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# Influence of titanium ions on spectroscopic properties of Strontiumaluminoborosilicate glasses

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## Abstract

SrO-Al<sub>2</sub>O<sub>3</sub>-B<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub> (SABS) glasses containing small concentrations of TiO<sub>2</sub> ranging from 0.2 to 0.8 mol% were prepared by a conventional melt quenching technique. Spectroscopic properties of the glasses viz., XRD, FTIR, Optical absorption, emission, and Electron paramagnetic resonance (EPR) were investigated. XRD Spectra revealed that these glasses were amorphous in nature. The FT-IR Spectra revealed the nature of bonding and the different structural units present in the glass network. The UV-vis absorption spectrum of these glasses exhibited two bands at about ~ 520 and ~695 nm. The photo emission spectra of these glasses excited with 420nm exhibited one luminescence band at about 475nm (blue emission). CIE color coordinates of prepared glass samples were calculated. The analysis of these results coupled with ESR spectral results has indicated that as the concentration of TiO<sub>2</sub> increased in the glass matrix, there is a gradual transformation of titanium ions from octahedral position to tetrahedral positions and were found to be responsible for rich blue emission. Along with these properties some physical parameters viz., density, molar volume, refractive index have been calculated.

## 1. Introduction

Strontiumaluminoborosilicate (SABS) glasses have wide range of applications in various fields such as optical lenses, electronic industry, radiation shielding and nuclear waste immobilization materials [1-6]. Transition metal ions have strong bearing on electrical, optical and magnetic properties of glasses. The range of applications of Strontiumaluminoborosilicate glasses can be further widened by doping a small quantity of TiO<sub>2</sub> to these glasses as it is observed to enhance the glass forming ability and chemical durability of the glasses [7]. In general, the ions of titanium, exist in the glass networks in Ti<sup>4+</sup> state and participate in the glass network forming with TiO<sub>4</sub>, TiO<sub>6</sub> and sometimes with TiO<sub>5</sub> (comprising of trigonal bipyramids) structural units [8,9]. However there are reports suggesting that these ions may also exist in Ti<sup>3+</sup> state in some of the glass matrices [10,11]. The objective of this paper is to have a broad understanding of influence of titanium ions on spectral properties of SrO-Al<sub>2</sub>O<sub>3</sub>-B<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub> glass system by a systematic study of optical absorption, luminescence, ESR and FTIR studies.

## 2. Experimental procedure

The following composition viz., 35 SrO-(5-x) Al<sub>2</sub>O<sub>3</sub>- 20B<sub>2</sub>O<sub>3</sub>-40SiO<sub>2</sub>:xTiO<sub>2</sub> with 0 ≤ x ≤ 0.8 mol% is chosen for the present study. These samples were prepared by melt quenching technique. The details of composition of samples are tabulated as Table 1.

Table 1. Composition of prepared titanium doped SABS glasses

S. No	Glass codes	SrO	Al <sub>2</sub> O <sub>3</sub>	B <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	TiO <sub>2</sub>
		mol%	mol%	mol%	mol%	mol%
1	SABST <sub>0</sub>	35	5	20	40	-
2	SABST <sub>2</sub>	35	4.8	20	40	0.2
3	SABST <sub>4</sub>	35	4.6	20	40	0.4
4	SABST <sub>6</sub>	35	4.4	20	40	0.6
5	SABST <sub>8</sub>	35	4.2	20	40	0.8

Titanium doped SABS glasses have been prepared by mixing analytical grade reagents of SrO, Al<sub>2</sub>O<sub>3</sub>, B<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub> and TiO<sub>2</sub> powders in appropriate amounts (all in mol%) in an agate mortar and melted in silica crucible at 1400<sup>0</sup> C in an automatic temperature controlled furnace for two hours. The resultant bubble free melt was poured in a brass mould and subsequently annealed at 450<sup>0</sup> C. The prepared glass samples were mechanically ground and optically polished to the dimensions of 0.1cm x 0.1 cm x 0.2 cm.

Density of the glasses was determined to an accuracy of (±0.0001) by the standard Archimedes Principle using o-xylene (99.9% pure) as buoyant liquid and the refractive index of the glass sample is measured by using Abbe's refractometer. The X-ray diffraction spectrum is recorded on a diffractometer with copper target (XRDARLXTRA) and nickel filter operated at 40KV, 30 mA. The electron spin resonance (ESR) spectra of the fine powder of the sample were recorded at room temperature. Infrared Transmission Spectra are recorded on a JASCO-FT-IR -53000 spectrophotometer with resolution of 0.1 cm<sup>-1</sup> in the spectral range 400–4000 cm<sup>-1</sup> using KBr pellets (300 mg) containing the pulverized sample (1.5 mg). The optical absorption (UV–Vis) Spectra is recorded on JASCO, V-570 Spectrophotometer from 200 to 1800 nm with Spectral resolution of 0.1 nm. The luminescence Spectra are recorded at room temperature on a photon Technology International (PTI) spectrofluorometer with excited wavelength 400 nm from 300 to 1200 nm.

## 3. Results and Discussion

### 3.1. X-ray diffraction spectra

XRD patterns for all prepared glass samples have been taken which are found to be similar. Perusal of Fig.1 shows two broad humps only suggesting thereby the glassy nature of the prepared glass samples with no traces of crystalloid. The study indicates that all the added amount of TiO<sub>2</sub> has entered the glass network [12].

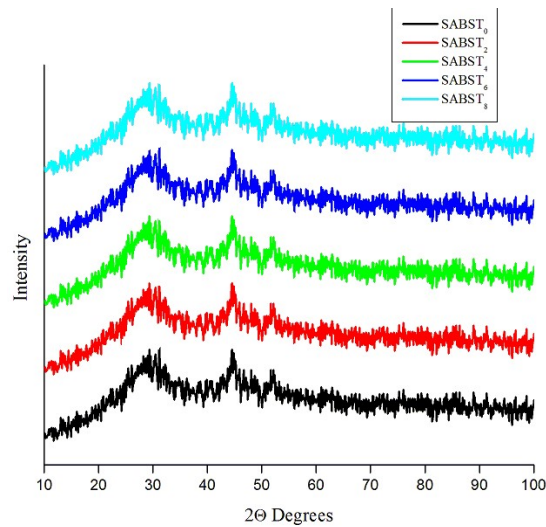


Figure 1.XRD spectra of titanium doped SABS glasses

### 3.2. Physical parameters

From the measured values of the density, refractive index and calculated average molecular weight; various physical parameters such as titanium ion concentration; mean titanium ion separation ; Polaron radius ; reflection loss; molar refractivity; optical dielectric constant and electronic polarizability that are useful for understanding optical properties of these glasses are evaluated and presented in Table 2.

Table 2. Physical properties of titanium doped SABS glasses

S.No	Physical Properties	Glasses				
		SABS	SABST <sub>2</sub>	SABST <sub>4</sub>	SABST <sub>6</sub>	SABST <sub>8</sub>
1	Density D (g/cm <sup>3</sup> ) (± 0.004)	3.3945	3.3951	3.3956	3.3962	3.3967
2	Transition ion concentration N <sub>i</sub> (10 <sup>20</sup> ions/cm <sup>3</sup> )(± 0.005)	-	0.52	1.03	1.55	2.07
3	Refractive index n <sub>d</sub> (± 0.0001)	1.6499	1.6511	1.6519	1.6521	1.6524
4	Interionic distance r <sub>i</sub> (Å) (± 0.005)	-	26.86	21.32	18.62	16.91
5	Polaron radius r <sub>p</sub> (Å) (± 0.005)	-	10.82	8.59	7.50	6.81
6	Field strength F <sub>i</sub> (10 <sup>-15</sup> cm <sup>-2</sup> ) (± 0.005)	-	0.26	0.41	0.53	0.65
7	Electronic polarizability α <sub>e</sub> (10 <sup>-21</sup> ions/cm <sup>3</sup> ) (± 0.005)	-	10.69	8.46	5.64	4.23
8	Reflection loss	0.0317	0.0318	0.0318	0.0319	0.0319
9	Molar refractivity R <sub>M</sub> (cm <sup>-3</sup> ) (± 0.005)	8.522	8.528	8.530	8.526	8.523
10	Optical dielectric constant ε <sub>o</sub> (± 0.005)	2.7221	2.7261	2.7288	2.7294	2.7304
11.	Molar volume (±0.004)	23.37	23.35	23.33	23.32	23.29

In the present work the progressive induction of  $\text{TiO}_2$  caused increase in glass density. Fig 2 demonstrates the variation of density and refractivity with dopant concentration.

The observed increase in the refractive index and density of the prepared glasses with the addition of  $\text{TiO}_2$  can be considered as an indication of increase in number of non-bridging oxygen associated with a structure contraction (i.e., shortening of the Si-O bonds) [13].

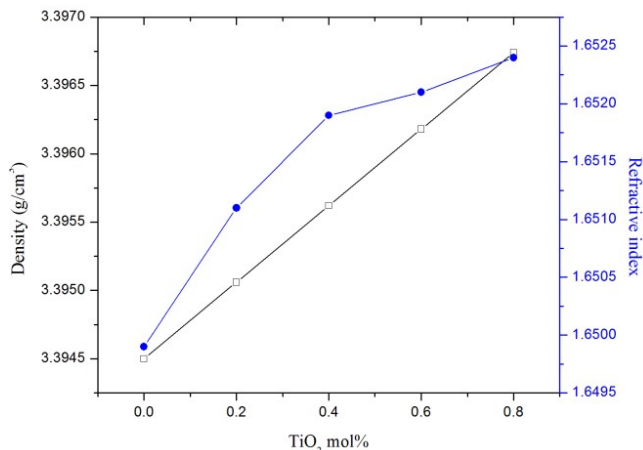


Figure 2. variation of density and refractive index of  $\text{SrO-Al}_2\text{O}_3\text{-B}_2\text{O}_3\text{-SiO}_2\text{:TiO}_2$  glasses

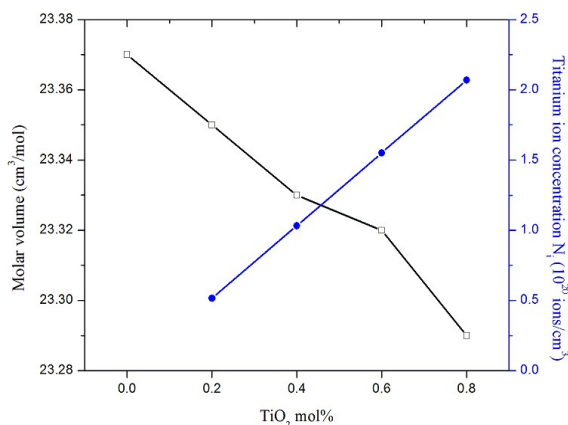
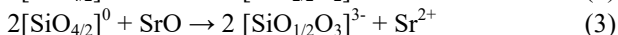
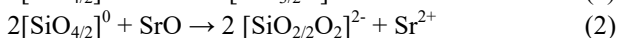
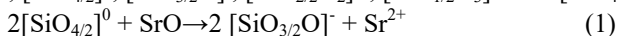


Figure 3. variation of molar volume and titanium ion concentration of  $\text{SrO-Al}_2\text{O}_3\text{-B}_2\text{O}_3\text{-SiO}_2\text{:TiO}_2$  glasses

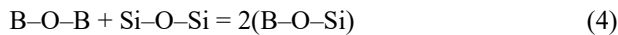
Fig 3 demonstrates the variation of molar volume and titanium ion concentration with dopant concentration. The molar volume is decreased with the addition of  $\text{TiO}_2$  to the glass matrix. This is in agreement with the observation of Stevels [14] that the  $\text{Ti}^{4+}$  ions have a contracting effect on the structure.

### 3.3. FTIR

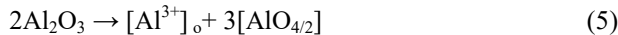
Among various constituents of  $\text{SrO-Al}_2\text{O}_3\text{-B}_2\text{O}_3\text{-SiO}_2$  glass composition,  $\text{SiO}_2$  is a well known glass former and expected to participate in the glass network with tetrahedral  $[\text{SiO}_4/2]^0$  units and all the four oxygens in  $\text{SiO}_4$  tetrahedral are shared. On addition of modifiers like  $\text{SrO}$ , the Si-O-Si linkage is broken and form Si-O-termination. Thus, the structure is depolymerized and there will be a formation of meta, pyro and ortho-silicates viz.,  $[\text{SiO}_4/2]^0$ ,  $[\text{SiO}_3/2\text{O}]^-$ ,  $[\text{SiO}_2/2\text{O}_2]^{2-}$ ,  $[\text{SiO}_{1/2}\text{O}_3]^{3-}$  and  $[\text{SiO}_4]^{4+}$ , as per the following chemical equations:



$B_2O_3$  is also a strong glass former, when it is mixed in the silicate glasses, the tetrahedral boron entities dominate in the silicate-rich domain, whereas trigonal boron entities prevail in the borate-rich side and form easily B–O–Si bridges. The highest stability occurs for fully polymerized glasses and can be related to the energetic of the reaction



This relation also suggests that the B–O–Si linkage is more stable relatively than the mixture of B–O–B and Si–O–Si linkages. Earlier spectroscopic studies like NMR on  $Al_2O_3$  mixed silicate glasses have indicated that aluminium ions occupy mainly tetrahedral ( $AlO_4$ ) and octahedral ( $AlO_6$ ) sites [15]:



The transformation of  $Al^{3+}$  from a network former to a network modifier in a melt with  $(Al^{3+} + Si^{4+})_2 O_5^{2-}$  stoichiometry can be expressed with the formalized equation as:

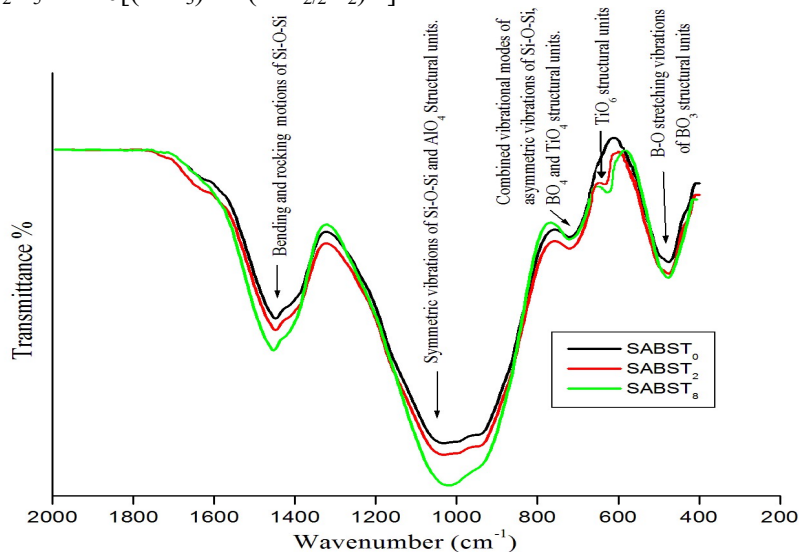
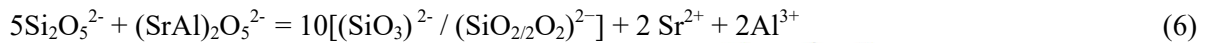


Figure 4. FT-IR spectra of SrO- $Al_2O_3$ - $B_2O_3$ - $SiO_2$ : $TiO_2$  glasses

However, some previous studies on other silicate glasses containing  $Al_2O_3$  have pointed out that  $Al(6)$  dominates the glass structure when  $Al_2O_3$  is present in low concentrations and  $Al(4)$  structural units prevail when  $Al_2O_3$  is present in higher concentrations [16]. Regardless of which participation is chosen, a coordination transformation of  $Al^{3+}$  in any of the compositions will cause a rapid increase in the relative intensities of IR bands of Si–O stretch vibrations [17]. Titanium ions are expected to exist in  $Ti^{4+}$  state in the studied glass. However the oxidation of  $Ti^{4+}$  ions to  $Ti^{3+}$  appears to be viable during melting and annealing processes. The  $Ti^{4+}$  ions are largely in six fold coordination in the glass networks. Tetragonally positioned  $Ti^{4+}$  ions do not induce the formation of any non bridging oxygen ions but octahedrally positioned ions may act as modifiers [18].

The Fourier transmission infrared spectra of  $TiO_2$  doped SrO- $Al_2O_3$ - $B_2O_3$ - $SiO_2$  glasses recorded at room temperature exhibited different bands due to the vibrations of borate, silicate, aluminum oxide and titanium structural units are shown in Figure 4. The bands observed are assigned to the following structural units based on the existing literature [19-22] as shown in Table 3.

1. The spectra exhibited a conventional band due to B–O stretching vibrations of  $BO_3$  structural units in the region  $1417$ - $1454\text{ cm}^{-1}$ .

2. Another band is identified at about  $1018\text{ cm}^{-1}$ . This band consists of combined vibrational modes of asymmetric vibrations of Si-O-Si and  $\text{BO}_4$  structural units.

3. A band is observed due to symmetric vibrations of Si-O-Si units and due to the vibrations of  $\text{AlO}_4$  structural units at about  $720\text{ cm}^{-1}$ .

4. Ti-O-Ti symmetric stretching vibrations of  $\text{TiO}_6$  units also contribute to the band observed at  $645\text{ cm}^{-1}$ .

5. A feeble band at about  $470\text{ cm}^{-1}$  attributed to the bending and rocking motions of Si-O-Si linkages is also observed

Table 3. FT-IR spectral data of  $\text{TiO}_2$  doped  $\text{SrO-Al}_2\text{O}_3\text{-B}_2\text{O}_3\text{-SiO}_2\text{:TiO}_2$  glasses

Glass samples			Band assignments
$\text{SABST}_0$ ( $\text{cm}^{-1}$ )	$\text{SABST}_2$ ( $\text{cm}^{-1}$ )	$\text{SABST}_8$ ( $\text{cm}^{-1}$ )	
468	474	470	B-O stretching vibrations of $\text{BO}_3$ structural units in the region
-	645	644	Ti-O-Ti symmetric stretching vibrations of such $\text{TiO}_6$ units.
721	719	717	Combined vibrational modes of asymmetric vibrations of Si-O-Si, $\text{BO}_4$ structural unit and vibrations of $\text{TiO}_4$ structural units.
1008	1034	1018	Symmetric vibrations of Si-O-Si and $\text{AlO}_4$ Structural units.
1417	1448	1447	Bending and rocking motions of Si-O-Si

### 3.4 Optical absorption

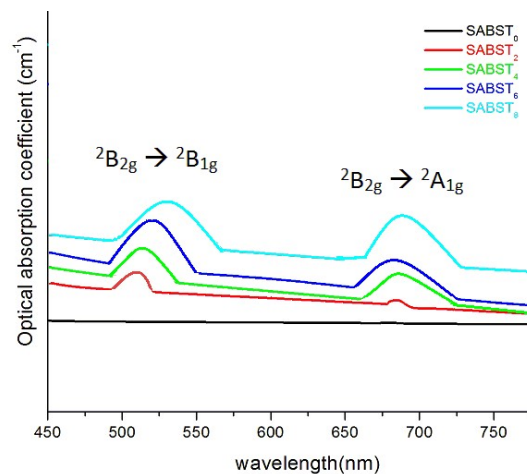
Figure 5. Optical absorption spectra of  $\text{SrO-Al}_2\text{O}_3\text{-B}_2\text{O}_3\text{-SiO}_2\text{:TiO}_2$  glasses

Fig. 5 shows the optical absorption spectra of SrO-Al<sub>2</sub>O<sub>3</sub>-B<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub>:TiO<sub>2</sub> glasses recorded at room temperature in the wavelength region 200–800 nm. For the TiO<sub>2</sub> free glass-ceramic sample (SABST<sub>0</sub>), cut off wavelength is observed at 304nm; with the increase in the concentration of TiO<sub>2</sub> (up to 0.8 mol %), the cut of wavelength is shifted to the higher wavelength side. This may be attributed to the fact that the excitation energy is less for non-bridging oxygen ion than a bridging oxygen ion. This could be confirmed by the observed increase in the recorded dispersion of glasses with increasing TiO<sub>2</sub> concentration, which in turn increases non-bridging oxygens [13]. Additionally, the spectrum of each glass sample exhibited two clearly resolved absorption bands at about 510 and 680 nm. These bands are assigned to <sup>2</sup>B<sub>2g</sub>→<sup>2</sup>B<sub>1g</sub> and <sup>2</sup>B<sub>2g</sub>→<sup>2</sup>A<sub>1g</sub> transitions of Ti<sup>3+</sup> ions, respectively [23–25]; with a gradual increase in the concentration of TiO<sub>2</sub> in the range 0–0.8 mol%, the half width and intensity of these two bands are observed to increase. The summary of the data on the positions of various bands in the optical absorption spectra of SrO-Al<sub>2</sub>O<sub>3</sub>-B<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub>:TiO<sub>2</sub> glasses are presented in Table 4.

Table 4. Optical absorption data of SrO-Al<sub>2</sub>O<sub>3</sub>-B<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub>:TiO<sub>2</sub> glasses

Glass samples	SABST <sub>0</sub>	SABST <sub>2</sub>	SABST <sub>4</sub>	SABST <sub>6</sub>	SABST <sub>8</sub>
Cutoff wavelength ( nm)	304	311	316	322	334
Theoretical Band gap (ev)	4.08	3.99	3.93	3.85	3.72
Direct band gap (eV)	4.08	3.98	3.93	3.86	3.71
Indirect band gap (eV)	4.05	3.99	3.93	3.83	3.7
Urbach energy (eV)	0.2352	0.2398	0.2457	0.247	0.268

The electronic configuration of Ti<sup>3+</sup> ion is 3d<sup>1</sup> with <sup>2</sup>D ground state. In octahedral field, the <sup>2</sup>D levels split into <sup>2</sup>E ground state and <sup>2</sup>T<sub>2</sub> excited state. In the tetragonally distorted octahedral field, the <sup>2</sup>T<sub>2</sub> state further splits into three <sup>2</sup>B<sub>2</sub> (namely |xy>, |yz> and |zx>) states, whereas the <sup>2</sup>E excited state splits into A<sub>1</sub>|3z<sup>2</sup>-r<sup>2</sup> and B<sub>1</sub>|x<sup>2</sup>-y<sup>2</sup> states by tetragonal distortion. For d<sup>1</sup> ions in tetragonally compressed octahedron, the ground state is B<sub>2</sub>|xy> [26]. Using Tanabe–Sugano diagrams for d<sup>1</sup> ions, the bands observed in the optical absorption spectra at about 510 and 680 nm are assigned, respectively, to <sup>2</sup>B<sub>2g</sub>→<sup>2</sup>B<sub>1g</sub> and <sup>2</sup>B<sub>2g</sub>→<sup>2</sup>A<sub>1g</sub> transitions of 3d<sup>1</sup> electron of the Ti<sup>3+</sup> ions.

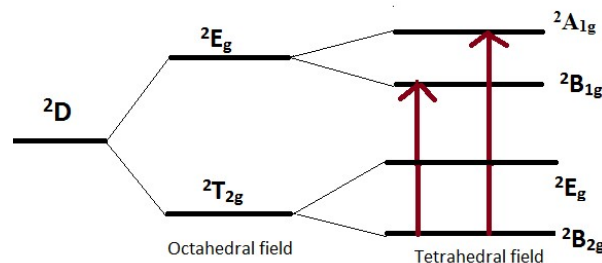


Figure 6. Energy level diagram of Ti<sup>3+</sup> in octahedral and tetrahedral fields

With the increase in concentration of TiO<sub>2</sub> up to 0.8 mol% in the sample, these bands are observed to shift towards a higher wavelength with increase in the intensity. These observations indicate increase in

the concentration of  $Ti^{3+}$  ions in the glass samples. Investigation of optical absorption edge in UV-vis region can be very useful in understanding the optical transitions and electronic band structures prepared glass materials [27]. It is possible to determine indirect and direct transition occurring in band gap by optical absorption spectra at the fundamental absorption edge of the material.

From the observed edge, the optical band gap of the prepared glass samples were calculated by drawing Tauc plots (fig 8 and fig 9) between  $(\alpha h\nu)^2, (\alpha h\nu)^{1/2}$  as a function of  $h\nu$  using the equation

$$\alpha(h\nu)h\nu = C (h\nu - E_0)^n \quad (6)$$

Here the exponent 'n' takes values 2 and  $\frac{1}{2}$  for direct and indirect transitions in amorphous materials [28]. From the Tauc plots of the prepared glass samples, it is observed that the energy gap values are systematically decreasing with the increase in the dopant concentration. The pure sample is most stable in the prepared glass samples. It could be said that the glass sample SABST<sub>2</sub> (highest energy gap) is the stable glass among titanium doped the Strontiumaluminoborosilicate glasses.

In amorphous materials, the absorption coefficient increases with the photon energy near the band gap [29]. when the energy of incident photon is less than the band gap, the increase in the absorption coefficient is followed with an exponential decay of density of states of the localized states in the gap [30]. the absorption edge here is called Urbach edge. The lack of crystalline long range order in amorphous materials is associated with a tailing of density states into normally forbidden energy [30]. The plots (fig 9) are drawn between the logarithms of the absorption coefficient,  $\ln(\alpha)$ , against photon energy,  $h\nu$ , for the different glass compositions. The Urbach energy is calculated, and tabulated in Table.4, by taking the reciprocals of the slopes of the linear portion in the lower photon energies of these curves.

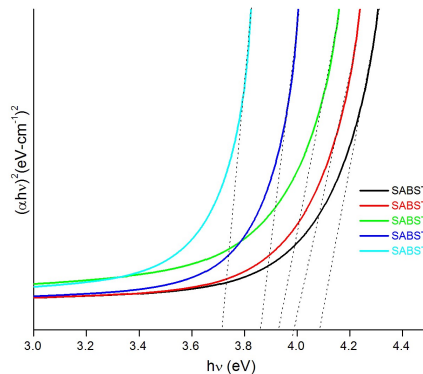


Figure 7. Tauc plots to evaluate direct band gap of SrO-Al<sub>2</sub>O<sub>3</sub>-B<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub>:TiO<sub>2</sub> glasses



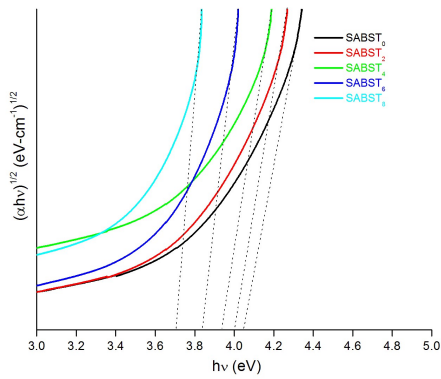


Figure 8. Tauc plots to evaluate indirect band gap of SrO-Al<sub>2</sub>O<sub>3</sub>-B<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub>:TiO<sub>2</sub> glasses

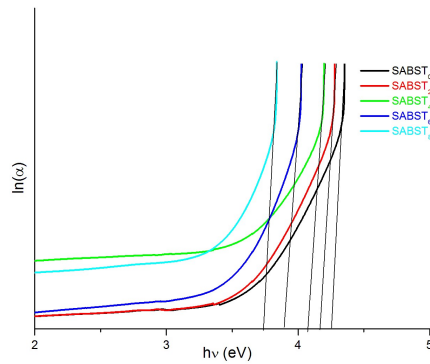


Figure 9. Plots of  $\ln(\alpha)$  and  $h\nu$  for SrO-Al<sub>2</sub>O<sub>3</sub>-B<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub>:TiO<sub>2</sub> glasses

### 3.5. ESR

The ESR spectra, recorded at room temperature, for the prepared glasses are shown in Fig: 10

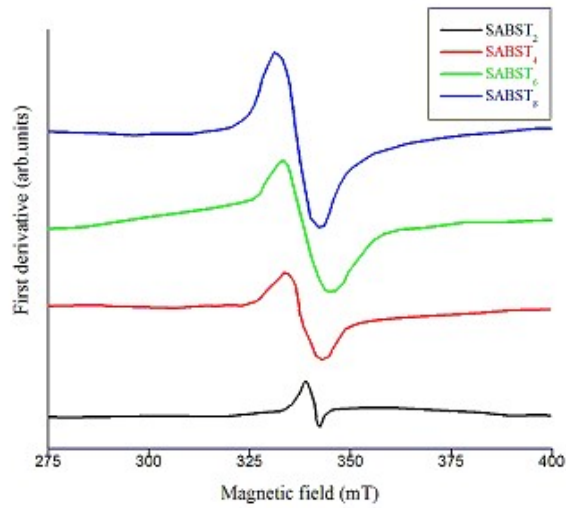


Figure 10. ESR spectra of TiO<sub>2</sub> doped SrO-Al<sub>2</sub>O<sub>3</sub>-B<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub>:TiO<sub>2</sub> glasses at room temperature

No ESR signal is detected in the spectra of undoped SABS glass samples. The spectra of titanium doped glasses exhibited a near symmetric signal with  $g=1.95$ . As the concentration of titanium is increased the half width of the signal is observed to increase considerably. The signal is identified is due to  $3d^1$  unpaired electron of  $Ti^{3+}$  ions situated in a tetragonally distorted octahedral field [31]. It indicates an increasing concentration of  $Ti^{3+}$  ions in the glass network. The presence of large concentration of such ions may distort the glass network more and induce bonding defects. The weak intensity of the signal is observed for glass  $SABST_2$  clearly indicates the presence of very low concentration of these ions in this glass.

### 3.6. Luminescence

Fig. 11 shows photo luminescence emission spectra of titanium doped SABS glasses at room temperature excited with the wavelengths corresponding to their absorption edge.

The spectrum of sample  $SABST_2$  exhibited an emission band at about 480 nm. As the concentration of transition metal is increased up to 0.8%, the intensity and the half width of this band is observed to decrease with gradual shift in the peak position towards lower wavelength. The detailed analysis of luminescence of closed-shell transition metal complexes including titanium by Blasse [32] indicated that both the tetrahedral and octahedral complexes of titanium ions do exhibit luminescence. The luminescence efficiency of octahedral complexes of substitutionally positioned  $Ti^{4+}$  ions is found to be much higher than tetrahedral complexes. The luminescence band is attributed to radiative recombination of self-trapped excitons (STEs) localized on a substitutionally positioned octahedral  $Ti^{4+}$  ions.

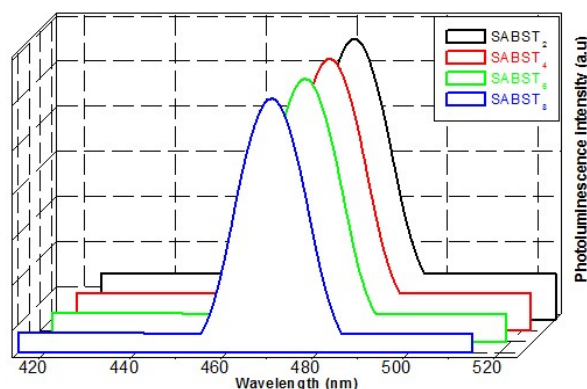


Figure 11. Emission spectra of  $SrO-Al_2O_3-B_2O_3-SiO_2:TiO_2$  glass

The emission band was illustrated further in a more detailed way by (M. Watanabe. et al) [33]. The valence band of this type of materials is normally formed by  $2p$  orbitals of  $O^{2-}$  ions. The glass sample must contain octahedrally positioned substitutional titanium ( $Ti^{4+}$ ) ions with  $(TiO_6)^{8-}$  structural units [33]. The charge transfer from  $O^{2-}$  takes place into the empty  $3d$  orbital of  $Ti^{4+}$  ion reducing it into  $Ti^{3+}$  state. The trapped  $d$  electrons when excited interact with the lattice vibrations due to electron-phonon interaction. This excitation will be annihilated by luminescence emission. The energy relaxation after photoexcitation promotes the spatial separation of electron-hole pairs [34]. The highest intensity of this peak observed for the sample  $SABST_2$  indicates that in this sample titanium ions mostly exist in  $Ti^{4+}$  state and occupy substitutionally positioned octahedral sites.

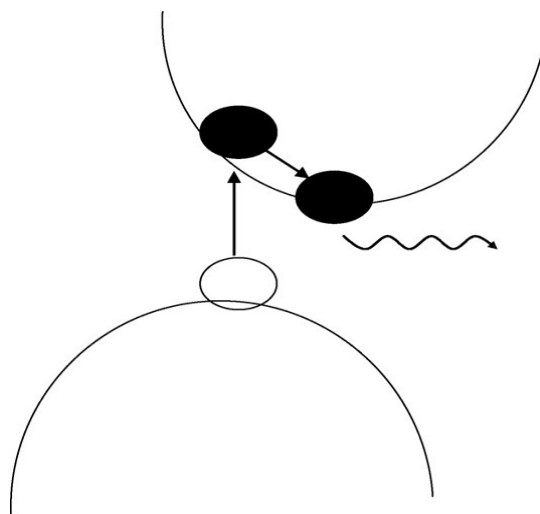


Figure 12. Mechanism of luminescence emission

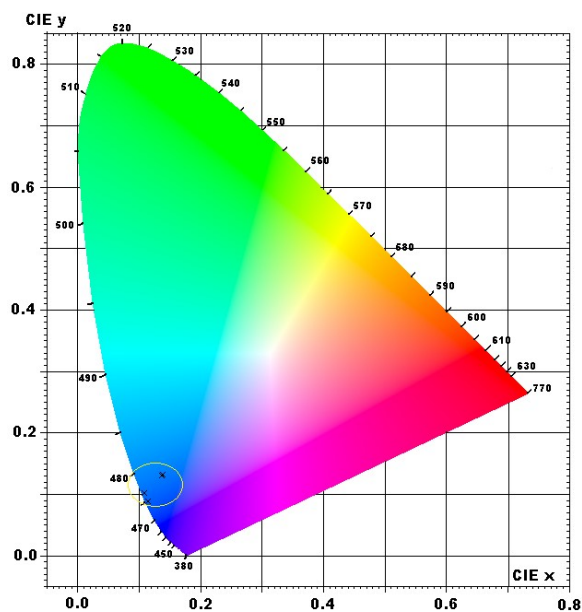


Figure 13. CIE diagram of titanium doped SABS glasses

The CIE chromaticity coordinates of  $\text{TiO}_2$  doped SABS glasses are calculated from their corresponding emission spectrum for better identification of luminescence properties. The CIE color coordinate system characterizes the color by two color coordinates  $x$  and  $y$ , which are highly useful in describing the exact emission color and color purity of the sample. The color of the prepared glasses are graphically represented in a two dimensional CIE  $x$ - $y$  plot and are depicted in the Fig. 13. The two color coordinates for the all glass samples are tabulated as Table. 5. From the table, the purity of prepared glass emission color may be confirmed. As these glass samples emit pure blue color, they may well suit for UV lamps and displays devices.

Table.5: Color coordinates of titanium doped SABS glasses

S.No	Glass samples	Emission peak nm	Color coordinates		Color
			X	Y	
1	SABST <sub>2</sub>	480	0.1094	0.1023	blue
2	SABST <sub>4</sub>	475	0.1151	0.0879	blue
3	SABST <sub>6</sub>	472	0.1368	0.1313	blue
4	SABST <sub>8</sub>	470	0.1379	0.1312	blue

## Conclusion

SrO-Al<sub>2</sub>O<sub>3</sub>-B<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub> glasses with different concentrations of TiO<sub>2</sub> were synthesized and optical absorption, ESR, IR and photoluminescence were recorded at room temperature. The summary of the conclusions drawn from the study of various spectral properties of titanium doped Strontiumaluminoborosilicate glasses as follows: XRD spectra of samples have indicated that the prepared glasses have amorphous nature and the samples contained randomly distributed grains at different phases. The prepared glass becomes optically more dispersive with a higher refractive index as the ratio of TiO<sub>2</sub> increase. The IR spectral studies indicated that as the concentration of TiO<sub>2</sub> increased in the glass matrix, there is a gradual transformation of titanium ions from octahedral position to tetrahedral positions. The optical absorption spectra of SrO-Al<sub>2</sub>O<sub>3</sub>-B<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub>:TiO<sub>2</sub> glasses exhibit bands due to the transitions of Ti<sup>3+</sup> ions indicating the existence of titanium ions in trivalent state in addition to the tetravalent state in these glass samples. This observation is supported by the ESR studies of the prepared glass samples.

The analysis of luminescence studies of titanium doped SABS glasses indicated that the SABST<sub>2</sub> glass exhibits the highest luminescence efficiency and in this sample titanium ions mostly exist in Ti<sup>4+</sup> state and occupy substitutionally positioned octahedral sites. The blue emission is characteristic of titanium ions and the CIE chromaticity coordinates suggests that the prepared glass material may be used in lamps and displays devices.

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