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Effect of Gamma Irradiation on Optical Properties of Barium Titanate Modified Bismuth Borate Glasses

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Abstract
In the present work a series of glasses has been synthesised by introducing Barium Titanate (BT) into the glass matrix ($70B_2O_3$-$29Bi_2O_3$-$1Dy_2O_3$) with BT varying from x = 0, 5, 10, 15, 20 and 25 weight percent. The prepared samples were irradiated with 25 kGy gamma dose using a ^{60}Co radioisotope. The effect of gamma radiations on the optical properties of samples was studied using UV-Vis spectroscopic measurements on the pristine and irradiated samples. A decrease in band gap energy (E_g) and an increase in Urbach energy (E_u) in the samples have been observed after irradiation. These changes may be attributed to the defects formation in the glass matrix. Also it has been found that with addition of BT into glass matrix they become radiation resistant and can be used as a potential candidate in nuclear industry.

Keywords
Glass, Barium Titanate (BT), UV-Vis Spectroscopy, Gamma Irradiation

I. Introduction
In the recent years, study of the irradiation effects on the glasses has drawn much attention of the researchers because of the increasing use of gamma radiations in the field of medicine and industry, space craft, optical fibre waveguides and also in nuclear power plants [1-2]. Since, properties of the glasses can be modified by changing their composition and by the synthesization methods also, they are transparent to visible light. So, glasses can be a good alternative of concrete which is usually used in shielding purposes [2-3]. Bismuth based borate glasses are supposed to have good radiation shielding properties due to its high atomic number and find their use in the nuclear engineering applications such as in nuclear reactors, hot cells and in encapsulation of radioactive wastes [4-6]. In the present work we have investigated the effect of gamma irradiation on the optical properties of ($70B_2O_3$-$29Bi_2O_3$-$1Dy_2O_3$)-xBT glass samples. Since, irradiation causes some structural changes in the glass matrix which in turn affects the various structural, physical and optical properties of the glasses. These changes are found to depend on the type and dose of radiation and on the composition of glass [4].

II. Experimental
The glass samples with composition ($70B_2O_3$:$29Bi_2O_3$:$1Dy_2O_3$) xBT; x=0, 5, 10, 15, 20, 25 weight percent, were prepared by conventional splat quenching technique. The weighed quantities of the chemicals B_2O_3 (Sigma Aldrich), Bi_2O_3 (Sigma Aldrich), Dy_2O_3 (Molychem) and barium titanate, prepared by solid state reaction route, were mixed in agate pestle-mortar for half an hour. The mixture was then put into an alumina crucible and transferred to a muffle furnace. The sample was melted at 1000^{0}C for half an hour. The melt was then poured onto a stainless steel plate preheated at 200^{0}C and was immediately pressed by another steel plate.

A. Gamma Irradiation
The samples were irradiated by γ-rays at room temperature using ^{60}Co γ-irradiator (Gamma Chamber-1200) with the dose rate 7.5 kGy/h, at IUAC, New Delhi. Studied samples were exposed to a dose of 25 kGy.

B. Optical Absorption Measurements
The optical absorption measurements were carried out for well-polished glass samples on Shimadzu-1601 double beam UV-Vis Spectrophotometer in the wavelength range 200-900 nm.

III. Results and Discussion
Fig. 1 shows the optical absorbance spectra of the prepared samples before and after irradiation. Study of the absorption spectra shows that there is a slight shifting of the band edge to the higher wavelength after irradiation.

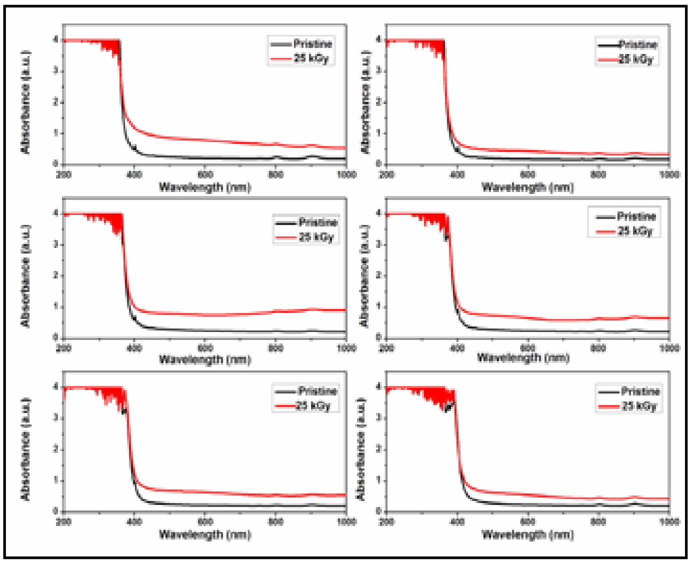

Fig. 1: Optical Absorption Spectra of BT-doped Bismuth Borate Glasses With Increasing BT Content Before and After Gamma Irradiation

The optical absorption coefficient has been calculated using the relation [7]:

$$\alpha(\nu) = \frac{A}{t}$$

where 'A' is the absorbance and 't' is the thickness of the sample.
The optical band gap energies of the samples have been calculated from Tauc's plots using the relation [7-8]:
$\alpha h\nu = B(h\nu - E_g)^n$
where B is a constant, known as band tailing parameter, hν is the incident photon energy and n is a constant that determines the type of optical transitions. In the present case we have calculated indirect optical band gap energies using n = 2. The plots between $(\alpha h\nu)^{1/2}$ and (hν), known as Tauc's plot have been used to calculate

optical band gap energies of the prepared samples. Figs. 2 and 3 show the Tauc's plots for pristine samples and irradiated samples respectively. The values of band gap energy (E_g) obtained from the plots are listed in Table 1.

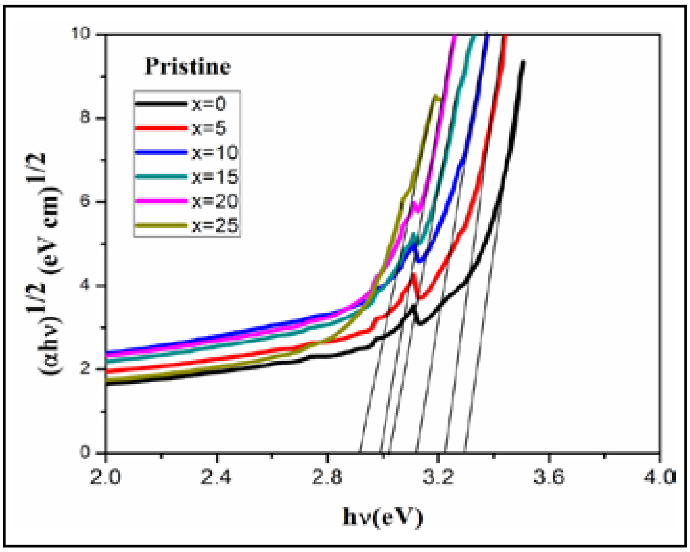

Fig. 2: Tauc's Plot for ($70B_2O_3$-$29Bi_2O_3$-$1Dy_2O_3$)-xBT Glass Samples Before Irradiation.

Perusal of the data indicates that there is a decrease in the values of optical band gap energies after irradiation. This decrease in values of E_g confirms the defects formation in the glass structure with irradiation. It is well known that irradiation of the glass samples causes displacements of ions and breaking of bonds, which results in the structural modifications in the glass matrix [9]. These changes in the structure can be responsible for the decrease in band gap energy. Also, from fig. 4 it is observed that as the value of x is increased, there is less decrease in value of E_g with irradiation. It means that with addition of BT, the glass system becomes radiation resistant.

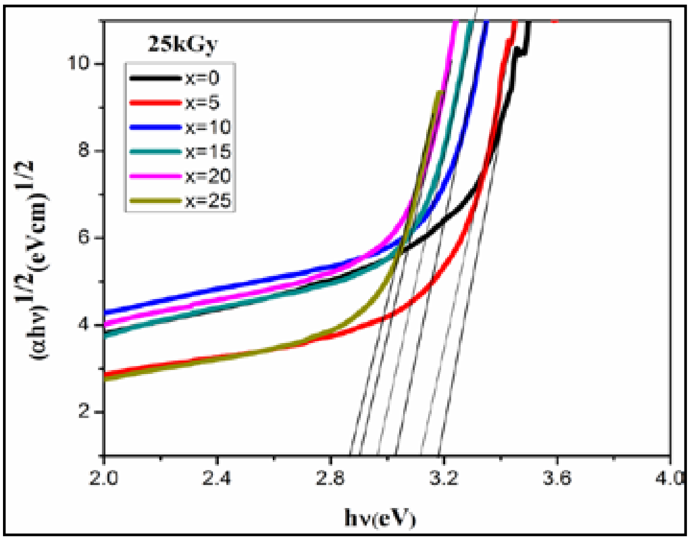

Fig. 3: Tauc's Plot for ($70B_2O_3$-$29Bi_2O_3$-$1Dy_2O_3$)-xBT Glass Samples After Irradiation

The Urbach energy which gives us information about the defect concentration or the disorder in the glass system has also been calculated for the samples before and after irradiation from the Urbach plots [10] and its values are given in Table 1. Perusal of the data indicates that after irradiation the values of Urbach energy has been increased which is an expected result.

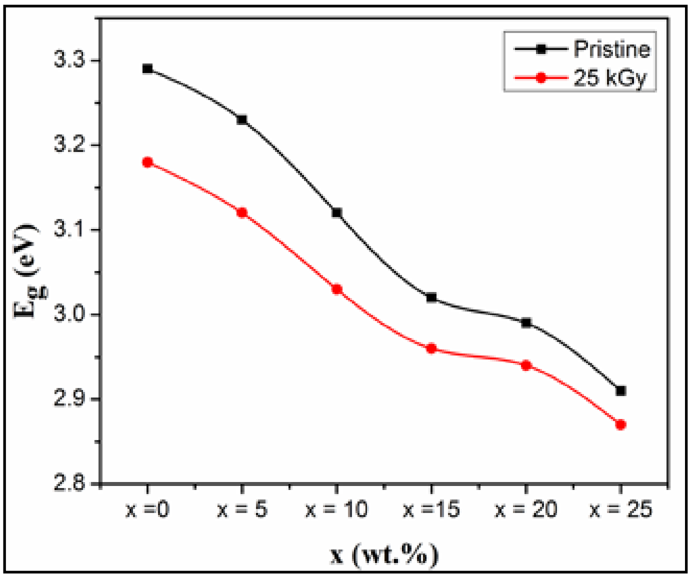

Fig. 4: Variation in Band Gap Energy for ($70B_2O_3$-$29Bi_2O_3$-$1Dy_2O_3$)-xBT Glass Samples With Absorbed Dose and Weight Fraction of BT

As irradiation causes defect formation in the glass system, hence disorderness increases. Fig. 5 shows the variation of Urbach energy with the absorbed dose and mole fraction of BT. From the given figure it is clear that with increase in the BT content in the glass matrix , there is an appreciable decrease in the Urbach energy.

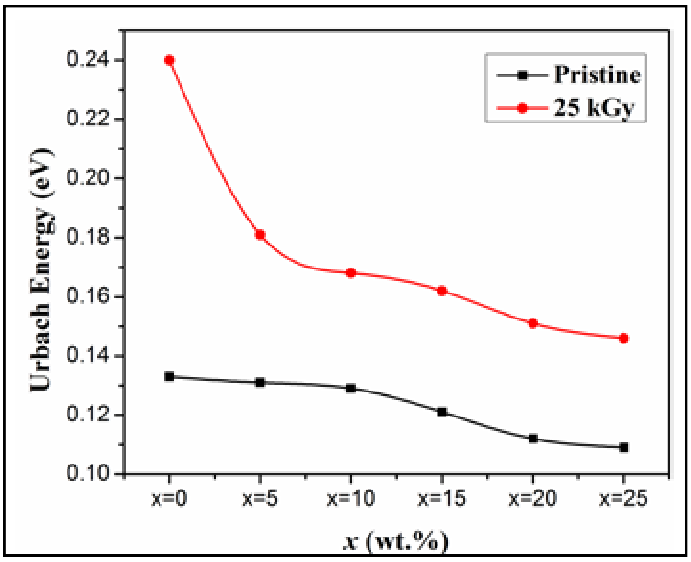

Fig. 5: Variation in Urbach Energy for ($70B_2O_3$-$29Bi_2O_3$-$1Dy_2O_3$)-xBT Glass Samples With Absorbed Dose and Weight Fraction of BT

IV. Conclusion

The optical absorbance spectra obtained for the samples showed no remarkable change in the absorbance spectra after irradiation. A decrease in the band gap has also been observed after gamma irradiation indicating the defects formation in the glass matrix. However, this decrease is found to be less in the glass samples as the amount of barium titanate is increased. The values of Urbach energy calculated for the irradiated samples have been found to decrease from 0.240 to 0.146 eV. Suggesting that with increase in the BT content in the glasses, they become more resistant to the gamma radiations. Hence such glasses can be potential candidates for radiation shielding purposes in the nuclear industry.

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Table 1: Optical Band Gap Energy (E_g) and Urbach Energy (E_u) of Pristine and Gamma Irradiated Glass Samples

Sample code	Band gap energy E_g (eV)		Urbach Energy E_u (eV)	
	Pristine	25 kGy	Pristine	25 kGy
x =0	3.29	3.18	0.133	0.240
x = 5	3.23	3.12	0.131	0.181
x = 10	3.12	3.03	0.129	0.168
x =15	3.02	2.96	0.121	0.162
x = 20	2.99	2.94	0.112	0.151
x = 25	2.91	2.87	0.109	0.146

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