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Effect of PbO on optical properties of tellurite glass

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ABSTRACT

Binary $(1-x)(TeO_2)-x(PbO)$, x = 0, 0.10, 0.15, 0.20, 0.25, 0.30 mol% glass system was fabricated using melt quenching method. X-ray diffraction (XRD) technique was employed to confirm the amorphous nature. The microanalysis of the major components was performed using energy dispersive EDX and X-ray spectrometry. Both the molar volume and the density were measured. FTIR and UV spectra were recorded at 400–4000 cm^{-1} and 220–800 nm, respectively. The optical band gap (E_{opt}), Urbach's energy (E_u), index of refraction (n) were calculated using absorption spectrum fitting (ASF) and derivation of absorption spectrum fitting (DASF) methods. Molar refraction R_m and molecular polarizability α_m have been calculated according to (ASF) method.

Introduction

This article will introduce tellurite glasses as some smart materials because the world has entered the Glass Age. Tellurite glasses based on tellurium dioxide (TeO_2) are of technological interest due to their superior physical properties [1–20]. Recently, application of tellurite glasses has been achieved, especially in blue converted WLEDs, self cleanliness, and Pb-Te-O glasses affected silicon solar cells have been investigated [1,4]. A comparative study of the elastic, shielding and anomalous elastic and optical behavior in tellurite glasses have been measured [15–18]. Structure and optical band gap of $(PbO)_x(ZnO)_{10}(TeO_2)_{90-x}$ glasses have been measured [19].

The present objective is to measure the optical band gap energy (E_{opt}), Urbach's energy (E_u) and index of refraction (n). The value of n were calculated using the absorption spectrum fitting (ASF) and the derivation of absorption spectrum fitting (DASF) methods. Molar refraction R_m, molecular polarizability α_m, reflection loss (R_L) and optical transmission coefficient (T), metallization (M) and dielectric constant (ε) and ion Pb^{+2} and Oxygen packing density (O.P.D) have been calculated.

Experimental methods

The $(1-x)(TeO_2)-x(PbO)$ glasses; x = 0, 0.10, 0.15, 0.20, 0.25, 0.30 glass system was fabricated from high purity oxides mixed in specific weights, tellurium oxide TeO_2 (Alfa Aesar, 99.99%) and lead oxide PbO (Alfa Aesar, 99.99%). The homogenization of the 15 g of chemicals mixtures was effected by repeated grinding using a mortar for 30 min. The mixtures were preheated in a crucible (alumina crucible) at 280 °C for 1 h in an electric furnace. The preheated crucible was then moved to the another electrical furnace and kept for one hour at a temperature 850–900 °C. The molten mixture then turned into a cylindrically shaped stainless steel split mould preheated at 280 °C. After the quenching process, the solidified sample was then annealed at 280 °C for 1 h to avoid the mechanical strain developed during the quenching process and then the solidified glass is allowed to cool down to the room temperature. The samples of the glasses were cut into required dimension (between 6 to 10 mm) using the low-speed diamond blade to make great parallel surfaces for the measurements of ultrasonic velocities. Using a polishing machine with sand paper, the two sample's surfaces for each of the glasses were polished to get a plane parallelism. An X-ray diffraction (XRD) system was used to confirm the amorphousity or crystallinity of each sample by using an X-ray powder

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diffraction instrument (X'Pert Pro Panalytical PW 3040 MPD) in the range of (2θ) from 4° to 90° and energy dispersive EDX (Scanning Microscope, JSM.6400).

Density measurement of the glass sample was carried out using a densitometer model (MD-300S Densimeter). The density resolution was estimated around ±0.001 g/cm^3. For each of the samples, the density was measured using the following relationship:

$$\rho = \frac{W_{air}}{(W_{air} - W_{water})} \quad (1)$$

where (W_{air}) and (W_{water}) each representing the sample's weights, respectively in air and distilled water. Molar volume calculated from density using the equation, ($V_m = M_{glass}/\rho_{glass}$), where ρ_{glass} = glass sample density and M_{glass} = glass molecular weight.

For each glass sample, the molar volume determined by the expression below:

$$V_m = \frac{\sum_i x_i M_i}{\rho_{glass}} \quad (2)$$

where (M_i) is the molecular weight of an oxide component (i) and (x_i) is its mole fraction.

The FTIR spectra were obtained by using the FTIR spectrometer [400–4000 cm^{-1} & resolution of 0.85 cm^{-1} by KBr pellet technique] (Spectrum 100 perkin elmer). The UV absorption spectra of 0.2 cm thickness were measured in 220–800 nm using UV–Vis-NIR spectrophotometer (UV-3600 Shimadzu).

Results and discussion

Fig. 1 shows the photo of the prepared glasses are homogeneous and transparent. Fig. 2 shows the X-ray diffraction (XRD) pattern and confirm amorphous nature of $(1 - x)(TeO_2) - x(PbO$ glasses, x = 0, 0.10, 0.15, 0.20, 0.25, 0.30 mol%. Fig. 3a–f is the EDX spectrum, which only shows Te, Pb and O elements. EDX Analysis is a technique employed for identification of the elemental composition of a given specimen, or an area of interest. The profiles of the EDX analysis showed the presence of all the mentioned elements in the prepared samples. The prepared glass samples were homogeneous, lime green color and became more transparent as PbO increases as shown in Fig. 1. XRD pattern represents the confirmation that the present glasses are of amorphous nature as shown in Fig. 2. Also, Fig. 3a–f shows the EDX spectra for lead tellurite glass samples. It is observed from the result obtained that the use of alumina crucible induces a partial dissolution of Al_2O_3 in the melt that modifies the original composition.

The density (ρ), molar volume (V_m) and the OPD for the present glass system are collected in Table 1. Density of the glasses studied increased from 4930 to 6231 (kg/m^3), while molar volume decreased from 32.37 to 28.67 (cm^3/mol) as shown in Fig. 4. The glass density increase may be due to the high PbO molecular weight (223.1994) which is more than that of TeO_2 (159.6) and hence, the present glass matrix becomes more dense. Oxygen packing density decreased from 62.00 to 59.28 (mol/L) with the

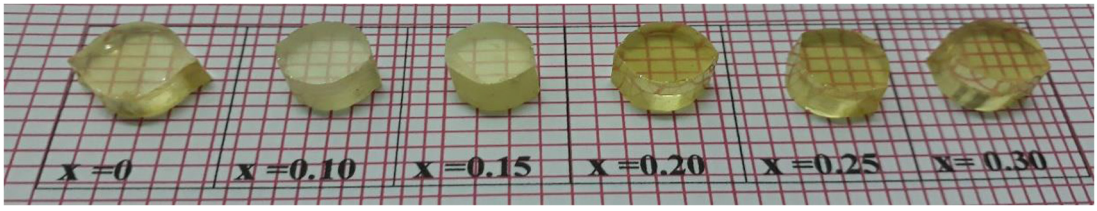

Fig. 1. Samples of $(1 - x)(TeO_2) - x(PbO)$ glasses, x = 0, 0.10, 0.15, 0.20, 0.25, 0.30 mol%.

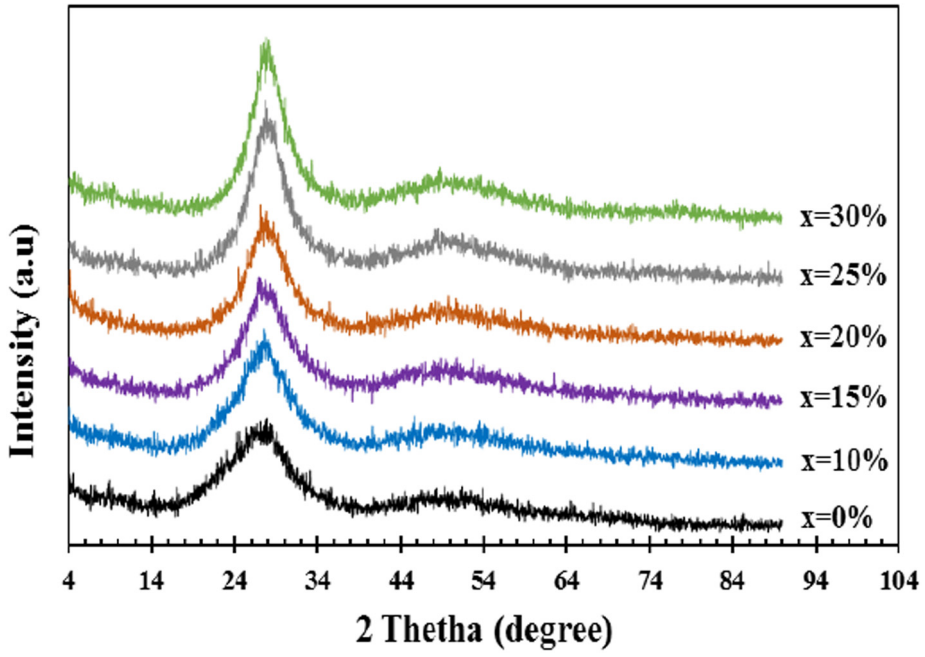

Fig. 2. X-ray diffraction (XRD) pattern of $(1 - x)(TeO_2) - x(PbO)$ glasses, x = 0, 0.10, 0.15, 0.20, 0.25, 0.30 mol%.