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ELECTRICAL PROPERTIES OF $CuO-MnO_2-B_2O_3$ GLASSES

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Abstract :

Due to the technological importance of $CuO-MnO_2-B_2O_3$ glasses, dc-conductivity measurement with increasing concentration of MnO_2 (in the range of 5-30 mol%) have been reported in the temperature range of 313-573 K in the present study. A plot of –log σ versus 1/T shows two different regions of conduction suggesting two types of conduction mechanisms switching from one type to another occurring at knee temperature. The DC conductivity increases with increase in temperature of the sample and also with increase of mol% of MnO_2 . Activation energy calculated from both regions (LTR and HTR) is below 1 eV. Thus electrical conduction is electronic. Activation energy in LTR and HTR are temperature independent but composition dependent.

Keywords : $CuO-MnO_2-B_2O_3$ glasses, DC-conductivity.

1. Introduction :

Now a days glasses have a prominent role in the field of electronics and have wide applications in industry, space research, computer memories etc. Since 1954 when the electronically conducting oxide glasses were discovered, glass formation and properties in transition metal oxide systems have been extensively studied due to their important semiconducting behaviour [1-4] Chaudhury [5] have discussed in brief the general procedure for making glass ceramic superconductors and some of their physical properties. All the glasses which become superconductors after properly annealing at higher temperatures are in general transition metal oxides (TMO) with copper ions. Ghosh et al [6] discussed the results of dc-conductivity of semiconducting vanadium bismuth oxide, containing 80-95 mol% vanadium pentaoxide in the 300-500 K temperature range on the basis of polaronic hopping model similarly they observed adiabatic hopping conduction. The electrical properties of $V_2O_5-B_2O_3$ glasses are discussed on the basis of small polaron hopping model by Culea et al [7]. The charge transfer mechanism plays a dominant role in semiconducting glasses. Dc-conducting and hopping mechanism in $Bi_2O_3-B_2O_3$ glasses has been studied by Yawale et al [8]. The physical and transport properties such as density, hopping distance, polaron radius, dc-conductivity and activation energy are reported by them. The small polaron hopping model is applied to the glass system. Dc-conductivity, density and infrared investigation have been carried out on Zno-$PbO-B_2O_3$ glasses by Doweldar et al [9]. Mandal et al [10] have reported the dielectric behaviour of glass system $BaO-PbO-TiO_2-B_2O_3-SiO_2$. The electric relaxation study of $V_2O_5-B_2O_3$ glasses has been done by singh et al [11].

2. Experimental Procedure :

2.1 Preparation of glass samples :

The glass samples were prepared in a fireclay crucible. The muffle furnace used was of Heatreat Co. Ltd. (India) operating on 230 volts A.C. reaching upto a maximum temperature of 1500 + 10°C. Glasses were prepared from A R grade chemicals. Homogenous mixture of an appropriate amounts of CuO MnO_2 and B_2O_3 (mole%) in powder form was prepared. Then, it was transferred to fire-clay crucible which was subjected to melting temperature (1300°C). The duration of melting was generally two hours. The homogenized molten glass was cast in steel disc of diameter 2 cm and thickness 0.7 cm. Samples were quenched at 200°C and obtained in glassy state by sudden quenching method. All the samples were annealed at 350° C for two hours.

2.2 Electrical Measurement :

The dc resistance of the glass samples was measured by using D.C. microvoltmeter, Systronics 412 India; having an accuracy of ±1 μV and input impedence 10 MΩ, by voltage drop method given by Kher et al [12]. Before electrical measurements all the samples were polished to smooth surfaces using fine quality emery paper. After application of conducting silver paint at either sides, the samples were used for electrical measurements. The silver paint acts like electrodes for all the samples.

3. Results and Discussion :

3.1 Dc-electrical Conductivity :

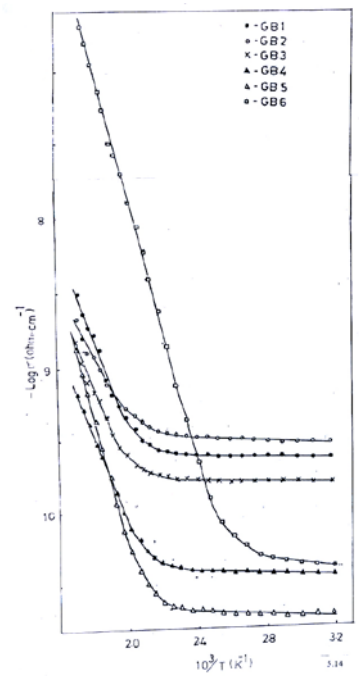

Fig. 1-Temperature Dependence of dc-electrical conductivity for the glasses of different compositions of CuO-MnO_2-B_2O_3

D.C. electrical conductivity of the glass samples is measured in the temperature range 313 to 573 K. The value of d.c. conductivity is found to be of the order of 10^{-10} to 10^{-11} ohm^{-1} cm^{-1} at 313 K. Fig 1 shows the plot of -log σ versus 1/T. It is observed that, the conductivity of all the glass samples studied increases with increasing temperature.

This plot is found to consists of two distinct straight linear regions called as low temperature regions (LTR) (313 to 413 K) and high temperature region (HTR) (523 to 573 K). In LTR conductivity increases linearly with increasing temperature at very slow rate where as in HTR conductivity increases linearly with increasing temperature at a faster rate. Obviously two activation energies and two conduction mechanisms are associated with electronic conduction in all the glasses studied. The same type of dc conductivity behaviour is reported in literature [8, 13, 14]. The activation energies are obtained from slope of the plot of log σ versus 1/T in both the regions and reported in table 1. It is observed that the activation energy is temperature independent but depends on composition. The activation energies obtained are found to be of order of borate vanadate and other semiconducting glasses reported in literature [4, 11, 15, 16, 17]. Activation energy calculated for both regions (LTR and HTR) is found to be less than 1 eV, thus the electrical conduction is electronic.[19] The kink temperature θ_c is the temperature at which the Arrhenius plot is divided in to two linear regions of different slopes. The kink temperature (θ_c) is determined from the plot of –Log σ versus 1/T and is reported in table 1. The kink

temperature θ_c for the series of glasses studied decreases with increasing mol% of MnO_2. The activation energy is also calculated at kink temperature and the values are reported in table 1. The inetecept on –log σ axis of - log σ versus 1/T plot gives the values of pre-exponential factor (–log σ_0)

Table 1 : Activation energies, Kink Temperature and Pre- exponential factor σ_o of $CuO\text{-}MnO_2\text{-}B_2O_3$ glasses

Glass No.	Composition (mol%) $CuO\text{-}MnO_2\text{-}B_2O_3$	Activation energy W (eV)		Kink Tempera-ture θ_c (K)	Activation energy at θ_c W (eV)	Pre-exponential factor σ_o (ohm x cm)$^{-1}$ 10^{-9}
		LTR (W_L)	HTR (W_h)			
G B1	20-5-75	0.0035	0.250	476	0.0754	15.8
G B2	20-10-70	0.0052	0.181	471	0.0603	6.60
G B3	20-15-65	0.0060	0.258	456	0.0517	5.62
G B4	20-20-60	0.0069	0.310	450	0.0431	3.16
G B5	20-25-55	0.0086	0.422	440	0.0388	14.7
G B6	20-30-50	0.0090	0.474	378	0.0345	1700

Table 1 reports the values of activation energy, kink temperature, pre-exponential factor of $CuO\text{-}MnO_2\text{-}B_2O_3$ glasses. The values of different parameters reported in the table agreed with the values reported for semiconducting glasses in the literature [4, 8, 11, 15-18]. Fig 2 shows the variation of activation energy (w) with MnO_2 mol% in LTR and HTR for the glass samples. Fig 3 shows variation of pre-exponential factor (-logσ_0) versus Composition for the glasses studied.

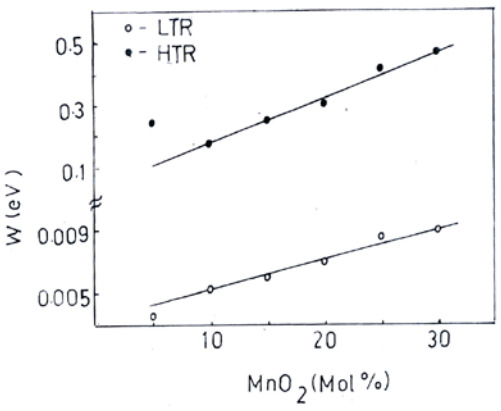

Fig 2 : Variation of activation energy (w) with MnO_2 mol% in LTR and HTR for the glass samples

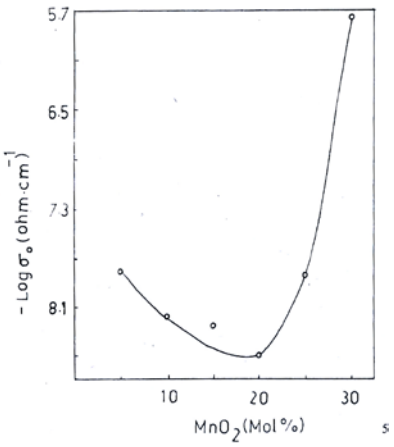

Fig 3 : Variation of Pre-exponential factor (-logσ_0) versus Composition for the glass samples.

4. Conclusions :

D.C. conductivity of CuO-MnO_2-B_2O_3 glass system is studied in the temperature range 313-573K. The activation energy are found to be in the range of semiconducting glasses. The electrical conduction is electronic.

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