OPTICAL TRANSITIONS OF Er\textsuperscript{3+} DOPED TELLURITE GLASSES

M. R. Sahar, Sulhadi  and M. S. Rohani

Advanced Optical Material Research Group, Physics Dept, Faculty of Science, Universiti Teknologi Malaysia, 81310 Skudai, Johor DT, Malaysia

ABSTRACT

Er\textsuperscript{3+} doped tellurite glasses of molar composition (80-x)TeO\textsubscript{2}-18ZnO-1MgO-1Li\textsubscript{2}O-(x)Er\textsubscript{2}O\textsubscript{3} system (0.5mol%≤x≤2.5mol%) have successfully been made by melt quenching technique. The absorption spectra were measured and the Judd-Ofelt analysis was performed. It is found that the spectrum of UV-Vis-NIR spectroscopy is consists of absorption peaks around 1530nm, 974nm, 798nm, 652nm, 544nm, 522nm, 488nm, 452nm, 444nm, and 406nm, and are correspond to the transitions from ground state \textit{4}I\textsubscript{15/2} to the excited state of \textit{4}I\textsubscript{13/2}, \textit{4}I\textsubscript{11/2}, \textit{4}I\textsubscript{9/2}, \textit{4}F\textsubscript{9/2}, \textit{4}S\textsubscript{3/2}, \textit{2}H\textsubscript{11/2}, \textit{4}F\textsubscript{7/2}, \textit{4}F\textsubscript{5/2}, \textit{4}F\textsubscript{3/2}, and \textit{2}H\textsubscript{9/2} respectively. The Judd-Ofelt parameters Ω\textsubscript{2}, Ω\textsubscript{4}, Ω\textsubscript{6} have been used to correlate between the composition and the change of structure of the host glass. It is found that the Er\textsuperscript{3+} content exhibits some influences on the spectroscopic properties of the optical transition for Er\textsuperscript{3+} ions.

INTRODUCTION

Tellurite glasses are known to be an important amorphous system that have many potential commercial applications. The TeO\textsubscript{2}–ZnO glass system is expected to have a unique optoelectronic properties [1] because of not only their low transition temperature but also their excellent infrared transmission [2,3] in the range of 0.4–6.0μm [4], which give them potential applications in pressure sensors or a new laser host [2]. It has also been reportedly earlier that these glasses are thermally stable for fiber drawing [5]. Meanwhile, zinc tellurite glasses are reported to be suitable host for optically active rare earth ions [6] and their double-clad Er\textsuperscript{3+}–doped tellurite single mode fibers, has shown their potential for use in fiber lasers and optical amplifier [7]. Due to their low phonon energy [5], these glasses have been the subject for the up–conversion emission. However, not much research on the characteristics of the glass doped with Er\textsubscript{2}O\textsubscript{3} has been reported in the literature. It is therefore the aim of this paper to report the latest development on the optical transitions of Er\textsuperscript{3+} doped tellurite glasses. All the results will be discussed with respect to their composition.

EXPERIMENTAL DETAILS

Erbium doped Tellurite glasses based on the (80-x)TeO\textsubscript{2}-18ZnO-1MgO-1Li\textsubscript{2}O-(x)Er\textsubscript{2}O\textsubscript{3} system (0.5mol%≤x≤2.5mol%) were prepared by melt quenching technique. Detail description on the glass preparation has been reported elsewhere [8]. The Parkin Elmer

Corresponding Author: m-rahim@dfiz2.fs.utm.my
UV-Vis-NIR Lambda 900 spectroscopy has been used to get the UV-Vis-NIR spectra, recorded in the range of 190–2000nm.

RESULTS AND DISCUSSION

Figure 1 shows the UV-Vis-NIR spectra of the (80-x)TeO$_2$-18ZnO-1MgO-1Li$_2$O-(x)Er$_2$O$_3$ glass system. The inhomogeneously broadened bands are assigned to the transitions from the $^4$I$_{15/2}$ ground state to the excited states of the Er$^{3+}$ ion. It can clearly be seen that the absorption peaks around 6535 cm$^{-1}$, 10266 cm$^{-1}$, 12531 cm$^{-1}$, 15337 cm$^{-1}$, 18382 cm$^{-1}$, 19157 cm$^{-1}$, 20491 cm$^{-1}$, 22123 cm$^{-1}$, 22522 cm$^{-1}$, and 24630 cm$^{-1}$ occur in all sample, which corresponding to the transitions from ground state $^4$I$_{15/2}$ to the excited state $^4$I$_{13/2}$, $^4$I$_{11/2}$, $^4$I$_{9/2}$, $^4$F$_{9/2}$, $^4$S$_{3/2}$, $^2$H$_{11/2}$, $^4$F$_{7/2}$, $^4$F$_{5/2}$, $^4$F$_{3/2}$, and $^2$H$_{9/2}$ respectively.

The radiative transitions within the $4f^n$ configuration of a rare earth ion can be analyzed by using the Judd and Ofelt theory [9,10]. In the framework of the J-O theory, the theoretical oscillator strengths $P_{cal}^{ed}$ may be expressed as a sum of transition matrix element, involving intensity parameter $\Omega_q$ with $q = 2, 4, 6$ [9-12], which depend on the host matrix, ie;

$$P_{cal}^{ed}(J,J') = \frac{8\pi^2 mc}{3h\lambda(2J+1)} \left(\frac{n^2+2}{9n}\right) \sum_{q=2,4,6} \Omega_q \times \langle \alpha SL,J|U^q|\alpha'S'L',J' \rangle^2$$

where $\lambda$ is the mean wavelength of the transition and $n$ is the refractive index, $\Omega_q$ are the Judd-Ofelt parameter and $\langle U^q \rangle$ are the double reduce matrix elements of unit tensor operators which are considered to be independent of host matrix.

Meanwhile, the experimental oscillator strengths $P_{exp}$ of the transitions can be obtained by integrating the absorbance for each band and using a relationship

$$P_{exp} = \frac{mc^2}{\pi e^2 N} \int \alpha(\nu) d\nu; \text{ where } \alpha(\nu) = \frac{\ln[I_0(\nu)/I(\nu)]}{d} = \frac{2.303E(\nu)}{d}, N \text{ is the number density of rare earth ions, } e \text{ the charge of the electron, } \nu \text{ the wavenumber, } E(\nu) \text{ the absorbance, and } d \text{ is the sample thickness [12].}$$

Since the experimental oscillator strength contain of an electric-dipole and magnetic-dipole contributions, one has to subtract the latter from the experimental oscillator strength to obtain only the electric-dipole contribution that can then be equated to the calculated oscillator strength. The magnetic-dipole contributions, $P_{md}$, can be obtained from the refractive index of the investigated glasses and the quantities, $P'$, $P_{md} = nP'$, as reported in [13,14].

The Judd-Ofelt intensity parameters $\Omega_q$ can be derived from the electric-dipole contributions of the experimental oscillator strengths using a least squares fitting approach. The matrix elements given in [14] may be used in the calculation and the result is presented in Table 2.

Corresponding Author: m-rahim@dfiz2.fs.utm.my
Figure 1: The absorption spectra of the Tellurite glasses

In general, the parameter $\Omega_2$ is related to the covalency and structural changes in the vicinity of the Er$^{3+}$ ion (short-range effect), while the $\Omega_4$ and $\Omega_6$ are related to the long-range effects. From Table 2, it can be seen that the $\Omega_2$ for the AK1 glass is the highest. This would indicate that this composition would exhibit the highest covalent character [15].

As the Er$_3$O$_5$ content increases, $\Omega_2$ becomes slightly decreases, which indicate that the covalent character decreases. The relationship between the J-O parameters as a function of mol% Er$_2$O$_3$ was plotted and shown in Figure 2.
From Figure 2, it can be seen that an addition of Er$_2$O$_3$ content from 0.5mol% to 1.0mol% shown that the J-O parameters obtained is in the order of $\Omega_2 \geq \Omega_4 \geq \Omega_6$. However, as the Er$_2$O$_3$ content is being increased to more than 1.0mol%, the value of J-O parameters is in the order of $\Omega_2 \leq \Omega_4 \geq \Omega_6$. This phenomenon can be explained on the basis of the electronegativity theory, whereby the smaller the electronegativity differences between cation and anion, the stronger the covalency of the bond [16]. It is known that the electronegativity for Er, Te and O elements, are 1.1, 2.0, and 3.5, respectively. As a consequence the covalency of the Er-O bond is lower than that of Te-O bond. Consequently, the value of $\Omega_6$ decreases with increases Er$_2$O$_3$ content.

Table 2: J-O parameter and spectroscopic ratio in the tellurite glasses

<table>
<thead>
<tr>
<th>Sample</th>
<th>$\Omega_2$($\times 10^{-20}$ cm$^2$)</th>
<th>$\Omega_4$($\times 10^{-20}$ cm$^2$)</th>
<th>$\Omega_6$($\times 10^{-20}$ cm$^2$)</th>
<th>($\Omega_4/\Omega_6$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AK1</td>
<td>5.99 ± 0.64</td>
<td>2.85 ± 0.70</td>
<td>2.43 ± 0.24</td>
<td>1.17</td>
</tr>
<tr>
<td>AK2</td>
<td>3.44 ± 0.56</td>
<td>2.85 ± 0.61</td>
<td>2.32 ± 0.21</td>
<td>1.23</td>
</tr>
<tr>
<td>AK3</td>
<td>2.60±0.55</td>
<td>2.67±0.60</td>
<td>2.22±0.21</td>
<td>1.20</td>
</tr>
<tr>
<td>AK4</td>
<td>1.76±0.40</td>
<td>2.58±0.43</td>
<td>1.86±0.15</td>
<td>1.39</td>
</tr>
<tr>
<td>AK5</td>
<td>1.17±0.33</td>
<td>2.35±0.37</td>
<td>1.46±0.13</td>
<td>1.61</td>
</tr>
</tbody>
</table>

Figure 2: J-O parameters as a function Er$_2$O$_3$ concentration in tellurite glasses

Corresponding Author: m-rahim@dfiz2.fs.utm.my
CONCLUSIONS

From the above discussions, some conclusion may be drawn.
1. The Judd-Ofelt theory could successfully be used to characterize the optical absorption spectrum of the glasses.
2. The value of $\Omega_2$ which related to the structural changes in the vicinity of the $\text{Er}^{3+}$ (short range effect) indicates the highly covalent environment of $\text{Er}^{3+}$ in glass matrix.
3. As the $\text{Er}_2\text{O}_3$ content in is being increases 0.5mol% to 2.5mol%, results in regular decreases of $\Omega_2$ from $(5.99 \pm 0.64) \times 10^{-20} \text{ cm}^2$ to $(1.17\pm0.33) \times 10^{-20} \text{ cm}^2$ and $\Omega_6$ from $(2.43\pm0.24) \times 10^{-20} \text{ cm}^2$ to $(1.46\pm0.13) \times 10^{-20} \text{ cm}^2$. This results indicating decreases the covalent character of the glasses.

ACKNOWLEDGEMENTS

The authors wish to thank the Ministry of Science, Technology and Innovation for their financial support under Vot 74532. We would also thanks to UTM for the continue support on this project.

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Corresponding Author: m rahim@dfiz2.fs.utm.my