻¹, 785 cm⁻¹, 871 cm⁻¹, and 1,100 cm⁻¹. The Te-O-Te bond symmetrical stretching or bending vibrations are what cause the band at 424 cm⁻¹ (Kamalaker *et al.*, 2012). In TeO₄ structural units, the band in the 664-671 cm⁻¹ (Kamalaker *et al.*, 2012) range presents the stretching vibrations of (Te_{ax}-O)_s. The peak of about 771-785 cm⁻¹ (Kamalaker *et al.*, 2012) explains the occurrence of (Te_{eq}-O) and (Te_{eq}-O)_s as vibrational modes of TeO₃ or TeO₃₊₁ units. The presence of NbO₆ octahedra, which is the glasses' distinctive

Table 1. Assignments of FTIR

Band position	Assignments	Reference
674 cm ⁻¹	presence of Te-O bonds	Pelosi <i>et al.</i> (2021)
855 cm ⁻¹	B-O bond stretching vibration in BO ₄ tetrahedra from diborate groups	Kaur <i>et al.</i> (2017)
1,224 cm ⁻¹	Stretching vibrations of B-O of BO ₃ units	Kaur <i>et al.</i> (2017)
2,100-3,500 cm ⁻¹	OH group	Surekha <i>et al.</i> (2020)

Table 2. Assignments of Raman band

Raman band	Assignments	Reference
424-442 cm ⁻¹	Symmetrical stretching or of Te-O-Te linkages or bending vibrations Te-O-Te linkages	Kamalaker <i>et al.</i> (2012)
664-671 cm ⁻¹	Symmetrical stretching vibrational modes of TeO ₄ units	Kamalaker <i>et al.</i> (2012)
771-785 cm ⁻¹	(Te _{eq} -O) and (Te _{eq} -O) _s as vibrational modes of TeO ₃₊₁ or TeO ₃ units	Kamalaker <i>et al.</i> (2012)
871-881 cm ⁻¹	Stretching vibrations of Nb-O bonds in NbO ₆ octahedra	Kamalaker <i>et al.</i> (2012)
1,070-1,100 cm ⁻¹	Stretching vibrations of B-O bonds in BO ₄ units from tri, tetra, and penta borate groups	Alajerami, Y.S.M., Abushab <i>et al.</i> (2017)

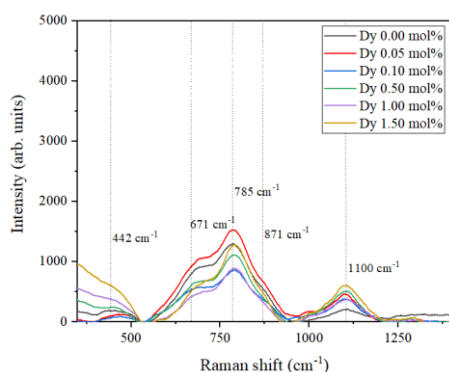


Figure 6. Raman shift of borotellurite glass doped with Dy^{3+} ion

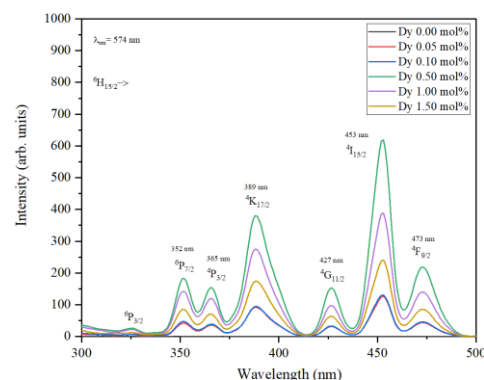


Figure 8. The excitation spectra of borotellurite glass doped with Dy^{3+} ion

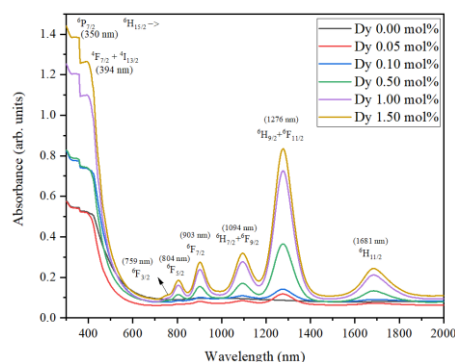


Figure 7. The absorbance spectra of borotellurite glass doped with Dy^{3+} ion

band and is indicated by the band at about 871-881 cm^{-1} (Kamalaker *et al.*, 2012), is shown in the spectra. Wavenumber 1100 cm^{-1} contains the final band stretching vibrations of B-O bonds in BO_4 units from tri, tetra, and penta borate groups (Alajerami *et al.*, 2017).

Optical Properties

Absorbance spectra

In the 600-2,000 nm region, Figure 7 illustrates the absorbance spectra of boro-tellurite glasses doped with Dy^{3+} ions. With an elevation in Dy_2O_3 concentration, a slight enhancement in absorption intensity is observed. The absorbance spectra feature 8 peaks at distinct transition states (from the $^6H_{15/2}$ to high states), as depicted in Figure 7: wavelengths of 350 ($^6P_{7/2}$), 394 ($^4F_{7/2} + ^4I_{13/2}$), 759 ($^6F_{3/2}$), 804 ($^6F_{5/2}$), 903 ($^6F_{7/2}$), 1094 ($^6H_{7/2} + ^6F_{9/2}$), 1276 ($^6H_{9/2} + ^6F_{11/2}$), and 1681 ($^6H_{11/2}$) nm (Do, 2019). Since the spin selection rule ($\Delta S = 0$) permits the transitions from $^6H_{15/2}$ to 6H_J and 6F_J in the NIR region, these transitions are frequently powerful. The $^6H_{15/2} \rightarrow ^6H_{9/2} + ^6F_{11/2}$ transitions are hypersensitive because they adhere to the selection

rules of $|\Delta J| \leq 2$, $|\Delta S| = 0$ and $|\Delta L| \leq 2$. Notably, an increase in dysprosium concentration corresponds to an augmentation in absorbance for each peak, aligning with the principles of the Beer-Lambert law.

Luminescence Properties

Excitation and Emission Spectra

The study of luminescence focused on the quenching excitation and emission wavelengths because for luminescence applications it is necessary to achieve a high intensity of the apparent light for cost-effective production. Therefore, the quenching point of dysprosium alloying must be sought, which can be found after doping with dysprosium and measuring the luminescence, which will be found as the intensity of the emission decreases. Initially, glasses with various Dy_2O_3 concentrations emitted a 574 nm wavelength, producing excitation spectra with seven peaks as shown in Figure 7. The transitions originating in the $^6H_{15/2}$ lower state to several higher states, including $^6P_{3/2}$, $^6P_{7/2}$, $^4P_{3/2}$, $^4K_{17/2}$, $^4G_{11/2}$, $^4I_{15/2}$, and $^4F_{9/2}$, resulted in the observed peaks at 324, 352, 365, 389, 427, 453 and 473 nm [14]. The possibility of stimulating the glasses with these wavelengths is clear from the current investigation, as the strongest excitation occurred at 453 nm (Figure 8). From absorption spectra found at 350 nm is the maximum absorption peak, but in excitation spectra found at 453 nm is the highest intensity peak. This is caused by the effect of the color appearing in the glass (yellow), causing the absorption peak to appear that does not correspond to the excitation peak. Figure 9 shows the peaks that were obtained the blue and yellow regions are represented by two large peaks at 482 ($^4F_{9/2} \rightarrow ^6H_{15/2}$) nm and 574 ($^4F_{9/2} \rightarrow ^6H_{13/2}$) nm, respectively, and a nominal peak at 661 ($^4F_{9/2} \rightarrow ^6H_{11/2}$) nm corresponding to the red region (Anjaiah *et al.*, 2015). The electron was excited to

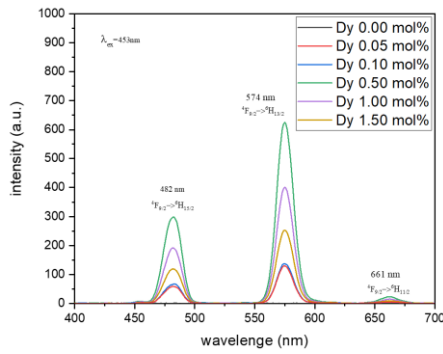


Figure 9. The emission spectra of borotellurite glass doped with Dy³⁺ ion

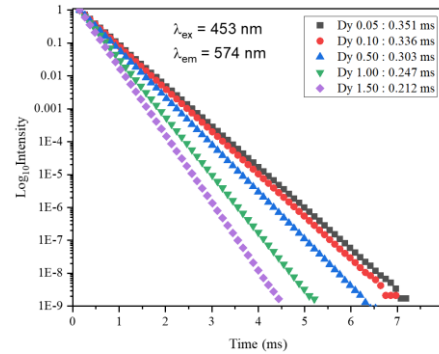


Figure 11. The energy level diagram of borotellurite glass doped with Dy³⁺ ion

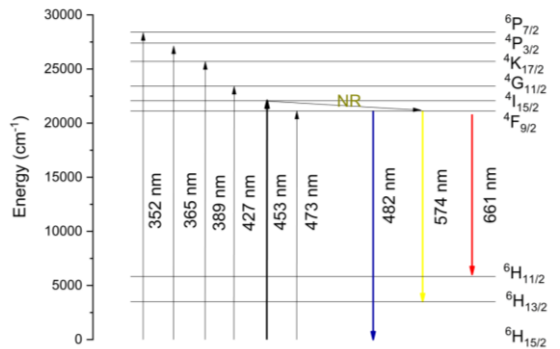


Figure 10. Diagram of the schematic energy levels illustrating excitation and emission

a higher excited state and from the higher excited state they deexcite non-radiatively (NR) by transitioning from the excited $^4F_{9/2}$ level to state $^6H_{15/2}$ (ground state) through which the radiative transition occurs at a wavelength of 574 nm ($^4F_{9/2} \rightarrow ^6H_{15/2}$) as seen in the energy level diagram (Figure 10). The intensity of the glass sample demonstrates emission spectra increase when the amount of Dy_2O_3 was increased by up to 0.50 mol%. The emission intensity decreases because of the quenching effect, a phenomenon occurring when the concentration of dysprosium reaches the saturation point and the sensitizer dysprosium atoms cross-relate with the Dy atom when they are too close to one another. As a result, 0.50 mol% was determined to be the ideal concentration for Dy_2O_3 doping in boro-tellurite glass.

Lifetime

The glass lifetime curve for the $^4F_{9/2}$ to $^6H_{13/2}$ transition at 453 nm (wavelength of excitation) and 574 nm (wavelength of emission) for the Dy³⁺ ion was identified. The duration of decay (lifetime) and

the duration of light emission are the targets of the lifetime measurement. Figure 11 was fitted by single exponential $I(t) = A \exp(-t/\tau)$ where A is a coefficient, $I(t)$ represents the intensity at time t , and τ denotes the lifetime (Dutczak *et al.*, 2013). Then Figure 11 illustrates the decay time of the level $^4F_{9/2}$ to the borotellurite glass doped with Dy³⁺ ion at concentrations of 0.05, 0.10, 0.50, 1.00, and 1.50 mol% with lifetime phosphorescence at excitation wavelengths of 453 nm and emission wavelengths of 574 nm. For 0.05, 0.10, 0.50, 1.00, and 1.50 mol% of Dy³⁺ ion doped borotellurite glasses, the observed decay times for the $^6H_{13/2} \rightarrow ^6H_{15/2}$ emission transition (574 nm) are found to be 0.351, 0.336, 0.303, 0.247, and 0.212 ms, respectively. From the above results, when the concentration of Dy_2O_3 increases, the lifetime decreases. Because lifetime is related to the phonon if phonon increases then lifetime decreases. When the concentration of lanthanide increases the effect of increasing phonon finally lifetime is decreased.

CIE 1931 Chromaticity Coordinates and CCT

The emission spectra were employed for determining the CIE chromaticity coordinates. As seen in Figure 12, they were plotted on the CIE 1931 chromaticity diagram, indicated by a spot in the white zone. When using the color coordinates obtained from the CIE diagram to find the Correlated Color Temperature according to the literature (Pawar *et al.*, 2017), which obtains a color temperature around 4000 Kelvin. It denotes this sample is a cool light source that generates white light. Because light sources with a CCT value lower than 3200 K are typically regarded as "warm" light sources, and those with a CCT of over 4000 K are typically regarded as "cool" light sources. The Y/B ratio determines whether the light has a yellowish white or blueish white, if it is greater than 1, it is yellowish white, otherwise it is bluish white.

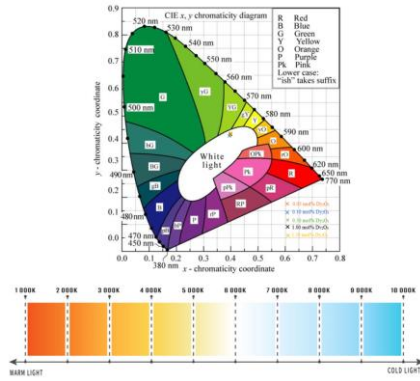


Figure 12. The CIE and CCT diagram of borotellurite glass dope with Dy^{3+} ion

The Y/B ratio is computed by dividing the yellow emission intensity by the blue emission intensity. At concentrations of Dy_2O_3 0.05, 0.10, 0.50, 1.00, and 1.50 the Y/B ratio is 2.216, 2.033, 2.098, 2.090, and 2.119 mol%, respectively. All of the above information is summarized in Table 3.

Judd Ofelt (JO) Parameter

Utilizing the Judd Ofelt (JO) theory, the possible use for lasing behavior is investigated. Both spectral and physical data were used to evaluate several properties. Using the peak

absorption area, glass thickness, and Dy_2O_3 concentration, one may compute the absorption $\epsilon(v) \cdot (m^2 \cdot mol^{-1})$ from pertinent transitions in energy $(v) \cdot (eV)$. Next, is employed to ascertain the experimental oscillator strength f_{exp} using a relation found in Equation 2 (Maheshvaran *et al.*, 2015). The refractive index of the medium is n , the total angular momentum of the ground state is J , the Judd Ofelt (JO) intensity parameter is $\Omega_{\lambda=2,4,6}$, and the doubly reduced matrix elements of the unit tensor operator of rank $\lambda = 2, 4$, and 6 are denoted by $\|U\|^2$. They are derived from the transition's intermediate coupling approximation, ψJ to $\psi' J'$ (Maheshvaran *et al.*, 2015).

$$f_{exp} = 4.32 \times 10^{-9} \int \epsilon(v) dv \quad (1)$$

$$f_{cal} = \frac{8\pi^2 m c v}{3h(2J+1)} \frac{(n^2+2)^2}{9n} \sum_{\lambda=2,4,6} \Omega_{\lambda} (\psi J \| U^{\lambda} \| \psi' J') \quad (2)$$

The energy levels for the Dy^{3+} ion glass transitions are shown in Table 4. The table shows the glass transition in different positions (wavelength). The estimated JO intensity characteristics for the Dy^{3+} ion 0.50 mol% glass is $\Omega_2 = 9.38 \times 10^{-20} \text{ cm}^2$, $\Omega_4 = 3.22 \times 10^{-20} \text{ cm}^2$, and $\Omega_6 = 2.73 \times 10^{-20} \text{ cm}^2$, follow in trend $\Omega_2 > \Omega_4 > \Omega_6$. As seen in Table 5, a similar pattern has been observed for other materials including GeO_2 -BaO-

Table 3. Coordinates of The CIE and CCT

Glass sample	Y/B ratio	Coordinates of The CIE (x,y)	CCT (Kelvin)
0.05 mol% Dy_2O_3	2.216	(0.398, 0.432)	3928
0.10 mol% Dy_2O_3	2.033	(0.393, 0.428)	4010
0.50 mol% Dy_2O_3	2.098	(0.394, 0.429)	3995
1.00 mol% Dy_2O_3	2.090	(0.396, 0.430)	3958
1.50 mol% Dy_2O_3	2.119	(0.397, 0.431)	3943

Table 4. For the measured absorption bands of Dy^{3+} ion 0.50 mol%, experimental and estimated oscillator strengths (f_{exp} & f_{cal}) are provided

Transition $^6H_{15/2} \rightarrow$	$f_{exp} (\times 10^{-6})$	$f_{cal} (\times 10^{-6})$
$^6F_{3/2}$	0.1057	0.2501
$^6F_{5/2}$	1.2643	1.3321
$^6F_{7/2}$	3.2505	3.0108
$^6H_{7/2}$	3.8899	3.9462
$^6F_{11/2}$	10.7397	10.7296
$^6H_{11/2}$	1.7618	1.8422

Table 5. J-O parameters (Ω_{λ}) of Dy^{3+} ion 0.50 mol% and glass

Glass code	JO parameter			Trends	Reference
	$\Omega_2 (\times 10^{-20})$	$\Omega_4 (\times 10^{-20})$	$\Omega_6 (\times 10^{-20})$		
0.5 mol% Dy_2O_3	9.38	3.22	2.73	$\Omega_2 > \Omega_4 > \Omega_6$	Glass sample
E0.5YTBL	8.01	1.69	1.74	$\Omega_2 > \Omega_6 > \Omega_4$	Maheshvaran <i>et al.</i> (2015)
GeO_2 -BaO- Ga_2O_3	8.73	1.44	1.33	$\Omega_2 > \Omega_4 > \Omega_6$	Pisarski (2022)
NSrODy	11.92	8.88	5.77	$\Omega_2 > \Omega_4 > \Omega_6$	Shoab <i>et al.</i> (2023)
$SrTa_2O_6$: Dy^{3+}	6.68	0.04	0.62	$\Omega_2 > \Omega_6 > \Omega_4$	Ilhan <i>et al.</i> (2022)
Dy05	5.47	2.17	0.83	$\Omega_2 > \Omega_4 > \Omega_6$	Hemalatha <i>et al.</i> (2022).

Table 6. Radiative transition probability (A_R), emission cross-section (σ), calculated branching ratios (β_R), and radiative lifetime (τ_R) for the sample of borotellurite glass

Transition $^4F_{9/2} \rightarrow$	λ_p (nm)	A_R from J-O (s ⁻¹)	σ ($\times 10^{-21}$ cm ²)	β_R		τ_R (ms)
				Exp.	Cal from J-O	
$^6H_{15/2}$	482	360.360	0.367	0.327	0.162	0.918
$^6H_{13/2}$	573	1432.623	3.050	0.650	0.644	
$^6H_{11/2}$	662	160.900	0.679	0.023	0.072	

Ga₂O₃, NSrODy, and Dy05. The higher magnitude of the Ω_2 parameters indicate stronger covalence of the active ion-oxygen ligand connection and less symmetry surrounding the active ion. The host matrix doping the Dy³⁺ ions possesses bulk properties such as viscosity, stability, and hardness, while the Ω_4 and Ω_6 parameters correlate with these characteristics, as reported in Table 5. To explore the luminescence properties of Dy³⁺ ion in glass, the JO theory was employed to ascertain radiative characteristics, including transition probability (A_R), branching ratio (β_R), radiative lifetime (τ_R), and stimulated emission cross-section (σ), for specific emission transitions, namely $^4F_{9/2} \rightarrow ^6H_{15/2}$ (blue), $^4F_{9/2} \rightarrow ^6H_{13/2}$ (yellow), and $^4F_{9/2} \rightarrow ^6H_{11/2}$ (red). The relevant formulas from existing literature (Hemalatha *et al.*, 2022) were utilized for these calculations, and the recorded outcomes are detailed in Table 6. Notably, the radiative transition probability for the $^4F_{9/2} \rightarrow ^6H_{13/2}$ transition was confirmed as greater, aligning with the observed emission spectra. The branching ratio, a vital factor in laser design, signifies the potential to achieve stimulated emission in any given transition, with the expectation that it exceeds 50%. In this investigation, the calculated branching ratio values consistently exceeded 0.5 in the case of yellow transition ($^4F_{9/2} \rightarrow ^6H_{13/2}$) in contrast to the blue ($^4F_{9/2} \rightarrow ^6H_{15/2}$) and red ($^4F_{9/2} \rightarrow ^6H_{11/2}$) transitions across all glasses. Furthermore, the calculated branching values concurred with experimental branching ratios. Another pivotal aspect of the glasses' lasing behavior was revealed through the stimulated emission cross-section, an essential parameter for designing low-threshold and high-gain lasers. The higher stimulated emission cross-section facilitated greater inversion of population, a critical feature for effective laser action.

Conclusions

Boro-tellurite glass consists of (30-x)TeO₂ - 30B₂O₃ - 10ZnO - 20BaO - 10Nb₂O₅ - xDy₂O₃ (where x = 0.00, 0.05, 0.10, 0.50, 1.00 and 1.50 mol%) physical properties such as density, refractive index, and molar volume do not show a trend in relation to the presence of Dy₂O₃. X-ray diffraction confirms

all of the samples are amorphous. FTIR structural and Raman spectra show peaks corresponding to the components present in the glass. The absorption spectra of Dy³⁺ ion doped glass show six peaks, with increasing absorbance as the concentration of Dy₂O₃ increases. Excitation and emission spectra show quenching at a Dy³⁺ ion of 0.50 mol%. Using emission spectra to calculate the CIE 1931 chromaticity coordinates, CCT, and Y/B ratio, results in a white region of light and is considered a "cold" light source. The luminescence decay curve decreases with increasing concentration of Dy₂O₃. In comparison to other glass sample quotations, the fluorescence potential is ranked highly according to the JO parameter. It is clear from all the results that this glass sample is appropriate for use in the development of a white light solid-state device application.

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