International Journal on Applications in Basic and Applied Sciences
Volume 4: Issue 1: November 2018, pp 8 – 14 www.aetsjournal.com ISSN (Online) : 2455 - 1007

Influence of Li_2O on Structural, Thermal and Mechanical Properties of B_2O_3-CdO-Li_2O Ternary Glass System

P. Shalini Priya Dharsini[1]and J.Selvarasi[2]
[1]Department of Physics, Government Arts College for Women, Salem-8
Tamil Nadu, India. e-mail: shalpurush@gmail.com
[2]Department of Physics, Indian Arts and Science College, Thiruvannamalai
Tamil Nadu, India. e-mail: selvarasiphysics@gmail.com

***Abstract*—** Glasses in the system $70B_2O_3$-(30-x)CdO-xLi_2O (BCdL) with different Li_2O contents (0, 5, 10, 15 and 20 mol%), has been prepared by standard melt quenching technique. XRD, SEM, FT-IR, DTA and ultrasonic studies have been employed to study the impact created by Li_2O on the structure of the prepared glasses. The amorphous nature of the glass samples is confirmed by absence of Bragg peaks in the XRD pattern.The pictorial representation of SEM image clearly postulates the homogeneous nature existing in overall surface and further confirms the amorphous nature of the glass samples. FT-IR spectra of the samples predict that the borate network consists of three and four-fold structural units and is affected as the concentration of Li_2O increases. The results of the IR spectra indicate Cd^{2+} ions behave as network former and Li^+ ions behave as network modifier. Thermal stability of the glasses against devitrification is studied using DTA was found to increase with the increasing concentration. Density and ultrasonic (shear and longitudinal) velocities of all the glass samples were measured using Archimedes principle and Pulse Echo technique respectively. The molar volume is calculated using measured density. Elastic properties, Poisson's ratio, microhardness and Debye's temperature are calculated using ultrasonic velocity and density data. The variation of above parameters with respect to the composition is analyzed in terms of structural change in the glass network.

***Keywords*—** *XRD, SEM, FTIR, DTA,Ultrasonic velocity*

I. INTRODUCTION

Borate- based glasses have created many more arenas where it triggered to explore for new variety of glasses with interesting structural peculiarities in view of fact to change its coordination number with oxygen between three and four and hence form various structural units in the glass network with the added dopant [1-4] and such a phenomenon is relatively special compared with silicate and phosphate glasses which form only tetrahedral coordinated units with oxygen. Glasses containing transition metal ions have been a great deal of interest owing to their oriented applications in the field of memory and photoconducting devices, cathode materials in batteries, magnetic materials. In addition,they are quiet potential in the improvement of solar energy converters, new tunable solid-state lasers and fibre-optic communication devices [5,6].

Cadmium oxide often represented as heavy metal oxide / divalent oxide falls under transition or d-block elements in the periodic table. They are so called as their place in the periodic table is between s and p block elements, and their properties intermediate between the elements of the s-block that are highly reactive metallic elements which typically form ionic compounds and the elements of the p-block that are largely covalent in nature[7].In general, the glasses based on CdO under ionic nature, resemble that of pure B_2O_3 with the glass transition region being thermally unstable and behave as a network modifier.Whereas under covalent nature,a progressive substitution of three to four-fold structural units is encountered and stimulates the formation of boron-oxygen rings composed of the connection of bridge oxygen between [BO_3] and [BO_4] units. On account of this fact, the trend to crystallization is impaired and the stability of the glass is improved. This means that, CdO act as a network former.The above fact catches the reason for CdO being called as divalent oxide,dual in nature and acting as network former and as modifier at the same time. Various studies on B_2O_3-CdO glass system are done by several researchers[8-10] and they have discussed about the dual nature, ability of the oxide against irradiation, structural properties,etc.

Lithium is widely used in lithium ion conducting batteries due to their light weight[11]. On account of its light weight and large electropositive character they have enormous usage especially in vacuum ultraviolet (vuv) optics, semiconductors lithography, phosphors, lasers, solar energy converters and in number of electronic devices.The glasses containing Li_2O was seen as bubble free, highly stable and moisture resistant suitable for systematic analyses[12].

In common, alkali borate glasses show anomalous behavior in physical properties, such as density, oxygen packing density, sound velocity and thermal property[13]. The alkali ions do not indulge in the network formation but occupy interstitial spaces. As a consequence, the structure of modified borate glasses is covalently bonded structural units, while the ionic bonds are formed between cationic and anionic units, and their bond strength depends on the specific alkali cation. Earlier results by nuclear magnetic resonance and Raman scattering measurements illustrates that the fraction of BO_4 units of alkali borate glasses decreases with a increase in size of an alkali ion.This fact indicates that the preference of large alkali induces more NBOs [14].

Hence it is deemed worthwhile to determine how the structural aspects of B_2O_3-CdO- Li_2O glasses with increasing concentration of lithium ions enlightens their structural, morphological, thermal and mechanical properties

II. EXPERIMENTAL PROCEDURE

Ternary glass samples were prepared using standard melt quenching technique. B_2O_3, CdO and Li_2CO_3 of reagent grade were taken as starting materials. Batches based on stochiometric ratio of $70B_2O_3$-(30-x)CdO-xLi_2O (where x= 0, 5, 10, 15 and 20 mol %) were weighed using digital balance of accuracy ±0.001g and mixed together in a agate mortar and grinded finely to obtain a homogeneous mixture. The aforementioned mixture is transferred to a porcelain crucible and kept inside the muffle furnace. Melting is carried out in a temperature range of 800-900 ˚ C under controlled conditions. The molten mixture was casted into a prewarmed copper mould of 10mm diameter and 6mm thickness. Then annealing of the glass samples were carried out at 450ºC for two hours to avoid the mechanical strain developed during the quenching process. Using diamond disc and diamond powder, the prepared glass samples were smoothened and polished to obtain perfectly plane surfaces. The samples prepared were chemically stable and non-hygroscopic.

According to the Stoch's expression, glass is a solid body with a flexible random structure.The construction and regularity of the glass structure depends on the chemical composition, the origin and the history of glass preparation[15,16]. Table I shows the nomenclature and composition of prepared glass samples.

2.1 Theory and Calculation

2.1 a) Spectroscopic study

The non-crystalline nature of the samples is confirmed by X-ray diffraction technique using diffractometers de rayons X-Inel- Equniox1000 at a range of 2θ= (10-100) degrees utilizing copper radiation with operating voltage of 40Kv 30 mA anode current.

The morphology of the samples was examined using Scanning Electron Microscope (SEM) with an acceleration voltage of 20 kv and working distance of 20-26 mm at high vaccum (Hv) mode. The materials for investigation are hot air oven dried for about 1 hour at 110˚ C, then coated with the help of gold coater using JEOL auto fine coater model JES-1600, coating time is 120 seconds,10 mA and deposited with a thin layer of gold on the sample and later taken for examination.

Thin pellets were made by compressing the samples using KBr for the infrared measurement. The infrared spectra were recorded using spectrum RX1 Perkin Elemer at a range of 400 cm^{-1} to 4000 cm^{-1} at room temperature with accuracy of 4 cm^{-1}

Table I.Nomenclature and composition of glass samples

S. No.	Nomenclature	Composition in mol%	Remarks
1	BCd	70 -30	
2	BCdL05	70 - 25 - 05	Mol% of B_2O_3 is constant
3	BCdL10	70 - 20 - 10	
4	BCdL15	70 - 15 - 15	
5	BCdL20	70 - 10 - 20	

2.1 b) Thermal study

Differential thermal analysis (DTA) has been carried out using Thermal Analyser NETZSCH-STA449F3 Jupiter instrument at a heating rate of 20°C/min in nitrogen gas atmosphere. Following parameters are calculated using DTA spectrogram.

(i) Glass stability factor (S) = $T_c - T_g$

(ii) Hruby's Parameter (K_{gl}) = = $(T_c - T_g) / (T_m - T_c)$

where T_g represents glass transition temperature, T_c, crystallization temperature and T_m, melting temperature.

2.1 c) Ultrasonic study

The longitudinal and shear velocities of the glass specimen were measured using the Pulse – Echo overlap method at 303K by making use of 5MHz X-cut and Y-cut transducers.These transducers were brought into contact with each of the samples by means of a couplant, in order to ensure that there was no air void between the transducers and the specimen. By applying constant pressure on the probe, the echo waveforms were obtained on the display unit and stored in the memory.

Ultrasonic velocity is calculated using the relation:

$$U = [2d/t]$$

where d and t are the thickness of the specimen (mm) and transit time in microsecond respectively.

2.1 d) Density

The density (ρ) of the prepared glass samples is determined by Archimedes principle using ionized water as buoyant at room temperature. The following relation is used:

$$\rho = \left[\frac{a}{a-b} \right] \rho_W$$

where, a is the weight of the glass samples in air, b is the weight of the glass sample in water and ρ_w is the density of water.

The elastic moduli and other parameters[17-19] of the glass specimen are calculated using the measured density, longitudinal velocity and shear velocity as given below,

(i) Molar volume $(V_m) = \dfrac{M}{\rho}$

(ii) Longitudinal modulus$(L) = \rho\, U_\ell^2$

(iii) Shear modulus $(G) = \rho\, U_s^2$

(iv) Bulk modulus $(K) = L - \left(\dfrac{4}{3}\right) G$

(v) Poisson's ratio$(\sigma) = \left(\dfrac{L - 2G}{2(L - G)}\right)$

(vi) Young's modulus $(E) = (1 + \sigma)\, 2G$

(vii) Acoustic impedance $(Z) = U_\ell \rho$

(viii) Microhardness $(H) = (1 - 2\sigma)\dfrac{E}{6(1+\sigma)}$

(ix) Debye temperature $(\theta_D) = \dfrac{h}{K}\left(\dfrac{9N}{4\pi V_m}\right)^{1/3} U_m$

where ρ, U_l, Us h, k, N, V_m and U_m are the density, longitudinal velocity, shear velocity, Planck's constant, Boltzmann's constant, Avogadro's number, molar volume and mean ultrasonic velocity respectively.

III. RESULTS AND DISCUSSION

A. XRD analysis

X-ray powder diffraction (XRD) is a primary and most common systematic technique used for phase identification of crystalline and amorphous materials that provide information about the crystal in the glassy matrix based on unit cell dimensions. The analyzing material is finely ground and homogenized to give complete information regarding solid type such as amorphous or crystalline material. They distinguish crystals in the glass matrix if the dimension of the crystals is greater than 100nm [20].The XRD pattern of $70B_2O_3$ - (30-x)CdO-xLi_2O samples are shown in the Fig.I. The analysis of the pattern from the figure show absence of continuous or discrete sharp peaks and long- range atomic arrangement that reflects to indicate amorphous nature ofthe prepared glass samples.

B. SEM analysis

The morphological investigation of the prepared glass samples, are taken using Scanning Electron Micrograph as shown in Fig. II. From the pictures, it is observed that different sized grain particles are distributed and the size of the particles varies in each micrograph. The particles are extremely angular and spherical in nature. Some sphere like agglomerates were found spreading in the glass surface, due to the deposition of amorphous apatite. These results are in agreement with the information provided by the XRD patterns.

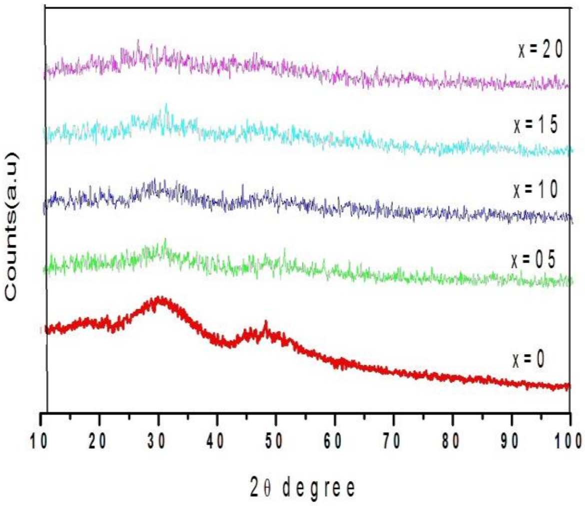

Fig. I X-Ray diffractogram for $70B_2O_3$ - (30-x)CdO-xLi_2Oglass samples

C. FTIR analysis

The FT-IR absorption spectrum occurs due to change in the dipole moment of the molecule and gives significant information about molecular vibrations as well as rotation associated with a covalent bond. It involves the twisting, bending, rotating and vibrational motions in the molecule. Borate glasses are very promising candidates for the application of infrared spectroscopy to determine various structural units. They possess rich chemistry and specific properties. The vibrational modes of the borate network are seen to be mainly active in three infrared spectral regions, which are similar to those reported by several workers [21-24].

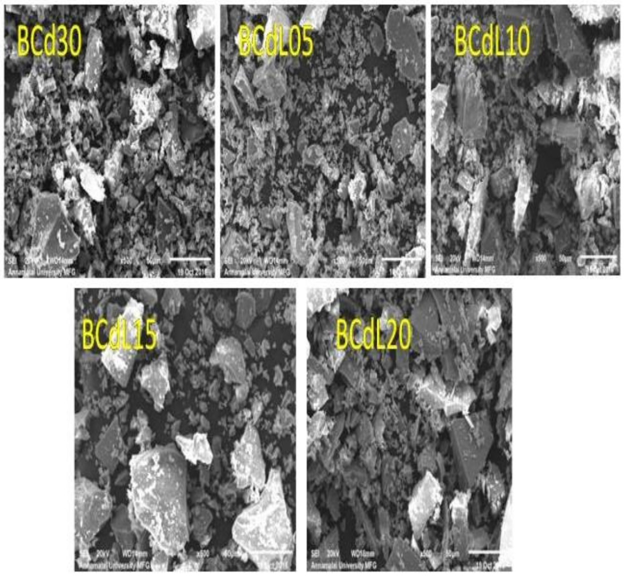

Fig. II. SEM photograph of the prepared glasses

(i) The first group which occurs at 1200 - 1600 cm^{-1} is due to the asymmetric stretching relaxation of the B-O bond of trigonal BO_3 units.
(ii)The second group lies between 800 - 1200 cm^{-1} and is due to the symmetric stretching of B- O bond of tetrahedral BO_4 units.
(iii) The third group is observed around 700 $cm^{-1}$and is due to bending of B- O-B linkages in the borate networks.

From Fig III, the broadening of IR bands indicates that there is no detectable variation in peak position to crystallization.The band around 1300 cm^{-1} is due the asymmetric stretching relaxation of the B-O bond of trigonal BO_3 units and 1035 cm^{-1} is due to the B- O bondstretching of BO_4 units. The intensity of the band due to tetrahedral borate groups are shifted higher and a reverse trend is observed in the bands due to triangular borate groups. The band around 700 cm^{-1} is due to bending of B- O-B linkages in the borate networks[25-28]. In binary B_2O_3- CdO, the band due to Li^+ is not detected but the addition of Li_2O in the glass matrix, a new band at 467$cm^{-1}$is observed. This band of Li_2O increase in intensity on further additionof Li_2O content. Eukondalu[29], Padmaja and Kistaiah,[30] also observed similar vibrations of Li cations in mixed alkali tungsten and zinc borate glasses respectively. The absence of peak at 806 cm^{-1} indicates the absence of boroxol ring formation. The band around 2700 - 3400 cm^{-1} is attributed to the molecular water or BOH vibrations.

When the modifier oxide Li_2O enters the glass network, the oxygen of these oxides break the local symmetry, while the cation Li^+ ions take the interstitial positions. Since B_2O_3 is more acidic than CdO, it takes up the oxide ions from Li_2O on priority for the modification of B–O–B bonds. Each BO_4 unit is linked to two such other units and one oxygen ion from each unit is linked with a metal ion and these linkages form long tetrahedron chains. This behavior is consistent with the variation of molar volume. Formation of BO_4 at the expense of BO_3 may decrease the molar volume as glass structure becomes more compact. This also indicates that Li_2O though act as modifier, occupy the interstitial position and account for closed network. Kamitos[31] reported through his IR studies on alkali oxide borate (Li_2O, Na_2O, K_2O) glasses and alkaline earth borate glasses (CaO, SrO, BaO). As the concentration of Li_2O is restricted upto 20mol% only tetrahedral coordination is more pronounced.

D.Differential Thermal Analysis

The DTA is very useful for determination of melting points of crystals and glass transformation and crystallization temperatures of glasses[32].In all samples, the DTA curve exhibits a small endothermic hump at lower temperature, which is characteristic of the transition temperature(T_g), single exothermic peak at high temperature region is characteristic of crystallization temperature(T_c). The exothermic peak is followed by an endothermic peak, which is characteristic of the melting temperature (T_m). Glass transition temperature (T_g) is one of the essential properties correlated with the viscosity of the glass and considerably dependent on the composition of the glass. Fig. IV shows differential analysis traces for BCdL glasses. From Table II, T_g, T_c, T_m, thermal stability and Hruby's parameter increases with increasing Li_2O concentration. This means that the stability against devitrification of the investigated glass system increases gradually with the increasing lithium ion concentration.

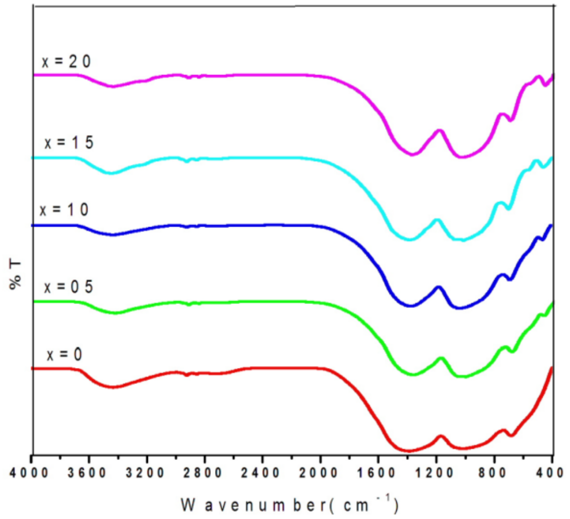

Fig. III FTIR spectra for $70B_2O_3$ - (30-x)CdO-xLi_2O samples

In binary BCd glass, the intermediate oxide CdO probably becomes a part of the glass structure along with the glass former B_2O_3. The successive replacement of Li_2O with higher bond strength (335±8.4 KJ/mole) in place of CdO with lower bond strength (235.6± 83.7 KJ/mol) increases T_g. Thus bond strength plays a vital role in increasing T_g congruently as the concentration of Li_2O increases thus promoting increased cross-link density between the atoms involved.

Thermal stability is an essential factor of consideration in the glass technology. It refers to a temperature range within which the glass does not tend towards crystallization. The higher the glass stability, the better is the glass quality. In general thermal stability should be greater than 100˚C to avoid microcrystal formation. For the glass system under study, the thermal stability increases with the Li_2O concentration and stability factor is also >100˚C and clearly depicts that the prepared glass sample is less prone to crystallization.

TableII. Values of glass transition temperature (T_g), crystallization temperature (T_c), melting temperature (T_m), thermal stability (S) and Hruby's parameter (K_{gl}) of BCdL glasses

Name of the sample	Glass transition temperature T_g/°C	Crystallization temperature T_c/°C	Melting temperature T_m/°C	Thermal stability S	Hruby's parameter K_{gl}
BCd	380	632	741	252	2.3119
BCdL05	402	694	810	292	2.5172
BCdL10	410	705	816	295	2.6577
BCdL15	416	720	824	304	2.9231
BCdL20	419	729	831	310	3.0392

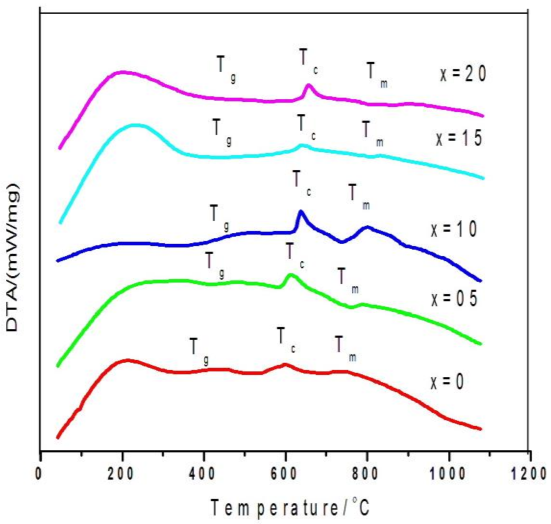

Fig.IV. DTA curve forprepared glass samples

E. Ultrasonic study

Ultrasonic, a non-destructive technique gained momentum owing due to its significance in understanding the structural characteristic of glass network. The measurements of ultrasonic parameters such as velocity as a function of composition, temperature and frequency are of immense interest in glass. These ultrasonic parameters in addition with density and molar volume are more informative about the changes occurred in the structure of glass network. Any change in the inter-atomic forces and potentials in the lattice structure is associated with the properties of the glasses. Thus, modification occurring in the lattice due to modifier doping can be directly noted [33].

Table III. Values of density, molar volume, longitudinal velocity and shear velocity of $70B_2O_3$ - (30-x) CdO-xLi_2O glass systems

Name of the sample	Density (ρ) 10^3 kgm^{-3}	Molar volume (V_m) cm^3/mol	Ultrasonic velocity ms^{-1}	
			Longitudinal (U_l)	Shear (U_s)
BCd	3.5556	24.55	4697.2	2698.6
BCdL05	4.0087	20.53	4997.3	2943.1
BCdL10	4.2342	18.28	5256.2	3190.7
BCdL15	4.3704	16.59	5418.2	3345.1
BCdL20	4.5189	14.96	5616.6	3497.8

The density and molar volume of each sample are listed in the Table III.The successive replacement of cadmium oxide by lithium oxide and the corresponding variations of density and molar volume cause a monotonic increase in the former and decrease in the later. Generally, density and molar volume shows opposite behavior to each other and also with the replacement of high density cadmium oxide(8.15g/cm^3)with low density lithium oxide (2.01g/cm^3) a decrease in density value is expected. But density increases from 3.5556 to 4.5189 g/cm^3 and molar volume decreases from 24.55 to 14.96 cm^3/mol%. These results are in accordance with the structural changes occurring in the coordination of the boron glass network, such that the addition of modifying alkali metal oxide Li_2O converted three coordinated boron BO_3 units to four coordinated boron tetrahedral and thus the network dimensionality and connectivity increases. In addition,the above fact can also be confirmed with the effect of replacing high ionic radii of cadmium(0.78Å) with low ion radii of Li^+ (0.58 Å)with which favors to occupy intrinsic position between B-O-Cd linkage and make them more compact.

As observed from earlier literature [34]**,**the increase in the density is related to the reconstitution of the glass rather than to the type of the structural units. Masao Kodama[35] also observed similar variations of density and molar volume. Since molar volume is directly associated to the spatial distribution of the oxygen in the glass network, their decrease may be due to increase of bridging oxygen and also depends on both density and molecular weight.

Both the ultrasonic velocities (Longitudinal (U_l) and shear (U_s) for the studied ternary glass system with variation of CdO and Li_2O content were listed in the Table. 3.The longitudinal ultrasonic velocity increases from 4697.2 to 5616.6ms^{-1} and the shear velocity increases from 2698.6 to 3497.8ms^{-1}. It is well known fact that in borate glasses, the added concentration of the Li_2O content, converts BO_3 trigonal to BO_4 tetrahedral units up to 33.3mol% of the modifier oxide, on further addition reconversion occurs from BO_4 to BO_3 with more non-bridging oxygen leading to a loosely packed network structure. In general, CdO is dual in nature acting both as network former and modifier. As a modifier, when its effective concentration(Li_2O+CdO) exceeds 33.3mol% a decrease in both velocities may occur.Since the effective concentration is <33.3 mole % increase in both longitudinal and shear velocity is observed. Therefore, the above fact strongly suggests that the excess of oxygen supplied by Li_2O has been utilized by Cd^{2+} and it is likely to be incorporated into the network as a glass former. A similar result was reported by Veeranna Gowda and Anavekar[36] on increasing Li_2O at the expense of PbO in B_2O_3- PbO - Li_2O glass system.

Elastic properties of solids are very significant, because their measurement gives information regarding the forces that are acting between the constituent atoms of a solid.This is important in interpreting and understanding the nature of bonding in the solids and non-destructive nature of the technique.Therefore the choice of appropriate solid material for particular purpose requires information about its mechanical properties. Hence, elastic properties are suitable for describing the glass structure as function of composition[37].

From Table IV the longitudinal, shear, bulk and Young's moduli shows a gradual rise over the entire range of composition of alkali ion in BCdL glass system. The substitution of alkali metal ions in place of Cd^{2+} strengthens the borate network and hence the glass structure. The increase in elastic moduli is due to the formation of bridging oxygen which makes the glass more compact. The large difference between L and G arises from volume effect. The change in volume due to compressions and expansions involved in longitudinal strain is pronounced while no change in volume is involved in shear strain. This indicates resistance to deformation and itis most probably due to large number of covalent bonds[38-41].

As stated by Rajendran et al,[42] Young's modulus is sensitive for any change in the nature of the chemical bond and its strength, while characterizing the glass structure, and bulk modulus is more sensitive in exploring the changes in the cross-link density and the bond stretching force constant. Since both the moduli value increases the above mentioned factors is enhanced with respect to Li_2O concentration.

The Poisson's ratio is the ratio of transverse and linear strains for linear stress. According to Rao[43], Poisson's ratio depends on the dimensionality of the network structure and cross-link density.A three dimensional network structure has a lower σ value probably between 0.1 - 0.2 than that of two-dimensional network structure with σ value between 0.3 - 0.5 since the number of bonds resisting a transverse deformation decreases in that order. From the Table IV, the observed decrease in the Poisson ratio with the addition of lithium oxide indicates the compactness or tight packing such that Li_2O has stronger effect than CdO on the density of the borate network structure and consequently the direct effect on the dimensionality of the network structure of these glasses. As the concentration of Li_2O increases BO_3 units are converted into BO_4 units and hence enhance the cross-link density and dimensionality of the glass network.

The increase in the values of acoustic impedance and microhardness with increase in mol% of alkali oxide is shown in Table V.The increasing trend in the values clearly confirms the rigidity of the glass structure. Further, the increase in microhardness strengthens the glass structure as the Li_2O content is increased. The continuous increase in microhardness reveals the absence of non-bridging oxygen and increases the degree of connectivity.

The Debye temperature θ_D is significant parameter and plays vital role in determination of elastic moduli and atomic vibrations in solids. θ_D represents the temperature at which nearly all the low frequency vibrational modes are excited which in turn increases the rigidity of the glass[44]. It is known that Debye temperature is directly proportional to the mean ultrasonic wave velocity. As both the longitudinal wave velocity and shear wave velocity increases θ_D also increases.

Table IV. Values of longitudinal, shear, bulk and Young's moduli and Poisson's ratio of BCdL glasses

Name of the sample	Longitudinal modulus L(GPa)	Shear modulus G(GPa)	Bulk modulus K(GPa)	Young's modulus E(GPa)	Poisson's ratio(□)
BCd	78.44	25.89	43.93	61.16	0.2537
BCdL 05	100.10	34.72	53.82	79.79	0.2345
BCdL 10	116.99	43.10	59.53	96.50	0.2083
BCdL 15	128.30	48.90	63.11	107.25	0.1920
BCdL 20	142.55	55.29	68.86	118.24	0.1832

TableV. Values of acoustic impedance, microhardness and Debye temperature of BCdL glasses

Name of the sample	Acoustic impedance Z ($10^7 kgm^{-2} s^{-1}$)	Microhardness H(GPa)	Debye temperature θ_D(K)
BCd	1.6701	5.5049	366.30
BCdL 05	2.0032	8.1251	422.90
BCdL 10	2.2257	10.9404	475.17
BCdL 15	2.3680	13.1518	513.63
BCdL 20	2.5380	15.8779	555.43

Table V show the variation of Debye temperature with Li_2O mol%. It is clear that θ_D increases with increasing concentration of Li_2O indicating that the rigidity and the cross-link density increases as the ratio of modifier to glass former increases. The increase in θ_D can also be attributed to the strengthening of the glass structure as revealed by the decrease in the molar volume and increase in the microhardness value.

IV. CONCLUSION

The following conclusions are drawn from the present study, XRD and SEM confirms amorphous nature of the prepared glass samples. IR spectra indicate that the structural role played by the Li_2O and CdO ions and preferentially get incorporated as modifier and former respectively. A progressive conversion of BO_3 to BO_4 structural units are also observed from the traces of IR spectra. Differential thermal analysis depicted an increase in T_g, T_c, T_m, stability and Hruby's parameter with the successive replacement of CdO by Li_2O and account for an increase in three-dimensional linkage and rigidity of the glass network. The density and molar volume is observed to agree with the general behavior of opposite trend, showing an increase in the former and decrease in the later respectively. All the moduli, acoustic impedance, microhardness and Debye's temperature values found to increase and Poisson's ratio decreases with the alkali ion concentration thus increasing the dimensionality and cross-link density of the as prepared glass samples. The improved stability make them promising candidate against irradiation and various dosimetric applications.

V.REFERENCES

[1] Hulpus, A.O., R. Ciceolucacel and I. Ardelean, 2008. Spectroscopic (FT-IR and Raman) studies on CuO-B_2O_3-PbO-Ag_2O glass systems. *J. Optoelect. &Advan. Mater.*, 10(12): 3209-3211.

[2] A.Tawansi, I.A. Gohar, D.Holland, N.A El. Shishtawi, 1988. *J.Phys.D:Appl.Phys*.21,607

[3] Ushida, H., Iwadate, Y. Hattori, T. Nishiyama, S. Fukushima, K. Ikeda,Y. Yamaguchi, M. Misawa, M. Fukunaga, T. Nakazawa and T. Jitsukawa, 2004. Network structure of B_2O_3-PbO and B_2O_3-PbO-$PbBr_2$ glasses analyzed by pulsed neutron diffraction and Raman spectroscopy. *Journal of alloys and compounds.*, 377(1-2):167-173.

[4] I.Yasui, H.Hasegawa,Y.saito and Y.Akasaka, 1990.*J.Non-Cryst.solids*,123,71

[5] Lakshmana Rao, J., G. Sivaramaiah, and N.O. Gopal, 2004. EPR and optical absorption spectral studies of Cu^{2+}iondoped in alkali lead tetraborate glasses. *Physica B*, 349:206-213.

[6] SanthanKumar , J., J. Lakshmi Kumari , M. Subba Rao , Sandhya Cole

,2013. EPR, optical and physical properties of chromium ions in CdO–SrO–B2O3–SiO2 (CdSBSi) glasses. *Optical Materials,* 35 :1320–1326

[7] Manal Abdel- Baki and Fouad El-Diasty,2006. Optical properties of oxide glasses containing transition metals: case of titanium – and chromium-containing glasses. *Current opinion in Solid state & Materials Science,* 10:217-229.

[8] Babanejad, S. A. F. Ashrafi and N. Salarzadeh, E. Ashrafi, 2012. Study the Optical properties of Amorphous Structure (Glassy) of B_2O_3-CdO Binary System. *Advances in Applied Science Research*, 3 (2):743-748

[9] M.Y. Nadeem and C.A. Hogarth,1986. *J.Mat.Sci.*,21:3829.

[10] C.A. Hogarth, and M.A. Ghauri, 1980. *J.Mat.Sci.*,15:409.

[11] VeerannaGowda,V.C. and R.V Anavekar,2005.Transport properties of Li_2O-MnO_2-B_2O_3 glasses. *Solid state ionics*, 176:1393-1401.

[12] Balaji Rao, R. and Rosario A. Gerhardt. 2008. Effect of alkaline earth modifier ion on the optical, magnetic and electrical properties of lithium nickel borate glasses. *J. Mat. Chem. Phy.*,112 : 186-197.

[13] Matsuda, Y., Y. Fukawa, M. Kawashima, S. Mamiya, M. Kodama and S. Kojima, 2009. Elastic properties and fragility of lithium borate glasses. *Phys. Chem. Glasses*, 50: 367-371.

[14] Chryssikos, G.D., E.I. Kamitsos and M.A. Karakassides, 1990. Structure of Borate Glasses. Part 2: The Alkali-Induced Network Modification Schemes in Terms of Structure and Properties. *Phys. Chem. Glasses.*, 31: 109.

[15] Alemi. A. A., H.Sedgi, A.R.Mirmohseni and V.Golsanamlu, 2007.Synthesis and characterization of holonium doped cadmium lead borate glasses. *Radiation effects and defects in solids,* 162(5):351-358.

[16] Stoch.L.,1992. Structure and crystallization of multicomponent glasses, *High.Temp.Mater.processes*,10:245-264.

[17] Venkata Subba Reddy, M., M. Sudhakara Reddy, C. Narayana Reddy and R.P.S. Chakradhar, 2009. Elastic properties of Na_2O-B_2O_3-V_2O_5 glasses. *J. Alloys and Compounds.*, 479: 17-21.

[18] Narayana Reddy and R.P. Sreekanth Chakradhar, 2007. Elastic properties and spectroscopic studies of fast ion conducting Li_2O-ZnO-B_2O_3 glass system. *J. Material Research Bulletin.,* 42: 1337-1347

[19] Vasantharani,P. and N. Sangeetha, 2013.Physical and elastic properties of lithium borate glasses using ultrasonic technique. *International journal of scientific research*,4(1):41-44.

[20] Medda,M.P.,A. Musinu.,G. Piccaluga,G.,1992.An x-ray diffraction technique of sodium borate glasses.*J.Non-Cryst.Solids*,150:76-79.

[21] Chaa.Y.J., J.H.Kimo, J.H.Yoonc, B.S.Lee, S.Chok, K.S.Jeongc, T.Kamatsud and H.G.Kim, Synthesis of dielectric polarizability and β-BaB_2O_4 crystallization in BaO-B_2O_3-TiO_2 glass. *J. Non – Cryst. Solids,* 429: 143-147.

[22] Doweidar, H., G. El-Damrawia and M. Al-Zaibania, 2013. Distribution of species in Na_2O–CaO–B_2O_3 glasses as probed by FTIR. *Vibrational Spectroscopy*, 68: 91–95.

[23] Bobkova, N.M. and S.A. Khot'ko, 2005. Zinc oxide in borate glass-forming systems. *Glass and Ceramics,* 62: 167-170.

[24] Verhoef, A.H. and H.W. Den Hartog, 1992. A molecular dynamics study of B_2O_3 glass using different interaction potentials. *J. Non-Cryst. Solids,* 146: 267-278.

[25] Abdelaziz,T.D., F.M. Ezzeldin, H.A. El Batal, A.M. Abdelshany,2014. Optical and FT infrared spectral studies of vanadium ions in cadmium borate glass and effects of gamma irradiation. *Molecular & Biomolecular spectroscopy*,131:497-501.

[26] Anjaiah J., C. Laxmikanth , Cephas John Lyobha ,N. Veeraiah and P. Kistaiah, 2015. Influence of Nd^{3+} ions on TL characteristics of Li_2O-MO-B_2O_3(MO = ZnO, CaO, CdO) glass system. *J Theor. Appl. Phys,* 9:119–125.

[27] Rani, S., S. Sanghi_, Anshu, A. Agarwal, N. Kishore. and V.P. Seth,2008. Effect of ZnO/CdO on the structure and electrical conductivity in Li_2O-MO-Bi_2O_3- B_2O_3 glasses (M = Zn, Cd). *J. Phys & Chem of Solids,*69 : 1855–1860.

[28] Anjaiah, J., C. Laxmikanth, N. Veeraiah. And P. Kistaiah, 2015. Infrared luminescence and thermoluminescenceof lithium borate glasses doped with Sm^{3+} ions. *Materials Science-Poland,* 33(1): 144-151.

[29] Edukondalu, A., B. Kavitha , M.A.Samee , Shaik Kareem Ahmmed, Syed Rahman, and K.Siva Kumar, 2013. Mixed alkali tungsten borate glasses – Optical and structural properties. *Journal of Alloys and Compounds.*, 552(5): 157-165.

[30] Padmaja, G and P.Kishtaiah, 2009. Infrared and Raman spectroscopic studies on alkali borate glasses: evidence of mixed alkali effect. *J. Phys. Chem.*, 113: 2397-2404.

[31] Kamitsos, E.I., 2003. Infrared studies of borate glasses. *Phys. Chem. Glasses.*, 44: 79.

[32] Shelby, J.E., 1997. Introduction to Glass Science and Tcchnology. *The Royal Society of Chemistry*, UK.

[33] Yasser B. Saddeek, 2004. Ultrasonic study and physical properties of some borate glasses. *Mater. Chem. & Phys.*, 83: 222-228.

[34] Gurinder Pal Singh, Parvinder Kaur, Simranpreet Kaur and D.P. Singh, 2012. Investigation of Structural, Physical and Optical properties of CeO_2-Bi_2O_3-B_2O_3 glasses.*PhysicaB*, 407: 4168–4172.

[35] Masao Kodama, 1991. Ultrasonic velocity in potassium borate glasses. *J. Non-Cryst. Solids,* 127:65-74.

[36] Veeranna Gowda, V.C. and R.V. Anavekar, 2004. Elastic properties and spectroscopic studies of lithium lead borate glasses, *Ionics,* 10: 103-108.

[37] Schreiber E, O.L. Anderson, N.Soga, 1973 Elastic constants and their measurement" (eds) J Robinson and S E Redka (New York: The Kingsport Press) pp. 191-196.

[38] Narayana Reddy ,C.and R.P. Sreekanth Chakradhar. Elastic properties and spectroscopic studies of fast ion conductingLi_2O–ZnO–B_2O_3 glass system. *Materials Research Bulletin,* 42 :1337–1347.

[39] Rao, B.G., H.G.K. Sundar and K.J. Rao, 1984. *J.Chem.Soc.Faraday Trans*,180:3491.

[40] Wang, B., Szu, M, Greenblatt,1991. *J.Non-Cryst.Solids*,134:249

[41] Damodarn,K.V. and K.J.Rao, *J.Mater.Sci*, 24:2380

[42] Rajendran, V., A. Nishara Begum, F.H. EL-Batal, M.A. Azzoz and H.A. EL-Batal. Microstructural dependence on relevant physical-mechanical properties on SiO_2-NaO_2- CaO-P_2O_5 biological glasses. (2002), *Biomaterials*. 23, 4263 – 4275.

[43] Rao, K.J., 2002. Structural chemistry of glasses. *Elsevier,* North Holland.

[44] Varshneya, A.K, 1994. Fundamental of inorganic glasses. *Academic Press*, Newyork.