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Optical Properties of Rare Earth Doped Borate Glasses

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Abstract: The main aim of present research work is to prepare borate glasses are prepared by melt quenching method by doping various concentrations of rare earth metals (Sm, Dy and Eu). The resultant glasses are characterized using UV-Visible spectrometer for studying optical properties. The optical band gap energies (E_g) and refractive indices (n) are found to be varying between 3.39- 3.56 eV and 2.260-2.299. The absorption spectra was recorded for Sm (1.0, 1.5 &2.0), Dy (1.0, 1.5 &2.0) and Eu (0.5, 1.0 &1.5) doped fixed concentration of borate glasses.
Keywords: Borate glasses; UV-Visible spectrometer; Optical band gap; Melt quenching method.

Introduction:

Borate glasses pertaining rare earth metal oxides have significant applications for solid state, luminescent applications, LASER hosts, lamp phosphors, broad band amplifiers, sensors, optical data storage devices and optical fiber communication systems [1]. Kim et al [2] investigated the luminescence property of rare earth doped bismuth borate glasses due to 4f-4f and 4f-4d electronic transitions in the visible light range. Padlyak et al [3] also studied luminescence properties of the Samarium doped borate glasses by studying the optical absorption and photoluminescence spectra. Venkata Rao et al [4] suggested that Dy^{3+} doped borate glasses are the candidate materials for yellow lighting applications in the visible range by studying optical properties. Shem et al [5] demonstrated that Sm^{3+} doped alkaline earth borate glasses are well suited materials for UV to Visible photon conversion layer for solar cell applications. Ivankov et al [6] revealed that the high content of Eu^{3+} has lead to the disappearance of broad band glass emission at the near UV range. But to the best of author knowledge there is no detailed report on the combine optical properties of Sm, Dy and Eu doped borate glasses. In this investigation an attempt has been made to study the optical properties of present glass materials.

Experimental Procedure:

The glasses of general formula 49.99 H_3BO_3-10SrF_2-10Bi_2O_3-20ZnO-10SiO_2-M (M = Sm_2O_3, Dy_2O_3 & Eu_2O_3) have been prepared by mixing them in appropriate quantity with the help of digital electronic balance. The chemicals of 99.9 % purity (Sigma Aldrich) are taken. All these compositions are mixed together and stirred in a porcelain crucible. The mixture is melted by placing it in a programmable furnace 1100^{0}C for 30min. The glass samples are taken out from the furnace and pour onto different metal plates. The plate is again annealed for 300^{0}C and as the result the glasses are obtained having transparent, pure and amorphous in nature. The samples are characterized by using UV-Visible spectrometer (UV-Visible-NIR JASCO spectrometer) for studying the absorption spectra, optical band gap energies and refractive indices.

Result and Discussions:

The optical absorption spectra of 49.99 H_3BO_3-10SrF_2-10Bi_2O_3-20ZnO-10SiO_2-M (M = Sm_2O_3, Dy_2O_3 & Eu_2O_3) is recorded and is shown in fig.1. In the absorption spectra of present amorphous materials maximum absorption wavelength (λ_m) is observed and is tabulated in Table.1. From Fig.1 (a) it is evident that low concentration of Sm, λ_m is decreased to 296 nm while the rest high Sm contents show the similar λ_m values (301 nm). Fig1. (b) Reveals that at the high concentrations of Dy, λ_m decreases to 290 nm. On the other hand the rest compositions exhibit the identical λ_m values (301 nm). But, interestingly Fig.1 (c) shows for all contents of Eu doped borate glasses perform the similar λ_m values of 301 nm. Comparatively, Sm doped glass shows few absorption peaks between wavelength range 1100-1400 nm while Dy-doped glass showed the absorption peaks possessing the left shift over the wavelength range 750-1400nm. These absorption peaks may be due to the presence of few impurities.

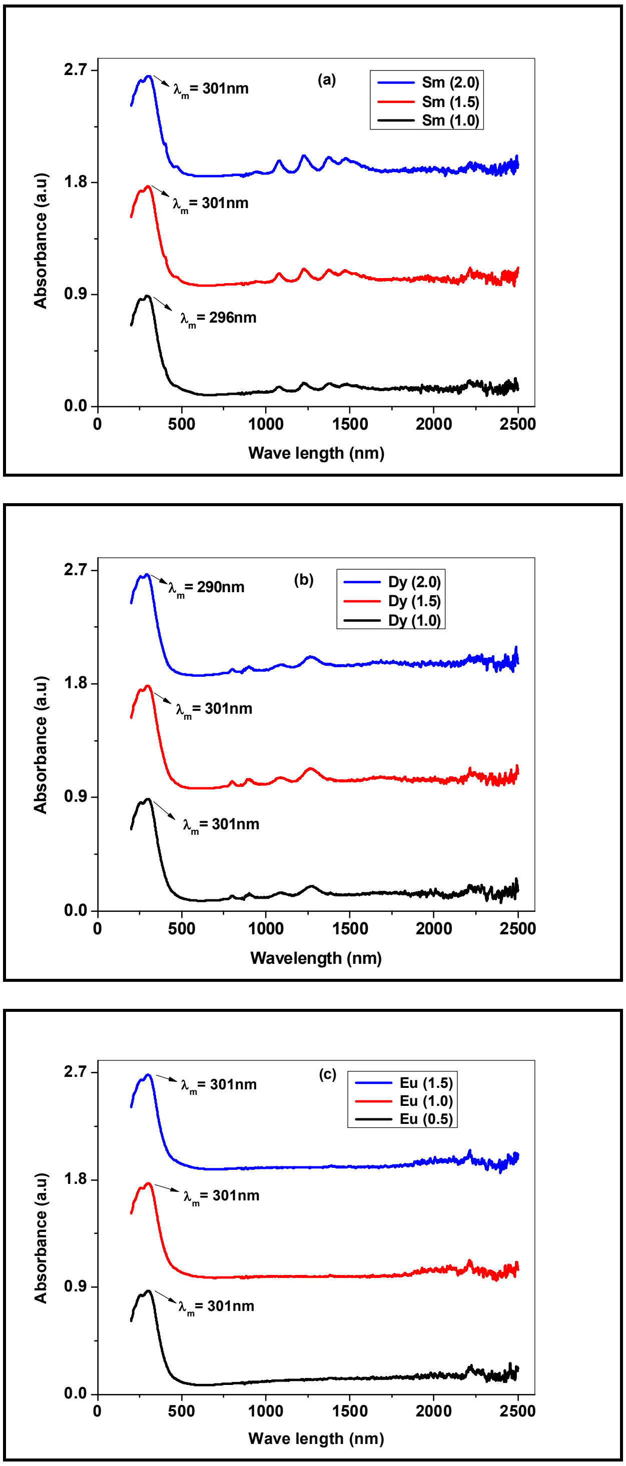


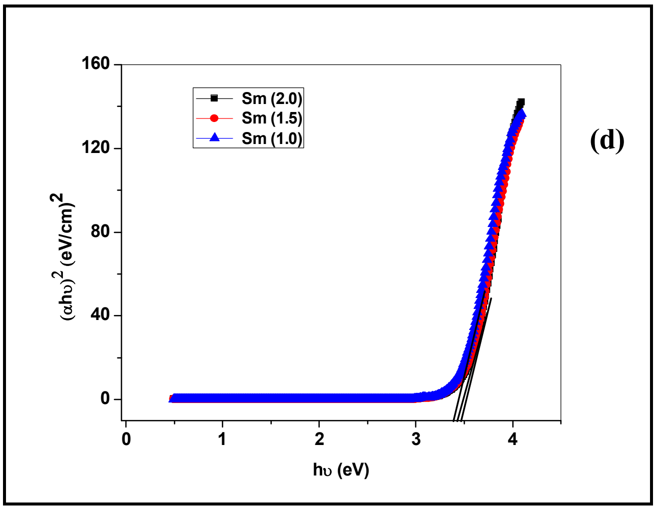
Fig. 1 Absorption spectra of (a) Sm (1.0, 1.5, and 2.0) (b) Dy (1.0, 1.5, and 2.0) & (c) Eu (0.5, 1.0, and 1.5) doped borate glasses

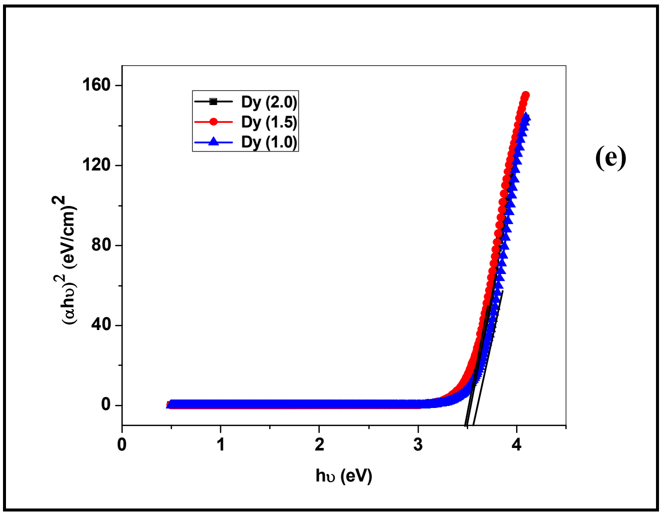
Table.1 Data for optical parameters of Sm, Dy & Eu doped borate glasses

S.No.	Sample	E_g (eV)	n	λ_m (nm)	A
1	$Sm_{1.0}$	3.46	2.283	296	0.888
2	$Sm_{1.5}$	3.42	2.292	301	1.761
3	$Sm_{2.0}$	3.39	2.299	301	2.647
4	$Dy_{1.0}$	3.56	2.260	301	0.882
5	$Dy_{1.5}$	3.51	2.271	301	1.781
6	$Dy_{2.0}$	3.51	2.271	290	2.667
7	$Eu_{0.5}$	3.49	2.276	301	0.868
8	$Eu_{1.0}$	3.48	2.278	301	1.761
9	$Eu_{1.5}$	3.47	2.281	301	2.681

The diffuse reflectance spectra are recorded in wavelength range of 200-2500 nm in order to determine the optical band gaps for the glass samples. Using the following equation Kubelka- Munk function of reflectance F(R) can be calculated [7].

$$F(R) = \frac{(1-R)^2}{2R} \quad \text{------------ (1)}$$





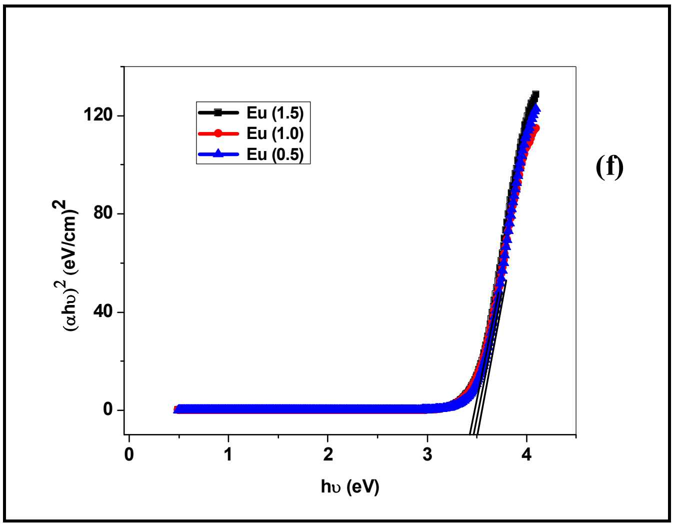


Fig. 2 $(\alpha h\nu)^2$ Vs photon energy plots of (d) Sm (1.0, 1.5, and 2.0) (e) Dy (1.0, 1.5, and 2.0) & (f) Eu (0.5, 1.0, and 1.5) doped borate glasses

The absorption coefficient α is directly proportional with F(R) and hence an equation for determining the band gap can be written as follows.

$(\alpha h\nu)^n = A\,(h\nu - E_g)$ ---------- (2)

Where A= Energy- independent constant that depends on transition probability, E_g= optical band gap, n= the kind of transition i.e. n=2 for direct transition, 2/3 for direct forbidden transition, ½ for indirect allowed transition, 1/3 for indirect forbidden transition and hν = photon energy. In the present study n = 2 is taken for direct transition. E_g values are determined and tabulated in table.1 by plotting $(\alpha h\nu)^2$ against the photon energy hν (eV) as shown in fig.2 and the slope of α tends to zero. The obtained band gaps are found to be varying between 3.39- 3.56 eV.

The refractive index (n) is calculated using the optical band gap energies (E_g) with the help of following formula.

$$\frac{n^2-1}{n^2+2} = 1-\sqrt{\frac{E_g}{20}} \quad \text{-------------- (3)}$$

In the present investigation for all the dopants of borate glasses the optical band gap energies are decreasing with increase of doping contents while refractive indices and absorbance (A) values are showing increasing trend with doping contents. This establishes a fact that there exists an inversely proportional relationship between E_g & n, A.

Conclusions:

The values of optical band gaps of the glass sample are due to direct transitions. Decreasing of E_g values confirms the extension of localized states into band gap. The observed variations in band gap are due to oxide ion polarizability and hence the structural changes may occur in the glass network with the replacement of rare earth oxides. So that, these materials can act as glass network modifier (GNM). The decrease of band gap energy in turn causes to increase of refractive index with doping content.

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