Elastic, thermoluminescence and dielectric characterization of lead antimony silicate glass composites doped by small concentrations of Cr_2O_3

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Abstract. A series of glass composites $[(\text{Sb}_2\text{O}_3)_{0.05}(\text{SiO}_2)_{0.65}] - [(\text{PbO})_{(0.3-x)} : (\text{Cr}_2\text{O}_3)_x]$ ($0 \leq x \leq 0.01$ mol%) were synthesized. Elastic, thermoluminescence, direct current (dc) conductivity and dielectric characteristics of these glass composite materials were studied. The investigations on these glass composites have indicated that the chromium ions exhibit two different oxidation states, such as Cr^{3+} and Cr^{6+} . The variation in poison ratio (σ) with micro-hardness (H) plots suggests that the glass composites were prepared with a strongly and covalently connected internal structure. The observed thermoluminescence output increased with an increase in the dose of UV-irradiation. The observed peak positions of these thermoluminescent curves were shifted towards higher temperature regions. The enhanced thermoluminescence output results even recommended that both e^- and h^+ trap centres were created at the deeper trap levels and contribute to thermoluminescence emissions at higher temperatures. The dc conductivity (σ_{dc}) and activation energy evaluations are also observed. Dielectric parameters such as density of energy states $N(E_f)$, temperature region of relaxation and loss tangent ($\tan \delta$) were calculated. The linear relationship between variation in alternating current conductivity (σ_{ac}) and activation energy suggests that good amounts of polaron hopping with an increase in Cr_2O_3 concentration in these materials were observed. The grades of loss tangent and the number of energy states near the Fermi level suggest that the materials prepared are highly useful in dielectrics.

Keywords. Elastic studies; micro-hardness; thermoluminescence; trap depth parameters; dc conductivity; temperature region of dielectric relaxation.

1. Introduction

Trivial dilutions of Cr_2O_3 mixed with antimony lead silicate glass composites are durable in thermal stability and exhibit high elastic limit as well as are exceptionally favourable materials as corrosion-resistive composites in many industrial and medical applications [1]. Sb_2O_3 added lead silicate glass materials exhibit almost similar chemical durability and micro-hardness like all other classical boro-silicate and phospho-silicate glass composites. These glass composites highly preferred in the area of thermostatics due to their high-chemical, thermal and mechanical resistance. Various previous studies (elastic, thermoluminescence and dielectric) on pure lead silicate glass composites reveal their credibility and necessity in the field of integrated thermoluminescence dielectric applications. The addition of PbO to these lead silicate glasses stimulates the large number of Pb-O-Si linkages and makes these glasses into chemically more inert and electrically more resistant. The addition of antimony oxide to these lead silicate glass composites enhances the translucence and refractive index [2]. Generally, magnitudes of an electron-phonon interaction between metal ions and the host glass composites induce higher grades of molar

volume and structural micro-hardness. Due to these reasons, the nucleation agent Cr_2O_3 has chosen to enhance the mechanical dielectric characteristics of antimony lead silicate glass composites [3]. The chemical endurance and different elastic modulus grades of these antimony lead silicate glass composites of chromium ions that exhibit various valence states were most useful as cathode resource materials. Small magnitude chromium oxide and lead silicate composites exhibit significant variations in chromaticity and thermoluminescence characteristics [4]. The chromium ions existing in different oxidation states, such as Cr^{3+} and Cr^{6+} were the reasons for variation in the colour of these glass composites. Generally, chromium oxide glass composites (partially alloyed) powders were most useful and durable as surface coating composite materials because of their rich hardness and non-corrosion characteristics [5]. In view of their industrial outcomes, especially in thermoluminescence dielectric resources, there has been a lot of investigation on glass composites of Cr_2O_3 . The reinforcing impact of growing stable metal oxides at the grain limits and durable corrosion barrier grades will make these chromium ions an important crystallizing material for all kinds of novel glass composites and glass ceramics [6]. Sb_2O_3 mixed lead silicate glass

composite materials are known for their high density and refractive index. Due to such interesting characteristics, these glass materials find different applications in non-linear optical devices, such as optical windows and elastic sensors. In this direction, chromium oxide-doped lead silicate glass materials have a crucial demand for the enhancement of appropriate materials for opto-electronic device applications [7–9]. To achieve higher thermoluminescence and to develop highly efficient dielectric resources for present investigation, we have chosen chemical composition of $[(\text{Sb}_2\text{O}_3)_{0.05}(\text{SiO}_2)_{0.65}] - [(\text{PbO})_{(0.3-x)}:(\text{Cr}_2\text{O}_3)_x]$ ($0 \leq x \leq 0.01$) to study the influence of PbO and Cr_2O_3 on the structural change in Sb_2O_3 and SiO_2 units and to develop various thermoluminescence dielectric device applications.

2. Experimental

The chemical composition of $[(\text{Sb}_2\text{O}_3)_{0.05}(\text{SiO}_2)_{0.65}] - [(\text{PbO})_{(0.3-x)}:(\text{Cr}_2\text{O}_3)_x]$ ($0 \leq x \leq 0.01$) was selected in the present synthesis of samples. These samples were made by an anticipated melt quenching technique. The quantified chemical composition is given as follows:

Suitable chemical powders, such as Cr_2O_3 , Sb_2O_3 , SiO_2 and PbO (all in mol%) have been chosen to bring about growth of the glass composite samples. Furthermore, these powders were mixed well in a dimensionally appropriate agate mortar. The finely mixed powder of these chemicals has been placed in a thick-walled platinum crucible for quenching in a programmed furnace. The temperature range of 1200–1225°C is maintained in the programmed furnace containing the mixed powder in a chosen crucible results in a bubble-free free transparent melt. Furthermore, the prepared melt was annealed at 300°C in a muffle furnace. The samples prepared were further dimensionally shaped into a length of 1 cm, breadth of 1 cm and thickness of 0.2 cm and optically polished for various physical, mechanical, thermoluminescence and dielectric characterizations. XRD-7000 (Shimadzu) was used to approve the different glassy phases of the glass materials. S-3700N (Hitachi) was used to record the scanning electron microscopy (SEM) images of the prepared glass materials. A Keithley 6514 Electrometer was used to carry out direct current (dc) conductivity measurements. Various instruments, such as an Ohaus digital balance of resolution (0.0001 g), ultrasonic Piezoelectric crystal oscillator, Nucleonix thermoluminescence reader, ambient temperature of 300°C with a linear heating rate of 5°C s⁻¹ and Hewlett-Packard 4263 B

LCR meter were used to characterize physical, mechanical, thermoluminescence and dielectric characterizations.

3. Results and discussion

3.1 Physical and mechanical studies

The observed X-ray diffraction patterns of all these glass samples exhibit no sharp peaks and the prepared samples are amorphous in nature. The surface micrographs (SEM) of these glass samples were expressed well in plain allocated non-crystalline regions. The density (ρ) evolution of these glass materials was carried out by the Archimedes principle by using *O*-xylene as the buoyant fluid. The observed ρ values of the present glass materials decrease with an increase in the concentration of Cr_2O_3 . Whereas the quantity calculated molar volume (V_m) follows the reverse trend. The other physical parameters, such as interionic distance (r_i) and polaron radius (r_p) decrease with an increase in Cr_2O_3 concentration. Contrarily, the calculated ion concentration (N_i) and field strength (F_i) were increased. It was found that the values of the refractive index (μ) of the present glass materials are decreased with an increase in Cr_2O_3 concentration. The ultrasonic velocities V_L (longitudinal) and V_s (shear) were recorded at room temperature greatly depending on material density. By using these ultrasonic velocity components, various elastic quantities, such as Young's, shear, bulk moduli, Poisson ratio and micro-hardness of these antimony lead silicate glass composite materials were evaluated. The observed grades of Young's, shear, bulk moduli and micro-hardness were increased with an increase in Cr_2O_3 concentration, whereas the Poisson ratio grades were decreased with an increase in Cr_2O_3 content. The following equalities are used to calculate Polaron radius (R_p), longitudinal elastic coefficient (L), shear modulus (η), Young's modulus (Y), Poisson's ratio (σ) and micro-hardness (H) parameters [10–13]:

$$R_p = 1/2\{\pi/(6N_i)\}^{1/3}, \quad (1)$$

$$L = \rho v_l^2, \quad (2)$$

$$\eta = \rho v_s^2, \quad (3)$$

$$Y = (1 + \sigma)2, \quad (4)$$

$$\sigma = (L - 2\eta)/2(L - \eta), \quad (5)$$

$$H = Y(1 - 2\sigma)/6(1 + \sigma), \quad (6)$$

where ρ is the density, V_l is the longitudinal velocity and V_s is the shear velocity.

The observed grades of all these elastic quantities with an increase in Cr_2O_3 concentration of the present glass composite materials are represented in figure 1. All observed grades of different physical and elastic parameters are represented in table 1. The variation in degree of compactness, the dimensions of the micro-crystals produced, variation in

Figure 1. Elastic properties of Cr_2O_3 -doped $[(\text{Sb}_2\text{O}_3)_{0.05}(\text{SiO}_2)_{0.65}]-[(\text{PbO})_{(0.3-x)}:(\text{Cr}_2\text{O}_3)_x]$ ($0 \leq x \leq 0.01$) glass materials. (a) Shows the variation of density, (b) shows the variation of Young's modulus, (c) shows the variation of shear modulus, (d) shows the variation of bulk modulus, (e) shows the variation of the Poisson ratio and (f) shows the variation of micro-hardness with concentration of Cr_2O_3 .

Table 1. Summary on physical and elastic properties of $[(\text{Sb}_2\text{O}_3)_{0.05}(\text{SiO}_2)_{0.65}]-[(\text{PbO})_{(0.3-x)}:(\text{Cr}_2\text{O}_3)_x]$ ($0 \leq x \leq 0.01$) glass materials.

Glass	Cr_0	Cr_2	Cr_4	Cr_6	Cr_8	Cr_{10}
Density (g cm^{-3})	2.8535	2.8513	2.8495	2.8479	2.8465	2.8455
Polaron radius (r_p) ($\text{\AA}$)	—	5.61	4.45	3.898	3.545	3.294
Refractive index (μ)	1.715	1.705	1.701	1.697	1.693	1.685
Y (Gpa)	29.069	29.204	29.535	29.69	29.79	29.95
G (Gpa)	13.4	13.53	13.76	13.88	13.96	14.062
K (Gpa)	11.66	11.55	11.49	11.46	11.47	11.49
σ	0.0846	0.0785	0.0727	0.0694	0.0668	0.0649
Y (Gpa)	29.069	29.204	29.535	29.69	29.79	29.95

the coordination of glass growing ions and the instabilities in the dimensions of the interstitial holes are some of the aspects that influence the density of the present glass materials. The observed grades of density and molar volume of the present antimony lead silicate glass composite materials were quite reversely varied with an increase in Cr_2O_3 content. Generally, under glass transition, all glass composite materials act as perfect elastic bodies. Different elastic moduli, such as Young's, shear and bulk were generally function as inter-atomic forces and nature of bonds involved in these glass composite materials. In numerous glass composites, the elastic modulus greatly depends on the atomic packing density and molar volume. The indistinguishable was also conveyed in the existing analysis of investigation. With an increase in Cr_2O_3 concentration, the natural linkages, such as Si-O-Si and Sb-O-Sb were substituted by a tougher Si-O-Cr (or) Pb-O-Cr linkages. The substitute of divalent Pb^{4+} ions by Cr^{3+}

ions leads to an increase in various elastic moduli in these glass composite materials with an increase in Cr_2O_3 concentration. The improvement grades of packing density with Cr_2O_3 content can be recognized by acquisitive rigidity in these glass composite materials which led to an increase in the different elastic moduli [14,15]. The quantities of Poisson's ratio and micro-hardness grades of these glass composites suggest that the prepared glass composites were exhibited an interconnected covalent structure.

3.2 Thermoluminescence studies

Figure 2 represents the thermoluminescence spectra of a series of $[(\text{Sb}_2\text{O}_3)_{0.05}(\text{SiO}_2)_{0.65}]-[(\text{PbO})_{(0.3-x)}:(\text{Cr}_2\text{O}_3)_x]$ ($0 \leq x \leq 0.01$) glass materials recorded at room temperature of 300°C under 0–15 min of UV-irradiation. These series of glass samples exhibited different intensities of TL glow curves under

Table 2. Summary on thermoluminescence of $[(\text{Sb}_2\text{O}_3)_{0.05}(\text{SiO}_2)_{0.65}] - [(\text{PbO})_{(0.3-x)}:(\text{Cr}_2\text{O}_3)_x]$ ($0 \leq x \leq 0.01$) glass materials recorded at room temperature.

UV dose	Glass	T_m (K)	τ (K)	δ (K)	ω (K)	u	E_τ (eV)	E_δ (eV)	E_ω (eV)
Under 5 min of UV irradiation	Cr ₂	478.3	14.8	16.7	34	0.563	2.411	2.117	2.253
	Cr ₄	480	17.2	22.4	41	0.574	2.035	1.770	1.893
	Cr ₆	482.8	24.4	25.2	52	0.563	1.216	1.200	1.213
	Cr ₈	487.2	34.3	34.8	67	0.487	0.802	0.851	0.830
	Cr ₁₀	484.6	29.8	30.4	55	0.478	1.157	0.988	0.978
Under 10 min of UV irradiation	Cr ₂	486.1	16.7	14.9	32	0.443	1.869	1.834	1.869
	Cr ₄	488.6	21.2	21.4	42	0.453	1.370	1.377	1.384
	Cr ₆	491.8	27.4	25.2	53	0.475	1.008	1.049	1.035
	Cr ₈	496.1	37.5	35.9	75	0.494	0.734	0.798	0.770
	Cr ₁₀	493.9	30.9	38.1	58	0.469	1.045	0.900	0.878
Under 15 min of UV irradiation	Cr ₂	491.7	14.7	16.3	35	0.518	1.332	1.127	1.270
	Cr ₄	493.3	21.3	21.7	43	0.514	1.163	1.168	1.176
	Cr ₆	496.4	25.4	25.6	53	0.492	0.824	0.838	0.836
	Cr ₈	501.3	36.3	36.7	76	0.499	0.610	0.677	0.634
	Cr ₁₀	497.7	32.7	35.3	66	0.514	0.648	0.741	0.746

Figure 2. Thermoluminescence of $[(\text{Sb}_2\text{O}_3)_{0.05}(\text{SiO}_2)_{0.65}] - [(\text{PbO})_{(0.3-x)}:(\text{Cr}_2\text{O}_3)_x]$ ($0 \leq x \leq 0.01$) glass materials under 0–15 min of UV-irradiation.

0–15 min of UV-irradiation. The observed peak intensities of all these samples with an increase in Cr_2O_3 concentration and UV exposure, increased. Once the prepared glass composite materials were subjected to temperature around 300°C , a minute magnitude of electrons would cause thermionic emission. In higher temperature regions, these induced electrons in these materials further added up with inherent D^+ defects resulting in high-intensification of thermoluminescence emission. With a gradual increase of UV exposure, the thermoluminescence light output under a dosimetric peak increased considerably and the peak was shifted towards slightly higher temperature. The comparison indicated an increase in the thermoluminescence emission of the highest intensity peak with the shifting of peak positions towards higher temperature with the change in different concentrations

of Cr_2O_3 . The values of trap depth parameters associated with the dosimetric peaks corresponding to all these series of glass materials of different Cr_2O_3 concentrations are computed by using conventional formulae and are presented in table 2. The following expressions are used to calculate various trap depth parameters of the present series of glass materials [16–18].

$$E_\tau = C_\tau [KT_m^2/\tau] - b_\tau [2KT_m], \quad (7)$$

$$E_\delta = C_\delta [KT_m^2/\delta] - b_\delta [2KT_m], \quad (8)$$

$$E_\omega = C_\omega [KT_m^2/\omega] - b_\omega [2KT_m], \quad (9)$$

where

$$\tau = T_m - T_1, \delta = T_2 - T_m \text{ and } \omega = T_2 - T_1.$$

$$C_\tau = 1.510 + 3(\mu - 0.42),$$

$$C_\delta = 0.976 + 7.3(\mu - 0.42),$$

$$C_\omega = 2.52 + 10.2(\mu - 0.42),$$

$$b_\tau = 1.510 + 3(\mu - 0.42), \quad b_\delta = 0 \text{ and } b_\omega = 1,$$

$$\mu = \delta/\omega.$$

T_m – peak temperature maximum,

T_1 – lower side temperature at half intensity,

T_2 – higher side temperature at half intensity,

μ – geometrical shape of symmetry factor.

Thermoluminescence on all these UV by irradiated $[(\text{Sb}_2\text{O}_3)_{0.05}(\text{SiO}_2)_{0.65}] - [(\text{PbO})_{(0.3-x)}:(\text{Cr}_2\text{O}_3)_x]$ ($0 \leq x \leq 0.01$) glass materials are studied. The observed sample (Ni_5) of a series of the present glass materials exhibits enhanced thermoluminescence emission under 0–15 min of UV-irradiation. The present glass materials were heated up

Figure 3. Variation of dc conductivity of $[(\text{Sb}_2\text{O}_3)_{0.05}(\text{SiO}_2)_{0.65}] - [(\text{PbO})_{(0.3-x)}:(\text{Cr}_2\text{O}_3)_x]$ ($0 \leq x \leq 0.01$) glass materials with $1/T$. Insets: (a) shows the variation of dc conductivity with activation energy, (b) shows the variation of dc conductivity with concentration of Cr_2O_3 and (c) shows the variation of activation energy with concentration of Cr_2O_3 .

to 300°C , there is a small magnitude of electrons which induce due to thermionic emission. These thermally induced electrons were adding up with the inherent D^+ defects in the glass network resulting in thermoluminescence emission around high-temperature regions. With a steady increase of UV exposure, the observed thermoluminescence light output under a dosimetric peak was increased significantly and the peak observed was shifting towards faintly higher temperature regions [19]. The comparison indicated an increase in the thermoluminescence emission of the highest intensity peak with the shifting of peak positions towards higher temperature with a change in different concentrations of Cr_2O_3 .

3.3 dc Conductivity studies

The observed dc conductivity (σ_{dc}) variations with inverse temperature ($1/T$) of these glass composites were almost linear in the temperature range of 27 – 150°C . Figure 3 represents the variations in dc conductivity grades with an increase in temperature up to 150°C . The insets (a) and (b) characterize variations in dc conductivity and activation energy grades of these antimony lead silicate glass composites with an increase in Cr_2O_3 concentration. Inset (c) characterizes variation in dc conductivity with AE. With an increase in Cr_2O_3 content,

Figure 4. Variation in the dielectric constant of $[(\text{Sb}_2\text{O}_3)_{0.05}(\text{SiO}_2)_{0.65}] - [(\text{PbO})_{(0.3-x)}:(\text{Cr}_2\text{O}_3)_x]$ ($0 \leq x \leq 0.01$) glass materials with temperature at a frequency of 1 kHz . The inset shows the variation of the dielectric constant of Cr_8 glass with temperature at different frequencies.

the dc conductivity grades were observed to increase up to $0.008 \text{ mol\%}$ of Cr_2O_3 , beyond this concentration it follows the reverse trend. In contrast, the activation energies decrease up to $0.008 \text{ mol\%}$ of Cr_2O_3 concentration. The data related to all these observations are presented in table 3. The tetrahedral or octahedral occupancy of antimony ions in these lead silicates greatly depends on the Sb_2O_3 content. The octahedral Sb^{3+} ions in these lead silicate glass composites used Pb^{4+} ions as modifiers, further, these were responsible for the creation of non-bridging oxygens. The tetrahedral Cr^{3+} ions are associated with dissimilar polymeric chains similar to that of Sb^{3+} ions in these lead silicate composites. The strong glass bridging linkages with silicate corner tetrahedral sites were formed through tetrahedral SbO_4 ions and interstitially cited octahedral SbO_6 ions in the glass composite network quicken the large number of bonding defects. The octahedral SbO_6 structural units dominate at low concentrations of Sb_2O_3 , whereas the other tetrahedral SbO_4 structural units dominate at high concentrations of Sb_2O_3 in the glass composite network. Generally, bonding defects and non-bridging oxygen produced during the formation of glass composite materials cause an increase in dc conductivity grades which were found at higher temperature regions due to thermally agitated charge carriers [20]. An increase in dc conductivity and a decrease in AE grades up to $0.008 \text{ mol\%}$ of Cr_2O_3 concentration were due to the mobility of Pb^{4+} ions in these glass composites.

Table 3. Summary on ionic conductivity of $[(\text{Sb}_2\text{O}_3)_{0.05}(\text{SiO}_2)_{0.65}] - [(\text{PbO})_{(0.3-x)}:(\text{Cr}_2\text{O}_3)_x]$ ($0 \leq x \leq 0.01$) glass materials recorded at room temperature.

Glass	Cr_0	Cr_2	Cr_4	Cr_6	Cr_8	Cr_{10}
$\sigma_{\text{dc}} (\times 10^{-3} \text{ ohm}^{-1} \text{ cm}^{-1})$	0.317	1.719	1.676	1.623	1.582	1.603
Activation energy (eV)	0.3566	0.0861	0.0974	0.1121	0.1309	0.1226

Figure 5. Variation of dielectric loss of $[(\text{Sb}_2\text{O}_3)_{0.05}(\text{SiO}_2)_{0.65}] - [(\text{PbO})_{(0.3-x)}:(\text{Cr}_2\text{O}_3)_x]$ ($0 \leq x \leq 0.01$) glass materials with temperature at a frequency of 10 kHz. The inset shows the variation of dielectric loss with temperature at different frequencies of Cr_8 glass.

Figure 6. Variation of ac conductivity of $[(\text{Sb}_2\text{O}_3)_{0.05}(\text{SiO}_2)_{0.65}] - [(\text{PbO})_{(0.3-x)}:(\text{Cr}_2\text{O}_3)_x]$ ($0 \leq x \leq 0.01$) glass materials with $1/T$ at 100 kHz. Insets: (a) shows the variation of activation energy with concentration of Cr_2O_3 , (b) shows the variation of ac conductivity with concentration of Cr_2O_3 and (c) shows the variation of ac conductivity with activation energy.

3.4 Dielectric studies

The variation of dielectric constant against an increase in temperature up to 250°C of all these series of glass composite materials was observed. The detailed traces of these grades are represented in figure 4. However, the variations of these dielectric constant values at various frequencies (1, 10 and 100 kHz) were shown in the inset of the same figure. The observed values of these parameters were increasing up to 0.008 mol% of Cr_2O_3 concentration. The observed variation in loss tangent grades was increasing with an increase in Cr_2O_3 concentration up to 0.008 mol%. The detailed loss tangent grades of traces in these glass composites are represented in figure 5. The inset of the same figure shows the variation in loss tangent at various frequencies (1, 10 and 100 kHz). The observed variations of ac conductivity grades against inverse temperature ($1/T$) for all these glass composites at a constant frequency of 10 kHz is represented in figure 6. The observed ac conductivity (σ_{ac}) grades were increasing significantly up to 0.008 mol% of Cr_2O_3 concentration, beyond these concentrations, these grades gradually decreasing with a significant increase in Cr_2O_3 concentration of glass composite materials. Activation energy for conduction and dipoles was evaluated from the ac conductivity and inverse temperature plots. The observed grades of these quantities were decreased up to 0.008 mol% Cr_2O_3 , beyond these concentrations, these grades further increased in Cr_2O_3 concentration. Density of energy states (near Fermi level) of these glass composites was also calculated. The observed grades of these were increased with Cr_2O_3 concentration till 0.008 mol%. All the information regarding dielectric quantities was represented in table 4. The charge polarization with these glass composites leads to an enriched range of the temperature region of relaxation and enhancement in loss tangent grades in all ranges of frequencies and temperatures. The enhanced relaxation effect in these glass composites with an increase in temperature in all ranges of frequencies was due to variation in dielectric loss till 0.008 mol% Cr_2O_3 concentration. Furthermore, the maxima of dielectric loss relaxation shift to lower temperature side till 0.008 mol% Cr_2O_3 concentration,

Table 4. Summary on dielectric observations of $[(\text{Sb}_2\text{O}_3)_{0.05}(\text{SiO}_2)_{0.65}] - [(\text{PbO})_{(0.3-x)}:(\text{Cr}_2\text{O}_3)_x]$ ($0 \leq x \leq 0.01$) glass materials.

Glass	Cr_0	Cr_2	Cr_4	Cr_6	Cr_8	Cr_{10}
σ_{ac} ($\times 10^{-8}$, $\text{ohm}^{-1} \text{cm}^{-1}$)	2.45	2.265	2.27	2.285	2.28	2.293
Temperature region of relaxation ($^\circ\text{C}$)	—	135–151	125–146	119–135	93–115	104–121
AE for dipoles (eV)	3.353	3.017	2.913	2.873	2.803	2.823
AE for conduction (eV)	1.731	1.331	1.301	1.262	1.206	1.221
Density of states $N(E_f)$						
Ast-Mut	—	3.156	3.232	3.432	3.279	3.321
Bter-Hdn	—	1.312	1.476	1.732	1.532	1.667
Pollak	—	3.181	3.267	3.456	3.331	3.392

beyond the concentration limit, it follows the reverse trend [21]. The glass assembly modifying ions such as Cr^{3+} and Pb^{4+} produce bonding defects in these materials, resulting in variations in dielectric characteristics. The bonding defects developed due to modifying ions, further form various informal routes for charge carriers in glass assembly leading to the development of space charge polarization. The ac conductivity grades of present antimony lead silicate materials at low frequency levels exhibit least grades of density of states, these grades agreed well with the quantum mechanical tunnelling model of dielectrics. These grades were even found to increase with the accumulation of Cr_2O_3 up to 0.008 mol%, suggesting the growth in free charge carriers or capacity of constrained defect energy levels for conduction in these glass composites [22]. The alkali Pb^{4+} ions improve the strength of dangling bonds, further they cause increase in Cr^{3+} ions at octahedral sites. With an increase in Cr_2O_3 concentration up to 0.008 mol% and a decrease in activation energies for both conduction and dipoles were due to minute order of cross-link in these antimony lead silicate glass composite materials.

4. Conclusions

In the present investigation, we have successfully synthesized $[(\text{Sb}_2\text{O}_3)_{0.05}(\text{SiO}_2)_{0.65}] - [(\text{PbO})_{(0.3-x)} : (\text{Cr}_2\text{O}_3)_x]$ ($0 \leq x \leq 0.01$) glass composite materials. The prepared glass composite materials were characterized by physical, mechanical, thermoluminescence, dc conductivity and dielectric techniques. The unbiased increase in elastic moduli with an increase in Cr_2O_3 concentration was due to the substitute of divalent Pb^{4+} ions by Cr^{3+} ions leading to an increase in Young's and shear moduli in these glass composite materials. The standards of Poisson's ratio and micro-hardness of these glass composite materials suggests that the Cr^{3+} ions of these antimony lead silicate glass composites strongly exhibit covalently connected structures. dc Conductivity and activation energies are also reported. The observed dielectric results of these glass composite materials suggested that there are both ionic and electronic conduction due to polaron hopping which seems to prevail over ionic conduction. An increase in space charge polarization was found to be responsible for the enhanced values of loss tangent and dielectric relaxation in these glass composite materials. The observed thermoluminescence spectra of the present materials suggested that the intensities of different peaks corresponding to the Cr^{3+} ions increase sharply from 0 to 0.008 mol% with an increase in the concentration of Cr_2O_3 , beyond this, the concentration intensity begins to decrease. Thermoluminescence studies on UV-irradiated all these glass composite materials were also reported. The observed sample (Cr_8) of a series of present glass composite materials exhibit enhanced TL

emission under 15 min of UV irradiation. All the observed different mechanical, luminescent and dielectric parameter values of $[(\text{Sb}_2\text{O}_3)_{0.05}(\text{SiO}_2)_{0.65}] - [(\text{PbO})_{(0.3-x)} : (\text{Cr}_2\text{O}_3)_x]$ ($0 \leq x \leq 0.01$) glass materials suggest that the sample Cr_8 might be most preferable for thermoluminescence dielectric device application.

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