IRSTI 54.057 https://doi.org/10.26577/ijmph.2024v15i1a11

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Vanadium oxides impact on the ZNO-SB_2O_3-B_2O_3 glasses dielectric and ac conduction mechanisms

Abstract. In the current study, we have looked into the glasses dielectric characteristics as a follow-up to our prior work on the influence of vanadium ions in spectral properties of ZnO-Sb_2O_3-B_2O_3 glasses. B_2O_3 glasses have garnered interest as dielectric materials in addition to their uses as optical functional materials. Glasses of ZnO-Sb_2O_3-B_2O_3 that ranged in V_2O_5 concentration (from 0 to 1.0 mol %) were prepared using the standard melt and quench procedure. The densities were determined based on Archimedes' principle. Using these densities, physical parameters such as molar volume (Vm), mean vanadium ion separation distance (r_i) and vanadium ion concentration (N_i), polaron radius (r_p), were determined and presented. It has been investigated how the samples dielectric constant (ε), dielectric loss (tan δ), and ac conductivity (σ_{ac}) change with temperature at various frequencies between 10^2 Hz and 10^6 Hz. The results were examined in relation to the number of oxidation states of the vanadium ions.
Key words: Borate glasses, Dielectric constant, ac conductivity, vanadium ions.

Introduction

In recent years, there has increased interest in the review of disordered materials hopping conductivity. The actual portion of the ac conductivity has a power law [1] frequency dependency, which is the main characteristic of hopping conduction. To explain the mechanism of conduction in those materials, they must look at the frequency-structured electric conductivity of amorphous compounds [2].This leads to flexible and complex fashions that make it possible to characterize the digital homes of various materials [3]. Knowing glasses electric conductivity is essential because it is required to act as an electrical insulator or conductor in many applications [4].The dielectric properties, which include the dielectric constant (ε), loss (tan δ) and ac conductivity (σ_{ac}) spanning a broad spectrum of frequencies and temperature, make it easier to determine how well they act as insulators.The magnificent ionic achieving glasses are extensively researched because of their use in powerful excessive power density batteries [5, 6] and in a few electrochemical devices [7, 8].

B_2O_3 glass structural model is coupled by BO_3 building blocks have been suggested [9-11]. The boroxol rings split off as the transitional glass temperature approaches, resulting in a more open structure. Glasses behavior as a host material is significantly influenced by its open structure, allowing sites to accommodate host ions over a much greater range of size and coordination number. Because they can be employed in a variety of solid state devices, borate glasses have drawn a lot of attention. These glasses all share the occurrence of localized states in the mobility gap, which results from the lack of long-range order and other fundamental flaws.

Most of the literature studies [12-16] reveals that, the heavy metal oxide glasses like Sb_2O_3-B_2O_3 glasses are very important optical materials with potential applications in non-linear optics, fast reacting optical switches, optical amplifiers and strong radioactive shielding materials due to their

high transparency, high polarizability and high refractive index.

We looked into the impact of vanadium ions on the spectral characteristics of ZnO-Sb_2O_3-B_2O_3 glasses in our earlier research [17]. The findings were examined in relation to the number of oxidation states of vanadium ions in the glass materials. As a follow-up to our prior research, we have looked at how the substitution of V_2O_5 affects the dielectric and ac conduction pathways in bulk amorphous ZnO-Sb_2O_3-B_2O_3 glasses spanning the temperature range of 303-523 K and frequency range of 10^2 to 10^6 Hz.

Materials and Methods

The present glass samples were synthesized by using the particular Analytic Reagent (AR) grade chemicals of ZnO (Merck, ≥99%), Sb_2O_3 (Merck, ≥99%), H_2BO_3 (TM Media, 99.5%) and V_2O_5 (SRL, 99.5%) in melt quenching process. The detailed composition was presented in the Table.1. The adapted procedure of glass synthesis was presented as a flow chart in Figure 1[17].

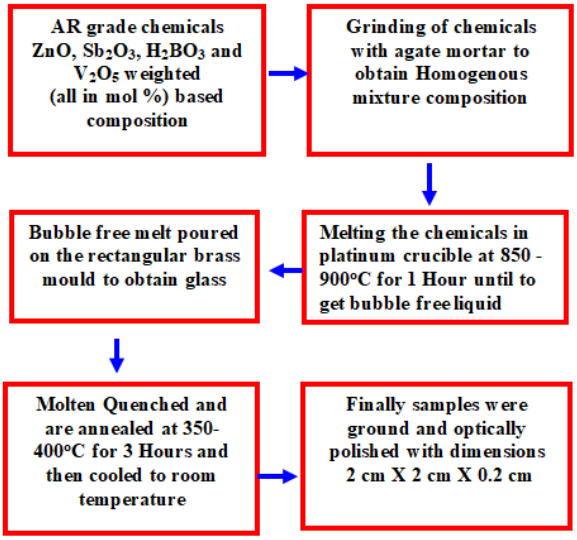

Figure 1 – Flow chart of various step involved in preparation of glass samples

Table1 – Composition of glass samples (all in mol%)

Sample Code	ZnO	Sb_2O_3	B_2O_3	V_2O_5
V_0	10.0	20.0	70.0	…..
V_2	10.0	19.8	70.0	0.2
V_4	10.0	19.6	70.0	0.4
V_6	10.0	19.4	70.0	0.6
V_8	10.0	19.2	70.0	0.8
V_{10}	10.0	19.0	70.0	1.0

The densities were determined based on Archimedes' principle, by measuring the weights of the sample in air as well as in O-xylene as a buoyant liquid [18]. Using these densities, the physical parameters viz., molar volume (V_m), mean vanadium ion separation distance (r_i) and vanadium ion concentration (N_i) etc., was determined using the standard relation [18].

XRD patterns were recorded with help of a SEIFERT X-pert PRO panalytical X-ray diffracto metre with CuK_α -radiation.The dielectric parameters capacitance (c) and dissipation factor (D) were measured in between silver electrodes by using LCR Meter (model HP 4263B) by varying temperature systematically between 30-250°C and a frequency range of 10^2 to 10^5 Hz.

Results

From the measured weights of glass samples in air and buoyant liquid, densities were calculated, using these densities, the other physical parameters viz., dopant ion concentration, interionic distance, polaron radius and molar volume etc., were evaluated by using standard relation [18] and same were presented in table 2.

Figure 2 depicts the XRD spectra of $ZnO\text{-}Sb_2O_3\text{-}B_2O_3$: V_2O_5 glasses. The XRD pattern of sample V_2 shows no sharp peaks, which suggest that the sample clearly shows amorphous nature. A broad peak at nearly about 20-30^o confirms the glassy nature of the prepared samples [19]. All the other samples were also exhibit the similar behavior.

The variations of dielectric constant and dielectric loss of $ZnO\text{-}Sb_2O_3\text{-}B_2O_3$ glasses infused with different amounts of V_2O_5 with frequency at ambient temperature were presented in Figure 3 and 4.

For pure glass sample ($ZnO\text{-}Sb_2O_3\text{-}B_2O_3$), the value of dielectric constants was 6.47 and loss tangent was 0.005 at ambient temperature (30^{o}C), at 100 kHz respectively. At a particular temperature, the dielectric constant and loss decreases with increasing frequency. At a particular temperature and frequency, the measured dielectric constant as well as tangent loss increases with increasing dopant concentration (inset of Figure 3 & Figure 4).

Table 2 – Physical parameters of $ZnO\text{-}Sb_2O_3\text{-}B_2O_3$: V_2O_5 glasses

Glass	Density d (g/cm^3)	Avg.Mol. weight($\overline{M}$)	Conc.of V^{5+} ions N_i (10^{20}/cm^3)	Inter ionic distance r_i (A^o)	Polaron radius r_p (A^o)	Molar Volume (cc/mol)
V_0	4.051	140.96	-	-	-	34.796
V_2	4.117	140.90	3.02	6.81	2.82	34.223
V_4	4.197	140.82	4.91	5.19	2.43	33.552
V_6	4.268	140.71	6.42	4.82	2.09	32.968
V_8	4.386	140.63	8.46	4.03	1.90	32.063
V_{10}	4.508	140.52	10.84	3.91	1.71	31.171

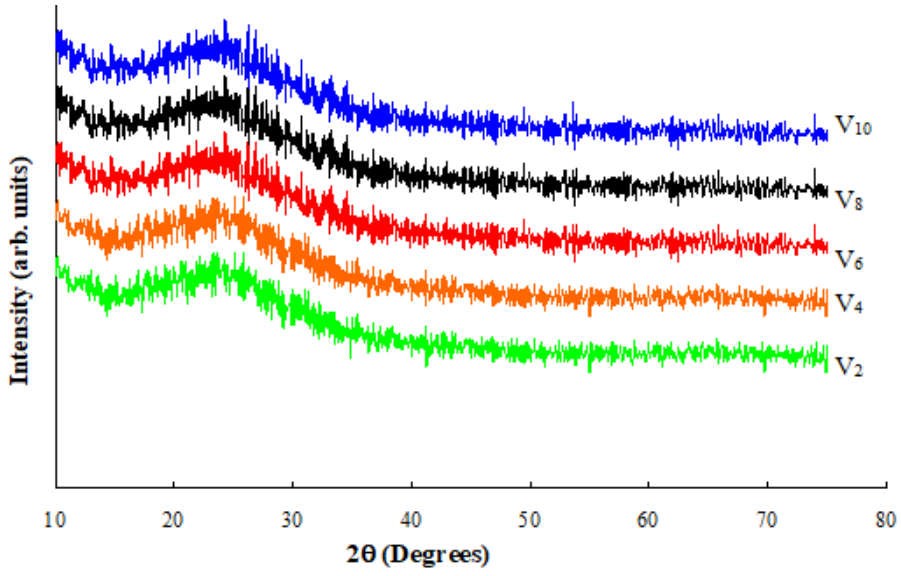

Figure 2 -XRD pattern of $ZnO\text{-}Sb_2O_3\text{-}B_2O_3$: V_2O_5 glasses

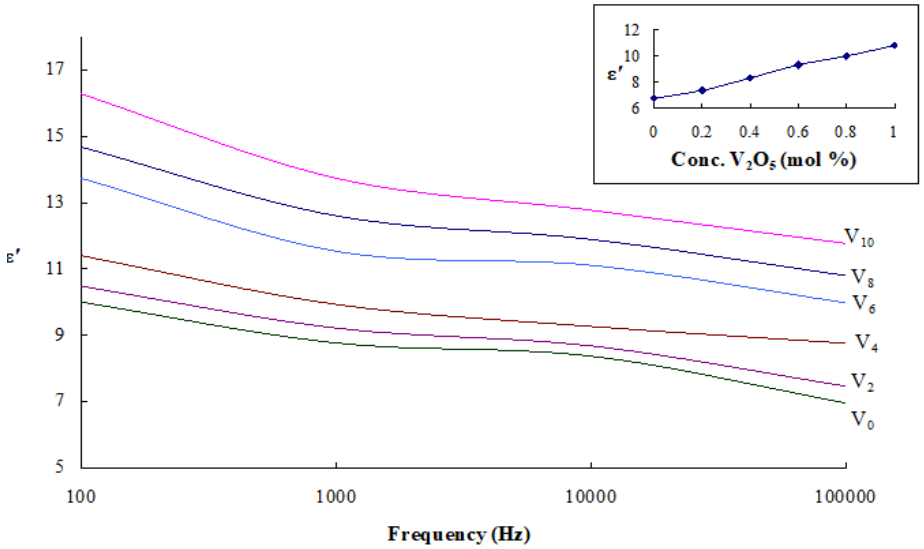

Figure 3-Variation of dielectric constant with frequency at room temperature of ZnO-Sb_2O_3-B_2O_3:V_2O_5 glasses. Inset represents the variation of ε' with the concentration of V_2O_5 at 100 kHz.

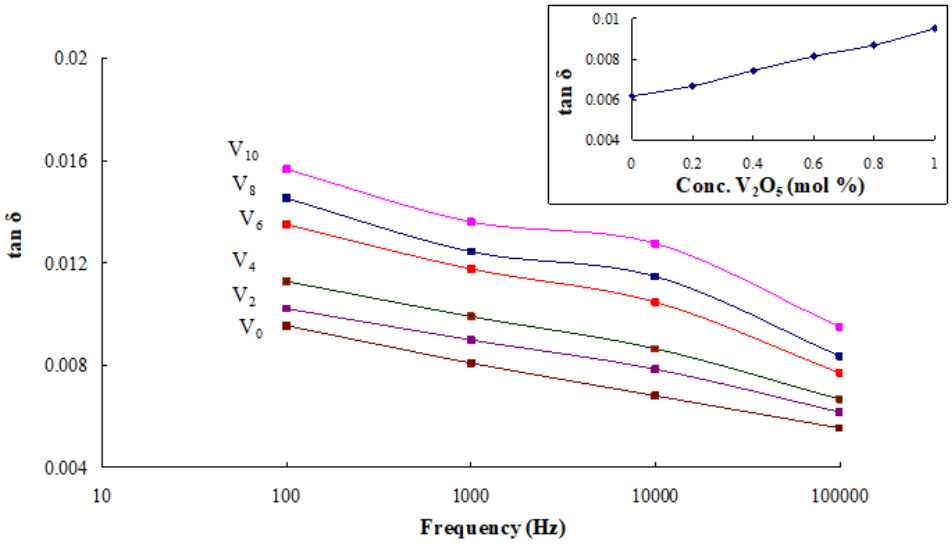

Figure 4 – Variation of dielectric loss with frequency at room temperature of ZnO-Sb_2O_3 -B_2O_3:V_2O_5 glasses. Inset represents the variation of tan δ with the concentration of V_2O_5 at 100 kHz

Figure 5 depicts the temperature sensitivity of dielectric constant at various frequencies for glass V_{10}. The value of dielectric constant is seen to grow along temperature, and this growth accelerates at low frequencies. The dependence of dielectric constant with temperature for other glasses also demonstrated the same trend.

A comparative plot of the temperature dependence at 1 kHz frequency for ZnO-Sb_2O_3-B_2O_3: V_2O_5 glasses were presented in Figure 6. The glass, doped with 1.0 mol% of V_2O_5 exhibits higher dielectric constant, maximum rate of growth of' dielectric constant with temperature.

Figure 7 displays a comparative plot of dielectric loss (tan δ) change with temperature for ZnO-Sb_2O_3-B_2O_3glasses infused with varying concentrations of V_2O_5 and recorded at 10 kHz.

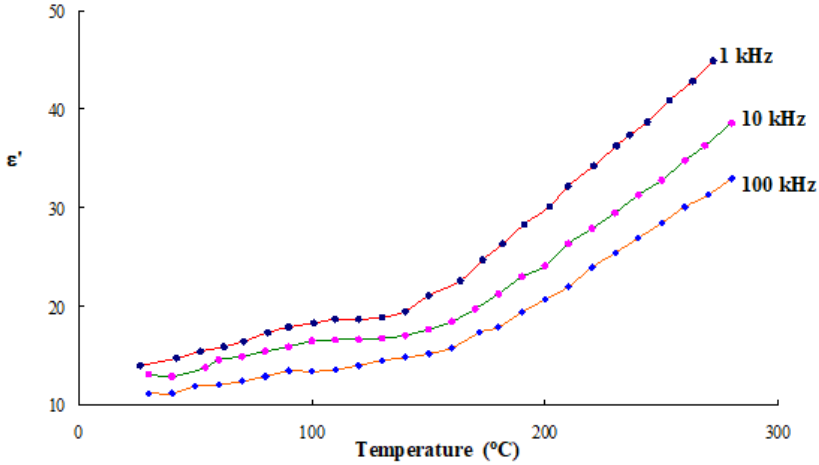

Figure 5 – Variation of dielectric constant with temperature at different frequencies of glass V_{10}

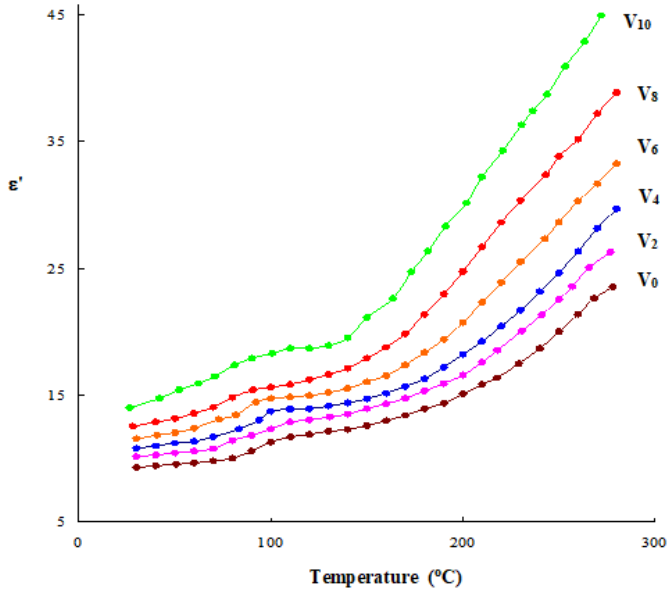

Figure 6- A comparison plot of variation of dielectric constant with temperature measured at 1 kHz for ZnO-Sb_2O_3 -B_2O_3: V_2O_5 glasses

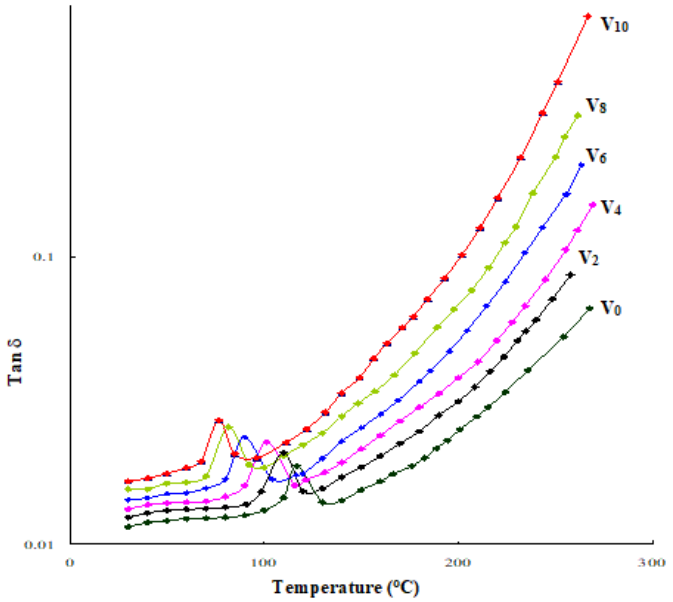

Figure 7- A comparison plot of variation of dielectric loss with temperature measured at 10 kHz for ZnO-Sb_2O_3-B_2O_3: V_2O_5 glasses

Discussion

Borate is well known glass former with possesses sp^2 planar BO_3 units and sp^3 tetrahedral BO_4 units. When Sb_2O_3, introduced in the borate glasses, Sb^{3+} ions exist as SbO_3 pyramids due covalent character of Sb-O bonds [20, 21]. In borate glass network, these SbO_3 units mainly act as a network former, through the formation of Sb-O-B bonds, BO_3 units are replaces the BO_4 units [22-25].

ZnO is, in general, a glass modifier and enters the glass network by breaking up the B-O-B, Sb-O-B linkages forms B-O-Zn [26]. However, ZnO may also acts as the glass network with ZnO_4 structural units [27]. Hence, ZnO-Sb_2O_3-B_2O_3:V_2O_5 glass community is an admixture of network formers, intermediate glass formers, and modifiers, however, the behavior of the ZnO and Sb_2O_3 strongly dependent on the composition of the glass samples.

With the addition of classic modifier oxide like V_2O_5 to the ZnO-Sb_2O_3-B_2O_3 glass community, the oxygens of such oxides typically, violate the local symmetry while cations occupies interstitial places by rupturing B-O-B, Sb-O-B and Zn-O-B links.

By comparing the pertained physical parameters data presented in Table 2, it has been observed that the density of glass increases from 4.051 to 4.508 g/cm^3 and molar volume decreases from 34.796 to 31.171 cc/mol.Such changes have been expected due to the replacement of heavy metal oxide Sb_2O_3 with molecular weight 291.52 gm/mol by the V_2O_5 with molecular weight 181.88 gm/mol. The decrease in inter ionic distance; polaron radius and molar volume suggest that the ions in the samples becomes much closer with increasing the concentration of V_2O_5.

By recollecting the data of dielectric characteristics like dielectric constant and tangent loss of present studied ZnO-Sb_2O_3-B_2O_3: V_2O_5 glasses clearly point out, a slow increase of dielectric characteristics up to 1.0 mol% of V_2O_5 (Inset of figures 3 and 4). This behavior of the glasses can be understood as follows, the vanadium ions in the present glass network, are anticipated to primarily occur in V^{5+} state along with the V^{4+} state. However, there is a good chance that the following equilibrium could occur when the glasses melt at greater temperatures. These results anticipated the possibility of taking place redox equilibrium between the V^{5+} and V^{4+} state by following equation (1)

$$2\,V^{5+} + O^{2-} \rightleftharpoons 2V^{4+} + \frac{1}{2}O_2 \uparrow \text{---} \qquad (1)$$

The V^{4+} ions create VO^{2+} complexes, which may function as modifiers and distort the network of glass, whereas the V^{5+} ions form locations with VO_5 trigonal bipyramidal structural units. Vanadium ions typically reside in the V^{4+} state and occupy modifying sites with rise of V_2O_5 up to 1.0 mol%. Such an increase ostensibly indicates a serious degree of disarray in the glass V_{10} network, in another words,

[28, 29] the vanadium ions are becoming more prevalent and actively taking the part of modifications of network with V_2O_5.

It is well known that, the polarizability in an insulating material is due to the contribution of four types of polarizations viz., electronic, ionic, dipolar, and space charge polarisation. Among these first one is due to electric stain and rapid process, second one is due to displacements of ions from their equilibrium positons, slower than the first one, third one is due to alignment of dipoles towards the external electric field, takes more time than the first two, whereas last one is due to migration of ions towards the opposite polarity electrodes, slowest process among four. From Figure 3 and 4, the frequency dependency of dielectric constant and dielectric loss at a room temperature shows that higher value of ε' and tanδ at lower frequency strongly confirms the contribution of space charge polarization in the glass samples.

In ZnO-Sb_2O_3-B_2O_3 glass (base sample), the dielectric loss (Tanδ) varies with temperature at any frequency exhibits a distinct peak at about 100°c suggesting dipolar relaxation of dielectric loss in the samples. With the introduction of V_2O_5 in the glass matric, the intensity and half width of these relaxation peaks increases and shift towards lower temperature. Similar results observed with increasing the concentration of V_2O_5 in glass matrix. Traditionally, the dielectric relaxations are described at a stable temperature using a variable frequency. V^{4+} ions are responsible for the relaxation effects seen in the current glass samples.Vanadium ions may predominately present in V^{4+} sate get involved with glass altering positions as evidenced by expansion of breadth and depth of relaxation peaks and the lowering of activation energy in the samples from V_2 to V_{10}. Regarding different concentrations of V_2O_5, Using these graphs, the effective activation energy (W_d) for the dipoles is computed using relation (2)

$$f = f_0 e^{\left(-W_d/KT\right)} \text{ ---} \quad (2)$$

Activation energy (W_d) for the dipoles is reported in Table 3 along with other significant information on dielectric loss. Glass V_{10} is reported to posses lowest activation energy, which supports the V^{4+} due to the VO^{2+} behaves as modifier in the glass network.

Table 3 – Data on dielectric loss and Activation energy of ZnO-Sb_2O_3 -B_2O_3: V_2O_5 glasses

Glass	Temp (°C)	Dielectric loss			A.E for dipoles(eV)
		1kHz	10kHz	100kHz	
V_0	30	0.008	0.007	0.005	
	100	0.009	0.008	0.006	2.8
	250	0.045	0.030	0.027	
V_2	30	0.009	0.007	0.006	
	100	0.011	0.010	0.007	2.65
	250	0.050	0.035	0.030	
V_4	30	0.011	0.010	0.007	
	100	0.014	0.011	0.009	2.54
	250	0.080	0.045	0.040	
V_6	30	0.013	0.014	0.009	
	100	0.016	0.013	0.011	2.31
	250	0.095	0.080	0.069	
V_8	30	0.014	0.010	0.009	
	100	0.018	0.015	0.012	2.20
	250	0.139	0.124	0.110	
V_{10}	30	0.015	0.012	0.011	
	100	0.020	0.018	0.015	2.08
	250	0.247	0.228	0.210	

The ac conductivity σac is calculated at different temperature by using relation (3).

$$\sigma_{ac} = \omega\varepsilon_o\varepsilon tan\delta \text{---} \quad (3)$$

Where, ε_o is the vacuum dielectric constant at 100 kHz frequency. Figure 8 shows the variation of log σ_{ac} against 1/T for glasses containing different concentration of V_2O_5 (measured at 100 kHz). The activation energy for conduction evaluates in the region of high temperatures (where it was possible to observe a nearly linear dependency of log σ_{ac} with 1/T) based on these graphs and presented in Table 4; the activation energy is decrease linearly with conductivity; it is shown the lowest possible for the glass V_{10} (inset (a) of Figure. 8).

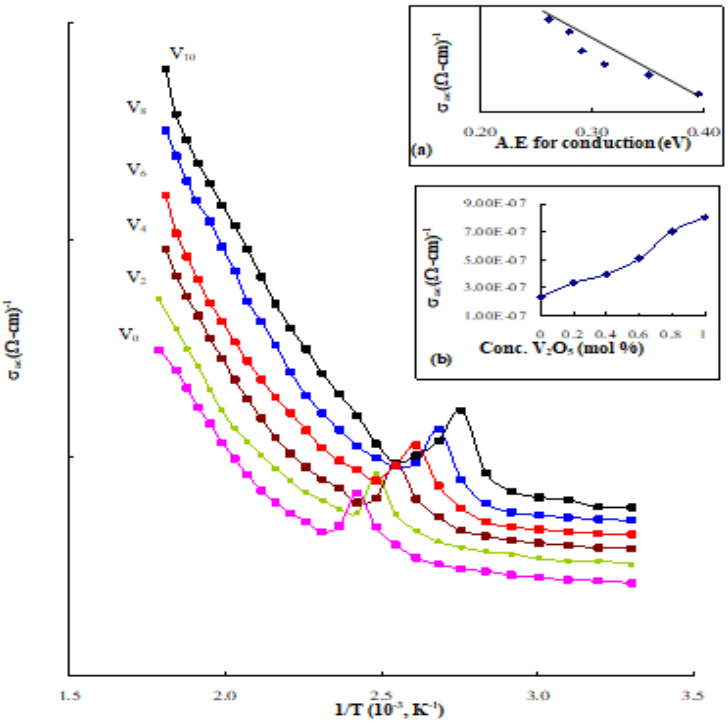

Figure 8 –Variation of ac conductivity with 1/T measured at 100 kHz for ZnO-Sb_2O_3-B_2O_3 glasses doped with different concentrations of V_2O_5. Inset a) represents variation of ac conductivity with activation energy, b) represents variation of ac conductivity with concentration of V_2O_5.

Table 4 – Summary of data on ac conductivity of ZnO-Sb_2O_3-B_2O_3: V_2O_5 glasses

Glass	N(E_f) in 10^{21} eV^{-1}/cm^3			AE for conduction (eV)
	Austin Butcher Pollack			
V_0	0.848	0.410	1.007	0.395
V_2	1.259	0.525	1.278	0.351
V_4	1.310	0.609	1.370	0.324
V_6	1.561	0.641	1.484	0.286
V_8	1.718	0.716	1.745	0.269
V_{10}	1.907	0.813	1.891	0.240

A connection that is almost linear is seen when log σ_{ac} is depicted on a graph as a function of the activation energy for conduction (Figure 8). This finding demonstrates increased conductivity is directly owing to charge carriers thermally enhanced mobility in the high temperature zone [30]. At x = 1.0 mol%, the conductivity curve with respect toV_2O_5 concentration reaches its maximum (Figure 8). The energy of activation for conduction showed a minimum at x = 1.0 mol% (inset of Fig. 8). These data point to a change in \ conductivity (from 0 to 1.0 mol% of V_2O_5) from largely electronic to primarily ionic [31].The ionic conductions active centers, the non-bridging oxygen molecules, the ion modifier contents, and the ionic transport all gradually increase. The low temperature component of conductivity, which is taking part in the progression of switching from $V^{5+} \Leftrightarrow V^{4+}$, can be interpreted using a quantum mechanical model [32]. It is discovered that the value of N (E_F) calculated by using standard equation (4)[33],

$$\sigma(\omega) = \lambda e^2 K_B T[N(E_F)]^2(\alpha')^{-5}\omega\left(ln\left({}^{\nu_{ph}}/_{\omega}\right)\right)^4 \text{ --- (4)}$$

Where $\lambda=\pi/3$ for Austin, $\lambda=3.66$ ($\pi^2/6$) for Butcher and $\lambda=\pi^4/96$ for Pollack, whereas the symbols N (E_F), σ, ω, e, K_B, ν_{ph} ($\sim 0.5 Å^{-1}$), T having standard meanings. The value of N (E_F) rises with rising V_2O_5 concentration up to 1.0 mol%, such changes are in line with past claims that vanadium ions predominately occur in the V^{4+} state and serve as modifiers in the samples.

Conclusions

In conclusion, $ZnO\text{-}Sb_2O_3\text{-}B_2O_3\text{:}V_2O_5$ glasses were prepared by systematic replacement of Sb_2O_3 with V_2O_5 0.1 to 1.0 mol%. In relation to V_2O_5 concentration, various electric and dielectric properties were measured and presented systematically. The perceived rise in dielectric constant (ε) and dielectric loss (tan δ) according to frequency and temperature, were explained contribution of space charge polarization in the glass sample and confirms the existence of equilibrium between $V^{5+} \Leftrightarrow V^{4+}$ ions in glass matrix. V^{4+} ions acts as a modifier in the glass samples. Among the studied glass samples, the glass with 1.0 mol% of V_2O_5 possess maximum ac conductivity, minimum activation energy for conductivity. Hence, V_{10} glass is better suited to accomplishing the desired electric conductivity in those glasses and these glasses have been used as electrode glass, optical amplifiers. This has been further confirmed with help of other studies like spectroscopic and non-linear optics.

References

1. Mott, Nevill Francis, and Edward A. Davis. *Electronic processes in non-crystalline materials*. Oxford university press, 2012.
2. Giuntini, J. C., D. Jullien, J. V. Zanchetta, F. Carmona, and P. Delhaes. "Electrical conductivity of low-temperature carbons as a function of frequency." *Journal of Non-Crystalline Solids* 30, no. 1 (1978): 87-98.
3. Elliott, S. R. "Defect pairing and the effect on AC conductivity in chalocogenide glasses." *Journal of Non-Crystalline Solids* 35 (1980): 855-858.
4. Doremus, R.H. Glass Science. NewYork: John Wiley & sons inc., 1994.
5. Kawamura, J., and M. Shimoji. "The AC conductivity of superionic conducting glasses $(AgI)_x–(Ag_4P_2O_7)_{1-x}$ (x= 0.8, 0.75, 0.7): Experiment and analysis based on the generalized Langevin equation." *Journal of non-crystalline solids* 79, no. 3 (1986): 367-381.
6. Dyre, Jeppe C. "A simple model of ac hopping conductivity in disordered solids." *Physics Letters A* 108, no. 9 (1985): 457-461.
7. Abelard, Pierre, and Jean François Baumard. "Dielectric relaxation in alkali silicate glasses: A new intepretation." *Solid state ionics* 14, no. 1 (1984): 61-65.
8. Ishii, Tadao. "Theory of classical hopping conduction: some general properties." *Progress of theoretical physics* 73, no. 5 (1985): 1084-1097.
9. Youngman, R. E., S. T. Haubrich, J. W. Zwanziger, M. T. Janicke, and B. F. Chmelka. "Short-and intermediate-range structural ordering in glassy boron oxide." *Science* 269, no. 5229 (1995): 1416-1420.
10. Youngman, R. E., and J. W. Zwanziger. "Multiple boron sites in borate glass detected with dynamic angle spinning nuclear magnetic resonance." *Journal of non-crystalline solids* 168, no. 3 (1994): 293-297.
11. Konijnendijk, Wo L., and J_M_ Stevels. "The structure of borate glasses studied by Raman scattering." *Journal of Non-Crystalline Solids* 18, no. 3 (1975): 307-331.
12. Marzouk, Samir Y., and Fatma H. Elbatal. "Infrared and UV–visible spectroscopic studies of gamma-irradiated Sb2O3–B2O3 glasses." *Journal of Molecular Structure* 1063 (2014): 328-335.

13. Holland, D., A. C. Hannon, M. E. Smith, C. E. Johnson, M. F. Thomas, and A. M. Beesley. «The role of Sb5+ in the structure of Sb2O3–B2O3 binary glasses—an NMR and Mössbauer spectroscopy study.» *Solid State Nuclear Magnetic Resonance* 26, no. 3-4 (2004): 172-179.

14. Imaoka, M., H. Hasegawa, and S. Shindo. "Properties and Structure of Glasses of B_2O_3–B_2O_3 System." *J. Ceram. Soc. Jpn.* 77, no. 8 (1969): 263-271.

15. Wood, Justin G., S. Prabakar, Karl T. Mueller, and Carlo G. Pantano. "The effects of antimony oxide on the structure of alkaline-earth alumino borosilicate glasses." *Journal of non-crystalline solids* 349 (2004): 276-284.

16. Soraya, M. M., Fatma BM Ahmed, and M. M. Mahasen. "Enhancing the physical, optical and shielding properties for ternary Sb_2O_3–B_2O_3–K_2O glasses." *Journal of Materials Science: Materials in Electronics* 33, no. 28 (2022): 22077-22091.

17. Narasimha Rao,N., Raghava Rao,P., Swamy, B.J.R.S.N., Chitti Babu, A., Sambasiva rao,T., Ramesh Babu, N.Ch.»The Influence of Vanadium Ions in Spectral Properties of ZnO–Sb_2O_3–B_2O_3 glasses."*International Journal for Modern Trends in Science and Technology.* 6 **(**2020): 201-207.

18. Naresh, P., SK Fakrudddin Babavali, A. Chitti Babu, P. Raghava Rao, and N. Narasimha Rao. "Optical studies of chromium doped zinc oxy fluoro borate glasses–A possible disordered material for tunable LASERS." *Materials Today: Proceedings* 46 (2021): 806-810.

19. Rao, L. Srinivasa, V. Ravi Kumar, P. Naresh, P. Venkateswara Rao, and N. Veeraiah. «Optical absorption and photoluminescence properties of anadium ions in 'lithium-tungsten-borate'oxide glasses.» *Materials Today: Proceedings* 5, no. 13 (2018): 26290-26297.

20. Mochida, N., and K. Takahashi. «Properties and structure of glasses in the systems MO3/2. BO3/2 (M: As, Sb, Bi)." *J. Ceram. Soc. Jpn.* 84 (1976): 413-420.

21. Marzouk, Samir Y., and Fatma H, Elbatal. «Infrared and UV–visible spectroscopic studies of gamma-irradiated Sb_2O_3–B_2O_3 glasses." *Journal of Molecular Structure* 1063 (2014): 328-335.

22. Dubois, B., J. J. Videau, M. Couzi, and J. Portier. «Structural approach of the ($xPbC_{l2}$−(1− x) Sb_2O_3) glass system." *Journal of non-crystalline solids* 88, no. 2-3 (1986): 355-365.

23. Miller, Philip J., and Charles A. Cody. «Infrared and Raman investigation of vitreous antimony trioxide.» *Spectrochimica Acta Part A: Molecular Spectroscopy* 38, no. 5 (1982): 555-559.

24. Raghavaiah, B. V., and N. Veeraiah. «The improved glass□forming ability and some physical properties of PbO–Sb_2O_3: Cr_2O3 glasses with As_2O_3 as additive." *physica status solidi (a)* 199, no. 3 (2003): 389-402.

25. Raghavaiah, B. V., C. Laxmi Kanth, D. Krishna Rao, J. Lakshman Rao, and N. Veeraiah. "Optical and magnetic properties of PbO–Sb_2O_3–As_2O_3 glasses containing vanadium ions." *Materials Letters* 59, no. 5 (2005): 539-545.

26. Azooz, M. A., and H. A. ElBatal. «Preparation and characterization of invert ZnO–B_2O_3 glasses and its shielding behavior towards gamma irradiation." *Materials Chemistry and Physics.* 240 (2020): 122129.

27. Colak, S., Cetinkaya, I., Akyuz, and F. E. R. H. U. N. D. E. Atay. «On the dual role of ZnO in zinc-borate glasses.» *Journal of Non-Crystalline Solids.* 432 (2016): 406-412.

28. Abdelouhab, R. M., R. Braunstein, and K. Baerner. «Identification of tungstate complexes in lithium-tungstate-borate glasses by Raman spectroscopy.» *Journal of non-crystalline solids* 108, no. 1 (1989): 109-114.

29. Rao, L. Srinivasa, M. Srinivasa Reddy, D. Krishna Rao, and N. Veeraiah. «Influence of redox behavior of copper ions on dielectric and spectroscopic properties of Li2O–MoO3–B2O3: CuO glass system.» *Solid State Sciences* 11, no. 2 (2009): 578-587.

30. El-Damrawi, G. «$PbCl_2$ conducting glasses with mixed glass formers." *Journal of Physics: Condensed Matter* 7, no. 8 (1995): 1557.

31. Montani, R.A., Frechero, M.A." The conductive behavior of silver vanadium–molybdenum tellurite glasses."*Solid State Ionics.* 158(2003):327-332.

32. Austin, I. G., and N. Fr Mott. «Polarons in crystalline and non-crystalline materials.» *Advances in physics* 18, no. 71 (1969): 41-102.

33. Naresh, P., N. Narasimha Rao, P. Raghava Rao, B. J. R. S. N. Swamy, A. Chitti Babu, and B. Suresh. «Dielectric features of ZnO− CaF_2− R_2O (R= Li, Na & K)− B_2O_3: CuO glasses." *Materials Today: Proceedings* 92 (2023): 1563-1567.

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Received 07 December 2023
Accepted 31 May 2024