Effect of Er2O3 and ErF3 on the optical properties of sodium oxyfluoroborate glasses

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Abstract

Glasses based on B2O3–Na2O–NaF doped with Er2O3 and ErF3 were prepared by the melt quench technique. Density was measured and molar volume was calculated. The density and molar volume increased with the increase of Er2O3 and ErF3 content. Optical absorption spectra were measured to study the optical properties and their dependence on the Er2O3 and ErF3. The refractive index is estimated and correlated with the wavelength, Er2O3, ErF3, density, and O/F ratio. Nonlinear refractive index, optical and magnetic susceptibilities, Abbe number, molar refractivity, electronic polarizability, and energy gap were also calculated and correlated with Er2O3 and ErF3 contents.

Keywords: Borate oxyfluoride glass, Absorption spectra, rare earth ion, refractive index, optical constants.

1. INTRODUCTION

Oxide glasses are attracting hosts for obtaining efficient luminescence in rare-earth ions. In them, borate glass is a suitable optical material with high transparency, low melting point, high thermal stability, and good rare-earth ions solubility [1,2,3].

The research for excellent hosts still attracts much attention from scientists. At present, heavy metal oxyfluoride glass [4,5,6,7] is considered to be one of the most promising materials because it can well combine good optical, mechanical and thermal-stable properties of the oxides with lower phonon energy of fluorides which can effectively reduce multiphonon decay of excited states in rare-earth ions and thus enhance the optical quantum efficiency [8,9,10].

Rare-earth ion-doped glasses are technologically important materials as they can be applied in lasers, white light-emitting diodes, light-converting, and optoelectronic devices [11, 12,13,14]. The optical properties of rare-earth ions in various glass systems like silicates, phosphates, borates, germinates, tellurites, fluorides, etc. have been studied and reviewed in the literature [14,15,16,17,18]. These ions can exist in different environments in the glass matrix; the study of the environment around the rare-earth ion is essential to understand the optical absorption and luminescent properties of rare-earth ion-doped glasses.

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Optical methods like UV-visible and infrared spectroscopy can give the average coordination number, bond lengths, local symmetry, or covalency of bonds between the rare-earth ion and the first shell neighbors [19]. Borate glasses are structurally more intricate as compared to silicate or phosphate glasses due to two types of coordination of boron atoms with oxygen (3 and 4). It is well established that the addition of metal oxides converts the boron coordination and the structural groups from one to another depending on the type and concentration of the metal oxides [20,21,22]. For special optical applications, the role of glasses as ultraviolet (UV) transmitting materials has increased in the last decade. The real UV transmission is limited by extrinsic charge transfer and s-p absorption bands due to trace impurities of metal ions such as Fe2+/Fe3+, Pb2+, etc., which are influenced by the glass matrix [23,24].

The refractive index as a function of wavelength is a critical design parameter for advanced photonic systems. Thus, the ability to estimate the refractivity of glasses based solely on their composition is of great value to both photonic designers and the materials scientists supporting those designs. Usually, the refractive index is known or measured, and then the polarization is calculated, such as with the Lorentz–Lorenz equation [25,26].

In the present oxyfluoroborate glasses doped with Er2O3 and ErF3, the refractive index is calculated and correlated with the wavelength in the UV–VIS range. The molar refractivity, nonlinear refractive index, electronic polarizability, Abbe number, energy gap, and absorption cross-section of the glasses
were calculated for different wavelengths. The effect of Er$_2$O$_3$ and ErF$_3$ on the determined optical properties is discussed.

2. EXPERIMENTAL TECHNIQUES:

The glasses were prepared from appropriate mixtures of H$_2$BO$_3$, Na$_2$O, NaF, Er$_2$O$_3$, and ErF$_3$. The batches were inserted into the furnace at 950 °C for 30 min in a platinum crucible and then poured into a brass mold to obtain bar samples with dimensions of 1 x 1 x (0.6-0.65) cm$^3$. Each glass sample was annealed near its glass transition temperatures, which depend on its composition for 1 h. Then the furnace was switched off and the sample was taken out after 24 h and prepared for measurements.

The densities of the prepared samples were measured by the Archimedean method using CCl$_4$ as an immersion liquid. The molar volume was calculated by the equation $V_m = (M/\rho)$, where $\rho$ is the density and $M$ is the molecular weight of the glass sample which is calculated as follows: $M = \sum (x_i/w_i)$, where $x_i$ and $w_i$ are the mole fraction and molecular weight of component $i$, respectively. The error of the density measurements was not more than ±0.001 gm/cm$^3$.

The optical absorption spectra of the samples were recorded using T80 UV/VIS double beam spectrophotometer (PG Instruments Ltd) in the range from 190 to 700 nm. The refractive indices of the obtained glasses were calculated from the UV absorption spectra.

3. RESULTS:

The values of the glass composition, density, average molecular weight, Er ion concentration per cm$^3$, and oxygen/fluorine O/F ratio of the present glasses are reported in Table 1. Fig. 1 shows the increase of the density and the molar volume with the increased of both Er$_2$O$_3$ and ErF$_3$ instead of Na$_2$O contents [27,28].

Table 1 Glass composition in mol%, density in gm/cm$^3$, average molecular weight, molar volume in cm$^3$, the concentration of Er ion per cm$^3$, and oxygen/fluorine ratio of the present glasses.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>B$_2$O$_3$ (mol%)</th>
<th>NaF (mol%)</th>
<th>Na$_2$O (mol%)</th>
<th>Er$_2$O$_3$ (mol%)</th>
<th>ErF$_3$ (mol%)</th>
<th>$\rho$ (gm/cm$^3$)</th>
<th>$V_m$ (cm$^3$/mol)</th>
<th>n(Er) x10$^{20}$ cm$^{-3}$</th>
<th>O/F</th>
</tr>
</thead>
<tbody>
<tr>
<td>BNN-1ErO</td>
<td>70</td>
<td>15</td>
<td>14</td>
<td>1</td>
<td></td>
<td>2.387</td>
<td>67.535</td>
<td>28.293</td>
<td>4.257</td>
</tr>
<tr>
<td>BNN-2ErO</td>
<td>70</td>
<td>15</td>
<td>13</td>
<td>2</td>
<td></td>
<td>2.481</td>
<td>70.740</td>
<td>28.513</td>
<td>8.448</td>
</tr>
<tr>
<td>BNN-3ErO</td>
<td>70</td>
<td>15</td>
<td>12</td>
<td>3</td>
<td></td>
<td>2.601</td>
<td>73.945</td>
<td>28.430</td>
<td>12.709</td>
</tr>
<tr>
<td>BNN-1ErF</td>
<td>70</td>
<td>15</td>
<td>14</td>
<td>1</td>
<td></td>
<td>2.310</td>
<td>65.952</td>
<td>28.551</td>
<td>2.109</td>
</tr>
<tr>
<td>BNN-2ErF</td>
<td>70</td>
<td>15</td>
<td>13</td>
<td>2</td>
<td></td>
<td>2.355</td>
<td>67.575</td>
<td>28.694</td>
<td>4.197</td>
</tr>
<tr>
<td>BNN-3ErF</td>
<td>70</td>
<td>15</td>
<td>12</td>
<td>3</td>
<td></td>
<td>2.399</td>
<td>69.198</td>
<td>28.844</td>
<td>6.243</td>
</tr>
</tbody>
</table>

Fig. 2(A and B) shows the UV-VIS absorption spectra at room temperature in the range from 190–700 nm of the present glasses undoped and doped with both Er$_2$O$_3$ and ErF$_3$ respectively. Absorption rises abruptly around a photon wavelength of 190 nm in all glasses depending on its composition. This wavelength is taken as optical absorption cut-off $\lambda_0$. The most intense absorption is produced by electronic transitions from the valence band to the conduction band of the crystal. These transitions give rise to absorption in the ultraviolet and are visible in the present oxyfluoroborate glasses doped with erbium ions (like silicates); they lead to intrinsic semiconduction when thermally excited. Several weak peaks were found at energies near those of the ultraviolet absorption edges; these correspond to energy in exciton absorption i.e. to
transitions involving levels between the valence and conduction bands. They are too weak and at too high frequencies to be interpreted as due to lattice vibrations.

The absorption peaks are at the same wavelength positions for Er$_2$O$_3$ and ErF$_3$ doped glasses while their intensity is higher for Er$_2$O$_3$ than ErF$_3$ doped glass. The increase of the intensity of the observed absorption bands with the increase of both Er$_2$O$_3$ and ErF$_3$ is shown in Fig. 3.

The refractive index, n, of a material is an important parameter for the design of glass-related devices [30]. According to the theory of reflectivity of light (Fresnel’s theory), the real part of n of the complex refractive index as a function of reflectance, R, and extinction coefficient, K, in the UV-VIS range is given by the quadratic equation,

\[
R = \frac{(n-1)^2 + K^2}{(n+1)^2 + K^2}
\]

where the appropriate root of the above equation is considered as the refractive index. The extinction coefficient, K, is determined by,

\[
K = \frac{\alpha \lambda}{4 \pi}
\]

where \(\lambda\) is the wavelength and \(\alpha\) is the absorption coefficient of the material which is given by.

\[
\alpha = \frac{2.303}{d} \cdot A
\]

where \(A\) is optical absorption and \(d\) is the sample thickness in cm.

The correlation between \(n\) and the wavelength in the UV-VIS range is shown in Fig. 4(A and B). The values of \(n\) corresponding to the spectral line element are calculated and given in Table 2.
Table 2 Refractive index according to the spectral line element and the dispersion of the present glasses.

<table>
<thead>
<tr>
<th>Spectral line (nm)</th>
<th>BNN1ErO</th>
<th>BNN2ErO</th>
<th>BNN3ErO</th>
<th>BNN1ErF</th>
<th>BNN2ErF</th>
<th>BNN3ErF</th>
</tr>
</thead>
<tbody>
<tr>
<td>C (656.3)</td>
<td>3.19538</td>
<td>2.63006</td>
<td>2.25549</td>
<td>3.43121</td>
<td>2.98382</td>
<td>2.76532</td>
</tr>
<tr>
<td>C' (643.8)</td>
<td>3.31329</td>
<td>3.45202</td>
<td>3.49017</td>
<td>3.66358</td>
<td>3.45549</td>
<td>3.35838</td>
</tr>
<tr>
<td>D (589.3)</td>
<td>3.50751</td>
<td>3.72254</td>
<td>3.76763</td>
<td>3.70520</td>
<td>3.57341</td>
<td>3.46243</td>
</tr>
<tr>
<td>e (546.1)</td>
<td>3.51445</td>
<td>3.72601</td>
<td>3.77457</td>
<td>3.70173</td>
<td>3.56994</td>
<td>3.47630</td>
</tr>
<tr>
<td>F (486.1)</td>
<td>3.07746</td>
<td>3.80000</td>
<td>2.58150</td>
<td>3.43815</td>
<td>3.06358</td>
<td>2.90405</td>
</tr>
<tr>
<td>F' (479.9)</td>
<td>3.46243</td>
<td>3.49711</td>
<td>3.46936</td>
<td>3.62890</td>
<td>3.42081</td>
<td>3.29942</td>
</tr>
<tr>
<td>g (435.8)</td>
<td>3.55526</td>
<td>3.68786</td>
<td>3.71561</td>
<td>3.70867</td>
<td>3.58035</td>
<td>3.41387</td>
</tr>
<tr>
<td>h (404.6)</td>
<td>3.35491</td>
<td>3.28902</td>
<td>3.19191</td>
<td>3.62890</td>
<td>3.38266</td>
<td>3.16416</td>
</tr>
<tr>
<td>i (365.01)</td>
<td>2.88324</td>
<td>2.55723</td>
<td>2.29364</td>
<td>3.34451</td>
<td>2.84509</td>
<td>2.63353</td>
</tr>
<tr>
<td>νd</td>
<td>16.021</td>
<td>8.489</td>
<td>389.798</td>
<td>32.264</td>
<td>17.749</td>
<td></td>
</tr>
<tr>
<td>νe</td>
<td>6.447</td>
<td>5.9364</td>
<td>5.393</td>
<td>29.5171</td>
<td>16.9893</td>
<td>19.1505</td>
</tr>
</tbody>
</table>

The variation of the refractive index, n, at the different spectral line elements with the composition of Er₂O₃ and ErF₃ is shown in Fig. 5.

Fig. 6 shows the variation of the refractive index with the density.
The refractive index of a glass is related through dielectric susceptibilities of cation-anion pairs present in the glass host. On the other hand, the presence of ionic bonds, such as those found in fluorides; reduces the refractive index due to the localization of electrons. This can be supported by calculating theoretically both optical, $\chi$, and magnetic, $\chi_m$, susceptibilities as follows [32,33].

$$\chi = 0.08\left[-\ln(0.102\Delta\chi^*)\right]^2 - 1$$

where $\Delta\chi^*$ = (electronegativity of anion) – (electronegativity of cation).

$$\chi_d = -(8.82 \times 10^{18} \times \alpha_e + 5.02 \times 10^{-6})$$

where $\alpha_e$ is the electronic polarizability is given by,

$$\alpha_e = 0.395 \times 10^{-24} \left[\frac{4.207 + k}{7.207 + k}\right] \frac{M}{\rho}$$

and

$$k = \ln\Delta\chi^* (\ln\Delta\chi^* - 4.564)$$

The above parameters were calculated and their values are reported in Table 3.
The molar refractive index is related to the structure of the glass and it is proportional to the molar electronic polarizability of the material, \( \alpha_{me} \), (in cm\(^3\) x 10\(^{-24}\)) through the following Clasius-Mosotti relation,

\[
\alpha_{me} = \frac{3}{4\pi N} R_m
\]

where \( N \) is the number of polarizable ions per mole and is assumed equal to Avogadro's number NA.

The calculated values of \( \alpha_{me} \) at different spectral line elements are given in Table 4.

Table 3 Optical susceptibility, polarizability, magnetic susceptibility, nonlinear refractive index, and non-linearity refractive index coefficient of the present glasses.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>( \chi )</th>
<th>( \alpha \times 10^{24} \text{cm}^3 )</th>
<th>( \chi' \times 10^{6} \text{cm}^2 \text{mol}^{-1} )</th>
<th>( n_2 \times 10^{11} \text{esu} )</th>
<th>( \gamma \times 10^{15} \text{cm}^2/W )</th>
</tr>
</thead>
<tbody>
<tr>
<td>BNN-1ErO</td>
<td>0.1710</td>
<td>4.1158</td>
<td>-41.3127</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BNN-2ErO</td>
<td>0.1714</td>
<td>4.1428</td>
<td>-41.5455</td>
<td>3.9099</td>
<td>4.397</td>
</tr>
<tr>
<td>BNN-3ErO</td>
<td>0.1717</td>
<td>4.1697</td>
<td>-41.7783</td>
<td>10.5259</td>
<td>11.697</td>
</tr>
<tr>
<td>BNN-1ErF</td>
<td>0.1706</td>
<td>4.0845</td>
<td>-41.0413</td>
<td>0.03224</td>
<td>0.0366</td>
</tr>
<tr>
<td>BNN-2ErF</td>
<td>0.1704</td>
<td>4.0801</td>
<td>-41.0027</td>
<td>1.16479</td>
<td>1.365</td>
</tr>
<tr>
<td>BNN-3ErF</td>
<td>0.1702</td>
<td>4.0757</td>
<td>-40.9641</td>
<td>2.49245</td>
<td>3.014</td>
</tr>
</tbody>
</table>

The values of \( \chi \) and \( \chi' \) of the present glasses are acceptable compared with those obtained for other glasses \([34,35]\). The refractive index of a glass depends on individual ions present in the glass and also the polarizability of cations. In general, the refractive index increases for highly polarizable cations. So that, the polarizability, \( \gamma \), of the present glasses is calculated to confirm this interpretation. Firstly, the molar refraction \( R_m \) is calculated and then \( \alpha_{me} \) \([36-38]\) as follows,

\[
R_m = \left( \frac{n^2 - 1}{n^2 + 2} \right) V_m
\]

where \( \frac{n^2 - 1}{n^2 + 2} \) called the molar refraction loss, and \( V_m \) is the molar volume of the glass. As the refractive index and molar volume increase, the corresponding increase in the molar refractive index can be predicted from Eq. (7). The calculated values of \( R_m \) at different spectral line elements are given in Table 4.

Table 4 Molar refractivity (cm\(^3\).mol\(^{-1}\)) and polarizability (cm\(^3\)) at C', d, e, F' and g lines of the present glasses.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>C' (643.8 nm)</th>
<th>d (587.6 nm)</th>
<th>e (546.1 nm)</th>
<th>F' (479.98 nm)</th>
<th>g (435.8 nm)</th>
<th>C' (643.8 nm)</th>
<th>d (587.6 nm)</th>
<th>e (546.1 nm)</th>
<th>F' (479.98 nm)</th>
<th>g (435.8 nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BNN-3ErF(_3)</td>
<td>22.166</td>
<td>22.694</td>
<td>21.837</td>
<td>22.079</td>
<td>22.496</td>
<td>8.829</td>
<td>8.986</td>
<td>8.630</td>
<td>8.769</td>
<td>8.907</td>
</tr>
</tbody>
</table>

Fig. 8 Variation of molar refraction with Er\(_2\)O\(_3\) and Er\(_3\)F\(_3\) of the present glasses.
It is observed that $\epsilon_{300}$ at different wavelengths increases with Er2O3 while it decreases in the case of ErF3 doped glass as shown in Fig. 9.

The energy gap $E_g$ can be calculated from $^{[39,40]}$

$$E_g = 20\left(1 - \frac{R_m}{V_m}\right)^2$$

$$E_g = \left[1.23\left(1 - \frac{R_m}{V_m}\right) + 0.98\right]^2$$

The energy gap, see Table 5 and Fig. 10 $^{[31]}$.

### Table 5 Energy gap at different wavelengths of the present glasses.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>$C_e$ (643.8 nm)</th>
<th>$e$ (546.1 nm)</th>
<th>$F'_g$ (479.98 nm)</th>
<th>$g$ (435.8 nm)</th>
<th>$C_e$ (643.8 nm)</th>
<th>$e$ (546.1 nm)</th>
<th>$F'_g$ (479.98 nm)</th>
<th>$g$ (435.8 nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BNN-1%ErF3</td>
<td>1.2030</td>
<td>0.9266</td>
<td>0.8203</td>
<td>0.8356</td>
<td>1.6427</td>
<td>1.5494</td>
<td>1.5107</td>
<td>1.5164</td>
</tr>
<tr>
<td>BNN-2%ErF3</td>
<td>2.0055</td>
<td>0.9341</td>
<td>0.7309</td>
<td>0.7309</td>
<td>1.6078</td>
<td>1.5521</td>
<td>1.4766</td>
<td>1.4766</td>
</tr>
<tr>
<td>BNN-3%ErF3</td>
<td>1.1144</td>
<td>1.0903</td>
<td>0.7309</td>
<td>0.7114</td>
<td>1.6128</td>
<td>1.6058</td>
<td>1.4766</td>
<td>1.4689</td>
</tr>
<tr>
<td>BNN-1%ErO3</td>
<td>0.7957</td>
<td>0.7741</td>
<td>0.7309</td>
<td>0.7234</td>
<td>1.5015</td>
<td>1.4933</td>
<td>1.4766</td>
<td>1.4736</td>
</tr>
<tr>
<td>BNN-2%ErO3</td>
<td>1.0009</td>
<td>0.9413</td>
<td>0.8678</td>
<td>0.8236</td>
<td>1.5754</td>
<td>1.5546</td>
<td>1.5282</td>
<td>1.5119</td>
</tr>
<tr>
<td>BNN-3%ErO3</td>
<td>1.1224</td>
<td>1.1319</td>
<td>0.9954</td>
<td>0.9605</td>
<td>1.6164</td>
<td>1.6196</td>
<td>1.5735</td>
<td>1.5614</td>
</tr>
</tbody>
</table>

The most important quantities for applications in the visible spectral range are:

- the central relative refractive index for the d line $n_d$ (formerly also $n_D$ or $n_e$ had been chosen),
- the central dispersion $(n_r-n_d)$,
- and the inverse of the dispersion relative to the refractive power, i.e., the Abbe number, $v_d$, which is given by,

$$V_d = \frac{n_d - 1}{n_F - n_C}$$

Formerly, also $v_s = (n_r-1)/(n_r-n_c)$ and $v_c = (n_r-1)/(n_r-n_c)$ were used. All the above optical quantities are calculated and given in Table 2. The interpretation of the Abbe number is quite simple: It quantifies in the visible range how many times the average deviation angle of a prism is larger than the spread angle of the white light. Thus, a large (small) Abbe number characterizes a relatively small (large) spread. There is an inverse relationship between the Abbe number and the refractive index in the optical glasses, which means the glass with a relatively high refractive index, has a relatively low Abbe number.

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Another interesting matter is the non-linearity refractive index, \( n_2 \), which is evaluated from [41]:

\[
 n_2 (10^{-13}\ esu) = \left[ \frac{68(n_d - 1)(n_d^2 + 2)}{v_d \left( 1.517 + \frac{(n_d^2 + 2)(n_d - 1)}{6n_d} \right)} \right]^{1/2}
\]

On evaluating this factor, it is easy to compute the non-linearity refractive index coefficient, \( \gamma \), as follows [42]:

\[
 \gamma (cm^2/W) = \frac{4 \pi n_2^7}{c n_d} (esu)
\]

where \( n_d \) is the refractive index at 589.3 nm, and \( c \) is the velocity of light. The values of \( n_2 \) and \( \gamma \) are given in Table 3.

4. Discussion

The values of the glass composition, reported in Table 1. Fig. 1 shows the increase of the density is attributed to the molecular weight of both Er2O3 and ErF3 being higher than that of Na2O, while the increase in molar volume is attributed to the increase of the B–B and then B–O bond length as discussed in our previous work [29].

From Figs. 2 (A and B) that the obtained absorption peaks are due to the electronic transition of the Er3+ ion from the ground state 415/2 [27] since the pure sample lacks any absorption peaks. These absorption bands which observed at 230 nm (43478 cm⁻¹), 255 nm (39216 cm⁻¹), 365 nm (27397 cm⁻¹), 381 nm (26246 cm⁻¹), 405 nm (24691 cm⁻¹), 450 nm (22222 cm⁻¹), 488 nm (20492 cm⁻¹), 520 nm (19231 cm⁻¹), 544 nm (18382 cm⁻¹) and 655 nm (15267 cm⁻¹) respectively are due to the transitions from the 415/2 ground state of Er3+ ion [27], to the various excited states of Er3+ ion which are: 4G9/2, 4G11/2, 2H9/2, 4F7/2, 2H11/2, 4S3/2 and 4F9/2 respectively. We see shown in Fig. 3, the increase of the intensity of the observed absorption bands with the increase of both Er2O3 and ErF3. This behavior is attributed to the increase of the Er3+ ion concentration per cm3 from 4.257–12.709x1020 and 2.109–6.243x1020 cm⁻³ for Er2O3 and ErF3 doped glasses respectively (see Table 1), which may absorb more energy to pumps from the ground energy state to the higher excited energy states.

The variation of the refractive index, \( n \), is shown in Fig. 5. It is observed that the refractive index increases with the increase of Er2O3 content while it decreases with ErF3 content. This may be due to the fact that Er2O3 instead of Na2O the concentration of oxygen ions is increased while adding ErF3 will decrease O2⁻ and increase F⁻ ions (see Table 1). Since O2⁻ has high polarizability (3.88) than that of fluorine ion (1.04), therefore refractive index increased in the case of Er2O3 while it decrease in the case of ErF3 doped glasses. Fig. 6 shows the variation of the refractive index with the density.

It is observed that the refractive index increase in the case of Er2O3 doped glass while it decreases with the density of ErF3 doped glass. This is due to the effect of the packing density of the glass [29].

Therefore the relationship between the refractive index and the O/F ratio, as shown in Fig. 7 [A and B], is a combination of the two effects: the structural packing of the glass networks with large and small cations and the localization/delocalization of electrons due to the nature of local bonds [31].

The values that both optical and magnetic susceptibilities are increased from 0.1710-0.1717, (-41.3127)–(-41.7783)x10⁻⁶ (cm3.mol⁻¹) for Er2O3 containing glass while decrease from 0.1706-0.1702, (-41.0413)–(-40.9641) x10⁻⁶ (cm3.mol⁻¹) for ErF3 doped glass. This is another reason that the refractive index is increased in Er2O3 doped glass while it decreased in ErF3 doped glass.

The value of \( R_m \), \( \alpha_{moe} \) and \( n \) is increased with the increase of the Er2O3 in the glass while it decreased in the case of ErF3 doped glass. The optical energy gap decrease with increasing cationic size (or anionic size). Referring to the O/F ratio its value is higher in the case of Er2O3 doped glass than in ErF3 glass. And since the ionic radius of O2⁻ (1.40 Å) is greater than F⁻ ion (1.26 Å). Therefore \( E_g \) is decreased by increasing Er2O3 than ErF3 contents. The values of \( n_2 \) and \( \gamma \) are increased with increasing both of Er2O3 and ErF3. Their values are acceptable compared with the other glasses [43,44].

5. REFERENCES:

26. R. Lorentz, R. Wied Ann. 11 (1880) 70.