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-xTeO_2 - 15PbO - 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 $\alpha\lambda$ is calculated using the equation

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

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.

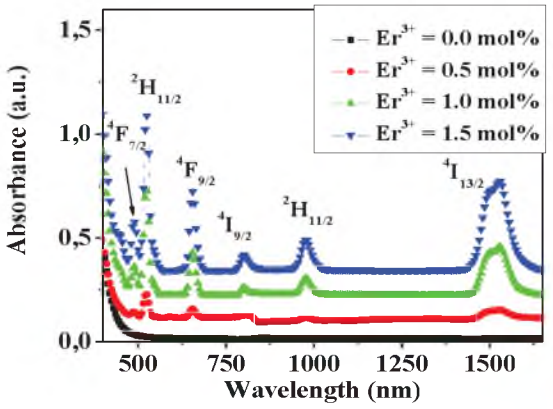

FIGURE 1. Absorption spectra of glasses for varying concentration of Er^{3+} ions.

3rd International Conference on Theoretical and Applied Physics 2013 (ICTAP 2013)
AIP Conf. Proc. 1617, 134-136 (2014); doi: 10.1063/1.4897122

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

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:

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

where B is a constant and ΔE_u is the width of the band tail of the electron states. Urbach energy is evaluated from the slope of the plot of ln α 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].

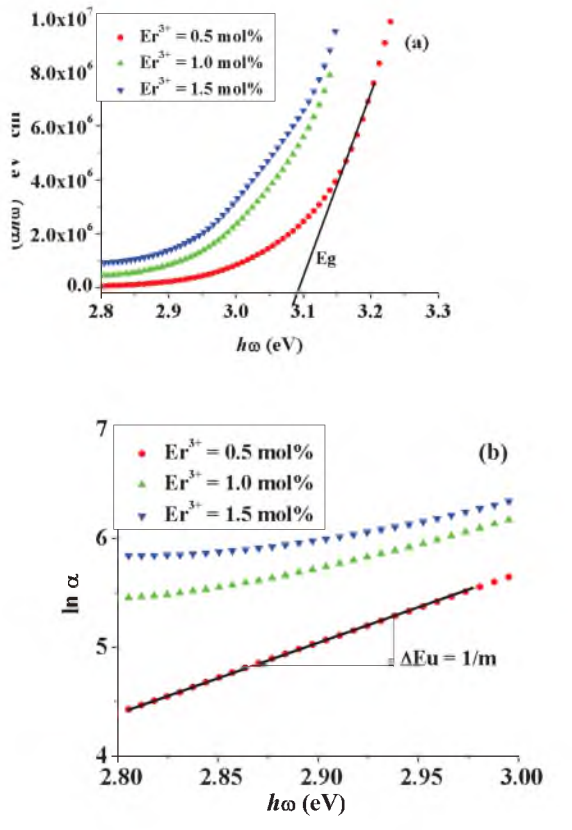

FIGURE 2. The calculated values of E_g and E_u

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.

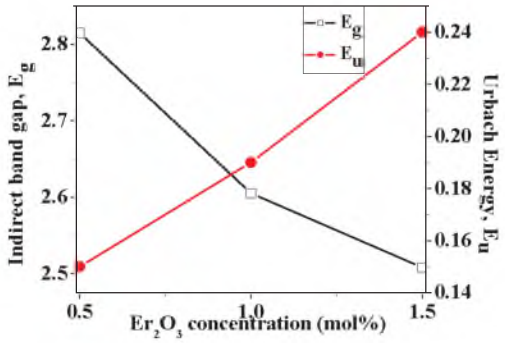

FIGURE 3. The Er_2O_3 concentration dependent E_g and E_u.

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

The authors gratefully acknowledge the financial support from MOHE via grants Vot. 4F083, 07J80, 06J39, 08J64 and 4L032 of GUP and ERGS.

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