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A Study of Optical Properties of Tetraborate Glass Containing MgO

Glasses with compositions (65%) $Na_2B_4O_7$ – (35-x)%V_2O_5 – (x)% MgO, where x=10, 15, 20, or 25, is were produced using conventional melt quenching technique. The shifting rate of absorption edge position, band tails energy (E_o) and optical band energy (E_{opt}) were investigated. The results showed all the values of E_o and E_{opt} for the glass compound can be possibly treated and their characteristics can be compared with the values that correspond to their identical semiconductors.

Keywords: Band tails energy; Tetraborate Glass; MgO; Optical band energy
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1. Introduction

Tetraborate glasses are a class of glasses that are technologically important and play an important role in various physical applications [1]. Optical absorption in solids occurs by several different mechanical processes, all of which involve the interaction between incident rays and the dipole moments of the material and thus the transfer of energy. Absorption likely occurs as a result of internal transitions between shell (D) electrons in transition metals. Optical absorption can also be created by transferring electrons from a neighboring atom to transition metal ions and vice versa [2].

Measurements of the dimensional optical absorption coefficient, in particular near the main absorption edge, have enhanced the study of optically induced electronic transitions, and also provide us with some insights into the beam structure and gap energy of crystalline and amorphous materials [2].

The optical absorption coefficient near the absorption edge in a number of amorphous semiconductors and insulators shows an exponential dependence on photon energy. It is subject to a quasi-experimental relationship [3]:

$$\alpha(\omega) = \alpha_0 \exp [\hbar\omega/E_0] \quad (1)$$

Here, $\alpha(\omega)$ represents the absorption coefficient, ω the angular frequency of incident radiation, α_0 is constant, and E_0 represents the energy of the beam tails for localized states. The optical absorption coefficient can be calculated by the following relation [4]:

$$\alpha(\omega) = \frac{1}{d}\ln(\frac{I_0}{I_t}) \quad (2)$$

where I_0 and I_t represent the intensity of the incident and penetrating rays, respectively and d represents the thickness of the sample under study. The optical gap energy (E_{opt}) in most semiconductors has been calculated using the following relationship [5]:

$$\alpha(\omega) = A\frac{(\hbar\omega - E_{opt})^r}{\hbar\omega} \quad (3)$$

where A is a constant, $\hbar\omega$ represents the photon energy, the exponent (r) is a coefficient depends on the type of emission or electronic transition responsible for absorption. The value of 1/2 represents the direct emission allowed, the value of 2 represents the permissible indirect emission, the value of 1/3 represents the direct emission present, while the value of 3 represents the indirect emission observed [6]

Borate glasses have been studied in recent years as there is a number of published research on how to prepare glass. Identify and identify the characteristics of these glassware through their compositions [7,8].

In this study, a number of laboratory experiments were conducted to study the optical gap energy, the beamwidth energy of the localized states, the refractive index, density and molar volume as functions of increasing the percentage of MgO oxide in the network of the glassware under investigation, as well as studying the infrared absorption spectra and knowing the beam positions and analyze it.

In addition, density of material, the most important to determining the mechanical and chemical properties, it is involved in determining the thermal and electrical insulation properties of materials [9].

2. Experimental Part

Glass aggregates have been prepared [65% $Na_2B_4O_7$ – (35-x)% V_2O_5 – x% MgO]. The values of x=10, 15, 20, and 25 were taken each time for oxide MgO. Highly-purified chemicals were used in the method of cooling the molten material suddenly and at room temperature. Each group was prepared after being weighed and mixed together in an alumina crucible, mixing using an alumina rod and melting

using an electric furnace with a maximum temperature of 1200°C. Each sample was placed in a furnace installed at a temperature of 200°C for one hour to reduce volatile substances and then the sample was introduced into the melting furnace for one hour. It was observed through the experiment that the fusion of the samples of these group is in the range of 1000-900°C based on the ratio of oxide (MgO) where the higher its proportions in the glass lattice, the higher the melting point than 900°C. Finally, the molten material is poured onto a mold designed for this purpose to obtain a disc between 2 and 4 mm.

3. Results and Discussion

Figure (1) shows the optical absorption spectra of the glass compound $Na_2B_4O_7$–MgO as a function of the wavelength and within the wavelength range 190-900nm. It is clear that the main absorption edge deviates slightly towards the short wavelengths as the amount of MgO in the compound increases.

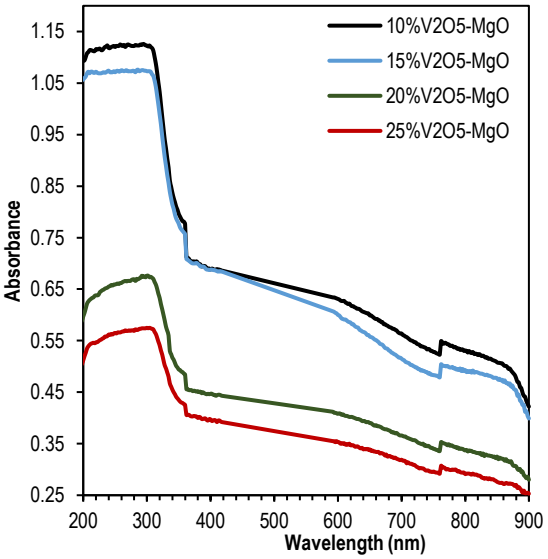

Fig. (1) Optical absorption spectra of the prepared glass as a function of the wavelength

Figure (2) shows the graph between $(\hbar\omega\alpha)^{1/2}$ and the energy of the incident photon where it is possible to calculate the optical gap energy from the same figure and the values of the optical gap energies (E_{opt}) have been drawn as a function of the oxide concentrations (MgO) in the glass compound under consideration as shown in Fig. (3). The log change of the optical absorption coefficient $\ln[\omega(\alpha)]$ as a function of the energy of the incident photon ($\hbar\omega$) is shown in Fig. (4) and from the diagram the energy of the beam tail is calculated using Eq. (1) as shown in Fig. (5).

Table (1) shows beam values as an optical function (E_{opt}), beam tail energy for localized states (E_o) and theoretically calculated values of refractive index with increasing oxide (MgO).

Table (1) Optical gap energy values, beam tail and refractive index of glass compound

MgO content (%)	E_o	E_{opt}
10%	0.998	3.352
15%	0.862	3.252
20%	0.771	3.058
25%	0.659	2.957

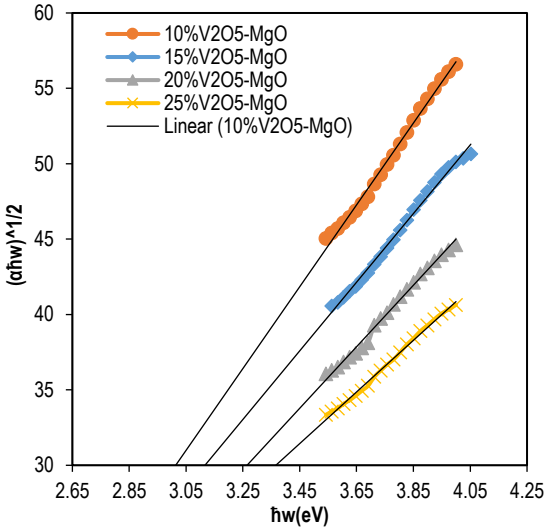

Fig. (2) Variation of $(\alpha\hbar\omega)^{1/2}$ as a function of the photon energy ($\hbar\omega$) for the prepared glass

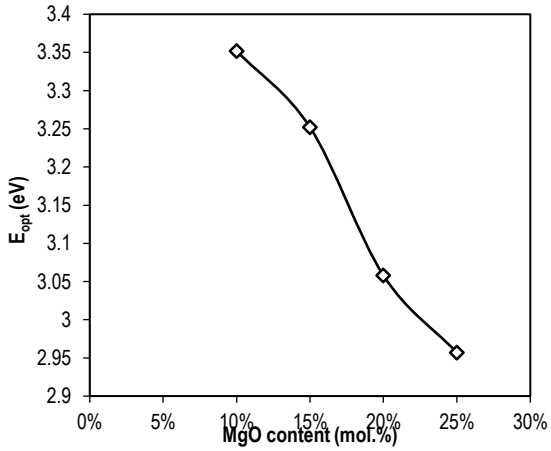

Fig. (3) The optical gap energy for the prepared glass as a function of the MgO content

4. Conclusions

The increase in density in the crystal structure of the models under investigation is closely related to the change in the composition of these glasses caused by the decrease in the atomic interval, which in turn produces tight and dense semiconductor glass. It is clear that the results of the optical absorption edge analysis of all glass lattices under research are well consistent with the theory of Mott & Davis [2] and this confirms with conclusive evidence the occurrence of indirect emission between beams in these glass aggregates.

It was found that the optical absorption edge deviates towards the longest wavelength in all binary

glass aggregates with increasing concentration of MgO in all the glasses. This is likely due to a change in the amount of unbridged oxygen ion with an increase in the ions of the element Mg. A decrease in the energy of the optical gap with an increase in the concentration of the amount of oxides leads to an increase in the degree of loss of order (disorder) in these glasses and in turn supports the theory of Mott & Davis [2].

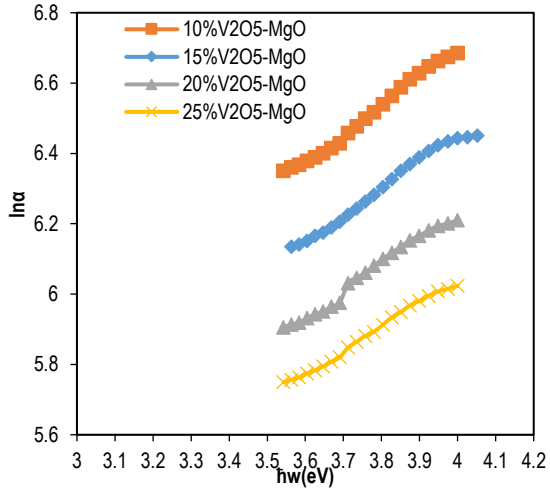

Fig. (4) Variation of Lnα for the prepared glass as a function of incident photon energy

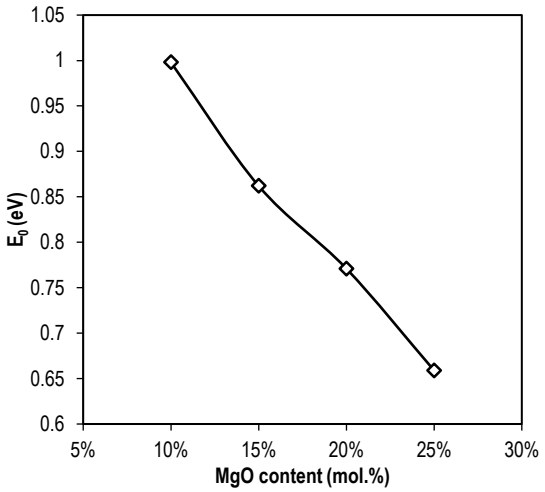

Fig. (5) The beam tail energy for the prepared glass as a function of the MgO content

References

[1] C. Gautam, A.K. Yadav and A.K. Singh, "A review on infrared spectroscopy of borate glasses with effects of different additives", *ISRN Ceram.*, 2012 (2012) 1-17.

[2] N.F. Mott and E.A. Davies, **"Electronic processes in non-crystalline materials**", Oxford University Press (2012).

[3] F. Urbach, "The long-wavelength edge of photographic sensitivity and of the electronic absorption of solids", *Phys. Rev.*, 92(5) (1953) 1324.

[4] P. Chimalawong et al., "Optical properties of the SiO_2-Na_2O-CaO-Nd_2O_3 glasses", *Amer. J. Appl. Sci.*, 7(4) (2010) 584-589.

[5] B. Eraiah and S.G. Bhat, "Optical properties of samarium doped zinc–phosphate glasses", *J. Phys. Chem. Solids*, 68(4) (2007) 581-585.

[6] S.K.J. Al-Ani and A.A. Higazy, "Study of optical absorption edges in MgO-P_2O_5 glasses", *J. Mater. Sci.*, 26 (1991) 3670-3674.

[7] V. Kundu et al., "Effect of V_2O_5 on structural, physical and electrical properties of bismuth borate glasses", *J. Optoelectron. Adv. Mater.*, 10(10) (2008) 2765-2770.

[8] W.J. Gawande, S.S. Yawale and S.P. Yawale, "Study of physical and electrical properties of Cuo-MnO_2-B_2O_3 Glasses", *Int. Res. J. Sci. Eng.*, 3(3) (2015) 77-83.

[9] E.J. Salih et al., "Study of some of the physical variables of a metal-based system using the powder method", *IOP J. Phys.: Conf. Ser.*, 1999(1) (2021).

[10] M.A. Hassan, *2nd Sci. Conf. Wassit Univ.* (2009) 756-784.

[11] S.N.S. Yaacob et al., "The Polarizability and Optical Characteristics of Zinc Phosphate Glasses Doped Terbium Embedded with Copper Oxide Nanoparticles", *Solid State Phenom.*, 290 (2019) 35-40.

[12] T. Tasheva and V. Dimitrov, "Synthesis, optical properties and structure of NiO-BaO-V_2O_5 glasses", *J. Chem. Technol. Metall.*, 52(2) (2017) 369-378.

