

Er³⁺–Pr³⁺ Boro-tellurite Glasses for Solid State White Light Emission

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Abstract

The Heavy metal oxide doped boro-tellurite glass samples with composition 50%TeO₂–29%B₂O₃–10%Bi₂O₃–10%Na₂O–0.5%Er₂O₃–0.5%Pr₂O₃ were prepared and analyzed with respect to the light emitting features. X-ray diffraction (XRD), and differential scanning calorimetry (DSC) have been done for the structural and thermal study. UV-VIS-IR absorption to get the information of different absorption bands as well transparency of synthesized glass. A broad visible spectral range is covered by the measured fluorescence spectra. The glass contains both Erbium (Er³⁺) and Praseodymium (Pr³⁺) ions, which is why almost all of the absorption peaks substantially overlap. All of the detected peaks may be assigned by careful study of the emission spectra. It was feasible to identify potential energy transfer mechanisms by comparing the energy level schemes of the Er³⁺ and Pr³⁺ ions. Due to their high quantum efficiency, the produced glasses may be used with white light emitting diodes.

1. INTRODUCTION

In last two to three decades, there has been a noticeable surge in interest in heavy metal oxide (HMO) glasses doped with lanthanide (Ln) elements. The range of uses for these glasses has expanded significantly to encompass contemporary, non-traditional technological domains [1, 2]. The goal of intensive study is to move the mean infrared absorption edge for laser glasses, optical technology and fibre optics. Trivalent lanthanide-doped HMO glasses have excellent optical characteristics, including emission and absorption. The Erbium Doped Fibre Amplifier (EDFA) series was developed to facilitate the commercialization of fibre optic communication technologies. Nonetheless, the need for a higher bandwidth is increasing due to the necessity for faster data transmission capacity. For instance, an Er³⁺ -doped fibre amplifier made of tellurite glass may offer a bandwidth of around 60 nm, which is

around 30 nm more than the current generation of EDFAs based on silica core fibre that has been doped with Er^{3+} ions [3]. To cover the 1.3 μm band, certain Pr^{3+} -doped fibre amplifiers have been studied [4]. Both 1.3 and 1.5 μm spectral regions may see signal amplification from chalcogenide glasses co-doped with Erbium and Praseodymium ions [5]. Effective energy transfer from Erbium and Praseodymium ions has the potential to increase Pr^{3+} emission's amplification efficiency in the 1.3 μm band [6]. Research on the compositional influence and the physical and spectroscopic characteristics of Er^{3+} codoped tellurite glass has received a lot of attention up to this point [7-9]. Tellurite glasses have the lowest phonon energies (700–800 cm^{-1}) among typical oxide glasses, such as silicate and phosphate glasses, and can accommodate more Ln ions in their matrix than other glass systems [10]. High linear refractive indices of around 1.65–2.32 are displayed by tellurite glasses [7].

For In the current study, we have carried out in-depth analyses of the absorption and luminescent spectra of the $\text{TeO}_2\text{-B}_2\text{O}_3\text{-Bi}_2\text{O}_3\text{-Na}_2\text{O}$ glass samples co-doped by Erbium and Praseodymium ions with the goal of producing glasses for the white light emission.

2. Samples Preparation

The batch composition was selected as 50% TeO_2 –29% B_2O_3 –10% Bi_2O_3 –10% Na_2O –0.5% Er_2O_3 –0.5% Pr_2O_3 which shows relevant high lanthanide stability and resistance against crystallization during reheating [11]. The chemicals were used in proper ratio to prepare the batch: tellurium oxide (TeO_2), Boron trioxide (B_2O_3), bismuth oxide (Bi_2O_3), sodium oxide (Na_2O), erbium oxide (Er_2O_3) and praseodymium oxide (Pr_2O_3). Proper mixing of all the ingredients was done to guarantee uniformity. In a muffle furnace set at 850 °C with an air environment, 15 g batches of alumina crucibles were melted to produce tellurite glass. The melt was poured over a stainless-steel mould that had been prepared to 300 °C, creating a layer that was 2-3 mm thick. The sample was kept 1.5 hours at a temperature between 280 and 300 °C for the annealing. The prepared glass was then cleaned and polished for the further spectroscopic studies. A computer-aided high resolution XRD system (Rigaku Smart Lab 9kW) was used to confirm the amorphous nature of glass. DSC is carried for the thermal study of the sample, it was carried out by TA instruments, USA, Q10. The absorption spectrum was recorded in the spectral range 250–2500 nm. Also, the luminescence spectrum was recorded at an ambient temperature at an excitation wavelength of 444 nm by Horriba, Jobin Vyon- Fluorolog -3 in emission range 300–850 nm, and wavelength.

3. RESULT AND DISCUSSION

3.1 XRD

X-ray diffractogram is essential technique for understanding and studying the phase and structure of the sample. Fig. 1 displays the indexed XRD picture of the (50%TeO₂-29%B₂O₃-10%Bi₂O₃-10%Na₂O-0.5%Er₂O₃-0.5%Pr₂O₃) sample taken in the 2 θ range of 10°–80°. According to the XRD data, the sample lacks a diffraction peak, indicating that it is glassy.

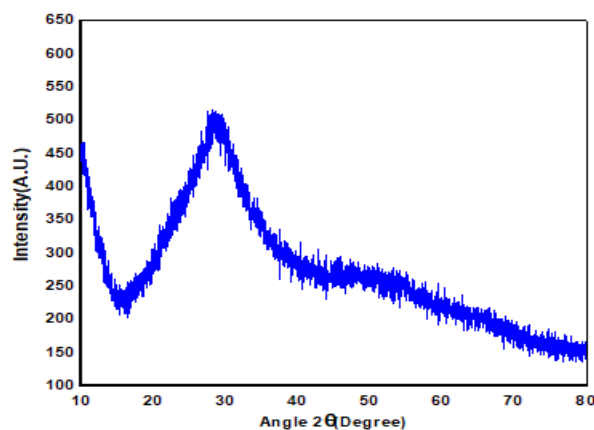


Figure .1 X-Ray diffractogram of 50%TeO₂-29%B₂O₃-10%Bi₂O₃-10%Na₂O-0.5%Er₂O₃-0.5%Pr₂O₃ sample

3.2 DSC

The DSC curves for glass samples (50%TeO₂-29%B₂O₃-10%Bi₂O₃-10%Na₂O-0.5%Er₂O₃-0.5%Pr₂O₃) in the 50–500 °C range are shown in Fig. 2. The endothermic peak and exothermic peaks represent the glass transition temperature, crystallization temperature, and melting temperature. The glass transition temperature (T_g), crystallization temperature (T_c) and melting temperatures were observed 310°C, 345°C and 425°C respectively.

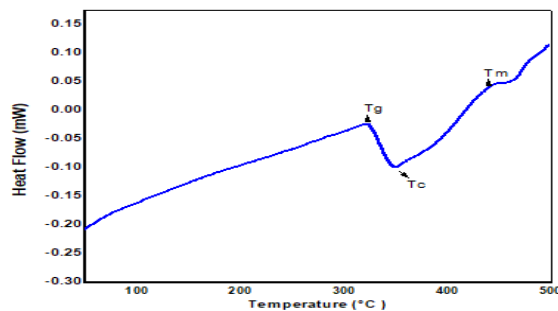


Figure.2 DSC plot of 50%TeO₂-29%B₂O₃-10%Bi₂O₃-10%Na₂O-0.5%Er₂O₃-0.5%Pr₂O₃ sample

3.3 Absorption Spectra

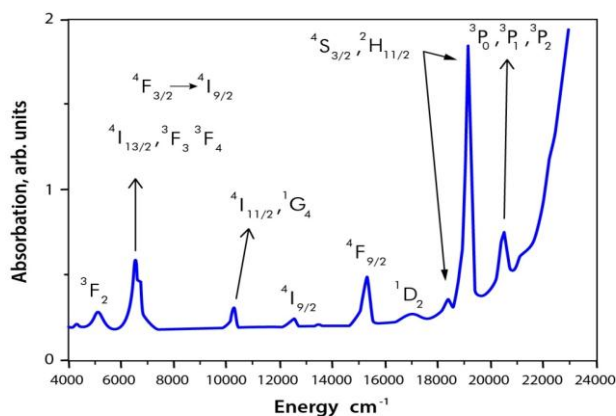
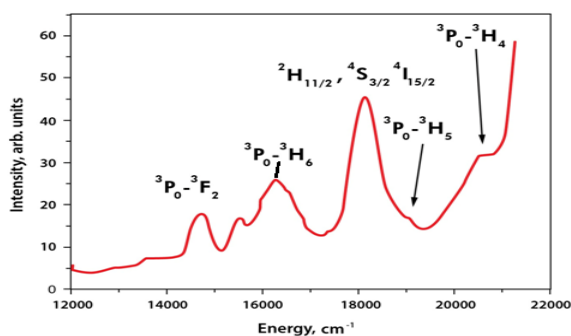


Figure. 3 Absorption spectra of 50% TeO₂–29% B₂O₃–10% Bi₂O₃–10% Na₂O–0.5% Er₂O₃–0.5% Pr₂O₃ sample

Fig. 3 displays the experimental absorption spectra of glass composed of 50% TeO₂–29% B₂O₃–10% Bi₂O₃–10% Na₂O–0.5% Er₂O₃–0.5% Pr₂O₃. Since both Er³⁺ and Pr³⁺ ions are present in the glass at the same time, almost all of the absorption peaks substantially overlap, making it impossible to distinguish between the contributions of the two ions. Thus, the Pr³⁺ (³H₄–³F₂) transition is responsible for a peak at around 5,000 cm⁻¹, the Pr³⁺ (³H₄–³F_{3,4}) transitions and the Er³⁺ (⁴I_{15/2}–⁴I_{13/2}) transition are responsible for a peak at approximately 6,500. The following peak, which occurs at around 10,200 cm⁻¹, is once more a superposition of the transitions Er³⁺ (⁴I_{15/2}–⁴I_{11/2}) and Pr³⁺ (³H₄–¹G₄). The Er³⁺ (⁴I_{15/2}–⁴I_{9/2} and ⁴I_{15/2}–⁴F_{9/2}) create two peaks at 12,300 cm⁻¹ and 15,300 cm⁻¹. The transition from Pr³⁺ ³H₄–¹D₂ is responsible for a faint feature at 17,000 cm⁻¹. The Er³⁺ ⁴I_{15/2}–⁴S_{3/2}, ²H_{11/2} transitions are attributed to a weak peak at 18,400 cm⁻¹ and an intense peak at 19,200 cm⁻¹. Lastly, the Pr³⁺ (³H₄–³P_{0,1,2}) transitions are assigned to a cluster of peaks ranging from 20,000 to 22,000 cm⁻¹.

3.4 Emission Spectra



Figure, 4, Emission spectra of 50% TeO₂–29% B₂O₃–10% Bi₂O₃–10% Na₂O–0.5% Er₂O₃–0.5% Pr₂O₃

The experimental emission spectra of the glass containing (50%TeO₂-29%B₂O₃-10%Bi₂O₃-10%Na₂O-0.5%Er₂O₃-0.5%Pr₂O₃) is displayed in Figure 4. Both ions are visible in the emission transitions, just as they were in the absorption spectrum. The most noticeable emission peak, located at approximately 18,000 cm⁻¹, is a superposition of the Pr³⁺ (³P₀-³H₅) transition and the Er³⁺ (²H_{11/2}, ⁴S_{3/2}-⁴I_{15/2}) transitions. The remaining peaks are "pure" Pr³⁺ emission bands, which are located at around 14,800 cm⁻¹ (³P₀-³H₅), 16,200 cm⁻¹ (³P₀-³H₆), and 21,000 cm⁻¹ (³P₀-³H₄).

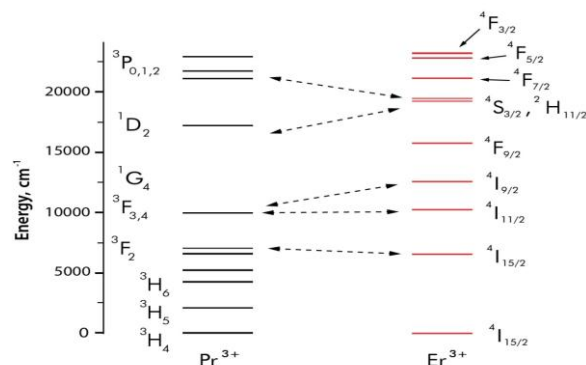


Figure 5. Energy levels of Erbium and Praseodymium ions

The energy levels of Erbium and Praseodymium ions are compared in Figure 5, which indicates the possibility of energy shift mechanisms between certain pairings of energy levels. As a result, the energy of the Pr³⁺ levels ³F_{3,4} and ⁴I_{13/2} and Er³⁺ levels ⁴I_{11/2} and ⁴I_{9/2} are almost equal; the same is true for the Pr³⁺ levels ¹G₄ and ⁴I_{11/2} and ⁴I_{9/2}. Lastly, there is a possibility of phonon-assisted energy shift between the ⁴S_{3/2}, ²H_{11/2} levels of Er³⁺ and the ¹D₂, ³P_{0,1,2} levels of Pr³⁺. It is important to note that electron-phonon interactions have a major role in Pr³⁺-doped glasses [12], and they have the potential to alter effective up-conversion transfers. Based on their overall spectrum distribution, this sample shows potential for use in white light emission. These lenses might be compared well to other rare earth doped lenses used in light-emission.

CONCLUSIONS

A novel promising glass luminophore (50%TeO₂-29%B₂O₃-10%Bi₂O₃-10%Na₂O-0.5%Er₂O₃-0.5%Pr₂O₃) synthesised for white light emitting diodes is disclosed. There is a high quantum efficiency in the glasses. The experimental absorption and emission spectra at room temperature were thoroughly examined. Every absorption and emission peak is formed in part by Er³⁺ and Pr³⁺ ions. Every peak was allocated using the conventional Dieke's diagram. Potential energy transfer mechanisms were discovered through the examination of the energy level schemes of the two ions. The glasses that have been created can be utilised for light-emitting diodes; additional research on their spectroscopic characteristics in conjunction with other rare earth ions is planned.

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