Enhancement in Electrical Conductivity of Lithium Alumina Borate Glasses

D. T. Dongare

S. S. S. K. R. Innani Mahavidyalaya Karanja (lad), Dist. Washim, Maharastra, India.

Email: dtdongare@gmail.com

Abstract

The ionic conducting glasses $35Li_2O$: (65-X) B_2O_3: X Al_2O_3 has been prepared with various compositions (where X = 0, 5, 10, 15, 20) by using melt quenching technique. The nature of glass samples were confirmed by XRD and SEM. The dc electrical conductivity of glass samples were measured by using four probes method at different temperature (323K-623K). It has revealed that dc conductivity obeys Arrhenius behavior, electrical conductivity of glass increases with increase in mole percent of aluminum oxide and temperature.

Keywords: dc conductivity, XRD, SEM, Arrhenius behavior.

1. Introduction

Electrical properties of glasses have been studied extensively for number of years due to their use in solid state devices and batteries. Introduction of metal oxide or alkali ions into glasses exhibit high conductivity as like semiconductor and can be used as solid electrolytes high energy density batteries (Fu, J., 1996). In the literature, it has been reported that Bi_2O_3 occupy both network forming and network modifier. Therefore physical properties and electric properties of these glasses exhibit discontinuous changes due to role of structural cations changes (Baia, L.et al, 2003, Bale, S. & Rahman, S., 2008). It is reported that it shows significant change in the electrical properties of glasses with change in composition and temperature (Dalal.S.et al, 2015, 2016).The electrical conductivity of lithium borate glasses has been investigated and special attention has been devoted to describe dielectric relaxation on the basis of dielectric parameters (Dongare D.T &.Lad A.B., 2015). Aim of present work is to study the electrical conductivity of lithium alumna borate glasses.

2. Material and Experimental Preparation

The starting material lithium carbonate, boric acid and aluminum oxide of AR grade purchased from Merc laboratory were used. The aluminum lithium borate glasses of composition were prepared by melt quenching technique (Ingram, M. D, 1987, Akridge, J. K., 1986). A homogeneous mixture of different composition has melted in ceramic crucible by keeping it into Muffle furnace equipped with digital temperature controller. The materials were melted at1150^0C for two hours with heating rate 30^0C/min and molted material is quenched in aluminum mould at room temperature (27^0C).The samples were annealed at 200^0C for 2Hrs in hot air oven. These samples were stored in desiccators and taken only at the time of measurement. The structure of sample was confirmed by the measurements of XRD using XPERT PRO DIFFRACTOMETER and SEM by using ZEISS Ultra SEM instrument. The samples were in circular disc shapes, polished by using sand paper. The good quality paint was applied on both flat surfaces of sample and after drying it was loaded in the sample holder of four probe method for conductivity measurement.

The DC conductivity of samples has been calculated by using following relation.

$$\sigma_{dc} = \frac{d}{RA} \qquad (1)$$

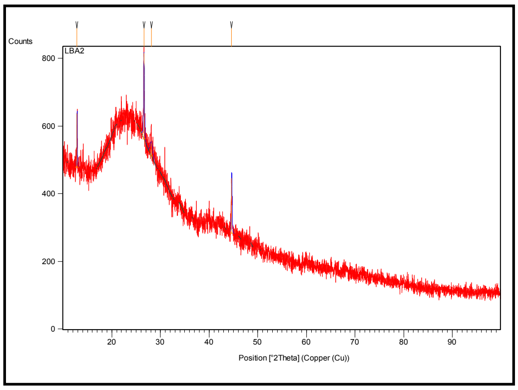
Where, d is the thickness of sample and A is the area of cross section.
Activation energy of glass material was determined by using Arrhenius equation

$$\sigma_{dc} = \sigma_0 \exp\,[-Ea/KT] \qquad (2)$$

3. Result and Discussion

a) XRD and SEM:

The XRD spectra of investigated samples have been found as shown in Fig.1. Only broad peak has been observed for glass samples, indicating that these glass samples are composed glassy phase. However, glass samples shows peaks superimposed on weak halo pattern in XRD, indicating partial crystallization. Therefore these samples are composed of the glassy phase and partially crystalline phase. X – Ray diffraction patterns recorded all samples shows a diffuse scattering over range of angles (2ɵ from 10° to 100°), which confirms amorphous nature of the sample. These types of structural changes have also been observed in scanning electron microscope (SEM) [Fig.2]



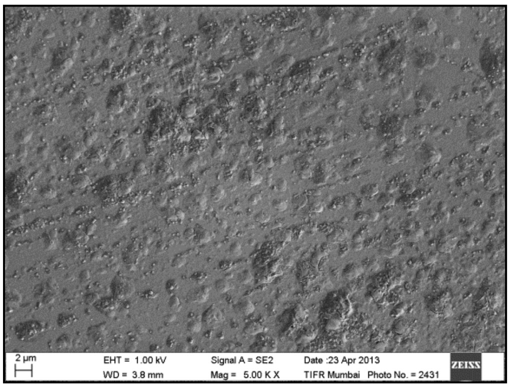


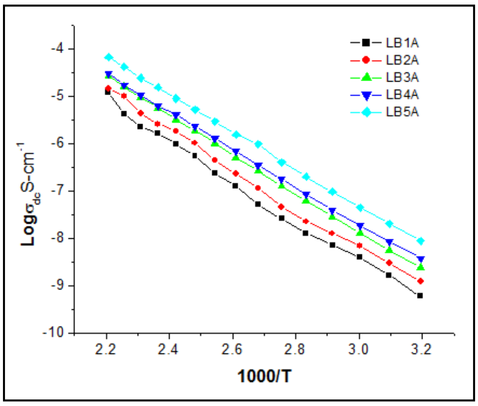
Fig.1.XRD of LB5A sample **Fig.2.**SEM of LB1A sample

b) DC conductivity:

The variation of conductivity as a function of $10^3/T$ for the glass samples of the series $35Li_2O$:(65-x) B_2O_3:xAl_2O_3 is shown in Fig.3. For all the samples, it is observed that the dc conductivity (σ_{dc}) obeys Arrhenius behavior. The activation energy calculated from the graph is listed in the Table.1. The compositional dependence of dc conductivity (σ_{dc}) at 323K and the activation energy (E_{dc}) of glass samples are shown in Fig.4. The conductivity (σ_{dc}) for the glass containing Al_2O_3 exhibits higher values than that for Al_2O_3 free glass where as the value of E_{dc} decreases with increase mole percent of Al_2O_3 content (Tuller H.et al, 1980). It is interesting to note that the σ_{dc} increases for about one order of magnitude for glass containing 20 mole % of Al_2O_3 reaching the value 2.75×10^{-7}S/cm. Such behavior is related to structural modifications, observed with the addition of Al_2O_3 as a result of interlinking between borate chain and aluminum tetrahedral unit. The variation of conductivity could be explained on Anderson & Staurt Model (Anderson L & Staurt D.A, 1954). According to this model; as the glass former ion is substituted by another glass former ion, the average intrinsic band distance becomes larger or smaller according to whether the substitution ion is large or smaller. In the present case ionic radius of Al^{+3} is bigger than that of B^{+3} therefore the addition of Al_2O_3 expands the lattice structure and enhances mobility of lithium ions. The result well agrees with the report (Doreau M el al.,1980,Gedam R. S. & Deshpande V. K., 2009), The improvement in ionic conductivity is attributed to mixed former effect between Al_2O_3 and B_2O_3.The highest conductivity has been observed for the LB5A sample ($2.75x10^{-7}$S/cm at 323K). The activation energy calculated from the slop of fitted line has been found to be 80±03eV for this series.

Table.1: *Activation energy and dc conductivity (323K) of LB1A-LB5A samples.*

Sample code	Mole % of Li_2O	Mole % of Al_2O_3	Mole % of B_2O_3	σ_{dc}S/cm	E_{dc} (eV)
LB1A	35	0	65	1.65E-7	0.8288
LB2A	35	5	60	1.68E-7	0.8283
LB3A	35	10	55	1.74E-7	0.8180
LB4A	35	15	50	2.6E-7	0.7879
LB5A	35	20	45	2.75E-7	0.7836



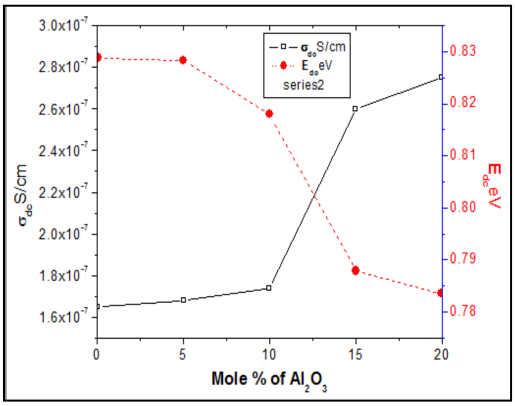


Fig.3: Variation of dc conductivity (σ_{dc}). **Fig.4:** Variation of E_{dc} & σ_{dc}

4. Conclusion

It is concluded that glass samples are composed of glassy phase. All glass samples obey Arrhenius behavior. The significant conductivity is observed for the samples which contain less than 50 mole percent of B_2O_3.The dual role of Al_2O_3 as both former and modifier has significant influence of ionic conductivity. The conductivity of glass increases with increase in mole percent of Al_2O_3 and highest conductivity is observed for the composition of LB5A sample.

5. Acknowledgement

I am thankful to Principal S. S. S. K. R. Innani Mahavidyalaya Karanja lad, TIFR Mumbai and Principal Vidyabharati Mahavidyalaya Amravati for providing facilities.

References

1. Fu, J. (1996).Super cooled Liquids and glasses. Journal of Physical. Chem., 37, 84-86.
2. Baia, L., Stefan, R., Popp J., Simmon S. & Kiefer W. (2003). Vibrational spectroscopy of highly iron doped B_2O_3–Bi_2O_3 glass systems. Journal Non Crystalline Solids, 324, 109-117.

3. Bale, S. & Rahman S. (2008).Effect of SiO_2/B_2O_3 Replacements on the Structure, Physicochemical and Electrical Properties of Bi_2O_3-Containing Glasses. Opt. Mater, 31, 333-337.
4. Dalal, S., Dahiya S. & Ahsima, Khasa S. (2015).Effect of substitution iron on structural, thermal &dielectric properties of lithium borate glasses. Material Research Bulletin, 70, 559-566.
5. Dalal, S., Dahiya S., Khasa, S. & Dahiya, M. S. (2016).Structural study and DC conductivity of vanadyldopped zinc lithium borate glasses. Journal of Integrated Science and Technology,4(1),1-4.
6. Dongare, D. T. &. Lad, A. B. (2015). Electrical conductivity and dielectric relaxation of lithium alumno borate glasses. International Journal of Metallurgical &Materials Science and Engineering, 5(1), 1-8.
7. Ingram, M. D. (1987).Ionic conductivity in glass. Phys. Chem. Glasses, 28(6), 215.
8. Tuller, H. A., Button, D. P. & Uhimann, D. R., (1980).DC conductivity and secondary structural relaxation in high conducting Li^+ glasses. Journal of Cryst. Solids, 40, 93.
9. Akridge, J. R. & Vourlis, H. (1986).Ionic conductivity measurements of doped ß- alumina compounds. Solid State Ionics, 18/19,608-611.
10. Anderson, L & Staurt D. A. (1954), Journal of J. Am. Ceram Soc., 37, 573.
11. Doreau, M., Abou, A. EIAnour. & Robert, G. (1980). Domain vitreux, structure et conductivity electrique des verres du system $LiCl/1bLi_2O/1b\ P_2O_5$. Material Research Bulletin, 15, 285-295.
12. Gedam, R.S. & Deshpande, V. K. (2009).Enhancement in conductivity of $Li_2O:B_2O_3:Al_2O_3$ glasses. Bull. Mater. Science, 32, 83-87.