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Physical and optical study of alkali and alkaline earth metals based phosphate glasses

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Abstract

The glass samples with chemical composition (mol%) of $10Na_2O$-$10SrO$-$10Gd_2O_3$-$70P_2O_5$, $15Na_2O$-$10SrO$-$10Gd_2O_3$-$65P_2O_5$, $10Na_2O$-$15SrO$-$10Gd_2O_3$-$65P_2O_5$, and $15Na_2O$-$15SrO$-$10Gd_2O_3$-$65P_2O_5$ which are referred as 1NSP, 2NSP, 3NSP and 4NSP, respectively, in this article, were prepared by the melt quenching technique. The obtained glass samples show 66% transmission. The density of the samples was calculated by using the Archimedes principle using water as immersion liquid at room temperature, the molar volume, the refractive index and UV-Vis spectroscopy are the other characterizations used in this work to evaluate our samples' properties. The density of the samples is increase with the increasing amount of sodium and strontium oxides, while the molar volume decrease for the increasing amount of these oxides. The refractive index of the prepared glass samples increase from 1NSP to 4NSP.

Keywords: Archimedes principle, density, phosphate glass, UV-Vis spectroscopy

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1. Introduction

The phosphate based glasses have many good properties like high transparency, low melting point, high thermal stability, high gain density, low dispersion, low refractive index and high solubility for rare-earth ions [1, 2]. Keeping in view these properties, phosphate glasses have a wide range of application including biomedical, agricultural, optoelectronic and sensor [3]. The problem with the phosphate glasses is that these glasses are very hygroscopic so many researchers are dedicated to improve the chemical durability of the phosphate glasses.

Various transition-metals, alkali and alkaline-earth oxides form glasses when melted with P_2O_5. These glasses have large possibility for application in many modern technologies like optical data transmission, solid state batteries, sensing and laser technologies [4].

The presence of Na_2O improves the RE ions solubility and as a result lead to the possibility of using a high concentration of dopants, which is very important for short length optical amplifiers [5, 6]. The interest in the sodium ions conducting glass systems is increasing, because they are promising glassy electrolytes for the development of high energy density batteries, particularly for sodium sulphur batteries [7].

The incorporation of SrO to phosphate glasses enhance their chemical durability, thermal stability and other physical properties. The addition of strontium to the phosphate structural network is accompany by depolymerization of the phosphate chains and the creation of non-bridging oxygen at the expense of bridging oxygen which can change the electrical, optical or magnetic properties of these glasses [8].

In this work we report alkali and alkaline earth based phosphate glass and characterized it for physical and optical properties.

2. Experimental details

A series of phosphate glasses having the compositions (mol%)

i) $10Na_2O$-$10SrO$-$10Gd_2O_3$-$70P_2O_5$ (1NSP)
ii) $15Na_2O$-$10SrO$-$10Gd_2O_3$-$65P_2O_5$ (2NSP)
iii) $10Na_2O$-$15SrO$-$10Gd_2O_3$-$65P_2O_5$ (3NSP)
iv) $15Na_2O$-$15SrO$-$10Gd_2O_3$-$60P_2O_5$ (4NSP)

where prepared by melt quenching technique. All chemical were taken in the oxides form with high purity up to 99.999%. According to composition the weighted chemical were first mix and then put in furnace for melting using alumina crucibles.

The homogeneously mixed chemical batch was melt at 1200°C and hold for 3 hours. After homogenously melting the chemical were pouring in a preheated mold for quenching. After the samples were quenched they are placed in another furnace at 300°C for annealing purposes. After annealing the samples were taken out of furnace, subsequently cut and polished with required dimensions. The cut and polished samples are show in the Figure 1. As a last step, the so prepared glass

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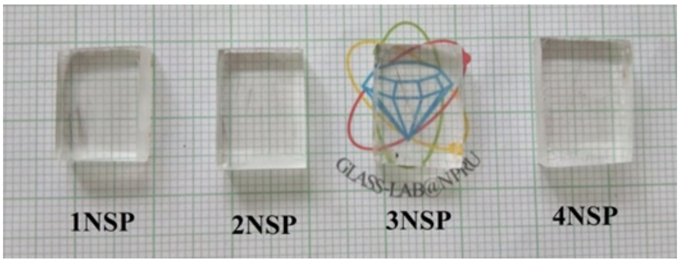

Figure 1 Picture of the prepared glass samples

samples were subjected to different type of characterization for defining the physical and optical properties.

2.1 Density calculation

Density and molar volume are vital and informative physical quantities of a glass which give information about changes in the geometrical configurations of the glass network, change in coordination, structural compactness, and variation of the dimensions of the interstitial holes [9].

The densities of the samples were measure by Archimedes principles using water as the buoyant fluid. After measuring the weight of samples in air and water the Eq.1was used to find the value of the density for the prepared glass samples [9, 10].

$$\rho = \frac{w_{air}}{w_{air} - w_{water}} \times \rho_{water} \quad (\text{g/cm}^3) \qquad (1)$$

where w_{air} is the weight of the samples in air and the w_{water} is the weight in water while 1.000 g/cm^3 is the density of the water.

2.2 Molar volume calculation

The equation use for the molar volume is given as

$$V_{mol} = \frac{M}{\rho} \quad (\text{cm}^3/\text{mol}) \qquad (2)$$

where V_{mol} is the molar volume, M is the molecular mass and ρ is the density of the samples.

3. Results and discussion

Figure 2 and 3 give the density and molar volume of the glass samples respectively. From Figure 2, it is clear that the density of the samples increase from 1NSP to 4NSP. The increasing amount of the alkali and alkaline earth metals, increase the number of the non-bridging oxygen and which cause a decrease in the volume of the network structure and this may be responsible for the increase in the density, i.e. decrease in the value of molar volume with the increase of the soda content in the sodium phosphate glasses studied [10].

The other reason is that the larger molar mass of SrO compared to Na_2O. So the addition of SrO which have larger cation potential, creates more compact metaphosphate network [11]. Furthermore, every Sr^{2+} substitutes two Na^+ in glass structure and leads to the decrease of the molar volume and as a result increases in the density of the glasses.

The refractive index shows an increasing trend, because the refractive index depends on the electron density of the anion in the glass. The important contribution come from the oxygen especially non bridging oxygen can be easily polarisable than the bridging oxygen. So the refractive index is increase as we increase the amount of the sodium and strontium in our glass samples.

The study of optical absorption in the UV-Vis regions is a useful technique for investigation of band structure and band gap energy in crystalline and non crystalline systems. Figure 5 represents the optical absorption spectra of all samples. Since there are no sharp absorption edges in spectra, which demonstrate the amorphous nature of samples [12].

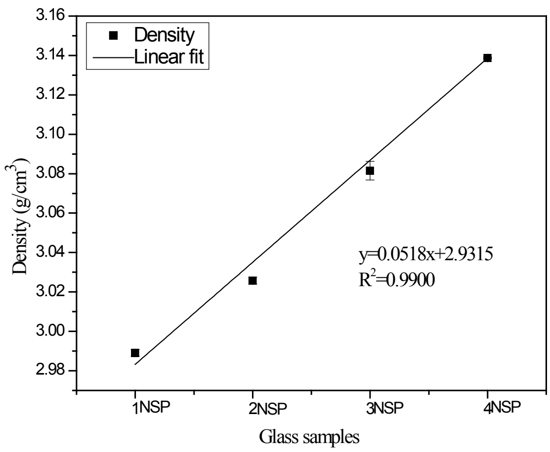

Figure 2 Density of the glass samples

Table 1 Physical properties of NSP glasses.

Samples	Density (g/cm^3)	Molar volume (cm^3/mol)	Refractive index
1NSP	2.9890±0.0017	50.9098	1.5387±0.0040
2NSP	3.0257±0.0018	48.9716	1.5424±0.0052
3NSP	3.0815±0.0047	48.7602	1.5797±0.0002
4NSP	3.1387±0.0003	46.5980	1.5541±0.0008

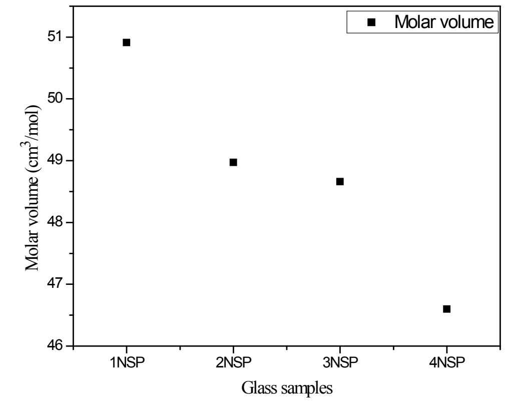

Figure 3 Molar volume of the glass samples

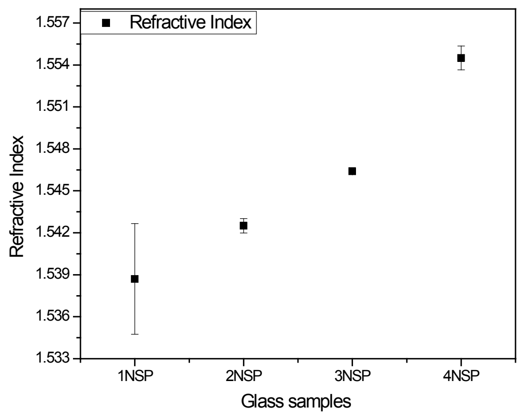

Figure 4 Refractive index of the glass samples

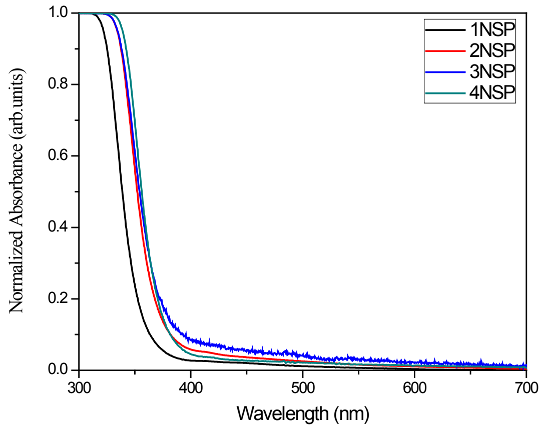

Figure 5 Absorption spectra of glass sample

4. Conclusions

The NPS glass samples were prepared by the conventional melt quench technique for different application. From the characterization it is clear that the density and refractive index of the glass increase with the increasing concentration of alkali and alkaline earth oxides, while the molar volume of the glass decrease with the increase concentration of alkali and alkaline earth oxides. The UV-Vis spectra show the absorption edge about 390 nm wavelength.

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