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Physical and structural properties of binary ZnO-TeO_2 glass system

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Abstract: Binary tellurite glass in the form *x*ZnO-(100-*x*) TeO_2 (*x* = 0, 5, 10, 15, 20, 25 and 30 mol%) have been prepared by the melt quenching technique. Density and molar volume of every glass composition have been measured and calculated. X-ray diffraction (XRD) analysis have been carried out in order to determine the amorphous phases in each of the glass samples. Fourier transform infrared spectroscopy (FTIR) measurement were proved the presented of TeO_4 group in all ZnO-TeO_2 glasses.

Keywords: Tellurite glass, Zinc oxide, Structural Properties

Tellurite based glasses have drawn considerable attention because the glassy phase can be formed over a wide range of concentrations. It has a superior physical property such as low melting temperature, high refractive index, high dielectric constant, low phonon energy, excellent third-order non-liner optical properties, better solubility of rare earth ions, large thermo-optic coefficient and good infrared transmission [1-5]. Because of their exceptional properties in tellurite glasses are promising materials for a broad range application including erasable optical recording media, optical switching devices, laser hosts, second harmonic generation, and Raman amplification [3-8].

ZnO-TeO_2 glass systems shows good and stable glass forming ability with a broad region. However, this glass formation strongly depends on the cooling rate and the size of the melt, especially in the TeO_2-rich regions [9]. These glass systems were used as a basis for multi-component optical glass synthesis, nuclear and solar energy technologies, and acousto-optic devices [10-12]. The main objectives of this present studies are to determine the preparation conditions of ZnO-TeO_2 transparent glass and characterize them by density, molar volume, x-ray diffraction (XRD) and Fourier transform infrared spectroscopy (FTIR) measurements.

Binary glass system of *x*ZnO-(100-*x*) TeO_2 (*x* = 0, 5, 10, 15, 20, 25 and 30 mol%) were fabricated by melting and quenching technique. High purity starting materials of ZnO (Alfa Aesar, 99.9%), TeO_2 (Alfa Aesar, 99.99%) were weighed with an appropriate amount (~35g) and mixed in mortar-pestle homogenously. Afterwards, the mixture on binary glass system was transferred into alumina crucible and preheat in electrical furnace at 400°C for 30 min. The electrical furnace was then increased up to 950°C at the rate 10°C/min for the melting process and kept at this temperature for 2 h. The melting glass sample was then poured into the preheated

rectangular stainless steel mould at 400°C for 30 min. After that, the glass sample was annealed at this temperature for 1 h to remove any thermal stress produced by non-uniform rapid cooling of the melt. The obtain glass samples was cut with the thickness ±5 mm and polished both side that being used for measurements of ultrasonic velocity.

The density of the glass samples was measured at room temperature by using Archimedes' Principle, where the sample was weighted in air and then in an immersion liquid (distilled water). The weight of sample in air and distilled water were measured by using an electronic weighing machine with the accuracy of ±0.001 g. The molar volume (V_m) was measured in cubic centimetre per mole (cm^3/mol). The molar volume has been calculated as:

$$V_m = \Sigma \frac{M_T}{\rho} \quad (1)$$

where M_T is the total molecular weight of the multi-component glass systems.

The amorphous or crystalline nature of the glass samples is confirmed by XRD characterization using a Philips X-ray diffractometer (PANalytical X'pert PRO PW 3040 MPD X-ray powder diffractometer) with Cu Kα radiation. The scans were performed from 2θ, range from 20° to 80° using 0.02° steps. The functional group of glass samples was verified via Perkin Elmer Spectrum 100 Series spectrophotometer within the range of 400-1200 cm^{-1} using Attenuated Total Reflectance (ATR) mode.

Figure 1 shows the variations value of density and molar volume respecting to the different amount of ZnO in tellurite glass systems. The density ZnO-TeO_2 glasses is increases from 4.879 to 5.283 g/cm^3 as the content of ZnO increases. In general, the increment in density for both glass system is attributed to the high molecular weight of additional oxide [13-18]. As the heavier atom is place in the lighter atom, the total molecular weight is increased hence the denser glass will produced. Theoretically, the molar volume (V_m) shows the opposite behavior with density of the glasses. In this studied, the molar volume is observed to decrease with the increasing of ZnO content for ZnO-TeO_2 glass systems. The molar volume of ZnO-TeO_2 glasses is decreasing from 32.712 to 25.768 cm^3/mol as presented Figure 1. This decrement value of V_m for this tellurite glass systems is due to the reduction interatomic spacing and bond length between the atoms [19-20].

Figure 2 presents the X-ray diffraction graph of ZnO-TeO_2 glass systems. The graphs were observed a broad halo peak at lower angle (below 40°) and no continuous sharp peak which illustrate a typical of fully amorphous glass structure with no signed of crystallization [21]. This demonstrates the presence of short-range atomic order and the absence of long-range atomic order in the glass samples. Besides, the XRD analysis also shown the main broad peaks of the glass samples shifts to the higher 2θ values which are 26°- 29° and this behavior designates a progressive modification of tellurite structure with the addition of ZnO content [21].

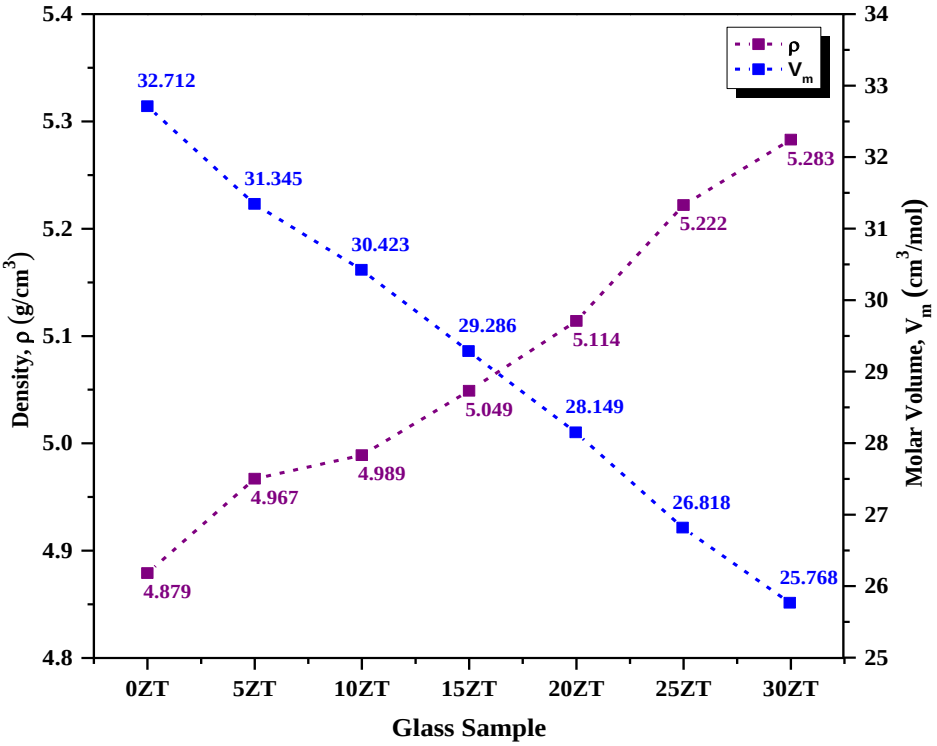

Figure 1: Density (ρ), molar volume (Vm) of binary ZnO-TeO_2 glass systems

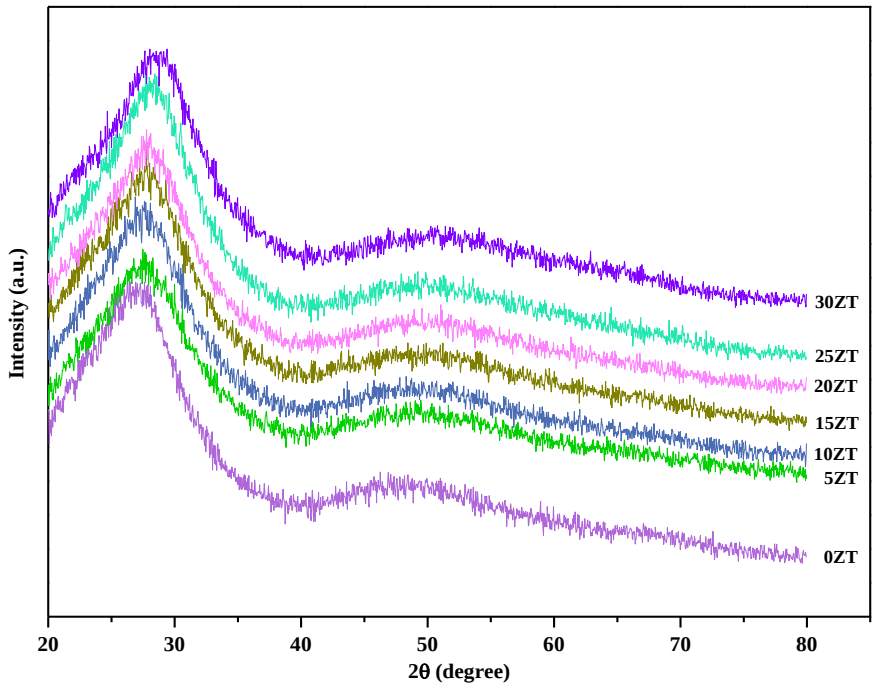

Figure 2: X-ray diffraction of ZnO-TeO_2 glass systems

The experimental FTIR spectra of $ZnO\text{-}TeO_2$ glass systems with variance amount of ZnO are presented in Figure 3. In general case, the infrared absorption characterization of pure TeO_2 is around 640 cm^{-1} [22-25]. The absorption band in the range 600-650 cm^{-1} is associated to the stretching vibrations of Te-O bond in TeO_4 group. In this works, it can be seen that there is only one absorption band for all the glass samples at a range 610 cm^{-1}. The existence of this bands has been approved that the presence of TeO_4 group in all $ZnO\text{-}TeO_2$ glass samples. Besides, it can be observed that from Figure 3, the intensity of the absorption band located at a range 610 cm^{-1} become shaper as the amount of ZnO increases from 15 to 30 mol%. This behavior is due to the increased of TeO_4 concentration which indicate the closed packed of the glass networks caused by more formation of bridging oxygen [26]. On the other hand, the disappearance of ZnO assignment band in the all glass samples at the regions between 400-550 cm^{-1} indicates that the zinc lattice is break down completely. The infrared transmissions band for all vibration mode of $ZnO\text{-}TeO_2$ glass systems is tabulated in Table 2.

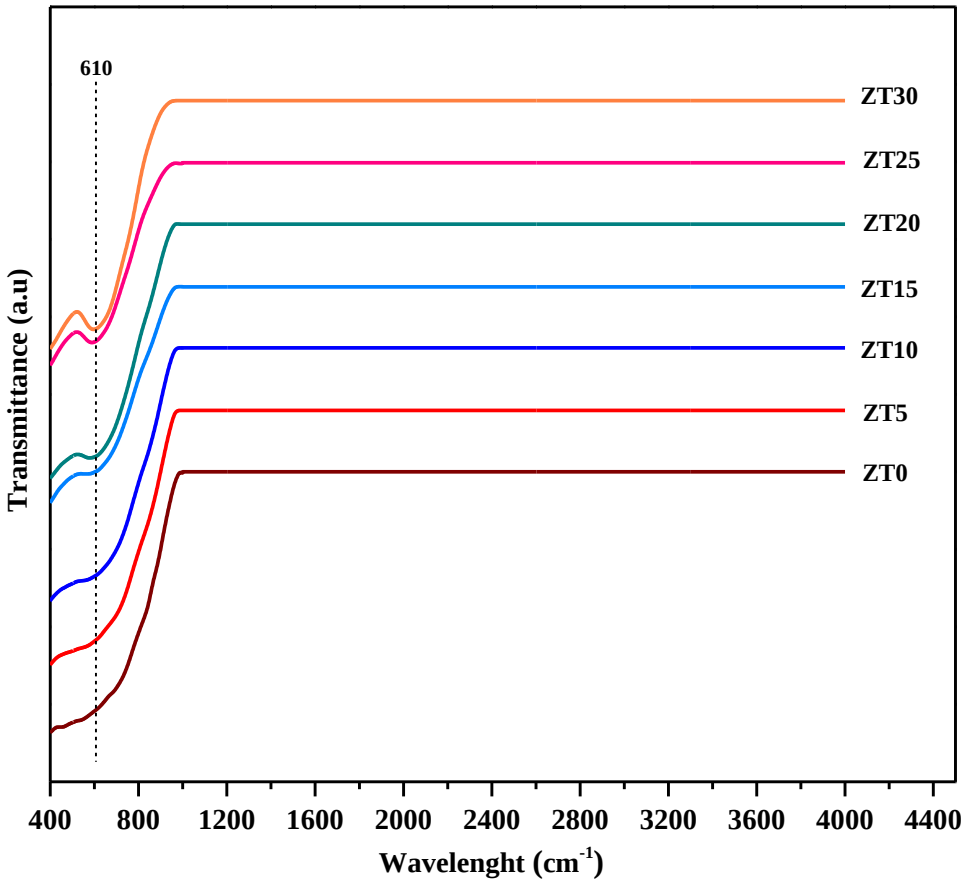

Figure 3: FTIR spectra of $ZnO\text{-}TeO_2$ glass systems

Table 2 Infrared transmission band assignments for $ZnO\text{-}TeO_2$ glass system

Wavelength (cm^{-1})	Vibration Mode	Reference
600-650	Stretching vibration Te-O in TeO_4 group	[25-27]

In conclusion, a series of binary tellurite glass in the form xZnO-(100-x)TeO_2 (x = 0, 5, 10, 15, 20, 25 and 30 mol%) have been successfully fabricated by using the melt quenching technique. The structural and elastic properties of $ZnO\text{-}TeO_2$ glass systems were found generally affected by the changes in the glass compositions. The density of binary $ZnO\text{-}TeO_2$ glasses increases as the ZnO content was added into the TeO_2 glass while molar volume decreases. The FTIR spectra of this binary glasses showed the strong band which located at 610 $cm^{-1}$and this band become sharper with the increase existence of ZnO content.

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