ELECTRICAL PROPERTIES OF SODA LIME SILICA GLASS DOPED WITH IRON (III) OXIDE AT DIFFERENCE TEMPERATURE

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ABSTRACT

The glasses in composition $64SiO_2$: 10CaO: $25Na_2O$: $1Fe_2O_3$ mol% was prepared by melt quench technique and their non-crystallinity has been established by XRD studies. The glasses were investigated for room temperature density and dc electrical conductivity in the temperature range 343–443 K. The molar volumes were estimated from density data. The corresponding bulk resistances of the sample at different temperature were measured and by knowing the geometrical dimension of samples, the dc conductivity (σ_{dc}) was determined. The activation energy was obtained from plot of the linear variation of the logarithm of conductivity with the reciprocal of temperature using equation. The result found that, the conductivity of glass increased with increasing temperature which confirms semiconductor behavior of glass sample.

KEYWORDS: glass, electrical properties, soda lime, XRD

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INTRODUCTION

Electrical properties of glasses have been studied extensively for several years because of their potential use in solid-state devices [1]. The mechanism of electrical conduction on semiconducting oxide glasses has generally been understood in the light of the small polaron hopping (SPH) model [2]. In 1989, Shimakawa [3] proposed a transport model based on multiphonon tunneling with weak electron-lattice coupling, which could explain the mechanism for dc conductivities for binary phosphate and tellurite glasses. The conductivity in pure transition metal ions doped glasses has always been observed to be semiconducting type because of polaron hopping between low and high valency states of transition metal ions. The polaron hopping of transition metal ions doped glasses depends on distance between transition metal ions and their concentration. If ions are also present along with transition metal ions, then the conductivity will be of mixed type, i.e., polaron and ionic [4].

Most common glasses are the soda lime silicate glass. Soda lime silicate glass have been widely used as the host material owing to their good glass forming nature at a low melting temperature compared to several other glass systems and also are more easily fabricated into various shapes [5].

There are reports that, Fe_2O_3 can improve electrical property of glass [6-9]. So, electrical property of soda lime silicate glass doped with Fe_2O_3 is interesting. In this study, the soda lime silicate glass doped with iron (Fe) were prepared in formula $64SiO_2$: 10CaO: $25Na_2O$: $1Fe_2O_3$ by the melt-quenching technique, The dc conductivity (σ) was determined at different temperature to elucidate the conduction mechanism.

MATERIALS AND METHODS

The Fe_2O_3 doped soda-lime silicate glasses of the composition $64SiO_2$: 10CaO: $25Na_2O$: $1Fe_2O_3$ were prepared by the melt quenching technique. All chemicals used in the present work, SiO_2, Na_2CO_3, CaO and Fe_2O_3 were of high purity (Fluka, 99.99%). Appropriate amounts of the raw materials were thoroughly mixed and ground in a pestle and mortar for half an hour. The prepared mixture was then heated in a high purity alumina crucible at 1350°C by an electric furnace for about 3 h to ensure complete melting of all components. The melt was then quickly poured into a preheated stainless steel mold and annealed at 500°C for 3 h and let it cooled down slowly to room temperature. The amount of the glass batch is 30g. The obtained glass was cut and finely polished into a size of 5 mm × 10 mm × 3 mm.

By applying Archimedes principle, the weight of the prepared glass samples was measured in air and in xylene using a 4-digit sensitive microbalance (AND, HR-200). Then, the density, ρ , was determined. The refractive index (*n*) of the glass samples was measured using an Abbe′ refractometer (ATAGO) with mono-bromonaphthalene as a contact layer between the sample and prism of the refractometer. The optical absorption spectrum of the prepared glass sample in the UV-VIS region from 300-1400 nm was recorded at room temperature using a uv-visible spectrophotometer (Shimazdu, UV-3100). Glassy nature of the samples was confirmed by X-ray diffractometer (Bruker D8 Advanced).

Samples for dc conductivity measurements was cut and finely polished into a size of 5 mm × 10 mm × 3 mm. Silver electrodes were painted on to the two major surfaces of the samples. Two probe method was employed and measurements were carried out in the temperature range 343–443 K. A constant voltage (20 V) was applied across the sample to measure current and converts to resistance. The resistivity and conductivity were calculated from area of glass sample.

RESULTS AND DISCUSSION

In general, glass sample is good optical quality and show a weak green color. The density and refractive index of glass are 2.58 g/cm^3 and 1.53 respectively.

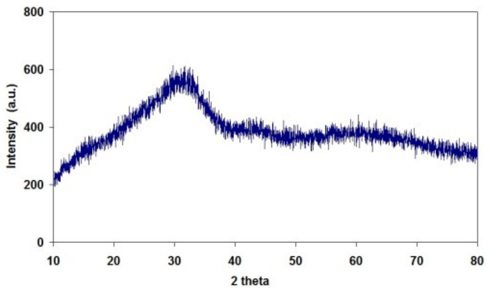

Fig. 1. XRD pattern of Fe_2O_3 doped soda lime silicate glass.

The amorphous nature of glass was confirmed by XRD pattern as shown in Fig. 1. XRD pattern of glass sample shows a hump at around the 2θ about 30°, indicating disordered structure and amorphous nature of glass samples.

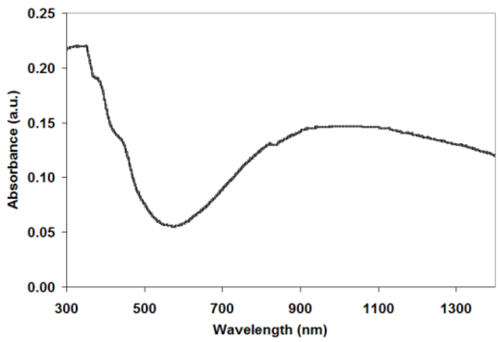

Fig. 3. Optical absorption spectrum of Fe_2O_3 doped soda lime silicate glass

From Fig.2., the absorption band is observed in the spectrum with the peaks around 380 and 435 nm are attributed to Fe^{3+} and board peak around 1,050 nm due to Fe^{2+}. The Fe_2O_3 doped glass shown the green color due to the homogeneous distribution of Fe^{3+} and Fe^{2+} ions in the glass matrices [10].

Table 1 shows the resistance, resistivity and conductivity of glass sample at different temperatures. It can be seen that, the resistance of glass decreased with increasing of temperature. This results confirms semiconductor behavior of glass sample. Fig. 3 shows the temperature dependence of the direct-current (dc) conductivity in the temperature range for which there is a linear variation of logarithm of the conductivity with the reciprocal of temperature. This behavior shows that in the present glass systems the following well-known Arrhenius law [11];

$$\sigma = \sigma_0 \exp(-W / kT) \quad (1)$$

where σ_0 is a constant for a given glass, k is the Boltzmann constant and W is the activation energy for conduction. The values of W and σ_0 were evaluated by using least-square fitting of the experimental data. The calculated values of σ (at 343 and 443 K), ln σ_0, σ_0 and W are 10.29 and 2.94×10^{-4} and 0.29 eV respectively.

Table 1. Resistance, resistivity and conductivity of glass sample at different temperatures

Temperature (K)	R(MΩ)	ρ (Ω-m)	σ (Ω^{-1}-m^{-1})
343	7602	17493.10	5.72×10^{-5}
353	4036	9287.31	1.08×10^{-4}
363	2042	4698.88	2.13×10^{-4}
373	1238	2848.78	3.51×10^{-4}
383	806	1854.70	5.39×10^{-4}
393	520	1196.58	8.36×10^{-4}
403	362	833.00	1.20×10^{-3}
413	241	554.57	1.80×10^{-3}
423	163	375.08	2.67×10^{-3}
433	107	246.22	4.06×10^{-3}
443	76	174.88	5.72×10^{-3}

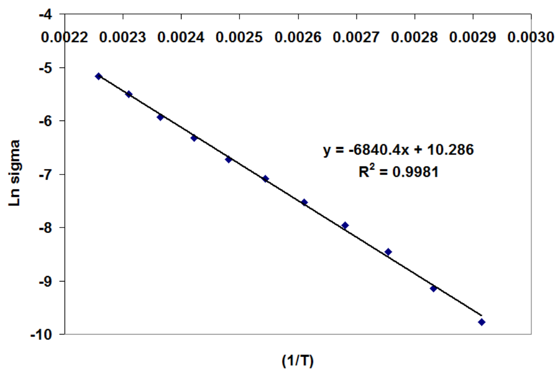

Fig. 4. Arrhenius plot for the $64SiO_2$: 10CaO: $25Na_2O$: $1Fe_2O_3$ glasses.

CONCLUSION

In this work, the glasses in composition $64SiO_2$: 10CaO: $25Na_2O$: $1Fe_2O_3$ mol% was prepared by melt quench technique and investigates their structural, physical and electrical properties. The results can conclude are as follows;

- The glass sample is good optical quality and shows a weak green color, correspond with optical spectra from uv-visible spectrophotometer
- The density and refractive index of glass are 2.58 g/cm^3 and 1.53 respectively.
- The amorphous nature of glass was confirmed by XRD pattern
- The conductivity of glass increased with increasing temperature which confirms semiconductor behavior of glass sample.

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