ISSN : 0974 - 7486 Volume 11 Issue 9

Materials Science

An Indian Journal

Full Paper

MSAIJ, 11(9), 2014 [298-301]

Dielectric and electrical properties of phosphate glass

P.Kothari

Department of Chemistry, Govt. P.G. College Berinag, Pithoragarh-262501, Uttarakhand, (INDIA)

E-mail: drpramodkothari@gmail.com

ABSTRACT

Measurement of the dielectric properties of different substances has been the subject of many researchers and various models have been proposed to interpret the experimental results. Dielectric measurements on ionic materials give useful information about dynamic processes involving ionic motion. In this paper the dielectric and electrical properties of SLBAP glass specimen was measured in a frequency range 100 Hz to 1 MHz and over the temperature range from 303 to 543 K.

KEYWORDS

SLBAP glass;
Melt quenching technique;
Electrical conductivity;
a.c conductivity;
Dielectric constant;
Dielectric loss.

INTRODUCTION

The electrical conductivity of glasses is of great technical importance and therefore frequently studied. Numerous theoretical models are proposed for the analysis of the electrical conductivity and each offers various approaches and interpretations. During the last three decades it has been studied in detail[1-25] in the case of transition metal oxide doped glasses, because of their semiconducting properties, switching behaviour and potential applications. The past literature reported the conductivity of Borate, Vanadate and Tellurite glasses and also of ternary silicate glasses containing transition metal ions[10,11-26]. Various models viz., Mott's model[27], Cohen, Fritzsche and Ovshinsky's (C.F.O) model[28], Davis and Mott's model[29] and sharp band edge model[30] have been suggested to explain the conductivity of transition metal ion doped glasses. These have been reviewed by Sayar and Mansingh[31]. However, only a very limited work have been reported for Phosphate glasses.

EXPERIMENTAL

A sodium-lead-barium-aluminium phosphate glass was prepared by melt quenching technique. The composition (by weight) was approximately $Na(PO_3)_6$ 70% -BaO 15%-PbO 10%-Al_2O_3 5%. For the measurement of dielectric properties the SLBAP glass specimen was coated with a layer of silver conducting paste. For the Electrical conductivity measurement, two opposite surfaces of the Glass specimens were coated with silver paint to form the electrodes. The value of capacitance (C) and the dissipation factor (D) of the SLBAP Glass specimen was measured using automatic Hewlett Packard Precision LCR Meter Model 4280A at the temperature range of 303 to 543K and over a frequency range 100 Hz to 1MHz.

RESULTS AND DISCUSSION

Dielectric measurements

The specimens was placed in a high temperature cell. The value of Capacitance (C) and the dissipation factor (D) of the glass specimens were measured at frequency of 100 Hz to 1 MHz from temperature range 303 K to 543 K and tabulated in TABLES 1 & 2.

TABLE 1 : Observed values of capacitance (C) and dissipation factor (D) of phosphate glass specimen (SLBAP) at fixed frequency with variation of temperature

Temp	100 Hz		1 KHz		10 KHz	
	C (10^{-12})	D (10^{-2})	C (10^{-12})	D (10^{-2})	C (10^{-12})	D (10^{-2})
303	2.223	8.456	3.375	11.768	3.105	6.097
323	2.431	23.223	3.897	12.763	4.888	8.071
343	2.442	33.997	4.567	16.064	5.678	10.983
363	3.094	42.654	4.699	14.349	6.789	11.105
383	3.418	67.098	5.458	22.941	8.113	17.602
403	3.812	110.987	7.879	42.163	10.232	18.409
423	3.888	218.316	6.109	64.322	10.489	25.198
443	4.201	460.573	11.445	89.407	10.992	28.559
463	6.295	800.163	12.444	290.789	11.397	45.662
483	9.081	1087.082	14.784	467.921	11.456	67.831
503	10.765	2398.765	17.453	896.021	11.487	70.439
523	11.223	4129.228	21.447	1100.812	12.119	177.982
543	13.997	5876.212	21.921	2400.789	12.983	280.765

TABLE 2 : Observed values of capacitance (C) and dissipation factor (D) of phosphate glass specimen (SLBAP) at fixed frequency with variation of temperature

Temp	100 KHz		1 MHZ	
	C (10^{-12})	D (10^{-2})	C (10^{-12})	D (10^{-2})
303	3.322	2.506	3.051	1.447
323	3.398	2.678	3.121	1.675
343	3.401	2.981	3.214	2.556
363	3.472	3.498	3.452	2.876
383	3.548	3.742	3.478	3.541
403	3.856	3.801	3.678	4.667
423	4.204	4.672	4.012	4.871
443	4.698	4.352	4.126	6.512
463	5.58	5.662	4.256	7.882
483	7.311	5.769	6.398	7.989
503	7.367	7.444	6.412	9.663
523	7.672	7.549	6.502	9.781
543	7.923	7.671	6.852	12.751

(a) Effect of frequency and temperature on dielectric constant (ε')

Dielectric constant (ε') and dielectric loss (ε'') were calculated by using the relation

$$\varepsilon' = Cd/A\,\varepsilon_0$$

$$\varepsilon'' = \varepsilon'/D$$

Where C is the Capacitance, d is the thickness of the sample and A is the area of the phase in contact with the electrode. In the second equation D is the dissipation factor and ε_0 is the permittivity of free space.

The dielectric constant (ε') was calculated for SLBAP Glass specimen in the frequency region from 100 Hz to 1MHz and covering the temperature range 303 to 543 K and collected in TABLES 3 & 4. The dielectric permittivity rises sharply towards low frequencies due to electron polarization effects.

At high frequencies, due to high periodic reversal of the field at the interface, the contribution of charge carriers (ions) towards the dielectric constant decreases with increasing frequency. Hence dielectric constant decreases with the increase of frequency. As can be seen from the TABLE 4, the nature of variation of dielectric constant is similar for glass specimen. At low temperature region the value of dielectric constant shows small increase with temperature. As the temperature increases, the dielectric constant shows a rapid increase for the glass specimen, which corresponds to the dielectric relaxation phenomenon. The temperatures, where the value of ε' rises with temperature, are higher for higher frequencies of measurements.

TABLE 3 : Calculated values of dielectric constant (ε') and loss (ε") for phosphate glass specimen (SLBAP) at some fixed frequency with variation of temperature

Temp	100 Hz		1 KHz		10 KHz	
	ε'	ε''	ε'	ε''	ε'	ε''
303	5.44635	64.40811	8.26875	70.2647	7.60725	124.7704
323	5.95595	25.64677	9.54765	74.80726	11.9756	148.3781
343	5.9829	17.59832	11.18915	69.65357	13.9111	126.6603
363	7.5803	17.7716	11.51255	80.23242	16.63305	149.7798
383	8.3741	12.4804	13.3721	58.28909	19.87685	112.9238
403	9.3394	8.414859	19.30355	45.78315	25.0684	136.1747
423	9.5256	4.363217	14.96705	23.26894	25.69805	101.9845
443	10.29245	2.234705	28.04025	31.36248	26.9304	94.29742
463	15.42275	1.927451	30.4878	10.48451	27.92265	61.15074
483	22.24845	2.046621	36.2208	7.740794	28.0672	41.37813
503	26.37425	1.099493	42.75985	4.772193	28.14315	39.95393
523	27.49635	0.665896	52.54515	4.773308	29.69155	16.68233
543	34.29265	0.583584	53.70645	2.237033	31.80835	11.32917

TABLE 4 : Calculated values of dielectric constant (ε') and loss (ε'') for phosphate glass specimen (SLBAP) at some fixed frequency with variation of temperature

Temp	100 KHz		1 MHz	
	ε'	ε''	ε'	ε''
303	8.1389	324.7765	7.47495	516.5826
323	8.3251	310.8701	7.64645	456.5045
343	8.33245	279.5186	7.8743	308.0712
363	8.5064	243.179	8.4574	294.0682
383	8.6926	232.2982	8.5211	240.6411
403	9.4472	248.5451	9.0111	193.0812
423	10.2998	220.458	9.8294	201.7943
443	11.5101	264.4784	10.1087	155.2319
463	13.671	241.4518	10.4272	132.2913
483	17.91195	310.4862	15.6751	196.2085
503	18.04915	242.4657	15.7094	162.5727
523	18.7964	248.9919	15.9299	162.8658
543	19.41135	253.0485	16.7874	131.6556

(b) Effect of frequency and temperature on dielectric loss (ε'')

The ε'' of SLBAP glass specimen has been measured in the temperature range of 303 K to 543 K at different frequencies and shown in TABLE 3 & 4. From these tables it is noticed that the general behavior shows an increase of ε'' with increasing frequency. On increasing the temperature at a fixed frequency, the dielectric loss decreases.

Conductivity measurements

The following relation calculates the a.c. conductivity of the samples.

$$\sigma(\omega) = \varepsilon_0 \omega \varepsilon'' = \varepsilon_0 (2\pi f) \varepsilon''$$

(a) Frequency and temperature dependence of a.c. conductivity

The a.c. conductivity of SLBAP Glass specimen has been calculated in the frequency range of 100 Hz to 1MHz and temperature range from 303 to 543 K. The values of a.c. conductivity are collected in TABLE 5. The a.c. conductivity decreases on increasing the temperature for different fixed frequency and increases with increasing the frequency for fixed temperature.

It is important to note that the graph of log σ(ω) against temperature are almost linear in the temperature range 303-543 K, which suggest the they follow Arrhenius equation[32] of the type

$$\sigma_{a.c.} = \sigma_0 \exp[-w/KT]$$

Where w is the activation energy and K is the Boltzman constant.

TABLE 5 : Calculated values of a.c. conductivity of phosphate glass specimen (SLBAP) at different frequency with variation of temperatures

Temp	100 Hz	1 KHz	10 KHz	100 KHz	1 MHz
	σ (ω)	σ (ω)	σ (ω)	σ (ω)	σ (ω)
303	35.59192	390.0745	692.6628	1802.997	2867.808
323	14.17241	415.2925	823.7213	1725.795	2534.285
343	9.72483	386.6818	703.1546	1551.748	1710.257
363	9.820588	445.4103	831.5027	1350.008	1632.519
383	6.89667	323.5919	626.8966	1289.604	1335.919
403	4.650051	254.1652	755.9738	1379.798	1071.89
423	2.411114	129.1775	566.1669	1223.873	1120.261
443	1.234898	174.1088	523.4921	1468.252	861.7698
463	1.065109	58.20475	339.4783	1340.42	734.4151
483	1.130963	42.97302	229.7107	1723.664	1089.252
503	0.60758	26.49283	221.8043	1346.049	902.5223
523	0.367974	26.49902	92.61197	1382.279	904.1493
543	0.322489	12.41889	62.8939	1404.799	730.8858

CONCLUSION

The present study shows that the mechanism of electrical conduction in SLBAP glass specimen is similar to that in transition metal oxide doped glasses, where the mechanism of ionic conduction takes place.

REFERENCES

[1] M.H.Cohen, H.Fritzsche, S.R.Ovshinsky; Phys.Rev.Lett., **22**, 1065 **(1969)**.

[2] N.F.Mott, E.A.Davis; Electronic Processes in Non-Crystalline Materials, Clarendon, Oxford, **(1979)**.

[3] N.F.Mott; J.Non-Cryst.Solids, **8-10**, 1 **(1972)**.

[4] D.Adler; J.Non-Cryst.Solids, **73**, 205 **(1985)**.

[5] A.E.Owen, W.E.Spear; Phys.Chem.Glasses, **17**, 174 **(1976)**.

[6] N.F.Mott; J.Non-Cryst.Solids, **1**, 1 **(1968)**.

[7] J.D.Mackenzie; J.Non-Cryst.Solids, **2**, 16 **(1970)**.

[8] M.I.Klinger; Rep.Prog.Phys., Part I, 225 **(1968)**.

[9] A.P.Schmidt; J.Appl.Phys., **39**, 3140 **(1968)**.

[10] L.Murawski, C.H.Chung, J.D.Mackenzie; J.Non-

Cryst.Solids, **32**, 91 **(1979)**.
[11] J.D.Mackenzie; J.Am.Ceram.Soc., **47**, 211 **(1964)**.
[12] J.D.Mackenzie; in J.D.Mackenzie, (Ed); Modern Aspects of the Vitreous State, Butterworth, London, **3**, 126 **(1964)**.
[13] H.J.L.Trap, J.M.Stevels; Phys.Chem.Glasses, **4**, 193 **(1963)**.
[14] R.A.Anderson, R.K.MacCrone; J.Non-Cryst.Solids, **14**, 112 **(1974)**.
[15] J.Allersma, J.D.Mackenzie; J.Chem.Phys., **47**, 1406 **(1967)**.
[16] J.G.Austin; J.Non-Cryst.Solids, **2**, 474 **(1970)**.
[17] D.Hulsenberg; J.Non-Cryst.Solids, **80**, 474 **(1986)**.
[18] L.Murawski; J.Non-Cryst.Solids, **90**, 629 **(1987)**.
[19] G.S.Linsley; J.Non-Cryst.Solids, **4**, 208 **(1970)**.
[20] A.Mogus-Milankovic, D.E.Day, G.J.Long, G.K.Marasinghe; Phys.Chem.Glasses, **37**, 57 **(1996)**.
[21] I.Ardelean, P.Pascuta; Electrical behaviour of Fe_2O_3–B_2O_3–CaO glasses, Studia Universitatis Babes-Bolyal, Romania, Physica, **(2001)**.
[22] T.Kennedy; PhD Thesis, Rensselaer Poly. Ins., **(1969)**.
[23] W.D.Kingery, H.K.Bowen, D.R.Uhlmann; Introduction to ceramic, J.Wiley, Singapore, New York, Chichester, Brisbane, Toronto, **(1991)**.
[24] H.H.Qiu, M.Kudo, H.Sakata; Mater.Chem.Phys., **51**, 233 **(1997)**.
[25] H.H.Qiu, H.Mori, H.Sakata, T.Hirayama; J.Ceram.Soc.Jpn., **103**, 32 **(1995)**.
[26] S.Roy, D.Chakravorty; J.Mater.Res., **9**, 2314 **(1994)**.
[27] E.A.Davis, N.F.Mott; Classical Mag., **22**, 903 **(1970)**.
[28] S.W.Martin, C.A.Angell; J.Non-Cryst.Solids, **83**, 185 **(1968)**.
[29] M.Sayer, A.Mansingh; Phys.Rev.B, **6**, 4629 **(1972)**.
[30] S.R.Elliott; Adv.Phys., **36**, 135 **(1987)**.
[31] K.Fnke; Prog.Solid State Chem., **22**, 1110 **(1963)**.
[32] T.Shjinoda, M.Wakitani, T.Nanto, N.Awaji, S.Kanagu; IEEE Trans.Electron Dev., **47**, 77 **(2000)**.