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EFFECT OF Li_2O ON THE PHYSICAL PROPERTIES OF Nd_2O_3 DOPED TELLURITE GLASS

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ABSTRACT

The effects of Li_2O on the physical properties of mixed alkali tellurite glasses of the system Nd_2O_3-(10-*x*) PbO-$_x Li_2O$-$89TeO_2$ such as refractive index and microhardness have been identified. The glass densities were varied from 5903.30 kg m^{-3} to 5710.43 kg m^{-3} with respect to mol % of Li_2O. The decreasing trend in density implies that addition with atomic masses less than PbO tend to decrease the packing density of the glass structures since the atomic masses of Li_2O and PbO are 29.88 and 223.19, respectively. However, the refractive indices and microhardness of the glass showed anomaly trend. From these results, other physical parameters such as reflection loss, molar refractivity, ionic concentration, electronic polarizability and inter-ionic separation have also been identified. The parameter non-linearly with respect to mol% of Li_2O content.

Keywords: Li_2O; tellurite glass; density; refractive index; microhardness; mixed alkali effect

INTRODUCTION

Glasses having high transparency, high chemical durability and excellent on thermal behavior as well as their optical and electrical properties are the key materials in microelectronics, optics and optical fiber technology. The outstanding interest of tellurite glass might due to their excellent optical properties in the mid infrared region. These glasses have smaller phonon energies than other oxide glasses such as silicate, phosphate and borate glasses which increase the quantum efficiency of luminescence from excited states of rare-earth ions and the upconversion efficiency [1, 2]. Incorporation of glass modifier could change the glass properties. Hence, it shows non-linearity behavior when certain modifier such as Li_2O is used. The nonlinear behavior normally occurs when one alkali ion is replaced by another alkali ion, keeping the total alkali content constant, then those oxide glasses. This phenomenon known as Mixed Alkali Effect (MAE) which occurs in a glassy or molten medium [3]. Mixed alkali glass

is considered as an important class of material due to its scientific as well as technological aspect. The majority of existing literature on MAE is based on dynamic studies and is observed for properties associated with alkali on movement such as electrical conductivity, ionic diffusion, dielectric relaxation and internal friction [4].
Therefore, in this work a study on the effect of Li_2O on the physical properties of tellurite glass is significantly been studied. In fact, a study on the MAE on the tellurite glass has not much been reported or published elsewhere.

METHODOLOGY

Tellurite glasses of the composition (10-x) PbO_xLi2O-$89TeO_2$ were prepared by using melt-quenched technique. The density was identified by Archimedes method using water as the immersion liquid. The refractive indices were measured by using Sellmeir fitting method. From the results obtained, the physical properties of the glasses have been obtained, in order to provide an insight into the atomic arrangements in a glass network. The concentration of the rare-earth ions is very important parameter because it affects the laser gain of the host material. The number density N of the laser-active ions i.e. the number of ions per cubic centimeter can be evaluated using the relation as given by [5]:

$$N(ions/cm^3) = \frac{x\rho N_A}{\overline{M}} \quad (1)$$

where ρ is the density of the glass, N_A is the Avogadro's number, x is the mole fraction of rare earth oxide and M is the average molecular weight of the glass.

Some other physical properties such as molar volume (V_M), polaron radius (r_p), inter nuclear distance (r_i), field Strength (F), dielectric constant (ε) and molar refraction (R_M) were determined from the density, average molecular weight, refractive index and concentration of the rare-earth ions, using standard formulae [4].

The dielectric constant (ε) can be calculated using the refractive index of the glass

$$\varepsilon = n_d^2 \quad (2)$$

The reflection loss from the glass surface can be computed from the refractive index using Fresnel's formula:

$$R = \left[\frac{(n_d - 1)}{(n_d + 1)}\right]^2 \quad (3)$$

The molar refractivity R_M for each glass can be evaluated using the formula:

$$R_M = \frac{\left[\frac{(n_d^2 - 1)}{(n_d^2 + 1)}\right]M}{D} \quad (4)$$

where M is the average molecular weight and D is the density in g/cm^3. The electronic polarizability α_e can be calculated using the formula

$$R_M = \frac{3(n_d^2 - 1)}{4\pi N(n_d^2 + 2)} \quad (5)$$

where N is the number of Neodymium ions per unit volume.

The polaron radius and inter-ionic separation can be calculated using the formulae

$$r_p = \left(\frac{1}{2}\right)\left[\frac{\Pi}{6N}\right]^{\frac{1}{3}} \quad (6)$$

and $$r_i = \left(\frac{1}{N}\right)^{\frac{1}{3}} \quad (7)$$

Table 1: Composition of Nd_2O_3- (10-*x*) PbO-*x*Li_2O-89TeO_2 glass

Sample	Sample Composition (mol%)			
	TeO_2	PbO	Li_2O	Nd_2O_3
S20	89	10.0	0.0	1
S21	89	9.0	1.0	1
S22	89	8.0	2.0	1
S23	89	7.5	2.5	1
S24	89	7.0	3.0	1
S25	89	6.5	3.5	1

RESULTS AND DISCUSSION

Good quality tellurite glass was successfully fabricated. A series of tellurite glass with respect to mol% of Li_2O is summarized in Table 1. The physical properties such as density and microhardness were measured. Table 2 shows the physical properties and it shows that the density decreases continuously for a further increase in Li_2O content. The glass densities varies from 5903.30 kg m^{-3} to 5710.43 kg m^{-3} with respect to mol % Li_2O. The decreasing trend in density implies that an addition of with lower atomic masses than PbO tends to decrease the packing density of the glass structures since the atomic masses of Li_2O and PbO are 29.88 and 223.19, respectively. Meanwhile, as depicted in Figure 1, the values of molar volume were found to be in the range of 28.41–28.13 cm^3 mol^{-1} with Li_2O content up to 2 mole % The V_m starts to increase slightly as the mol% of Li_2O increase to 2.5 mol%. The result shows a decremental trend of curvature as the Li_2O content increase to 3.5 mol% which show the nonlinear behavior.

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Table 2: Physical properties of Nd_2O_3 (10-*x*) PbO-*x*Li_2O-89TeO_2 glass

Physical properties	Glass sample					
	S20	S21	S22	S23	S24	S25
Density(ρ) (g/cm^3)	5.903	5.861	5.825	5.769	5.751	5.710
Microhardness, Hv(GPa) under~98N force	3.261	3.261	3.261	3.261	3.261	3.261
Refractive Index (n)	1.649	1.649	1.649	1.649	1.649	1.649
Molecular weight(M) (g)	167.73	167.73	167.73	167.73	167.73	167.73
Molar Volume (V_M) (cm^3)	28.410	28.410	28.410	28.410	28.410	28.410
Ion concentration N ($x10^{20}$ ions/cm^3)	4.240	4.260	4.280	4.260	4.280	4.270
Dielectric constant	2.720	2.670	2.660	3.340	3.000	2.690
Reflection loss	0.060	0.058	0.058	0.086	0.072	0.059
Molar refractivity	10.350	10.000	9.930	12.240	11.170	10.040
Electronic polarizability (10^{-25})	3.476	6.763	6.761	8.412	7.700	6.969
Inter-ionic separation (10^{-8})	1.587	1.994	1.995	2.004	2.004	2.009
polaron radius (10^{-9})	6.396	8.038	8.040	8.0759	8.0763	8.098

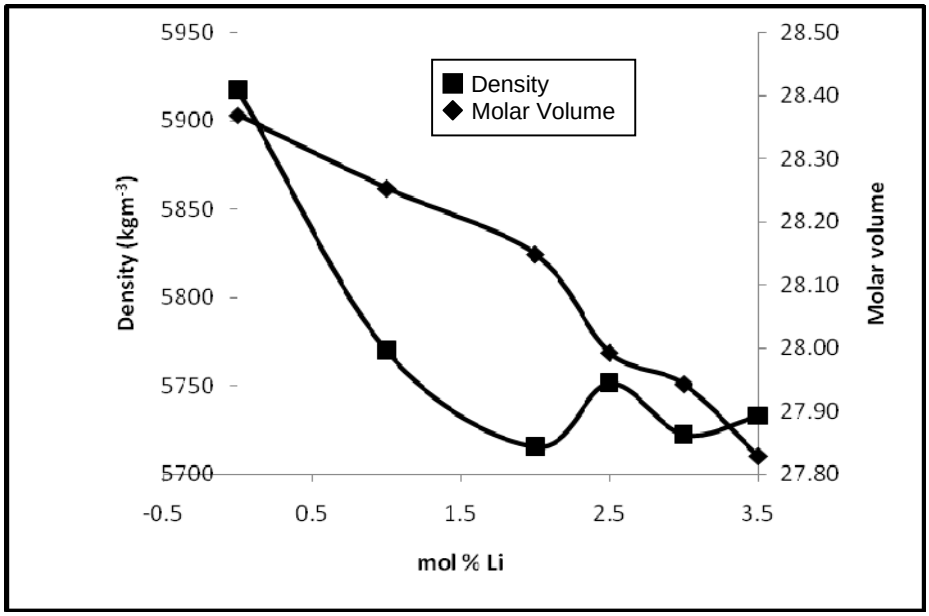

Figure 1: Density and molar volume of Nd_2O_3-(10-*x*) PbO-*x*Li_2O-89TeO_2 glass

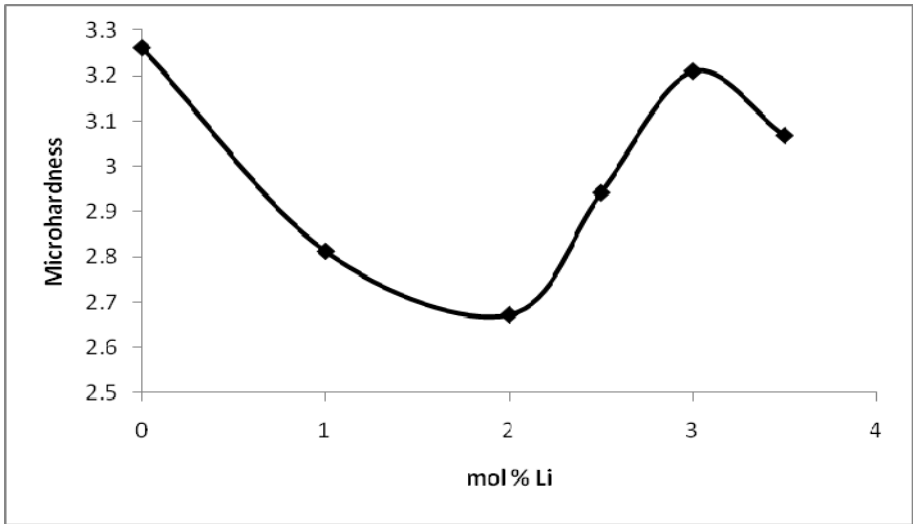

Figure 2: Microhardness of Nd_2O_3-(10-*x*) PbO-*x*Li_2O-89TeO_2 glass

Figure 2 shows the results of microhardness. From the result, the microhardness values of the glass shows a nonlinear behavior as the values decreased from 3.261 GPa to 2.672 GPa as the Li_2O content increase up to 2 mol% . However, it starts to increase to 3.209 GPa at 3 mol% Li_2O and decrease back to 3.067 GPa with further Li_2O content. The decrease in microhardness was attributed to the expansion of the glass network due to formation of NBOs [8]. However, with the incorporation of Li_2O, the nonlinearity trend has been observed. Similar anomaly trend of result has also been shown by the

refractive indices as depicted in Figure 3. Hence, the other physical parameters such as molar refractivity, ionic concentration, electronic polarizability, polaron radii and inter-ionic distances are also been evaluated. It is observed that the above parameters also vary non-linearly with respect to Li_2O content. These trends of results show the occurrence of mixed alkali effect that might be contributed from Li_2O.

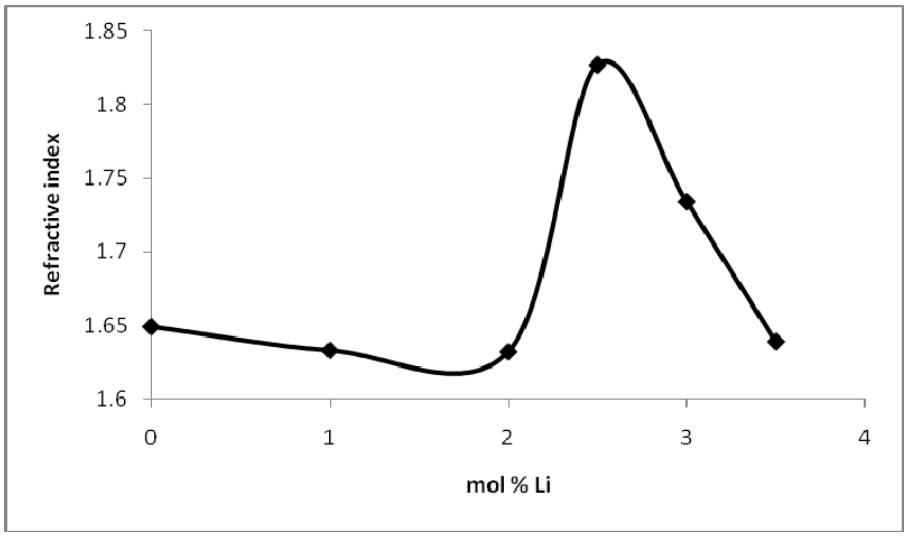

Figure 3: Refractive index of Nd_2O_3-(10-*x*) PbO-*x*Li_2O-89TeO_2 glass

CONCLUSION

A series of tellurite glass were succesfully fabricated. The physical properties of Nd_2O_3-(10-*x*) PbO-*x*Li_2O-89TeO_2 glass system such as the microhardness, refractive index, molar refractivity, ionic concentration, electronic polarizability, polaron radii and inter-ionic distances are calculated in order to study anomaly behavior of the MAE.

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