Preparation of Glass Material and Its Physical Properties

Azman Kasim
Nurbaisyatul Ermiza
Wan Aizuddin Wan Razali

ABSTRACT

Glass is an amorphous material that could be prepared by using variety of techniques. The most well known and practically used methods are sol-gel and melt-quenched techniques. In most research work, the melt-quenched technique has been widely used and the techniques will be discussed in details in this report. This paper will explains the research methodology of the overall experimental procedure which includes the materials selection, weighing process, powder mixing, milling process, melting process, annealing and cooling process. Some explanation on the measuring of the basic physical properties also will be given. In this works, series of glass samples have been successfully prepared at the Glass Preparatory Lab., UiTM. Good quality of glass sample has been obtained as a result of the proper standard procedure of glass preparation. The glass sample has then undergone certain measurement in term of their physical properties. The data has been analysed and discussed.

Keywords: *glass, melt-quenched techniques, milling, annealing*

Introduction

Glass is an amorphous material made from inorganic materials at high temperatures. As it is cooled down, the glass become rigid but has never been crystallized. By glass we usually understand a hard material, often transparent or translucent, which is made by heating together a mixture of materials such as sand, limestone and soda at a very high temperature. In history, glass is believed to be found in the Middle East 7000 BC but the development of glass had just started in early of 20th century. A uniqueness of glass properties and its application in science and technology has gained considerable attention to scientists and researchers to work on it.

In science and technology, glass has been used in many applications such as in optical data transmission, detection, sensing, laser technologies and batteries application. Therefore, this paper will discuss the techniques that have been used to fabricate a glass material as well as its some physical properties. In this work, a series of tellurite glass has been well fabricated by using melt-quenched techniques. A discovery of Tellurite in the past few decades has been a great deal of interest in the search of glass materials due to their high reputation on technological and scientific applications. Tellurite glass are excellent in infrared transmission [1], low melting temperatures [2], high refractive indices [3], high dielectric constant [4], chemically and thermally stabled [5].

Experimental Details

The sample of tellurite glasses were prepared from certified reagent grades of TeO_2 (99.95% purity), Li_2CO_3 (97% purity), PbO (98% purity) and Nd_2O_3 (99.995% purity). The chemicals were firstly mixed thoroughly in Platinum crucible before being heated to about 1000^{o}C for half an hour. After the batch was completely melted, the melt was cast onto the preheated stainless steel for annealing process at 300°C for five hours in order to reduce any residual stress before being cooled down to room temperature. The glass density was measured by Archimedes's method by using toulene as an immersion liquid. Meanwhile, the molar volume of the glass was calculated through the mathematical derivation between the density and the molar mass of the glass. Figure 1 illustrates the flowchart of glass preparation.

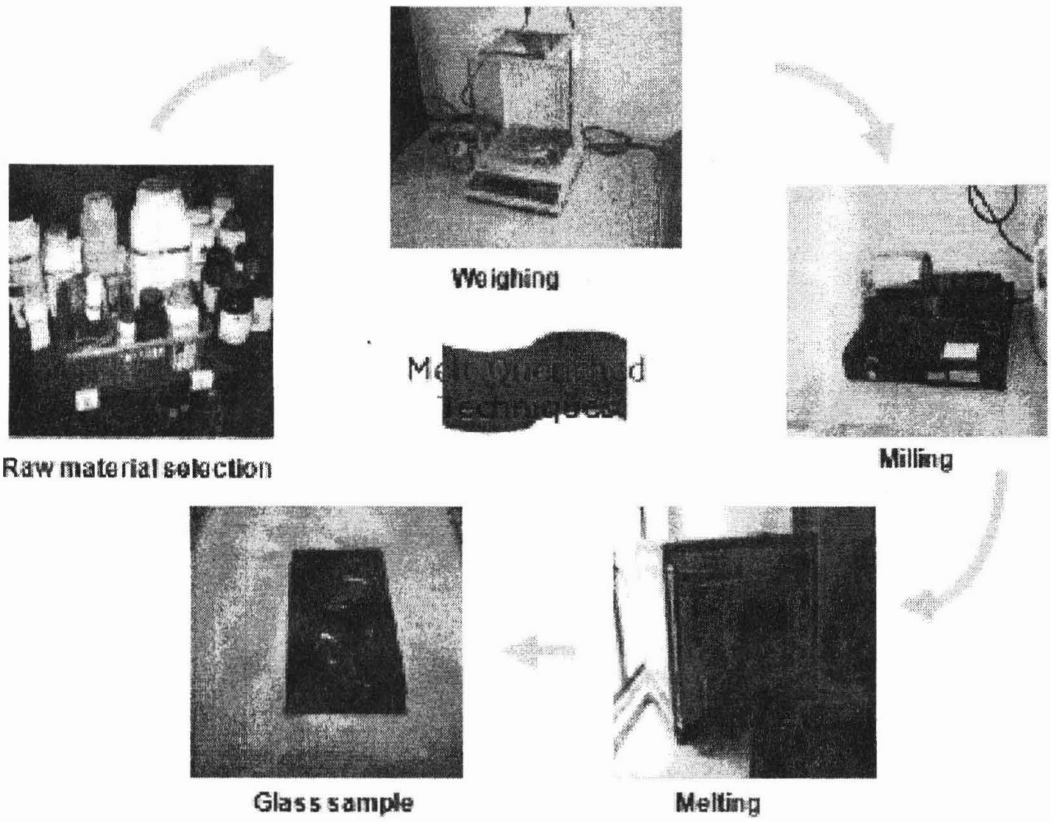

Figure 1: A flowchart of glass preparation

Results and Discussion

In this work, a serie of tellurite glass has been successfully fabricated by using melt-quenched techniques. Melt-quenched is a conventional technique that used other then sol-gel techniques to produce a glass samples. It deals with quite high temperature in order to melt the selected raw material before the molten being left to cool down to room temperature. Hence, tellurite glass of the system (88-x)TeO_2-10PbO-2Li_2O-xNd_2O_3 has been successfully prepared with difference mol% of Nd ranging from x = 0.5mol% - 3.0mol%. The glass samples obtained are in a good quality which is relatively high chemical durability since they show no sign of devitrification. Physically, the glass obtained are clear and transparent and non hygroscopic. The glass is visualized as yellowish in colour by which it comes from the effect of the Nd. It has been shown in Table 1 as the color is changing from light yellow to yellow in color with respect to mol% of Nd. Similar trend of results had also been attained by El-Mallawany *et.al* in their works [6]. The glass coloration depends on the incorporation of glass composition.

Table 1: The composition of (88-x)TeO_2-10PbO-2Li_2O-xNd_2O_3 glass system.

Sample	Sample Composition (mol%)				Colour	Visual	Remark
	TeO_2	PbO	Li_2O	Nd_2O_3			
S11	87.5	10	2	0.5	Light Yellow	Glass	Clear, Not Hygroscopic
S12	87.0	10	2	1.0	Light Yellow	Glass	Clear, Not Hygroscopic
S13	86.5	10	2	1.5	Light Yellow	Glass	Clear, Not Hygroscopic

S14	86.0	10	2	2.0	Yellow	Glass	Clear, Not Hygroscopic
S15	85.5	10	2	2.5	Yellow	Glass	Clear, Not Hygroscopic
S16	85.0	10	2	3.0	Yellow	Glass	Clear, Not Hygroscopic

The physical properties of tellurite glass have been tabulated in Table 2. As depicted in Table 2 and Figure 1, the graph shows a linear increment as the Nd_2O_3 incorporated into the Te glass system ranging from 0.5 mol % to 3 mol%. The density of the Te glass varies from 5895 kgm^{-3} to 5926 kgm^{-3}. The 0.51% increment of density implies that an addition of Nd_2O_3 with higher atomic masses than TeO_2 tend to increase the packing density of the glass structures. The atomic masses of TeO_2 and Nd_2O_3 are 159.60 and 336.48 respectively. This results are in agreement with Komiyama (1980) in his work who found that the introduction of Nd into glasses tends to develop a more tightly packed glass structure by compacting the electron clouds surrounding the O^- due to their high charge and coordination number [7].

Table 2: Results of glass density and molar volume of tellurite glass

Sample	Sample Composition (mol%)				Density (kg/m^3)	Molar Volume (cm^3 /mol)
	TeO_2	PbO	Li_2O	Nd_2O_3		
S11	87.5	10	2	0.5	5895.56 $\pm$ 1.48	27.86
S12	87	10	2	1	5897.48 $\pm$ 1.93	27.99
S13	86.5	10	2	1.5	5905.1 $\pm$ 1.64	28.11
S14	86	10	2	2	5910.48 $\pm$ 1.56	28.24
S15	85.5	10	2	2.5	5911.62 $\pm$ 1.47	28.38
S16	85	10	2	3	5926.75 $\pm$ 4.27	28.46

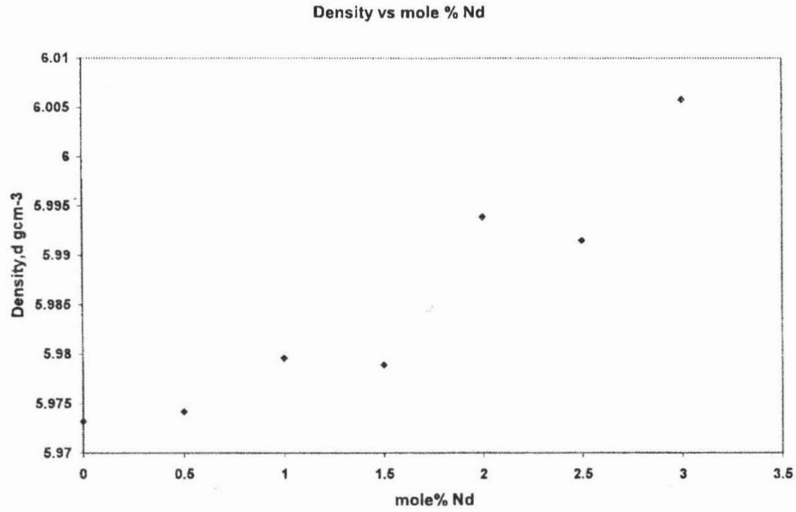

Figure 2: A variation of Tellurite glass density as a function of mole% of Nd. The line is drawn for guides to the eye.

Meanwhile, Figure 3 shows the variation of the molar volume against the Nd_2O_3 content. From Table 2, it shows an increment trend of curvature with respect to mol% of Nd content. The results are found to vary from 27.86 cm^3 / mol at 0.5 mol% to 28.46 cm^3 /mol at 3.0 mol%. The replacement of Tellurite atoms by Neodymium atoms explains the observed gradual increases in molar volume with increase the rare-earth modifier content. The result shows that the changes in molar volume are due to the changes in the glass structure. In general, the increase of molar volume indicates an increase in the interatomic distances. Therefore, the compactness of the glass will decrease and more non-bridging oxygen (NBO's) will be created, thus decreases the rigidity of the glass.

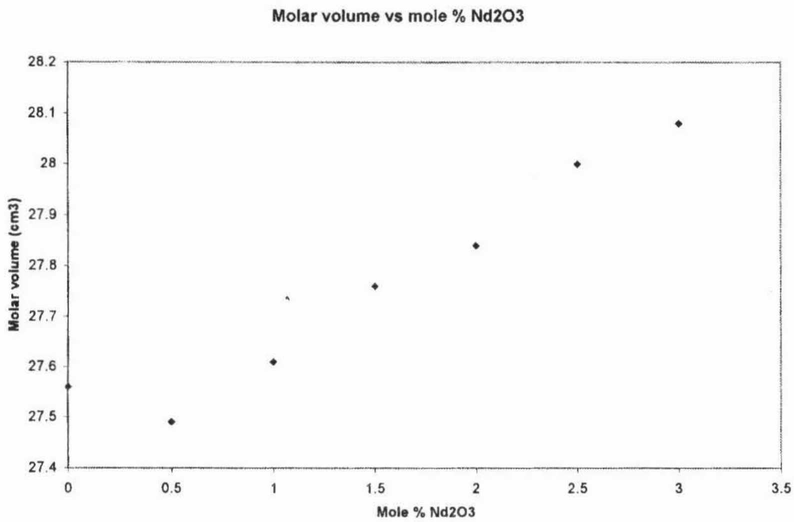

Figure 3: The variation of molar volume of Tellurite glass. The line is drawn for guides to the eye.

Conclusion

A serie of tellurite glass of the system $(88\text{-}x)TeO_2\text{-}10PbO\text{-}2Li_2O\text{-}xNd_2O_3$ has been successfully prepared by using melt-quenched techniques. The results show that these glasses are in a good quality as they possess clear, non hygroscopic properties as no sign of devitrification has been shown. Some of their physical properties have been successfully investigated by mean of their density and molar volume. The results are found monotonically varies with respect to mol% of Nd.

Acknowledgement

The authors wish to thank the UiTM Pahang for the support and MOHE for the financial support under the FRGS grant.

References.

[1] M.R. Sahar, N. Noordin, (1995) J. Non-Cryst. Solids, 184, pp137-140

[2] M.Udovic, P.Thomas, A.Mirgovodsky, O.Durand, M. Soulis, O.Mason,(2006) J. Solid State Chem., 179

[3] T. Minami, I. Komiyama, M.Tanaka, (1980) J. Non-Cryst. Solids 42 pp469.

[4] A. Abd El-Moneim, (2002) J. Mat.Chem Physics, 73, pp318-322

[5] X. Shiqing, W.Guonian, Z. Junjie, D. Shixun, H. Lili,(2004) J. Non-Cryst. Solids, 336, pp230-233.

[6] El-Mallawany,R., Dirar Abdalla,M., Abbas Ahmed,I.,(2008), J.Mat.Chem.Phys. Vol.109,No.2-3, 291-296

[7] Komiyama, T., (1980), J.Non-Cryst.Solids, Vol.18, No.1, 107-118