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Optical Properties of Silver-Vanadium-Phosphate Glasses

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Abstract

The glasses with the composition of xAg_2O-$50V_2O_5$-$(50-x)P_2O_5$ (where x = 5,10,15,20,30 and 40 mol%) were synthesized using melt quenching technique and their optical properties were carried out through UV-Visible spectrophotometer. The absorption spectra of these glasses were recorded at room temperature in the wavelength range 200-1100nm. The optical band gap energies were calculated using Tauc plot. The calculated energy band gap values are ranging from 2.075 to 2.834 eV. The refractive index and polarizabilities of oxide ions have been calculated using Lorentz-Lorentz relation. The calculated refractive index and polarizabilities of these glasses in the range of 2.443 to 2.703 and 9.8877×10^{-24} to $13.590\times10^{-24}cm^3$.

Keywords: Energy band gap; Silver oxide; Phosphate glasses.

1. Introduction

Phosphate glasses are most important materials and they have been used extensively for lasers and fiber amplifiers[1,2]. Compared to other glasses, phosphate glasses are more limited in their use because they are highly hygroscopic in nature [3]. Since these glasses have lower glasss transition temperature, they are more

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compatible with fabrication process in the development of optical devices.

Metal doped non-crystalline materials have been the subject of increasing interest due to their prospective utilization for photonic applications[4-11]. Special attention has been given to noble metal due to their remarkable optical properties owing to the Surface Plasmon Resonance(SPR)[12-14].

The absorption in the ultraviolet (UV) and visible region gives an idea of the optical energy band gap in amorphous materials. Also, it gives crucial information about the band structure.

The aim of the present study is to investigate the role of Ag_2O content on optical band gap, refractive index and polarizability of oxide ion in Vanadium-Phosphate glasses.

2. Experimental

The glass samples having composition xAg_2O-$50V_2O_5$-$(50-x)P_2O_5$ (where x = 5,10,15,20,30 and 40 mol%) were prepared using conventional melt quenching method.The appropriate weights of Analar grade chemicals (Ag_2O, V_2O_5, and $NH_4H_2PO_4$) were taken in a mortar, grounded well using pestle for 15 min and heated at 900°C for 2 hrs. After the completion of heat treatment, the molten liquid was cast onto a brass mould and quickly pressed with another brass mould. The result is in the form of glass and these glass samples were used for further studies.

The optical absorption spectra were recorded at room temperature in the wavelength range from 200 to 1100 nm by using a Shimadzu UV-Visible spectrophotometer UV-1800. The optical absorption coefficient $\alpha(\lambda)$ was calculated from the absorbance A, and the thickness of the sample d, by using the following relation,

$$\alpha(\lambda) = 2.303\frac{A}{d} \tag{1}$$

The refractive index(n) of these glasses has been calculated using the relation

$$\frac{n^2-1}{n^2+2} = 1-\sqrt{Eg/20} \tag{2}$$

Where E_g is energy band gap.

Electronic polarizability (α_e) of the constituent ions is another important property, which was calculated from the relation

$$\frac{n^2-1}{n^2+2}(V_m)=4/3\pi N\alpha_e \tag{3}$$

Where N is the Avogadro number, V_m is molar volume and α_e is the electronic polarizability.

3. Results and Discussion

The measured energy band gap values,calculated refractive index and polarizability values are tabulated in the Table 1 . The typical optical absorption spectra of the glass system as shown in Figure 1.

Name of the glass composition	Energy band gap (eV)	Refractive index(n)	Polarizability(α_e) cm^3
AG-5	2.834	2.4430	13.590×10^{-24}
AG-10	2.782	2.4582	11.7213×10^{-24}
AG-15	2.075	2.7039	12.2869×10^{-24}
AG-20	2.728	2.4741	11.5011×10^{-24}
AG-30	2.481	2.5525	9.8877×10^{-24}
AG-40	2.535	2.5647	10.01123×10^{-24}

Table 1.Optical band gap, refractive index, polarizability of oxide ion

An expression of absorption coefficient a as a function of photon energy $h\nu$ for direct and indirect inter-band electronic transition can be written as,

$$\alpha h\upsilon = B\left(h\upsilon - E_{opt}\right)^n \tag{4}$$

Where B is a constant and $h\nu$ is the photon energy, E_{opt} is the optical energy band gap and n is a number which characterizes the transition process. The optical absorption coefficient values are well fitted to direct band gaps and their values can be determined from the expression (4). By extrapolating the absorption coefficient to zero absorption in the $(ah\upsilon)^2$ vs $h\upsilon$ plot at $(ah\upsilon)^2=0$, as shown in Figure 2.

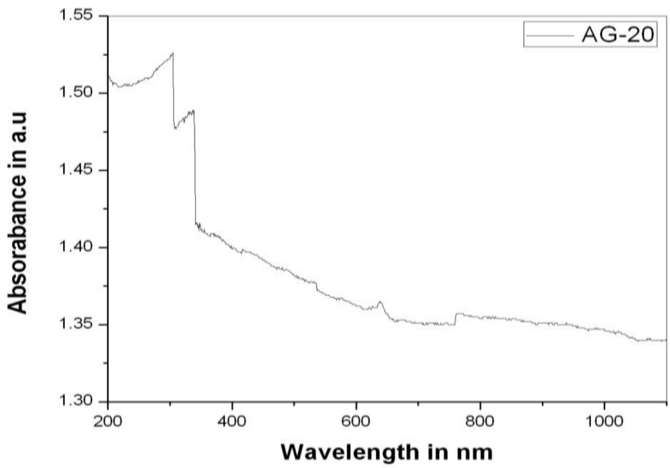

Figure 1.A typical absorption spectrum of Silver-Vanadium-Phosphate glass.

Variation of energy band gap as a function of Ag_2Omol% is shown in Figure 3. It is observed that, there is decreasing trend of energy band gap with respect to Ag_2O mol%. But at 15 mol % of Ag_2O there is sudden drop of band gap energy has been observed. As can be seen from the table 1, refractive index increases and polarizability values decreases with silver concentration except at 15 mol% of Ag_2O. The drop of energy band gap at 15 mol% may be due to change in internal structure of glass matrix. The same trend has been observed in elastic and switching properties of these glasses reported earlier [15, 16].

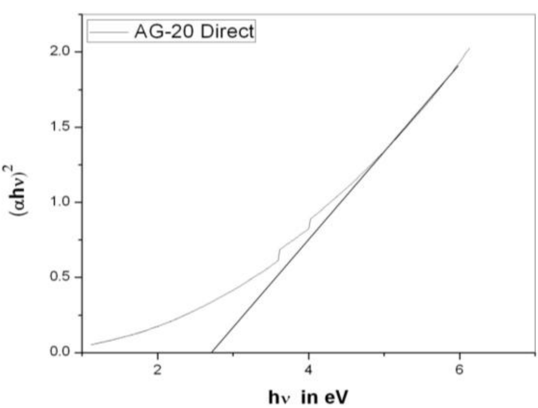

Figure 2. A typical graph of $(\alpha h\upsilon)^2$ versus $h\upsilon$

Increase in refractive index and decrease in polarizability suggest the less compactness of the glass structure. In otherwords incorporating Ag_2O into vanadium-phosphate glass network starts opening the glass structure to some extent . The increasing the absoption edge with Ag_2O indicates the increase in number of non-bridging oxygen's, fluctuation in bond angle distortions and bonding defects with increase of Ag_2O. Such changes leads to depolymerization in the glass network and increase the degree of localization of electrons thereby increasing the donar centres in the glass matrix [17].

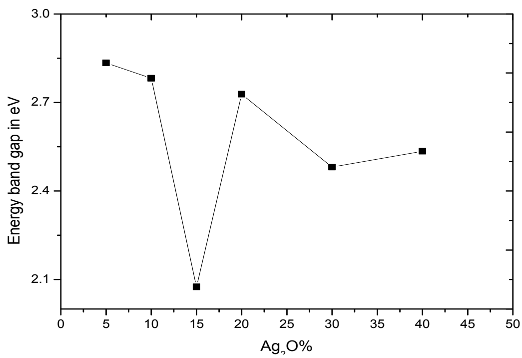

Figure 3.Variation of energy band gap with Ag_2O mol%

4. Conclusion

The glasses of different compositions of Silver vanadium phosphate glasses have been successfully prepared by melt quenching method. The optical energy band gap, refractive index and polarizability of these glasses were determined. These values are well matched with the other glasses as reported in the earlier literature. The addition of silver oxide into vanadium-phosphate glass matrix is capable of depolymerization in the glass network and increase the degree of localization of electrons and consequently decreases the optical band gap energy.The increase in refractive index and decrease in polarizability has been observed due to less compactness of the glass network.

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