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OPTICAL TRANSITIONS OF Er^{3+} DOPED TELLURITE GLASSES

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ABSTRACT

Er^{3+} doped tellurite glasses of molar composition (80-x)TeO_2-18ZnO-1MgO-1Li_2O-(x)Er_2O_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 $^4I_{15/2}$ to the excited state of $^4I_{13/2,}$ $^4I_{11/2,}$ $^4I_{9/2,}$ $^4F_{9/2,}$ $^4S_{3/2,}$ $^2H_{11/2,}$ $^4F_{7/2,}$ $^4F_{5/2,}$ $^4F_{3/2,}$ and $^2H_{9/2}$ respectively. The Judd-Ofelt parameters Ω_2, Ω_4, Ω_6 have been used to correlate between the composition and the change of structure of the host glass. It is found that the Er^{3+} content exhibits some influence on the spectroscopic properties of the optical transition for Er^{3+} ions.

INTRODUCTION

Tellurite glasses are known to be an important amorphous system that have many potential commercial applications. The TeO_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^{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_2O_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^{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_2-18ZnO-1MgO-1Li_2O-(x)Er_2O_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

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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_2-18ZnO-1MgO-1Li_2O-(x)Er_2O_3 glass system. The inhomogeneously broadened bands are assigned to the transitions from the $^4I_{15/2}$ ground state to the excited states of the Er^{3+} ion. It can clearly be seen that the absorption peaks around 6535cm^{-1}, 10266cm^{-1}, 12531cm^{-1}, 15337cm^{-1}, 18382cm^{-1}, 19157cm^{-1}, 20491cm^{-1}, 22123cm^{-1}, 22522cm^{-1}, and 24630cm^{-1} occur in all sample, which corresponding to the transitions from ground state $^4I_{15/2}$ to the excited state $^4I_{13/2,}$ $^4I_{11/2,}$ $^4I_{9/2,}$ $^4F_{9/2,}$ $^4S_{3/2,}$ $^2H_{11/2,}$ $^4F_{7/2,}$ $^4F_{5/2,}$ $^4F_{3/2,}$ and $^2H_{9/2}$ 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 Ω_q with q = 2, 4, 6 [9-12], which depend on the host matrix, ie;

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

where λ is the mean wavelength of the transition and n is the refractive index, Ω_q are the Judd-Ofelt parameter and $\left\langle \left\| U^q \right\| \right\rangle$ 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 $P_{\exp} = \frac{mc^2}{\pi e^2 N}\int \alpha(\bar{\nu})d\bar{\nu}$; 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 Ω_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.

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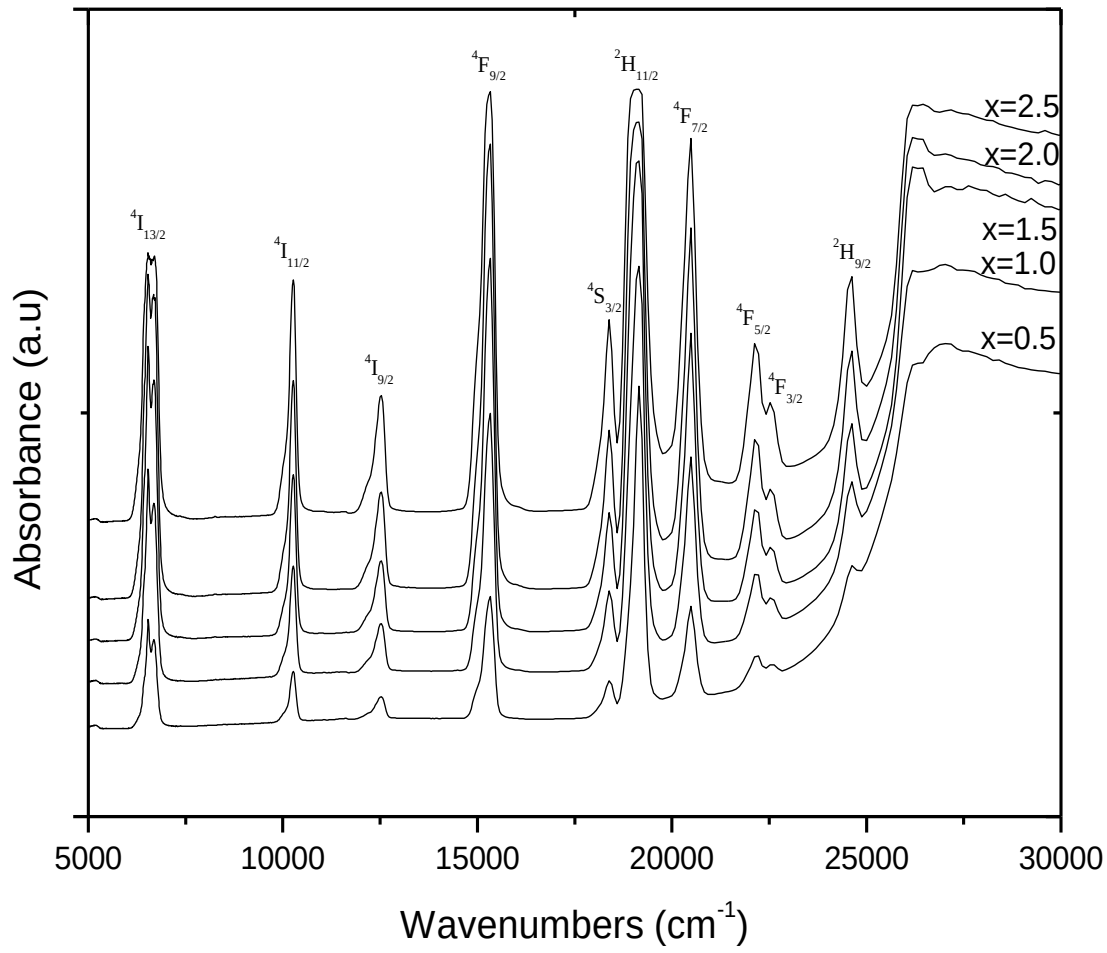

Figure 1: The absorption spectra of the Tellurite glasses

In general, the parameter Ω_2 is related to the covalency and structural changes in the vicinity of the Er^{3+} ion (short-range effect), while the Ω_4 and Ω_6 are related to the long-range effects. From Table 2, it can be seen that the Ω_2 for the AK1 glass is the highest. This would indicate that this composition would exhibit the highest covalent character [15].

As the Er_3O_2 content increases, Ω_2 becomes slightly decreases, which indicate that the covalent character decreases. The relationship between the J-O parameters as a function of mol% Er_2O_3 was plotted and shown in Figure 2.

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From Figure 2, it can be seen that an addition of Er_2O_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_2O_3 content is being increased to more then 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 Ω_6 decreases with increases Er_2O_3 content.

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

Sample	Ω_2 ($\times 10^{-20}$) (cm^2)	Ω_4 ($\times 10^{-20}$) (cm^2)	Ω_6 ($\times 10^{-20}$) (cm^2)	(Ω_4/Ω_6)
AK1	5.99 ± 0.64	2.85 ± 0.70	2.43 ± 0.24	1.17
AK2	3.44 ± 0.56	2.85 ± 0.61	2.32 ± 0.21	1.23
AK3	2.60±0.55	2.67±0.60	2.22±0.21	1.20
AK4	1.76±0.40	2.58±0.43	1.86±0.15	1.39
AK5	1.17±0.33	2.35±0.37	1.46±0.13	1.61

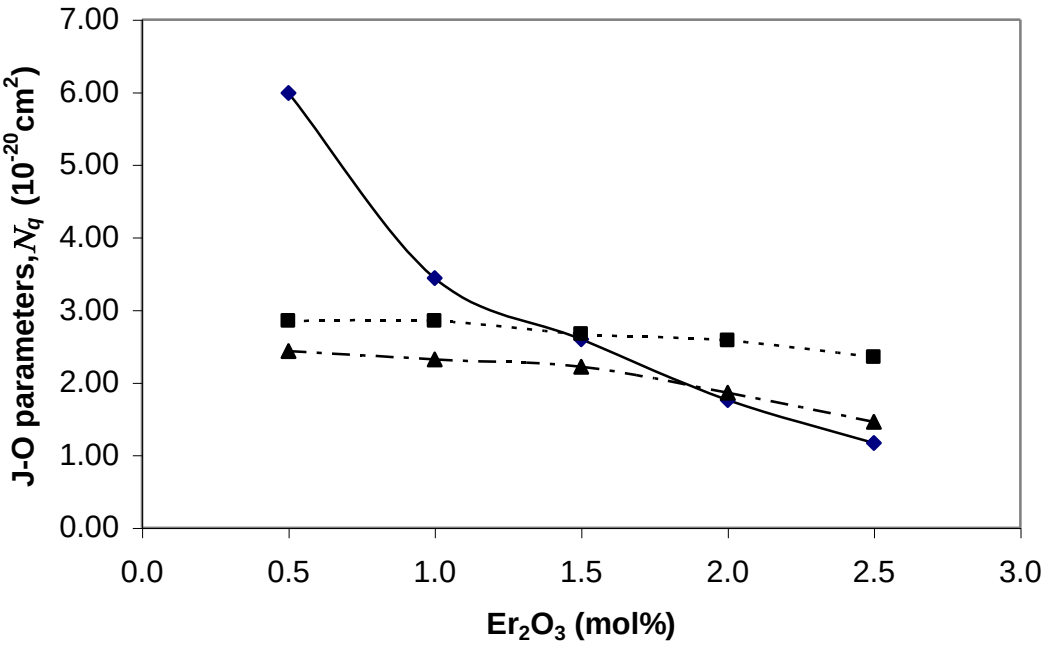

Figure 2**:** J-O parameters as a function Er_2O_2 concentration in tellurite glasses

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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 Ω_2 which related to the structural changes in the vicinity of the Er^{3+} (short range effect) indicates the highly covalent environment of Er^{3+}in glass matrix.
3. As the Er_2O_3 content in is being increases 0.5mol% to 2.5mol%, results in regular decreases of Ω_2 from (5.99 ± 0.64) x10^{-20}cm^2 to (1.17±0.33) x10^{-20}cm^2 and Ω_6 from (2.43±0.24) x10^{-20}cm^2 to (1.46±0.13) x10^{-20}cm^2. This results indicating decreases the covalent character of the glasses.

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