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Research Article

Study and Characterization of Lithium, Magnesium Borate Based Ternary Glasses

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Abstract **–** By employing the melt quench process, four samples of the Lithium-Magnesium-Borate (Li, Mg, and Borate) glass system and glasses with various compositions were created. Physical, optical, and dielectric qualities have all been studied. The samples were polished after being annealed. Utilizing X-ray equipment, the specimen's X-ray diffraction measurement was assessed. According to XRD data, the samples shows a significant degree of amorphous nature. The displacement technique was used to calculate the density. The outcome demonstrated that density increased as Li concentration increased. The prepared samples' densities rise from 1.22 to 1.68 g/cm^3. As Mg concentration increased, the molar volume "Vm" decreased. Molar volume falls from 53.63 cm^3 /mole to 50.68 cm^3 /mole. The oxygen packing density is measured to be between 55.93 mol/cm^3 and 58.60 mol/cm^3. Optical data of the sample was evaluated. The measured data of optical absorbance and transmittance in the scope of 300 nm to 800 nm while using SHIMADZU UV-1800 Spectrophotometry at room temperature. It was discovered that the optical band gap, or "Eopt," decreased as Mg concentration increased. Increasing the Mg concentration was shown to decrease the refractive index. The recorded value is between 3.12 to 2.38. The tested samples' dielectric displayed shrink behavior in terms of capacitance, dielectric constant, and dielectric loss.

Keywords – Ternary Glass, XRD Analysis, Absorbance, Transmittance, Optical Properties,

I. Introduction

Glass has many practical functions in our lives, such as offering protection. When we drive a car, it shields us from obstacles and harsh air. Televisions and mobile displays both utilize it. Offices can also be decorated with it [1]. Glasses are the most investigated host materials because of the relative ease of their fabrication, flexibility to add active ions in different concentrations, shaping and the possibility of easily obtaining bulk samples when compared to single crystalline matrices. [2]. The word "glass" is derived from the Late-Latin word "gleesome" which meant something that was clear and shiny. In science, the term glass is used much wider serve. When glass is heated its structure exhibits moves to liquid state. In this wider sense glass is turn into different conditions such as metallic alloys, ionic metals, aqueous solution, molecular liquids and polymers. For many applications bottles, polymers glasses and acrylic glasses easily convert into silica glasses. In physics, glass is defined as, it is a solid which melts and turns into glass. Glass is often used when any solid melt it appears a glass transient temperature. If cooling is rapid, then crystal of glass 2 prevented due to cooling and liquid is freeze into solid state at Tg (temperature) usually structure of glass in metastable condition. [3]. The most common glass that is produced in significant quantities for commercial usage is soda lime glass or soda lime silicate glass. Soda lime glass is mostly used to prepare beverage containers, glass windows, incandescent, and fluorescent lamp envelopes. These glasses have excellent visual transmission, strong electrical resistance, and great durability [4]. Lead glass is a technically term. It is not an accurate term to explain lead glasses, the reason is that glass lacks a crystalline structure instead of amorphous solid. Silica and boron oxide are combined with a small quantity of alkali to create a family of glasses with high resistance and a low thermal conductivity [5]. Commercial glass from the family of aluminosilicate has varying amounts of alkali and alkaline materials, such MgO and CaO. Aluminosilicates with low alkaline content exhibit strong resistivity and elastic moduli values. Metals that are "glassy" are non-crystalline materials. It contains metalloids and pure metals alone or in combination. It is a type of glass that have resistance to heat, chemicals and electrical. It is used to making chemicals apparatus, industrial equipment including pipes thermometer and ovenware. Pyrex contains Borosilicate and open about one third to common glass [6]. Properties of glass can be divided into physical, chemical, optical, mechanical and thermal. Glass is an amorphous solid. It is an inorganic material that is both hard (even when it is thin) and can be brittle (in case of lightly hit). Due to its unique composition, there is no regular pattern or distribution of atom, ions and molecules They are different from crystalline solid and that Contains atoms, ions and molecules that are repeated in an order and in periodically in all directions. As regard its physical properties, some glasses need temperature up to 650°C (1202°F) to melt and some other needs 1650°C (3002°F). Its standard density is 2500 kg/m3 that vary depending on the type of material that makes up different types of glass. The relative density ranges from 2 to 8 times the density of water, which makes it lighter than aluminum (relative density is 2.7) but ultimately heavier than steel (relative density 7.85 g/ cm3 [7].

Borate glass is widely used due to its promising properties including the effective atomic number, high transparency, low melting point, high temperature stability and good solubility of rare earth (RE) ions. Lithium acting as modifier can reduce the hygroscopic nature of borate and improve the stability by forming ionic bonds with oxygen (non-bridging oxygen). These bonds are responsible for the formation of color centers [8]. Several alkaline and alkali earth metals are used as a second modifier to alter the glass structures, to open up the network structure, to reduce the bond strength and to minimize the stickiness of the glass [9]. We use MgO as a second modifier to enhance the release of electrons and to reduce the hygroscopic nature of borate glass [10]. Numerous studies confirming the excellent features of LMB glass such as high mechanical strength, relative moisture resistance and the non-linear response make them potential candidates for medical and industrial applications [11].

Borate-based ternary glasses are a type of glass composed of three main components: boron oxide (B_2O_3), a network-forming oxide, combined with two other oxides, typically alkali metal oxides (e.g., Na_2O, K_2O, Li_2O), alkaline earth metal oxides (e.g., CaO, MgO, BaO), or transition metal oxides (e.g., Fe_2O_3, Al_2O_3). These glasses have a wide range of applications due to their unique properties, including optical transparency, low melting points, and high chemical durability. Borate system has been classified as good host for rare earth ions (REIs) doping due to its distinct properties and wide scientific implementations for radiation dosimeter, optical fiber, amplifier, display and laser [12]. Over the years, lithium and magnesium have broadly been utilized as a modifier in borate glass system to reduce the inherent hygroscopicity and enhance the hardness by creating more non-bridging oxygen (NBO) bonds which in turn are interrelated to the color centers development [13]. Besides, varied alkali metals and alkali earth metals have been exploited as an additional modifier in borate glasses to improve their structure by minimizing the bonding interactions and viscosity [14]. The borates glass is a basis for most commercially available glass, which is one of the most important glass former. Borate glass possesses unique properties such as low melting point, high thermal stability, and the possibility of adding heavy elements as a modifier. The addition of heavy metal oxides such as lead and bismuth in glass improves glass density to be used as shields for gamma rays. Also, add some oxides such as lithium and sodium oxide to reduce the melting point for the glass prepared [15]. Borate is a mixture of boron and oxygen that produces boron oxyanions. Trigonal or tetrahedral structures are possible for these. s. In nature, boron mainly appears as borate, such as in borate minerals and borosilicate's. Derivates of boric acid, or B(OH)3, are called borates.

$B(OH)3 + 2H2O \rightleftarrows [B(OH)4]^{-} + [H3O]$.

II. Literature Review

Different Researcher used different techniques and Different composition to develop glass. Emran Eisa Saleh prepared a glass samples composed of (60-x) B2O3-xBi2O3–30PbO–10Li2O (x = 0, 10, 20, 30, 40 mol%) were prepared for utilize as shields for gamma rays and fast neutrons, using the melt-quenching technique. The studied samples were symbolized as Bi0.0–Bi10–Bi20–Bi30–Bi40 according to the Bi content values. The results indicated that the addition of Bi2O3 increased the MAC and Zeff and reduced the HVL, MFP, and buildup factors. Also, the results showed that the prepared glass labeled Bi40 has the best shielding properties compared to the other samples [16]. This work focuses on the luminescence properties of Eu2O3-doped borate glasses developed by the high temperature-melting method. The appropriate spectroscopic methods have been used to selectively analyze absorption, excitation, energy transfer, and photo-stimulated luminescence (PSL). Transparent luminescent LMgGBEu glasses were developed by the melt quenching method using Gd3+ and Eu3+ additives in the glasses. It was observed that the quenching phenomenon limited the emission of Eu3+. The luminescence spectroscopy proved the existence of the energy transfer from Gd3+ to Eu3+. The presence of a distinct individual peak at 312 nm in PL indicated the existence of energy transfer. The decay kinetic characterizations of these glasses at λexc= 403 nm and λemi= 598 nm have shown that a decrease in the decay time with increasing Eu3+ is subject to nonradioactive quenching [17]. Jun Ho Lee, et al, examined for regulate chalcogenide glass's (CG) infrared transmission edge and refractive indices divergence in the protracted infrared (LWIR) region, a simple process for configurational filtering is provided. For a certain CG composition, the molecular weights and median bond strength are readily available quantities that are used to represent c in this SAHO framework. In the compositions and Ge-Sb-S, two archetypal CG-forming systems serve as examples of the empirical composition dependency on c, which further plays a significant role in deciding. This discovery offers a chance that can be anticipated based solely on the approximation coefficients of CG, making it easier to complete the Infrared and visible countess schematic [18].

In this present work, Lithium magnesium borate glasses are a form of glass with the major component's lithium, magnesium, and boron oxides. These glasses can be used in a variety of industries, including optoelectronics, nuclear waste immobilization, and solid-state batteries. One of the primary applications of lithium magnesium borate glasses is as solid-state electrolytes in batteries. Because of their strong ionic conductivity and stability, these glasses are a possible alternative to traditional liquid electrolytes in lithium-ion batteries. In addition, they can be utilized as the electrolyte in solid-state magnesium batteries.

Lithium magnesium borate glasses are also employed in the manufacture of optical fibers, where their low refractive index and low dispersion make them ideal as cladding material. They may also be used to make optical filters, lenses, and other optical components. Lithium magnesium borate glasses are employed in nuclear waste immobilization, in addition to optoelectronics and batteries. The glasses can be used to encase radioactive waste, preventing its discharge into the environment. These glasses are an appealing solution for this application due to their strong chemical resistance and low melting temperature. Because of attractive property of optoelectronics and optical fibers, I selected this composition lithium magnesium borate to explore it properties.

III. Experimental Technique

Consider Four samples of the Lithium-Magnesium-Borate (Li, Mg, and Borate) glass system and glasses with various compositions were developed by melt-quenching method. The prepared samples' densities rise from 1.22 to 1.68 g/cm^3. As Mg concentration increased, the molar volume "Vm" decreased. Molar volume falls from 53.63 cm^3 /mole to 50.68 cm^3/mole. The oxygen packing density is measured to be between 55.93 mol/cm3 and 58.60 mol/cm^3. Optical data of the sample was evaluated. The measured data of optical absorbance and transmittance in the scope of 300 nm to 800 nm while using SHIMADZU UV-1800 Spectrophotometry at room temperature. It was discovered that the optical band gap, or "Eopt," decreased as Mg concentration increased. Increasing the Mg concentration was shown to decrease the refractive index. The recorded value is between 3.12 to 2.38. The glass used to create laboratory glassware can come in a variety of varieties, each having unique properties and uses. Its key characteristic is of thermal expansion, enabling it to be further resistant towards thermal shock compared to other glasses. Borosilicate glass is a form of clear glass made of boron oxide and silica.. Each sample is assigned the following code: BLM-0, BLM-1, BLM-2, BLM-3

	Lithium	Magnesium	Boron	Oxygen
Elements	"Li"	"Mg"	"Br"	"O"
Atomic no (Z)	3	12	5	8
Atomic mass (A)	6.941 u	24.305 u	10.811 u	16u
Boiling point (K)	1,342 °C	1,091 °C	4,000 °C	-183 °C
Crystal structure	nine hexagonal stacking layers	body-centered cubic (bcc)	α-rhombohedral and β-rhombohedral (α-R and β-R).	cubic crystal structure
Appearance	silvery-white	silvery-white meta	brown, amorphous solid	In normal conditions oxygen is a colorless, odorless
Density (g/cm^3)	0.53 g/cm^3	1.738 g/cm^3	2.3 g/cm^3	1.141 g/cm3
Atomic Radius	182 pm	0.16 nm	85 pm	60 pm

The sample codes for each composition are connected to the variance in the sample. the following composition is present in four samples. In a laboratory, melt-quenching technology was used to create lithium, magnesium, and borate glasses. The material was finely ground and warmed for 30 minutes. For three hours, the prepped samples were heated to 950°C, where they melted. Glass analysis, which involves calculating glass parameters, is used to forecast glass qualities [19].

IV. Results and Discussion

The various physical traits that were noted for the provided glass samples helped to clarify the composition of glass. Four samples BLM0, BLM1, BLM2, and BLM3via made using melt-quenching technique, the displacement technique was applied to assess density of such prepared product (glass)70%(H3BO3) - (30-x) %Li2CO3–x% MgO (0≤x≤10). Every composition that has been doped with MgO's density value is measured. Density levels range from 1.22 to 1.68 g/cm3. The results showed that the density of the glass samples gradually increases from 1.22 to 1.68 g/cm3 at the expense of MgO. Because MgO has high molecular weight as compared to the Lithium and carbon compounds (6.94 and 12.01 respectively). The OPD values enhances from 55.93 to 58.60 mol/cm3, but the molar volume reduces from 53.632 to 50.68 cm3. This might be because the oxygen atoms in the tested glass system were packed closer together after the addition of MgO to their compositions.

A. *Physical Observation*

Sample	Density (g/cm^3)	Mol % of MgO	"N" For MgO (10^{21})	Polaron radius of MgO (10^{-8})	Inter-nuclear distance of MgO (10^{-7}) cm	Field Strength (10^{16}) cm^{-2}	OPD $(mol/cm^3)10^2$	Molar volume (cm^3)
BLM-0	1.22	0.00	0	0	0	0	55.93	53.63
BLM-1	1.38	0.02	0.23	6.57	1.6	0.56	56.98	52.29
BLM-2	1.51	0.04	0.46	5.22	1.2	0.89	57.58	51.41
BLM-3	1.68	0.06	0.71	4.51	1.12	1.19	58.60	50.68

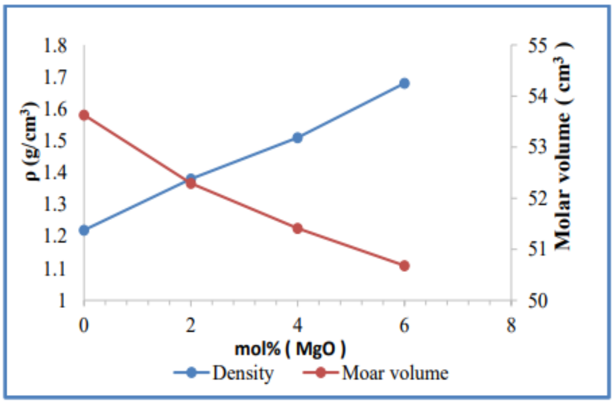

Fig 1. Log (f) Graph plotted against (mol% MgO Vs. Density)

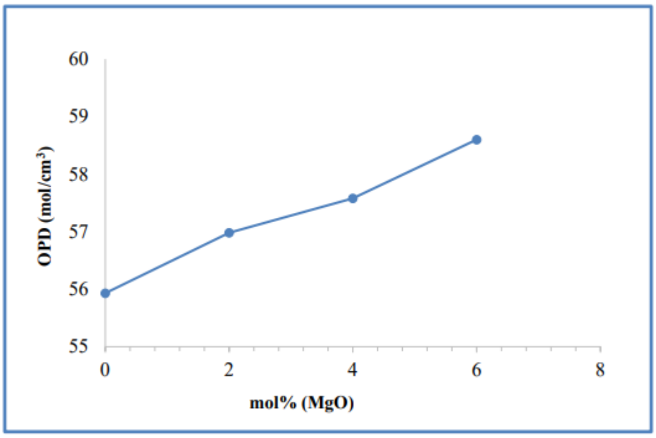

Fig 2. Graph plotted against (mol% MgO Vs. Oxygen Packing Density)

B. *Optical Properties and Their Results*

A The medium having refractive as well as extinction Coefficient are intimately correlated with the optical characteristics of lithium, magnesium, and borate glasses. The most significant optical characteristics are the absorption and refraction of light.

C. *Optical Absorbance*

The In optics, ratio of incident to transmitted radiant power via a substance is known as absorbance, while ratio of incident to transmitted spectral radiant power referred as spectral absorbance. The graphs are plotted between wavelength and optical absorbance. An instrument known as spectrophotometer used to estimate the light quantity being absorbed in the sample.

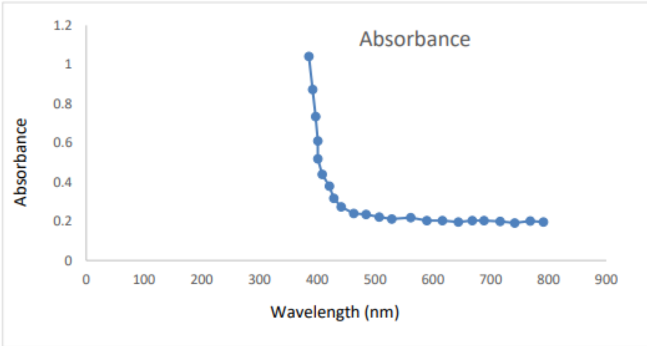

Fig 3. Graph plotted against wavelength vs absorbance (BLM-0)

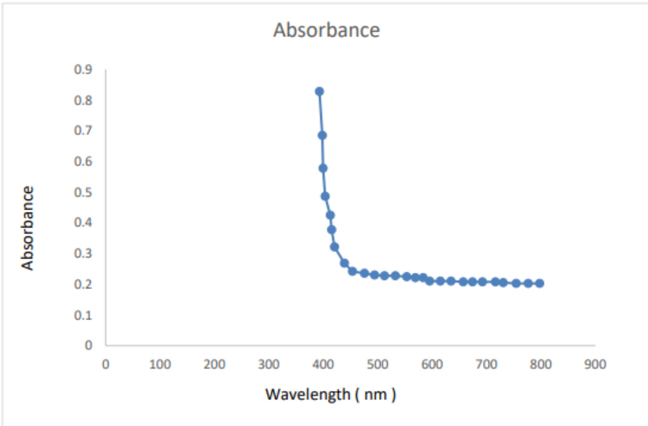

Fig 4. Graph plotted against Absorbance vs wavelength (BLM - 1)

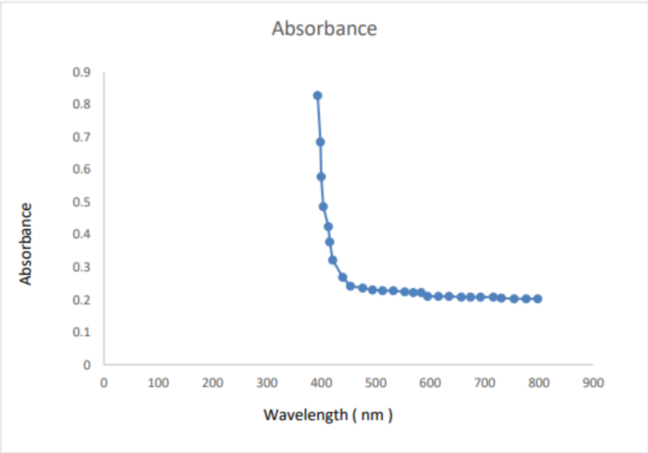

Fig 5 Graph plotted against Absorbance vs wavelength (BLM – 2)

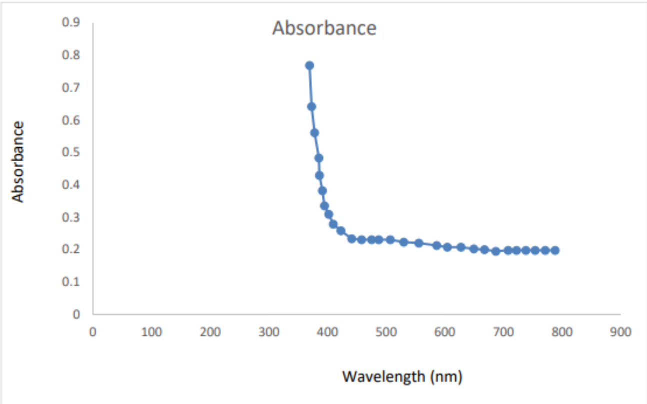

Fig. 6 Graph plotted against Absorbance vs wavelength (BLM – 3)

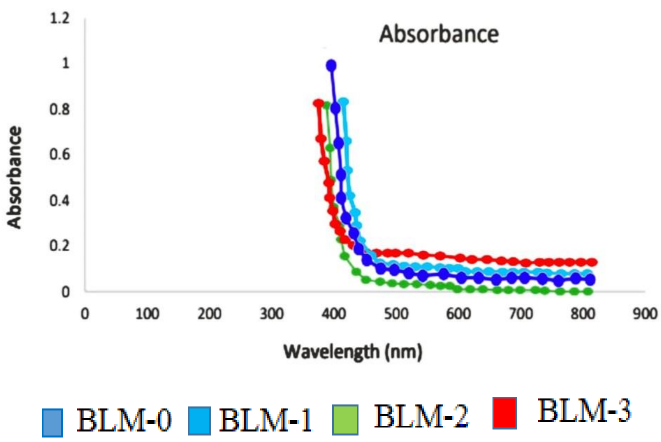

Fig. 7 Graph plotted against Absorbance vs wavelength (BLM-0), (BLM-1), (BLM-2), and (BLM-03).

D. *Optical Absorbance*

The ratio of the transmitted optical power to the incident optical power for a certain item, such as an optical system, is referred to as transmittance. The transmissivity is the same for transmission through flat, unstructured surfaces. Higher wavelength indicates multiphoton absorption has a greater influence on optical performance, however, band gap bent via electronic transition bounds optical window. The excited electrons bridge prohibited band-gap to absorb photons with sufficient energy. The quantity of light penetrates via sample and pass towards detector referred as transmittance. The light quantity that the sample is able to absorb is measured by its absorbance.

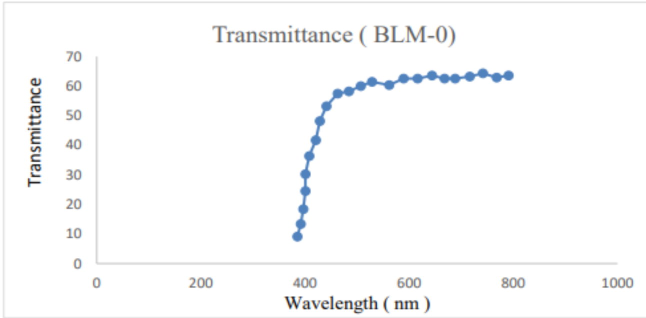

Fig 8. Graph plotted against Transmittance Vs Wavelength (BLM-0)

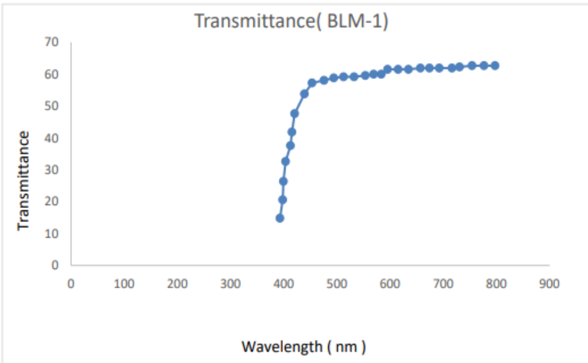

Fig 9. Graph plotted against Transmittance Vs Wavelength (BLM-1)

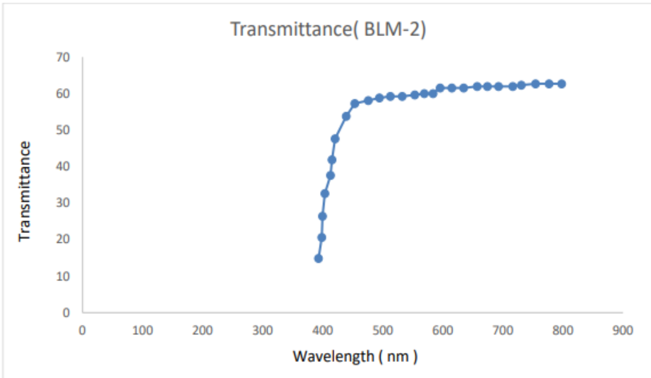

Fig 10. Graph plotted against Transmittance Vs Wavelength (BLM -2)

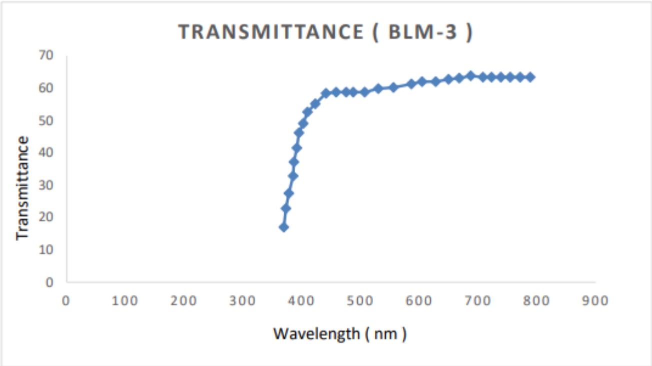

Fig 11. Graph plotted against Transmittance vs wavelength (BLM-3)

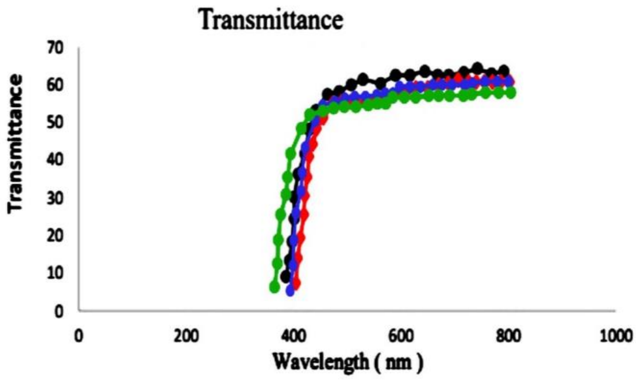

Fig 12. Graph plotted against Transmittance vs wavelength (BLM-0), (BLM-1), (BLM-2), (BLM-3)

E. Optical Energy Band Gap

According to Davis and Mott theory, the optical band gap energy Eg can be obtained for optical materials by using the marginal value from which the absorption is beginning to appear directly or indirectly. The location of the edge about absorption spectrum could be used to locate band that corresponds to the difference between the conduction and valence bands. The impact having optical material to ions the radiation electrons distribution is described by such parameter. Absorption co − efficient α is measured by:

$\alpha = 2.03 \text{ x } A / d$

A = absorbance, d = thickness of pellets

Energy band gaps is obtained by plotting a graph between hυ and (αhν)1/2

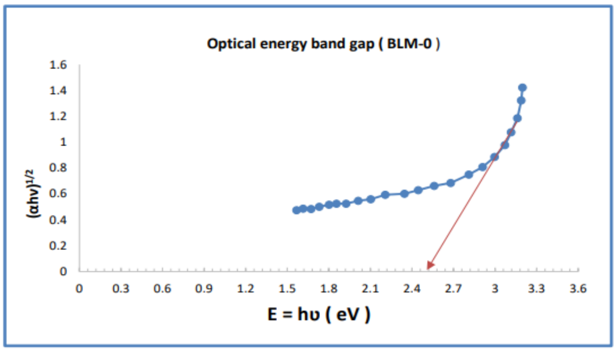

Fig 13. Graph plotted against E = hυ (eV) and (αhν)1/2

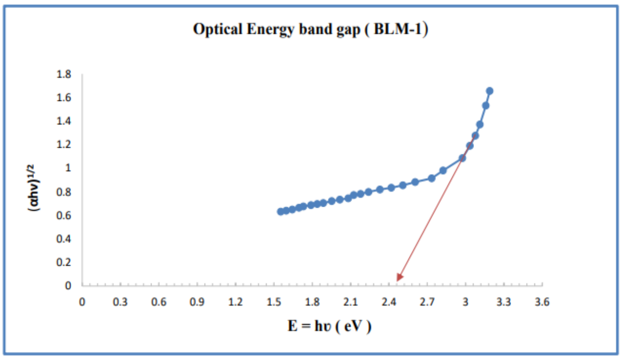

Fig 14. Graph plotted against E = hυ (eV) and (αhν)1/2

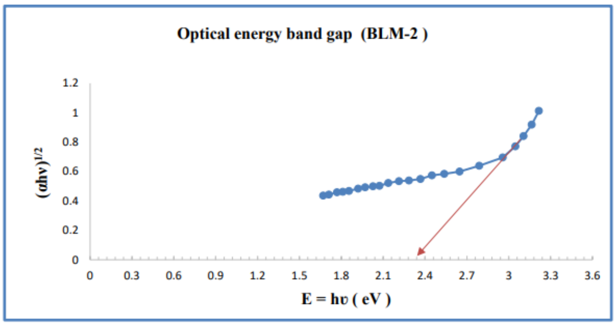

Fig 15. Graph plotted against E = hυ (eV) and (αhν)1/2

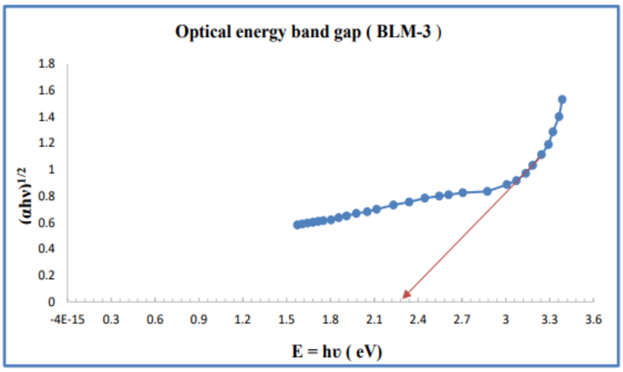

Fig 16. Graph plotted against E = hυ (eV) and (αhν)1/2

F. Comparison

Sample	Optical energy band gap (eV)
BLM-0	2.52
BLM-1	2.46
BLM-2	2.34
BLM-3	2.28

Refractive index and density both decrease with temperature, and vice versa. However, a refractive index, temperature, and concentration plot may be created by integrating the temperature impact in this association. It is employed to figure out the dispersive and focusing powers of prisms. It is also utilized for thermophysical property evaluation of hydrocarbon and petroleum mixes. As observed in the preceding rows, research on substrates' refractive indices can be helpful in a variety of industries.

Sample's Composition	Refractive Index (n)
BLM-0	**3.12**
BLM-1	**2.89**
BLM-2	**2.42**
BLM-3	**2.38**

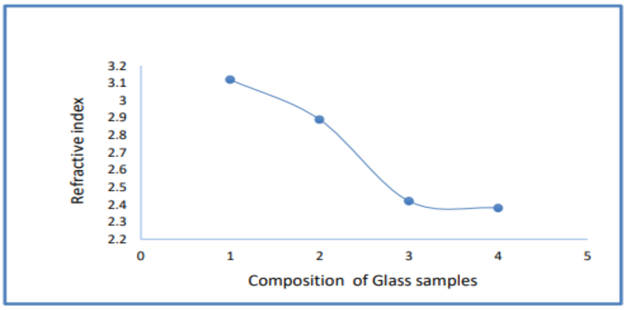

Fig 17. Graph plotted against (Composition of glass samples Vs. Refractive Index)

Graph shows that RI value decreases, when composition of MgO increases. Additionally, we discovered that MgO doping causes a drop in the refractive indices.

G. XRD Analysis

XRD represent the no sharp peaks, which confirms the amorphous nature of the glass.

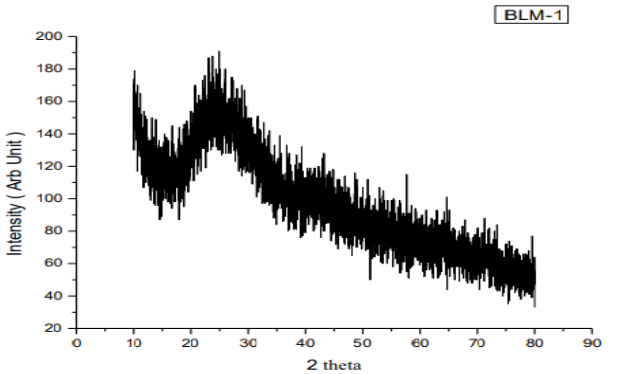

Fig 18. Graph plotted against (2 theta Vs. Intensity) BLM-1

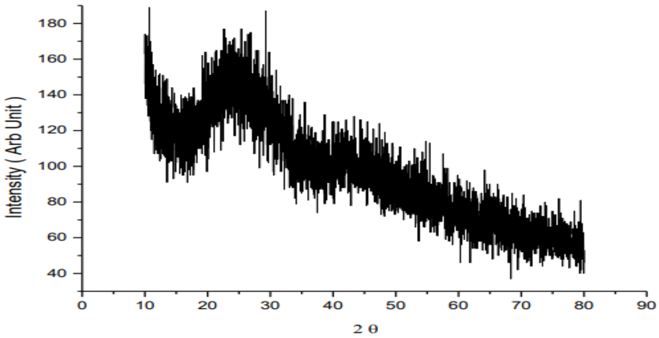

Fig 19. Graph plotted against (2 theta Vs. Intensity) BLM-5

H. Dielectrics Properties

Since polarization affects how quickly electrons align when an external field is applied, polarization increases at low frequencies. Because dipoles cannot participate in the polarization process at high frequencies, polarization decreases at those frequencies as well as capacitance. By increasing mol% of a dopant, the samples' capacitance changes. Samples have a high capacitance at low frequencies. The value of capacitance declines substantially at higher frequency with increasing the mol% of dopant. The curve is a straight line at higher frequencies, and the capacitance value is at its lowest in that range. It suggests that the dielectric polarization of MgO does not affect capacitance at higher frequencies. The interracial polarization effect is another factor contributing to the sudden drops in capacitance.

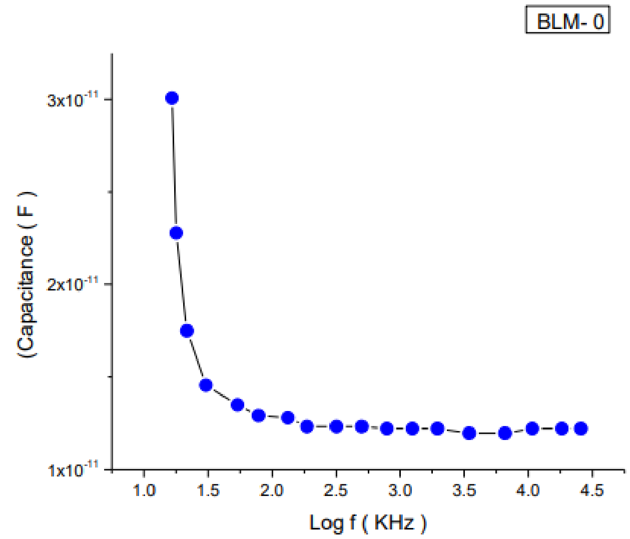

Fig 20. Graph plotted against (Log(f) Vs. Capacitance for BLM-0)

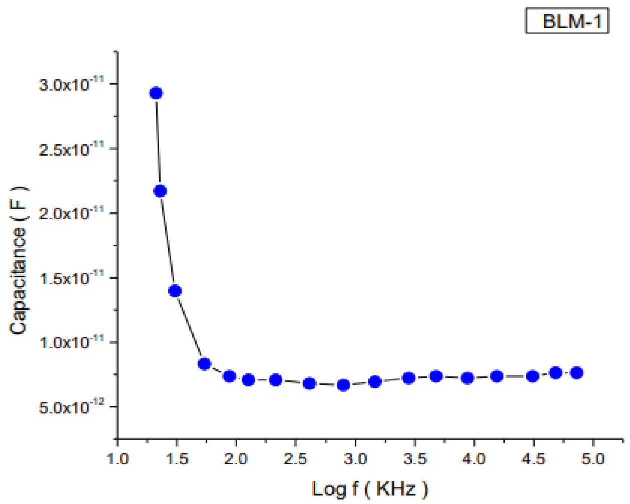

Fig 21. Graph plotted against (Log(f) Vs. Capacitance for BLM-1

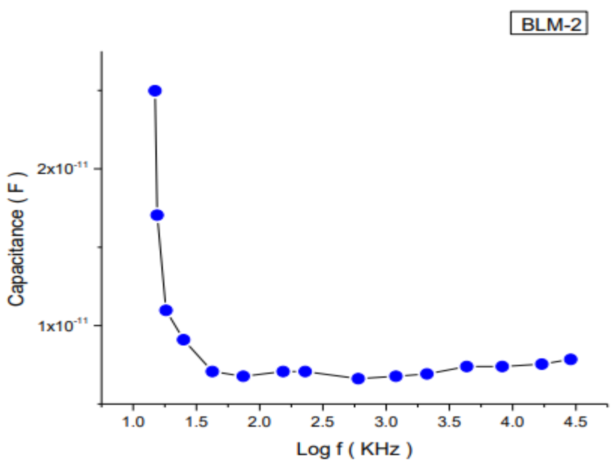

Fig 22. Graph plotted against (Log (f) Vs. Capacitance for BLM-2)

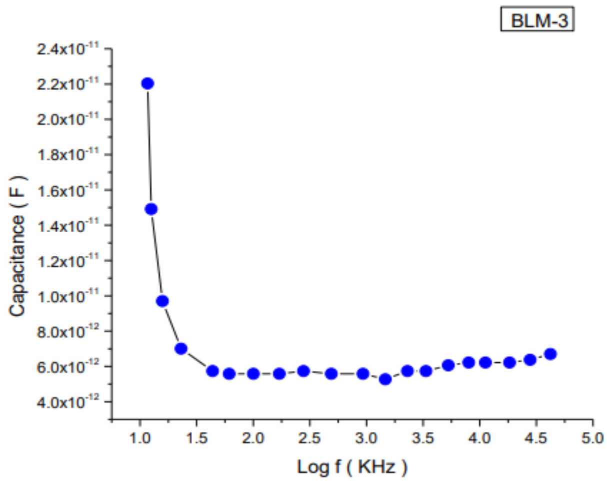

Fig 23. Graph plotted against (Log (f) Vs. Capacitance for BLM-3)

V. CONCLUSION

Four samples were prepared by doping MgO borate glasses with Lithium, to prepare the sample, the melt quenching technique is used, With increasing mol% of dopant, sample density increases from 1.22 to 1.68 g/cm^3 and molar volume decreases from 53.63 to 50.68 cm^3. The value of Oxygen packing density rises from 55.93 to 58.60mol/cm^3, Increasing the mol% of MgO decreases the Polaron radius. When Concentration of MgO increases, then ion concentration and field strength also increases, by increasing the mol% of dopant, the refractive index decreases from 3.12 to 2.38, At the expanse of MgO, the Urbach energy 'Eu' reduced from 2.52 to 2.28 eV, by adding the mol% of dopant to reduce capacitance. At high frequencies, the dielectric constant and the dielectric loss is reduced. For to calculate the density, I use the displacement method, for to measure the Optical properties, I use a Spectro photo meter, for to calculate the Dielectric data, I use the LCR meter.

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