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ELECTRICAL AND OPTICAL PROPERTIES OF FE_2O_3 ADDED LITHIUM BOROSILICATE GLASS

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Abstract:

The effect of Fe_2O_3 addition on the electrical Conductivity and optical absorption of lithium borosilicate glasses has been studied. It has been observed that, with addition of Fe_2O_3, the electrical conductivity decreases. This has been attributed to the increase in the tetrahedral network of the glasses at the cost of NBOs, which in turn decreases the mobility of lithium ions. The increase in tetrahedral network strengthens the glass which is supported by the observed increase in the density with Fe_2O_3 addition. This is also supported by the increase in refractive index observed. The optical absorption results show the peaks corresponding to Fe^{3+} which is more likely to favor the tetrahedral arrangement than octahedral one. Thus there is a nice correlation obtained among the electrical conductivity and optical properties in the present work.

Key words: electronic conductivity, density, optical absorption, refractive Index.

Introduction:

Lithium conducting glasses are prospective electrolyte materials for solid state batteries and have been studied widely in last few decades [1, 2]. When the transition metal oxides are added in glass system, it gives different colouring mechanism and electronic conductivity of the system also increases [3-5]. Optical properties of a few transition metal oxide doped glass systems have been studied earlier. However, systematic investigations in this regard are still lacking. Hence in the present work, the influence of Fe_2O_3 addition on the electrical and optical properties of lithium borosilicate glass have been studied.

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Experimental methods:

The Glasses studied in the present work can be represented by the general formula $30Li_2O$: XFe_2O_3: $(70 - X)(1/7\ SiO_2{:}6/7\ B_2O_3)$ where X = 0.0, 0.1, 0.5, 1.0, 2.5. The finely mixed powders of Li_2CO_3, Fe_2O_3, B_2O_3, SiO_2 of high purity (>99.5%) were melted in platinum crucible at 1100^0C for one and a half hour. The melts were stirred from time to time to attain homogeneity and quenched in an aluminum mould at room temperature in air. The glasses so prepared were annealed for two hours. FTIR pattern confirms different stretching bonds of silicate and borate groups in the samples present.

The Electrical conductivity of the glass samples was studied in the temperature range from 610K to 470K using high resolution dielectric analyzer. The optical absorption studies were done with the help of Avaspec spectrometer in the wavelength range from 200nm to 1000nm. The densities of these samples were measured by Archimedes' Principle with toluene as immersion liquid. Refractive index studies were done by abbe Refractometer and its correlation with density has been studied. The Transport number measurements were done by Keithley electrometer, using dc polarization technique.

Results and Discussion:

The FTIR spectra of the samples added with Fe_2O_3 at levels X= 0.0, 1.0, 2.5 addition show absorption peaks at certain wavelengths. The peaks observed at 1345 cm^{-1}, 1021 cm^{-1}, 979 cm^{-1} lines are due to B-O stretching, Si-O stretching, and similar results have been reported for

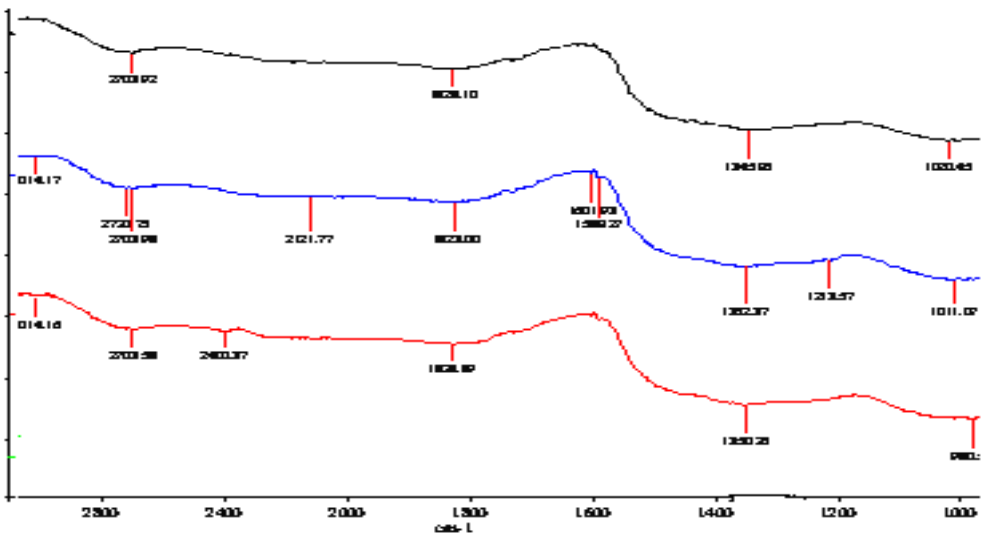

Figure 1. FTIR spectra of the samples added with Fe_2O_3 X= 0.0, 1.0, 2.5

lithium borosilicate glasses earlier.

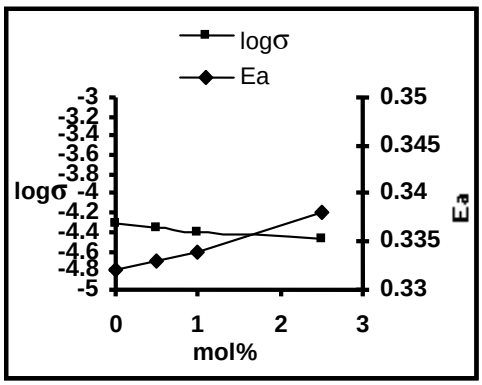

Figure 2. variation of logσ and Ea with mol% of Fe_2O_3.

The variation of electrical conductivity and activation energy as a function of Fe_2O_3 content is shown in Figure 2. It is observed that the electrical conductivity, as a function of Fe_2O_3 content, is decreased continuously. The total electrical conductivity depends on the ionic and electronic contribution. The lithium content in all the 2glass samples is kept fixed. Wu et al and Zhong et al have proposed that the borate groups consume oxygen to form tetrahedral boron units. Fe^{3+} ions also form tetrahedral and octahedral coordination in the glass network. The tetrahedral coordination of Fe^{3+} is more common than the six fold coordination in many of the glasses. Both of these Fe^{3+} sites can be considered as substitutional and subjected to strong interaction between its external orbitals and the p-orbitals of the neighbouring oxygens [6]. The tetrahedral formation of Fe^{3+}ions in the altered glass network reduces the number of non-bridging oxygens (NBOs) in the system. The mobility of the lithium ions gets reduced. So the ionic contribution to the total conductivity is decreased. The electronic contribution also plays a major role to the total conductivity [7]. The transport number measurement plots are shown in figure 3.

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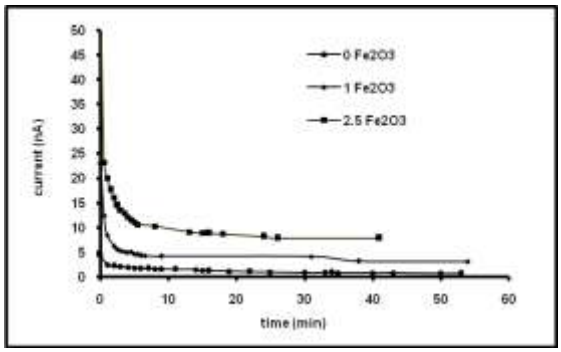


Figure 3 Transport number measurements

It is seen that the electronic conductivity t_e increases with the increase of Fe_2O_3 content. Total conductivity depends on the combined effect ionic and electronic contribution. In the present system ionic conductivity decreases and electronic conductivity increases. The resultant effect is a decrease in the total electrical conductivity but it is marginal as as observed in the conductivity plot.

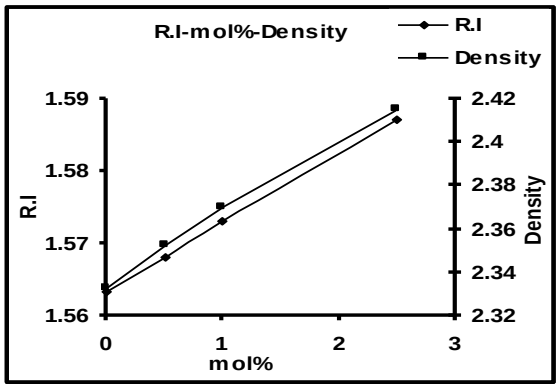
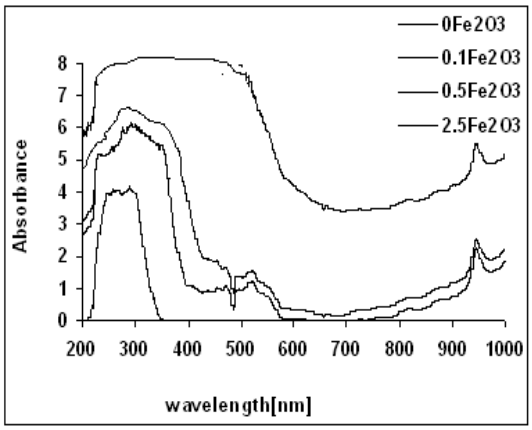


Figure 4. Refractive Index and density results of Fe_2O_3 content at levels X=0.0, 0.5, 1.0, 2.5.

Figure 4 illustrates the variation of refractive index and density. Both values are increasing with Fe_2O_3 content. Increase in density shows strengthening of glass network by the tetrahedral formations in the structure. It supports the reduction in the non-bridging oxygen causing less mobility of ions in the network. Refractive index is a wavelength dependent parameter and the values are measured by Abbe Refractometer at 589nm wavelength. When light passes from a rarer medium to denser medium its velocity decreases and then the refractive index of the medium increases. So the experimental values of refractive index and

density are mutually agreeing.



Figure[5] Variation absorption and wavelength with Fe_2O_3 added at levels at X=0.0, 0.1, 0.5, 1

Figure [5] depicts the variation of Absorption and wavelength of the samples of Fe_2O_3 added at levels X=0.0, 0.1, 0.5, 2.5. When Fe_2O_3 content is increased there is a complete absorption of UV lines and also absorption at 520nm, 410nm peaks in visible region. It is due to the presence of Fe^{3+} States of the Fe-ions. Fe^{3+} ions are expected to occupy tetrahedral positions in the glass matrix [8]. Absorption at 920nm is due to Fe^{2+} ions. Intensity of the lines are increased when Fe_2O_3 content is increased.

Conclusion:

FTIR spectra confirms 1345 cm^{-1}, 1021 cm^{-1} , 979 cm^{-1} peaks which are due to B-O stretching, Si-O stretching, and Si-O-B stretching in the glass matrix. The total electrical conductivity plot shows a decrease in the value by the addition of Fe_2O_3. There is a decrease in the ionic conductivity and increase in the electronic conductivity. The combined effect shows a marginal reduction in the total conductivity. Refractive index and density plot shows that both values are increasing. It supports tetrahedral formation in the glass network. Addition of Fe_2O_3 shows absorption at 410nm and 520nm in the visible region. It is because of the transition in the Fe^{3+} energy levels.

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