# Erbium Concentration Dependent Absorbance in Tellurite Glass

E. S. Sazali, M.S. Rohani*, M. R. Sahar, R. Arifin, S. K. Ghoshal and K. Hamzah

*Advanced Optical Material Research Group, Department of Physics, Faculty of Science*
*Universiti Teknologi Malaysia, 81310, Skudai, Johor Bahru, Johor, Malaysia.*
*\* Email: mdsupar@utm.*

**Abstract.** Enhancing the optical absorption cross-section in topically important rare earth doped tellurite glasses is challenging for photonic devices. Controlled synthesis and detailed characterizations of the optical properties of these glasses are important for the optimization. The influence of varying concentration of $Er^{3+}$ ions on the absorbance characteristics of lead tellurite glasses synthesized via melt-quenching technique are investigated. The UV-Vis absorption spectra exhibits six prominent peaks centered at 490, 526, 652, 800, 982 and 1520 nm ascribed to the transitions in erbium ion from the ground state to the excited states $^4F_{7/2}$, $^2H_{11/2}$, $^4F_{9/2}$, $^4I_{9/2}$, $^2H_{11/2}$ and $^4I_{13/2}$, respectively. The results are analyzed by means of optical band gap $E_g$ and Urbach energy $E_u$. The values of the energy band gap are found decreased from 2.82 to 2.51 eV and the Urbach energy increased from 0.15 to 0.24 eV with the increase of the $Er_2O_3$ concentration from 0 to 1.5 mol%. The excellent absorbance of the prepared tellurite glasses makes them suitable for fabricating solid state lasers.

**Keywords:** Rare earth, tellurite glass, absorption, energy band gap, Urbach energy.

## INTRODUCTION

Tellurium oxide $TeO_2$ based glasses are highly efficient for the development of optical devices [1-3]. Moreover, the assimilation of rare earth ions can stabilize the metastable crystalline phase leading towards widespread applications [4, 5]. We prepare $Er^{3+}$ doped lead-tellurite glass using the conventional melt-quenching method. The results for the optical absorption related to optically-induced transitions and the band arrangement are presented. The main objective is to examine the absorption of the $Er_2O_3$ doped $TeO_2$ - $PbO$ - $PbCl_2$ by using UV-Vis measurements. The energy band gap $E_g$ and Urbach energy $E_u$ are determined. Our results are in good agreement with other findings.

## EXPERIMENTAL WORK

A series of glasses of the form 80-x$TeO_2$ - 15$PbO$ - 5$PbCl_2$ - x $Er_2O_3$ with $0.0 \leq v \leq 1.5$ mol% are prepared by using melt quenching technique. The room temperature optical absorption of these samples is measured in the wavelength range of 200-1000 nm using UV-VIS-NIR spectroscopy. The optical absorption coefficient αλ is calculated using the equation

$$\alpha(\lambda) = 2.303 \frac{A}{d} \qquad (1)$$

where A is absorbance and d is the sample thickness.

## RESULTS AND DISCUSSION

Figure 1 shows the UV-Vis-NIR absorption spectra for all the $Er^{3+}$ doped glasses. Six prominent absorption peaks are observed centered at 490, 526, 652, 800, 982 and 1520 nm corresponding to the $^4F_{7/2}$, $^2H_{11/2}$, $^4F_{9/2}$, $^4I_{9/2}$, $^2H_{11/2}$ and $^4I_{13/2}$ levels.
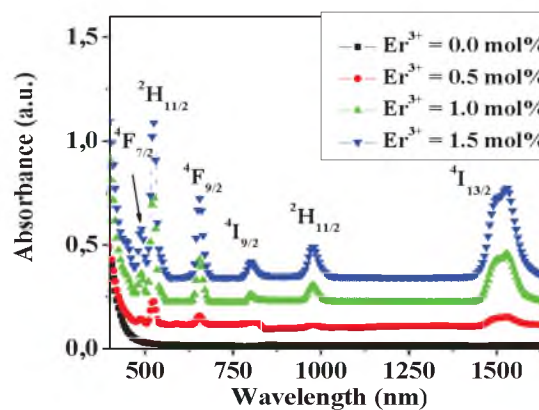


**FIGURE 1.** Absorption spectra of glasses for varying concentration of $Er^{3+}$ ions.

$$\alpha(\omega) = \frac{const}{\hbar\omega}(\hbar\omega - E_g)^n \qquad (2)$$

where $\hbar\omega$ is the photon energy. The value of $E_g$ can be obtained by extrapolating the linear part of the $(\alpha\hbar\omega)^{1/2}$ against phonon energy $\hbar\omega$ as shown in Fig. 2a. The value n is 2 for the indirect transitions. The interactions of photons with lattice vibrations take place at this allowed indirect transition.

The Urbach equation given by:

$$\alpha(\omega) = B\exp(\frac{\hbar\omega}{\Delta E_u}) \qquad (3)$$

where B is a constant and $\Delta E_u$ is the width of the band tail of the electron states. Urbach energy is evaluated from the slope of the plot of ln $\alpha$ versus $\hbar\omega$ Fig. 2 b.The calculated values of $E_g$ and $E_u$ are summarized in Table 1. Figure 3 displays the $Er_2O_3$ concentration dependent $E_g$ and $E_u$. The value of $E_g$ is found to decrease from 2.82 to 2.51eV as the $Er^{3+}$ content is increased from 0.5 to 1.5 mol%. This decrement is attributed to the generation of higher nucleation sites for the crystallization due to the incorporation of $Er^{3+}$ ions into the glass system [6]. The magnitude of $E_g$ obtained by us is comparable to the earlier observation on Te-based glass systems [7, 8].
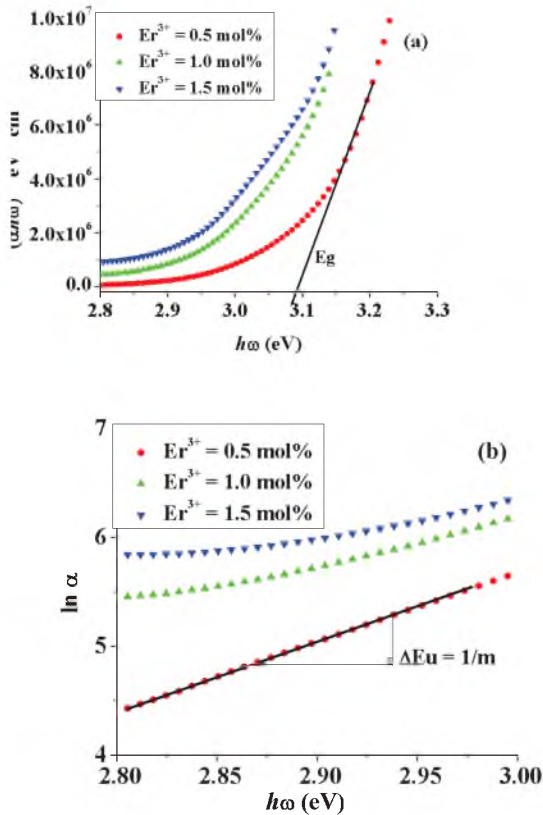


**FIGURE 2.** The calculated values of $E_g$ and $E_u$

**TABLE 2.** Erbium concentration dependent indirect optical band gap $E_g$ and Urbach energy $E_u$.

| $Er_2O_3$ contents mol% | $E_g$ eV | $E_u$ eV |
|---|---|---|
| 0.5 | 2.82 | 0.15 |
| 1.0 | 2.61 | 0.19 |
| 1.5 | 2.51 | 0.24 |

The decrease in the activation energy is related to the higher electropositive character of the host material that tends to provide favorable nucleation sites for the crystallization suitable for the electrical conduction [9]. Furthermore, $E_u$ is found to be increase from 0.15 to 0.24 eV as the dopant concentration is increased. The obtained values are in the range of amorphous semiconductors 0.046 and 0.66 eV as reported by Davis and Mott [10]. Figure 3 illustrates the strong functional dependence of $E_g$ and $E_u$ on $Er_2O_3$ concentration.
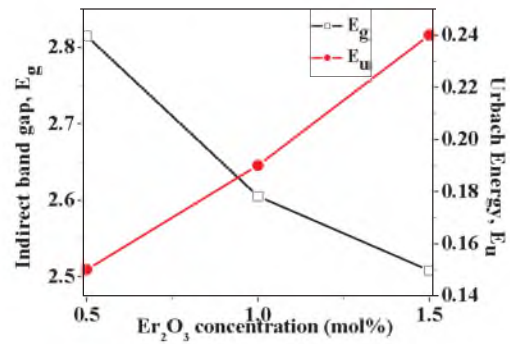


**FIGURE 3.** The $Er_2O_3$ concentration dependent $E_g$ and $E_u$.

## CONCLUSIONS

The effects of $Er^{3+}$ contents on the absorption characteristics of lead tellurite glass are analyzed through $E_g$ and $E_u$. The absorption spectra for all the $Er^{3+}$ doped glass samples with different dopant concentration shows six peaks with varying intensities. The robust dependence of $E_g$ and $E_u$ on $Er_2O_3$ content is observed and the mechanism is understood. We establish the tunability of absorbance characteristics by altering $Er_2O_3$ contents useful for optimization of device functionality.

## ACKNOWLEDGMENTS

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