Berivan M. Abdullah [1]
Aynoor B. Kamal [1]
Hiyam M. Ahmed [1]
Malak J. Ali [2]

[1] Department of Physics, College of Education for Women, University of Kirkuk, Kirkuk, IRAQ
[2] Department of Physics, College of Education for Pure Sciences, University of Al-Hamdaniya, Ninawa Governorate, IRAQ

Effect of V_2O_5–MgO Addition on Some Structural and Physical Properties of $Na_2B_4O_7$

In the present study, the effect of variable addition MgO of glasses consisting of 65% $Na_2B_4O_7$ – 35-x%V_2O_5 – x% MgO, where (x) represents the MgO, produced by the traditional melt quenching technique. study of the structural, and optical properties of magnesium oxide variable addition containing glasses has been investigated. The XRD results confirmed the samples' amorphous character. The density of the glass network is proportional to the amount of magnesium oxide present. The experimental findings indicate that the infrared spectra of these glasses are mostly characterized by the presence of two groups, namely BO_3 and B_2O_7. Furthermore, the displacement of the band position diminishes as the concentration of MgO oxide in the glass network enhances.

***Keywords*:** Melt quenching; Magnesium oxide; Glasses; $Na_2B_4O_7$
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1. Introduction

Advances in glass and ceramic technology enable researchers to develop and produce glass materials with diverse optical, structural, electrical, or thermal properties, making them suitable for application areas requiring special properties [1,2]. Glass is a highly transparent, amorphous material that is a melting of an inorganic component without crystallization. High-performance borate glasses are used for various applications. Choosing the right glass for different applications is crucial for successful product design. The physical properties of glass determine its ability to resist damage and prevent failure [3].

Oxides like TeO_2, V_2O_5, WO_3, Bi_2O_3 and others do not form glass on their own, but they form glass easily when mixed with other glass-forming oxides [4]. A better glass network can be formed by mixing more than one glass material [5]. Glasses containing divalent ions such as Mg^{2+}, Zn^{2+}, and Ca^{2+} play an important role in the formation and modification of the glass structure [6,7]. Understanding the dependence of physical properties on the microstructure of the glass is crucial for designing suitable materials for specific applications. The physical and chemical properties of borate glasses can be changed by adding a lattice modifier (alkali and alkaline earth oxides). Borate glasses have been extensively studied over the years to elucidate the nature and concentration of the different borate units that form the glass lattice. In glasses containing two glass components such as Bi_2O_3 and V_2O_5, the coordination and connectivity numbers of both borate and vanadate species can vary in a complex manner as a result of modification when a modifier oxide is added to the glass component. It is generally understood that modification is an O_2 ion reaction, which leads to structural changes, and the creation of non-bridging oxygen is the first step. Alkali-modified borate glasses containing divalent oxides such as ZnO, BaO, PbO, MgO, and CuO show interesting behavior in the glass lattice structure [8,9]. The aim of this work is to determine the role of V_2O_5 and MgO in $Na_2B_4O_7$ glasses, by investigating the structural, physical, and optical properties.

The objective of this work is to characterize the role of V_2O_5 and MgO in glasses $Na_2B_4O_7$, by investigating the structural and optical properties.

2. Experimental Part

Glass aggregates were prepared [65% $Na_2B_4O_7$ – (35-x) % V_2O_5– x% MgO]. The values of x=10, 15, 20, and 25, where x is for the MgO weight. After being weighed and mixed together in an alumina crucible, prepared the highly purified chemicals by cooling the molten material suddenly and at room temperature. Each group was melted using an electric furnace with a maximum temperature of 1200°C. Each specimen was subjected to a furnace set at a temperature of 200°C for one hour to decrease volatile compounds, before being moved to a melting furnace for another hour. It was observed through the experiment that the fusion of the samples of these groups is in the range of 900-1000°C based on the ratio of oxide (MgO), where the higher proportion in the glass lattice corresponds to the higher the melting point. Finally, the molten material is poured onto a mould designed for this purpose to obtain a disc between 2-4 mm.

3. Results and Discussion

Density is a crucial characteristic of products. In many applications, precise density calculations and measurements are required to determine the dimensions of the pores within the body, as well as the dimensions

of voids and gaps. Additionally, it contributes to the evaluation of the materials' thermal and electrical insulation qualities in addition to their mechanical and chemical properties [10,11].

The density of all three specific sample groups was determined using the Archimedes principle. A calibration balance with a precision of 0.01 g, an immersion liquid (toluene), and a density of 30.86 g/cm^3 at ambient temperature was used. The density has been calculated using the algebraic relationship provided in reference [12]

$$\rho_G = \rho_L[\frac{W_{air}}{W_{air}-W_{liq}}] \quad (1)$$

Here, W_{air} and W_{liq} denote the mass of the sample before and after immersion in air and immersion fluid, respectively, and in the same way, ρ_L represents the density of the immersion fluid and ρ_G represents the density of glass

Molar volume can be accurately determined by utilizing the measured density and the weight of one mole of the sample through the following equation:

$$V_m = \sum_i \frac{X_i M_i}{\rho_G} \quad (2)$$

Thus, the symbols X_i and M_i denote the molar fraction and molecular weight, respectively, of the sample specifically in issue (ith)

Figure (1) shows the molar volume and density of the glass compound $Na_2B_4O_7$-V_2O_5-MgO. Typically exhibit inverse behavior. It is clear that when the mass of MgO in the sample increases, the density decreases and the molar volume increases. Table (1) indicates that the density of the sample decreases from 1.546 to 1.3806 g/cm^3, while the molar volume increases from 113.017 to 116.9275 g/mol as the percentage of MgO in the sample increases. The fluctuations in density within semiconductor glass are linked to the structural modifications resulting from variations in the interatomic distance. Table (1) tabulates this change in the glass compound's density and molar volume.

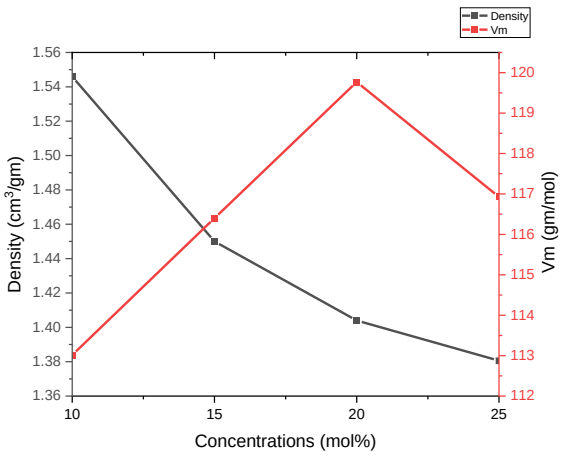

Fig. (1) Density and molar volume as a function of the MgO content in the glass structure ($Na_2B_4O_7$-V_2O_5-MgO)

Table (1) Density and molar volume values of MgO content in the glass structure ($Na_2B_4O_7$-V_2O_5-MgO)

MgO content (mol %)	ρ (g/cm^3)	V_m (g/mol)
10%	1.546	113.017
15%	1.45	116.399
20%	1.404	119.77
25%	1.3806	116.9275

The analysis of x-ray diffraction (XRD) pattern verified the amorphous structure of the glass sample. The sensitivity of the vitreous state matrix to crystallization is responsible for the applicability of XRD analysis. The XRD pattern of amorphous materials differs significantly from that of crystalline materials, characterized by broad circles instead of sharp rings. The glass samples selected showed no crystalline qualities.

Figure (2) shows the XRD patterns of one sample from each group of prepared samples, as this figure did not show any acute intensity with respect to the angle (2θ) for a wide range of angles. The lack of a crystal peak gives evidence that the glass samples are amorphous in character [13].

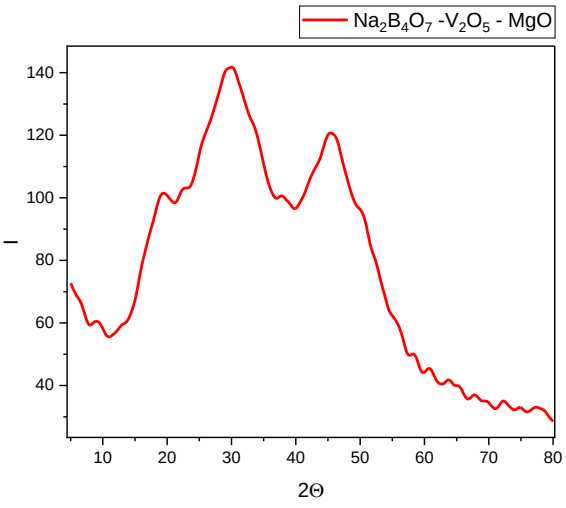

Fig. (2) XRD pattern of the prepared glass

Figure (3) shows the absorption spectra of $Na_2B_4O_7$-V_2O_5-MgO at room temperature. Table (2) shows the locations of the absorption beams as a function of the MgO concentration. An absorption band is seen at 700–705 cm^{-1} at all MgO concentrations. This band is attributed to the frequency of the $(B_2O_7)_2^-$ chemical group.

The frequency linked to the BO_3 group is most likely indicated by the absorption band observed at 1000-1078 cm^{-1}. On the other hand, the $(B_2O_7)_2^-$ group's frequency is linked to the absorption band that can be seen at 1300-1359 cm^{-1}. The presence of the double bond Mg=O is responsible for the absorption band observed at 1100-1138 cm^{-1}, and the formation of the same double bond is also responsible for the absorption

band observed at 1000-1078 cm^{-1}. Figure (4) shows how the band at 900-943 cm^{-1} shifts in position as MgO concentration is increased [14].

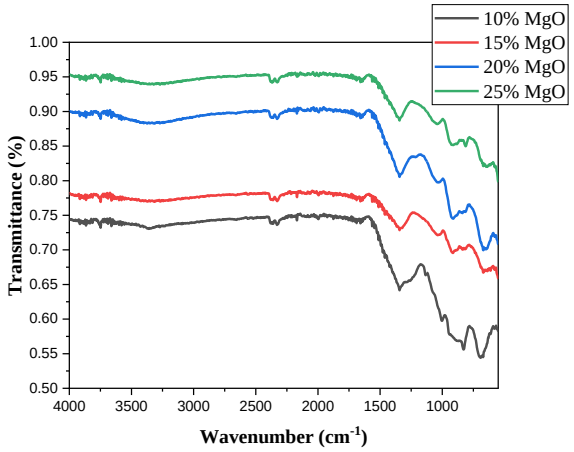

Fig. (3) Infrared absorption spectra of the glass structure ($Na_2B_4O_7$-V_2O_5-MgO) for different contents of MgO

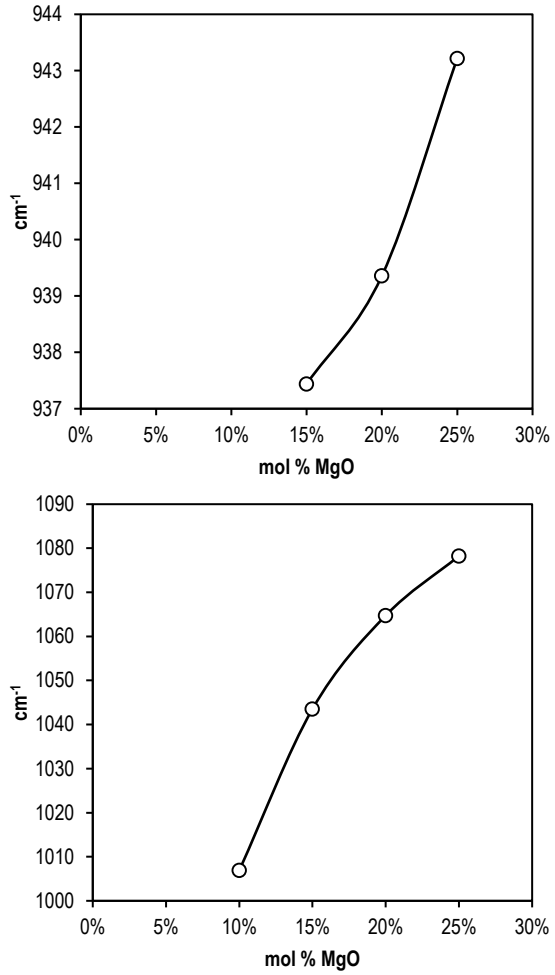

Fig. (4) Absorption beam location changes with increasing amount (MgO) of the glass compound ($Na_2B_4O_7$-V_2O_5-MgO)

4. Conclusion

A set of four samples was prepared, by introducing different amounts of MgO (10, 15, 20, 25 mol%) into [65% $Na_2B_4O_7$ – (35-x) % V_2O_5] glass structure. It is clear that when the amount of MgO in the sample increases, the density decreases and the molar volume increases the decrease in density in the crystal structure is closely related to the change in the composition caused by the decrease in the atomic radii. The fluctuations in density within semiconductor glass are linked to the structural modifications resulting from variations in the interatomic distance. The observed changes in composition are caused by the conversion of structural units from BO_3 to BO_4, which means an increase or decrease in non-bridge oxygen, and these results are consistent with the results of other researchers [15,16]. The glass samples showed no crystalline structures. The results of optical absorption edge are consistent with the Mott and Davis theory [15,17], which confirms the occurrence of indirect emission between bands in these glass aggregates. The glass compounds generally exhibit a small deviation with increasing concentration of the introduced oxide (MgO). On the other hand, the absorption increases as the concentration of the oxide in the glass aggregates is increased.

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Table (2) Values of infrared beam locations for different contents of MgO in glass structure ($Na_2B_4O_7$-V_2O_5-MgO)

MgO content (mol %)	3600	1600	1500	1300	1000	900	800	700	600	500
10%	3394.83	1647.26	1510.31	1344.43	1006.88		823.63	705.97		532.37
15%	3416.05	1653.05	1427.37	1350.22	1043.52	937.44		700.18		524.66
20%	3406.4	1645.33	1427.37	1350.22	1064.74	939.36			694.4	532.37
25%	3421.83	1649.19		1359.86	1078.24	943.22	875.71		698.25	526.58

