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Complex optical study of V_2O_5–P_2O_5–B_2O_3–GO glass systems by ultraviolet–visible spectroscopy

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ABSTRACT

In the present work, complex optical parameters such as absorption, extinction coefficient, refractive index, optical conductivity, real dielectric constant and imaginary dielectric constant of V_2O_5–P_2O_5–B_2O_3–GO glass systems have been studied. The melt quenching method was adopted for the preparation of V_2O_5–P_2O_5–B_2O_3–GO glass systems. The conformation of glassy phase in sample was done through X-ray diffraction analysis. The optical parameters were analyzed using ultraviolet–visible spectroscopy. The dispersion of graphene oxide in V_2O_5–P_2O_5–B_2O_3–GO glass systems significantly affects the complex optical parameters. The extinction coefficient, real dielectric constant and imaginary dielectric constant gradually increase after 225–600 nm. Whereas, optical conductivity shows gradual increase around 225 nm.

1. Introduction

Conducting glass is important class of materials science, which has modern potential applications in certain optical devices or effects. There are several important optical parameters associated conducting glasses, which determining its optical and optoelectronic applications. Additional interest in conducting glass has risen due to its excellent thermal, chemical, dielectric, mechanical, and biological properties. Because of these desirable engineering properties, they have found several applications as engineering materials and new uses constantly appear.

In glassy materials, ordering range is very short. This aspect of glassy materials that is lack of grain boundaries play very important role in various modern applications such as aerospace industry, telecommunications, photonics and solid oxide fuel cells [1,2]. The control on complex optical properties allows their application in ultra-high speed optical and optoelectronic switches to enhance the speed of internet and next generation computer [3,4]. Understanding of the optical parameters of conducting glass has increased their potential applications for optical and memory switching devices [5,6]. Kang et al. studied the optical and dielectric properties of glasses at terahertz frequencies. In this study far infrared absorption in glassy materials is used to analyze the terahertz radiation absorption behavior [7]. Therefore conducting glasses exhibit potential optoelectronics applications such as thermal imaging, night vision and mid-infrared light delivery [8,9]. Inspiring from the above discussion, we planned to study the complex optical parameters of V_2O_5–P_2O_5–B_2O_3–GO glass system. The graphene oxide (GO) is prominent candidate for improvement of optoelectronics properties, therefore graphene dispersed in V_2O_5–P_2O_5–B_2O_3 glass network [10,11].

Mohammad et al. studied the transparency around solar maxima and refractive index of conducting glass (SnO_2: F) in comparison with silicon. The direct and indirect transitions for conducting glass (SnO_2:F) are observed around 4.1–2.6 eV, respectively for solar cells application [12]. Agnihotri et al reported preparation of conducting glass (SnO_2:F) of 3 ohm per square sheet resistance for potential solar cell applications. The optical study of conducting glass shows that layers exhibit 90% optical transmission at the solar maximum 0.5 μm [13]. Haralampieva et al. reported the optical and structural properties of BaO–V_2O_5 and Fe_2O_3–BaO–V_2O_5 glasses. Both glass systems possess high polarizability affecting to linear and non-linear optical properties [14]. The optical and other physical properties of semiconducting xV_2O_5-1-xCdO glasses have been reported by Ghosh et al. The Davis and Mott theory was used analyzed the fundamental absorption edge for all the glasses [15]. The room temperature and low temperature optical study of vanadate glasses based on the system V_2O_5–P_2O_5 was measured in the range 20–25000 cm^{-1} by Anderson et al. No significant temperature effect

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was observed on absorption spectra shape and peak positions [16]. Kabi et al. studied the optical properties of CdI_2 doped silver vanadate glass-nanocomposites. In the glass system, crystalline volume fraction increases with the increase of CdI_2 content. Therefore, optical properties are also significantly affected [17]. Ghoneim et al. studied the optical properties of lithium doped vanadate glasses. The concentration of lithia significantly affects the structure and optical properties of vanadate glasses [18].

The literature survey of vanadate based glasses, in the context of optical properties shows that very few reports present on the optical aspect of vanadate glasses. Only primary optical properties studied in these articles. To the best of our knowledge, no single report present on the complex optical parameters of vanadate glasses such as extinction coefficient, refractive index, optical conductivity, real dielectric constant and imaginary dielectric constant. All these complex optical parameters estimated using ultraviolet–visible spectrum.

2. Experimental

In the present work, AR grade chemicals were used for the preparation of glass samples. The glass system of the compositions of $60V_2O_5$–$5P_2O_5$–$(34-x)B_2O_3$–xGO by varying concentration with an interval $x = 1$, 2, 3, 4 and 5 mol% were prepared by a regular melt-quenching method. For the convenience, these glass systems represented for the value of $x = 1$, 2, 3, 4 and 5 mol% by G1, G2, G3, G4 and G5, respectively. In proper stoichiometry, chemicals were weighed and mixed together. This mixture was crushed in order to make homogenized and keep for melting in alumina crucible in a muffle furnace at 1073 K for 4 h. Subsequent to this step, mixture was poured onto stainless steel plate for quenching purpose. In order to avoid internal strain, the sample was conditioning at 573 K for 2 h.

The materials were characterized through X-ray diffraction (XRD) (Rigaku Miniflex-II, X-ray diffractometer) for confirmation of glassy phase in as-prepared samples. Similarly, the optical properties of samples were acquired using ultraviolet–visible spectroscopy (Agilent Cary 60 UV–Vis Spectrophotometer). In the present work for high accuracy and reproducibly, absorption spectrum collected after baseline correction with the help of silicon substrate. Similarly, absorption spectrums of samples were measured for five times to nullify experimental errors.

3. Results and discussion

Fig. 1 shows the XRD pattern of $60V_2O_5$–$5P_2O_5$–$(34-x)B_2O_3$–xGO. The entire 2θ pattern does not contain any sharp peaks. This reflects quenching employed for preparation of glasses is proper. Besides that pattern contains broad hump between 20 and 30°.

Fig. 2 shows the UV–VIS spectrum of $60V_2O_5$–$5P_2O_5$–$(34-x)B_2O_3$–xGO glass system, studied in the range 200–600 nm. The critical analysis of absorption curve shows the deep around 225 nm. Beyond 225 nm, absorption increases up to 325 nm and then decreases in visible region. The absorption tail of the as-prepared samples shifted to lower wavelength with increasing concentration of GO. This shows that band gap of prepared samples increases with increasing concentration of GO [19].

Fig. 3 depicts the variation of extinction coefficient of $60V_2O_5$–$5P_2O_5$–$(34-x)B_2O_3$–xGO glass system as a function of wavelength. The plot clearly shows that extinction coefficient curve increases linearly the wavelength. The extinction coefficient is measure of trapping light [20]. Therefore, we conclude that wavelength beyond 225 nm trapped in sample and degree of trapping of light increase linearly. On other hand, the wavelengths between 200 and 225 nm are not trapped in samples. Because, the variation of extinction coefficient nearly constant between 200 and 225 nm. The highest value of extinction coefficient observed for the sample G4 and G5. This shows that sample trapping of light increase with increasing concentration of GO.

Fig. 4 shows the variation of refractive index as a function of wavelength. Plot clearly shows that samples offers low refractive index on shorter wavelength side, whereas the value of refractive index increase on longer wavelength side up to 330 nm. Beyond 320 nm, refractive index decreases gradually. The highest value of refractive index is observed for G4 at 330 nm. With the increasing concentration of GO, refractive index also increases for all samples. In case of G5, the value of refractive index is decrease. This may be due to excess content of GO. In other words, the concentration of GO for G4 that is $x = 4$ is optimum concentration value to achieve highest value of refractive index for $60V_2O_5$–$5P_2O_5$–$(34-x)B_2O_3$–xGO glass system.

Fig. 5 represent the optical conductivity plot of $60V_2O_5$–$5P_2O_5$–$(34-x)B_2O_3$–xGO glass samples. The highest value of optical

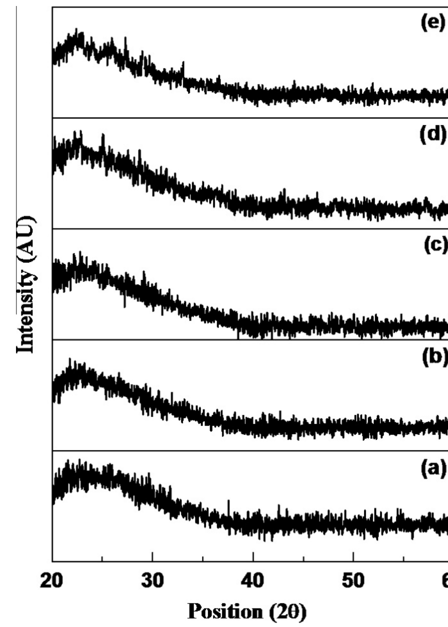

Fig. 1. XRD patterns of $60V_2O_5$–$5P_2O_5$–$(34-x)B_2O_3$–xGO for: (a) G1, (b) G2, (c) G3, (d) G4 and (e) G5.

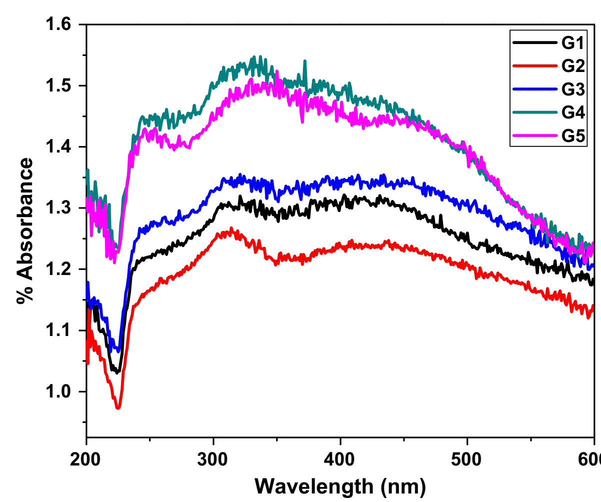

Fig. 2. UV–VIS spectrum of $60V_2O_5$–$5P_2O_5$–$(34-x)B_2O_3$–xGO glass system.

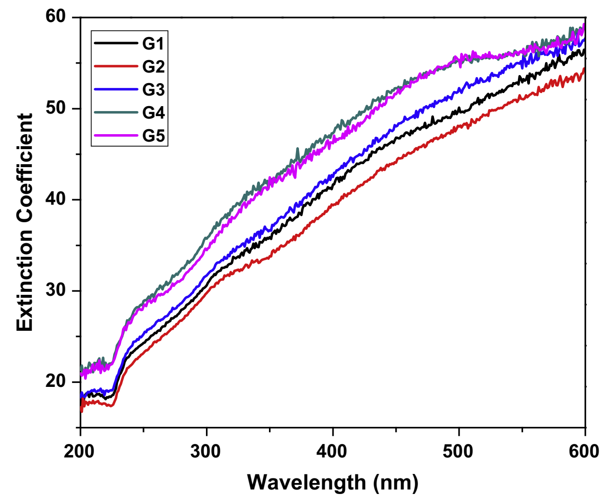

Fig. 3. Variation of extinction coefficient of $60V_2O_5$–$5P_2O_5$–$(34 - x)B_2O_3$–xGO glass system as a function of wavelength.

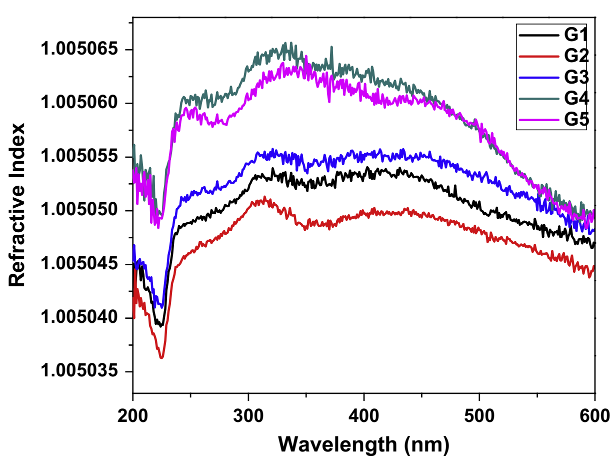

Fig. 4. Variation of refractive index of $60V_2O_5$–$5P_2O_5$–$(34 - x)B_2O_3$–xGO glass system as a function of wavelength.

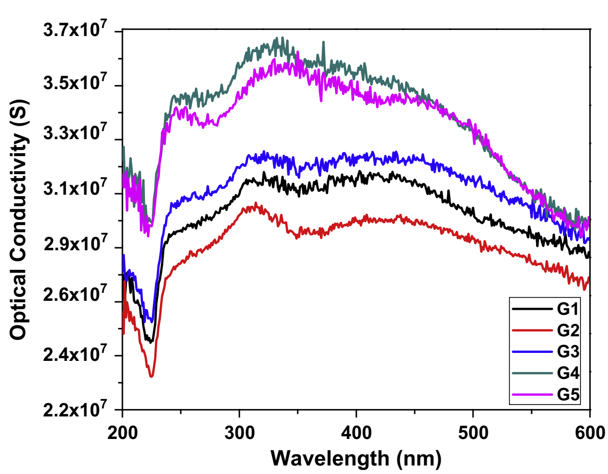

Fig. 5. Variation of optical conductivity of $60V_2O_5$–$5P_2O_5$–$(34 - x)B_2O_3$–xGO glass system as a function of wavelength.

conductivity is acquired by the sample G4, whereas the lowest value by G2. This also reflects the value of optical conductivity tuned by concentration of GO.

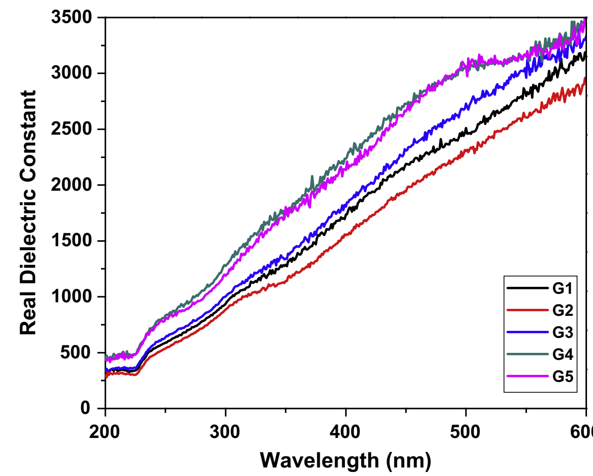

Fig. 6. Variation of real dielectric constant of $60V_2O_5$–$5P_2O_5$–$(34 - x)B_2O_3$–xGO glass system as a function of wavelength.

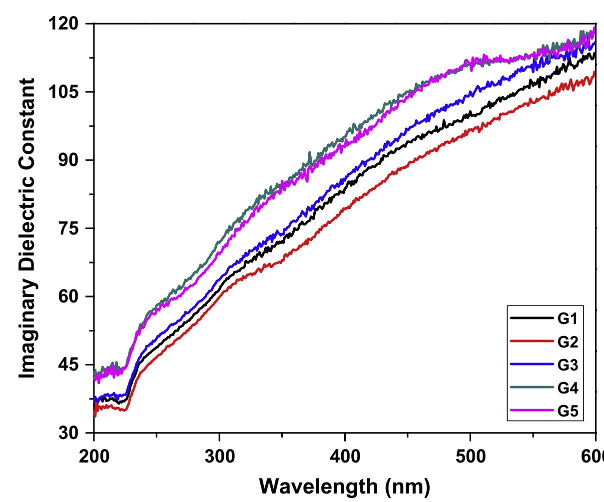

Fig. 7. Variation of imaginary dielectric constant of $60V_2O_5$–$5P_2O_5$–$(34 - x)B_2O_3$–xGO glass system as a function of wavelength.

Fig. 6 shows the real dielectric constant variation as a function of wavelength. The value of real dielectric remains almost constant up to 225 nm. After 225 nm, value of real dielectric constant increases gradually up to 600 nm. The highest value of real dielectric constant was found to be for G5. Real dielectric constant is measure of slow down of velocity of light. In our case, G5 mostly slow down the velocity of longer wavelengths [21].

Fig. 7 shows the variation of imaginary dielectric constant as a function of wavelength. Imaginary dielectric constant assess absorbs energy from an electric field due to dipole motion. In our case, G4 and G5 nearly have the same strength to absorbs energy from an electric field due to dipole motion [20]. The magnitude of imaginary dielectric constant increases from 225 nm up to 600 nm.

4. Conclusions

In the summary of present work, we have studied the complex optical parameters of $60V_2O_5$–$5P_2O_5$–$(34 - x)B_2O_3$–xGO glass system. The highest value of extinction coefficient was found to for G5, which is also supported by the real and imaginary dielectric constant curve. This shows that dispersion quantity of graphene

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oxide significantly alter the extinction coefficient, real and imaginary dielectric constant. The samples show gradual increase in absorption around the 225 nm, which results in increase of refractive index and optical conductivity. The highest value of absorption associated with the G4, which results in high value of refractive index and optical conductivity.

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