

## OPTICAL TRANSITIONS OF Er<sup>3+</sup> DOPED TELLURITE GLASSES

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### ABSTRACT

Er<sup>3+</sup> doped tellurite glasses of molar composition (80-x)TeO<sub>2</sub>-18ZnO-1MgO-1Li<sub>2</sub>O-(x)Er<sub>2</sub>O<sub>3</sub> 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 <sup>4</sup>I<sub>15/2</sub> to the excited state of <sup>4</sup>I<sub>13/2</sub>, <sup>4</sup>I<sub>11/2</sub>, <sup>4</sup>I<sub>9/2</sub>, <sup>4</sup>F<sub>9/2</sub>, <sup>4</sup>S<sub>3/2</sub>, <sup>2</sup>H<sub>11/2</sub>, <sup>4</sup>F<sub>7/2</sub>, <sup>4</sup>F<sub>5/2</sub>, <sup>4</sup>F<sub>3/2</sub>, and <sup>2</sup>H<sub>9/2</sub> respectively. The Judd-Ofelt parameters Ω<sub>2</sub>, Ω<sub>4</sub>, Ω<sub>6</sub> have been used to correlate between the composition and the change of structure of the host glass. It is found that the Er<sup>3+</sup> content exhibits some influences on the spectroscopic properties of the optical transition for Er<sup>3+</sup> ions.

### INTRODUCTION

Tellurite glasses are known to be an important amorphous system that have many potential commercial applications. The TeO<sub>2</sub>-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<sup>3+</sup>-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<sub>2</sub>O<sub>3</sub> 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<sup>3+</sup> 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<sub>2</sub>-18ZnO-1MgO-1Li<sub>2</sub>O-(x)Er<sub>2</sub>O<sub>3</sub> 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

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

The radiative transitions within the 4f<sup>n</sup> 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;

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

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

$$P_{exp} = \frac{mc^2}{\pi e^2 N} \int \alpha(\bar{\nu}) d\bar{\nu}; \text{ where } \alpha(\bar{\nu}) = \frac{\ln[I_0(\bar{\nu})/I(\bar{\nu})]}{d} = \frac{2.303E(\bar{\nu})}{d},$$

$N$  is the number density of rare earth ions,  $e$  the charge of the electron,  $\bar{\nu}$  the wavenumber,  $E(\bar{\nu})$  the absorbance, and  $d$  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.

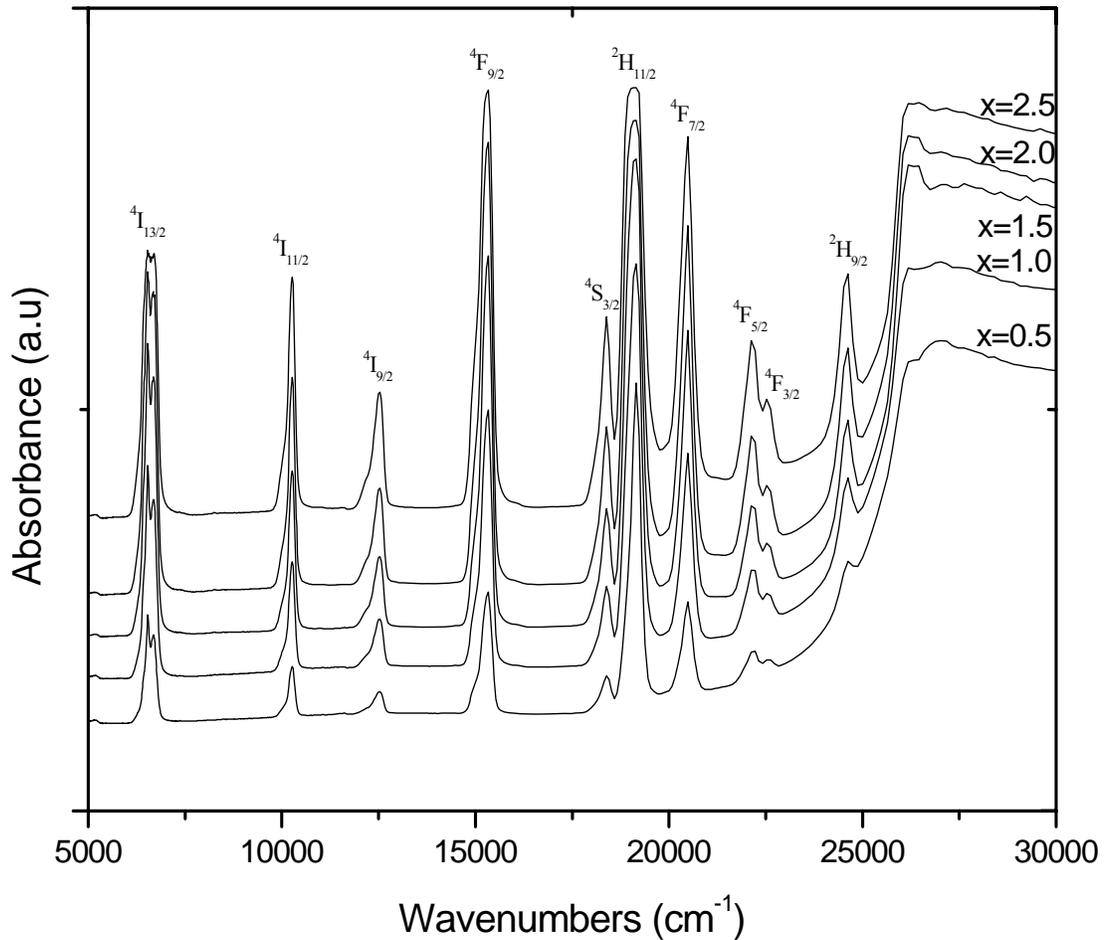


Figure 1: The absorption spectra of the Tellurite glasses

In general, the parameter  $\Omega_2$  is related to the covalency and structural changes in the vicinity of the  $\text{Er}^{3+}$  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  $\text{Er}_2\text{O}_3$  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%  $\text{Er}_2\text{O}_3$  was plotted and shown in Figure 2.

From Figure 2, it can be seen that an addition of  $\text{Er}_2\text{O}_3$  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  $\text{Er}_2\text{O}_3$  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  $\text{Er}_2\text{O}_3$  content.

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

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

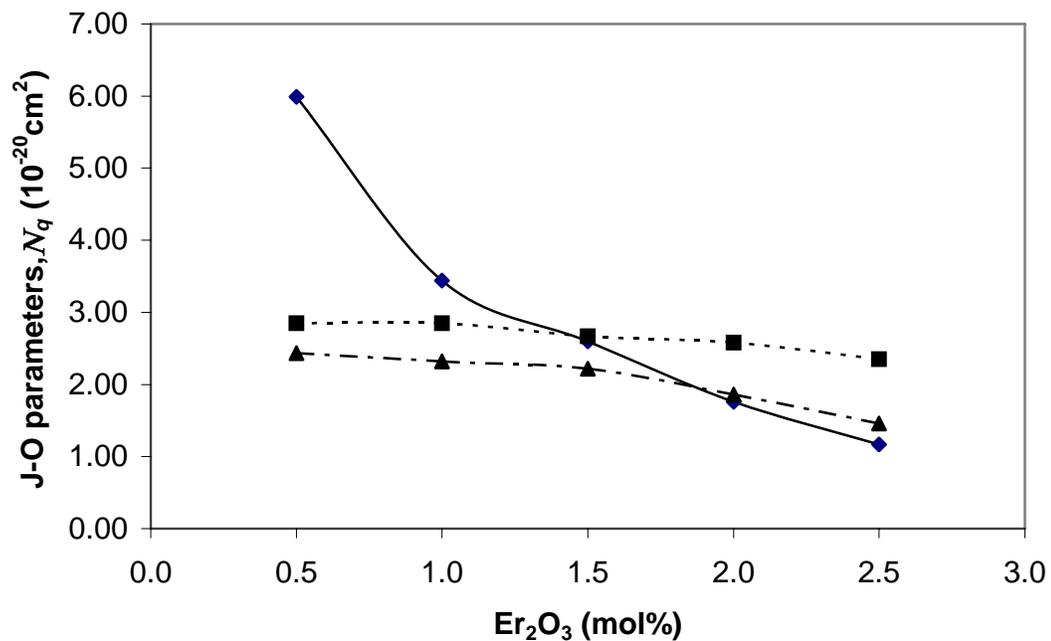


Figure 2: J-O parameters as a function  $\text{Er}_2\text{O}_2$  concentration in tellurite glasses

## 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  $(1.17 \pm 0.33) \times 10^{-20} \text{cm}^2$  and  $\Omega_6$  from  $(2.43 \pm 0.24) \times 10^{-20} \text{cm}^2$  to  $(1.46 \pm 0.13) \times 10^{-20} \text{cm}^2$ . This results indicating decreases the covalent character of the glasses.

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