Influence of Melting Period in the Thermal Stability and Physical Properties of TeO_2–ZnO Glass System

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Abstract

Tellurite glasses of the $70TeO_2$-30ZnO systems have successfully been made by melt quenching technique. The influence of melting period in the thermal stability and physical properties of glass has been investigated by means of TG/DTA and density measurement. The thermal parameters, such as the glass transition temperature (T_g), crystallization temperature (T_c) and melting temperature (T_m) were successfully determined. It is found that an increasing of melting period in the preparation of tellurite glasses from 15 minute to 75 minute results in increasing of T_g from 327°C to 331°C. This glass system was found to posses a wide range of glass stability from 79°C - 104°C. However, for the melting time which is more than 30 minute, the density of glasses decreases from 5.50 g/cm^{-3} to 5.46 g/cm^{-3} while the molar volume increases from 24.75 cm^3/mol to 24.94 cm^3/mol.

***Keyword*:** melting time; thermal parameters; physical properties.

INTRODUCTION

Glass has gained considerable attention due to their multi application. Tellurite glass has attracted most researchers to work on it due to their good stability and scientific application. (El-Mallawany, 2002). The glass material can be formed using variety of techniques, such as cooling techniques from the liquid state, vapour condensation, pressure quenching, solution hydrolysis, anodization, sol-gel formation and bombardment of crystal by high energy particles or shock wave. Among these techniques, cooling from the liquid state is by far the most important and most widely used (Uhlmann and Kreidl, 1983). Meanwhile BØrger *et al*. (1992) reported that for α-TeO_2 based glass, the extremely high cooling rate, which is more than $2x10^2$ °C/s must be applied. In this work the $TeO-_2$ – ZnO glass system can be obtained by using ~1°C/min of cooling rate, while the glass forming range of 17.2mol% to 37.6mol% ZnO is valid for a cooling rate of about 10°C/s. In this paper, Tellurite glass has been used as a host while zinc oxide (ZnO) as a modifier. Conventional melt quenching technique has been applied throughout the glass preparation. The influence of melting period in the thermal stability and physical properties of TeO_2–ZnO glass systems were investigated.

EXPERIMENTAL DETAILS

The erbium doped zinc-tellurite glasses in the $70TeO_2$-30ZnO systems were prepared by melt quenching technique. Batches of 10 g were prepared from commercial powders of TeO_2 (purity 99%), ZnO (purity 99%). A well-mixed mixture was milling for 0.5h before being melted in platinum crucible at 1000°C for 0.5h. After a required viscosity is achieved, the melts is quenched between two brass plates followed by annealing at 260°C for 5h before allowed to cool down to room temperature.

Pyris Diamond TG/DTA (Thermogravimetri / Differential Thermal Analyzer) was used to determine the thermal characteristics of the glasses. 10 mg glass samples were heated in the TG/DTA furnace with a heating rate of 10°C/min from 25°C to 900°C. The density measurements of glass samples were made with a digital balance based on Archimedes principal using a Precisa Model XT 220A. A sample was first weighed in air. After being weighed in air, the sample was immersed in toluene. The density (ρ) was calculated using equation,

$\rho = \rho_l \frac{W_A}{W_A - W_l}$; where W_A is the weight of sample in air, W_l is the weight in immersion fluid and ρ_l is the density of the immersion fluid. Toluene (ρ_l = 0.8690 g cm^{-3}) was used, as it does not react chemically with the sample.

The density data can used to calculate the molar volume (V_m) using equation, $V_m = \frac{M}{\rho}$; where M is the glass molecular weight calculated from composition.

RESULTS AND DISCUSSION

Series of $70TeO_2$-30ZnO glass systems have successfully been made by melt quenching technique with various melting period. The DTA curve for the glasses show a broad endothermic hump corresponding to the glass transition temperature T_g. This transition is followed by one exothermic peak corresponding to crystallization temperature T_c and other endothermic event corresponding to the melting temperature T_m. The temperature difference ($\Delta T=T_c-T_g$) corresponding to the thermal stability of glasses is also calculated.

Meanwhile, the TG/DTA curves from some samples are shown in Fig.1. As depicted from Table 1 and Fig 1, as the melting period varied from 15minute to 45, minute T_g increased from 327°C to 332°C. The increases in glass transition temperature is due to the cleavage of the networks hence increase in the rigidity of the network formed by TeO_4 tbp units the increase in T_g also can be associates to the increasing number of non-bridging oxygen atoms in the glasses (Tastumisago *et al.*, 1994; Abd El-Moneim, 2002).

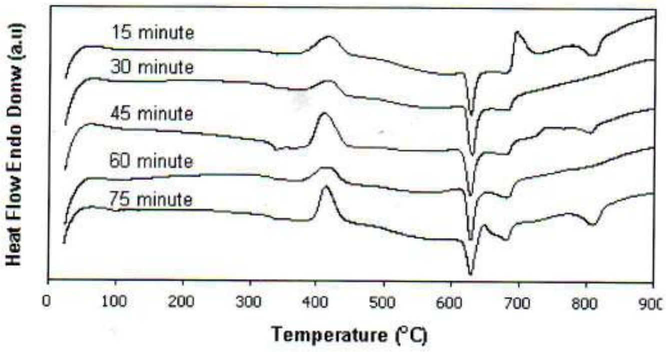

Figure.1 DTA curve of 70TeO$_2$-30ZnO glass system

Table 1 Thermal characteristics, densities and molar volume of glass samples variation the melting time.

Sample No	Composition (mol%) TeO$_2$	ZnO	Melting Time	T_g (C)	T_c (C)	T_c-T_g (C)	T_m (C)	Density (g/cm^3)	Molar Volume
S1	70.0	30.0	15	327	415	88	627	5.50	24.747
S2	70.0	30.0	30	329	416	87	630	5.50	24.734
S3	70.0	30.0	45	332	410	78	628	5.48	24.820
S4	70.0	30.0	60	330	415	85	629	5.48	24.862
S5	70.0	30.0	75	330	413	83	630	5.46	24.938

From the table, the crystallization temperature, Tc shows highest result (416°C) as the melting period is 30 minute which shows that the glass tend to be not crystallized easily (Kawasaki et al., 2003). The melting temperature posses highest result (630°C) as the melting period is at 30minute and 75minute respectively, which indicates that increases in the density of the network the glass (Abd El-Moneim, 2002). As the melting period is varying from 15minute to 45minute, ΔT is found to decrease from 88°C to 78°C.

The densities and molar volume of the sample glasses system are shown in Table 1. The variations of density with the melting period are shown in Fig.2. From Table 1 and Fig. 2, it can be seen that the density of glass system decreases with respect to the melting period is as it decreases from 5.50g/cm^3 to 5.46g/cm^3. A molar volume glasses systems were plotted against the melting time are shown in Fig. 3. From Fig. 3, as the melting period varies from 30minute to 75minute, the molar volume increases from 24.747 (cm^3/mol) to 24.938 (cm^3/mol).

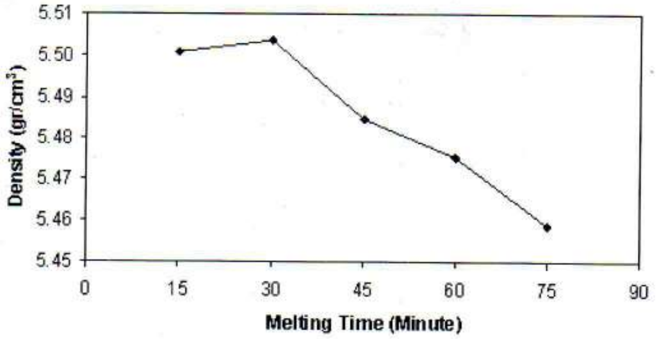

Figure 2 Density of 70TeO$_2$-30ZnO glass systems as a function of melting period

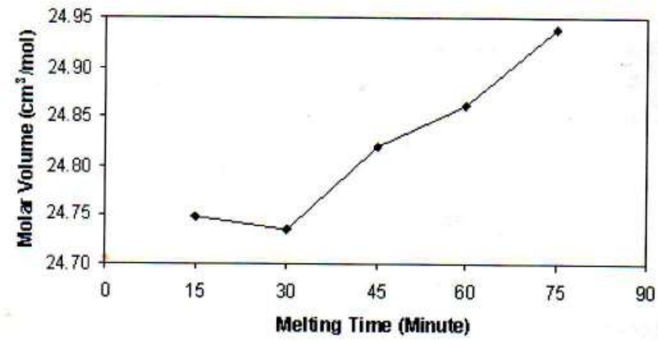

Figure 3 Molar volume of 70TeO$_2$-30ZnO glass systems as a function of melting period

CONCLUSIONS

From the above discussions, some conclusion may be drawn.

1. The melting period as it varies from 15minute to 45minute will results in the increases of T_g from 327°C to 332°C, which implies the increases in the rigidity of the network, by having a continuous tellurite network and 4–coordinated.Te atoms.
2. As the melting period is 30minute, the crystallization temperature as well as the melting temperature posses highest results which is 416°C and 630°C respectively.
3. ΔT is decreases from 88°C to 78°C, as the melting period varies from 15minute to 45minute,
4. The density of glass samples decrease with the melting period from 5.50g/cm^3 to 5.46g/cm^3.

5. The molar volume increases from 24.747 (cm^3/mol) to 24.938 (cm^3/mol) with respect to melting period.

REFERENCES

1. Uhlmann, D.R. Kreidl, N.J., *Glass: Science and Technology*. Vol.1. New York: Academics Press, (1983).
2. A. Nukui, T. Taniguchi, M. Miyata, *J. Non-Cryst. Solids* 293-295 (2001) 255.
3. M.R. Sahar, N. Noordin, *J. Non-Cryst. Solids* 184 (1995) 137.
4. H. BØrger, K. Kneipp, H. Hobert, W. Vogel, *J. Non-Cryst. Solids* 151 (1992) 134.
5. R. El-Mallawany, *Tellurite Glasses Handbook: Physical Properties and Data*, CRC Press LLC, 2002.
6. L.L. Neindre, S. Jiang, B.C. Hwan, T. Luo, J. Watson, N. Peyghambarian, *J. Non-Cryst. Solids* 255 (1999) 97.
7. D.L. Sidebottom, M.A. Hruschka, B.G. Potter, R.K. Brow, *J. Non-Cryst. Solids* 222 (1997) 282.
8. S. Marjanovic, J. Toulouse, H. Jain, C. Sandmann, V. Dierolf, A.R, Kortan, N. Kopylov, R.G. Ahrens, *J. Non-Cryst. Solids* 322 (2003) 311.
9. M. Tastumisago, T. Minami, Y. Kowada and H. Adachi, *Phys. Chem. Glasses* 35 (1994) 89.
10. A. Abd El-Moneim, *Mater. Chem & Phys* 73 (2002) 318.
11. S. Kawasaki, T. Honma, Y Benino, T. Pujiwara, R. Sato, T. Komatsu, *J. Non-Cryst. Solids* 325 (2003) 61.
12. G. Wang, Xu, S. Dai, S. Yang, J. Hu, L. Jiang, Z. *J. Non-Cryst. Solids* 336 (2004) 102-106.
13. G. Wang, Zhang, J. Dai, S. Yang, J. Hu, L. Jiang, Z. *Physics Letters A* 341 (2005) 285-290.