THE EFFECT OF Yb^{3+} ON CORROSION OF LEAD OXYCHLORIDE TELLURITE GLASSES

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For science and humanity

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ABSTRACT

A series of tellurite glasses based on (80-x)TeO_2-10PbO-10$PbCl_2$-xYb_2O_3 where $0.0 \leq x \leq 3.0$ mol% had successfully been prepared by conventional melt quenching technique. The glass was stable in air and the structural phase was determined using X-ray diffraction technique. The transition temperature, T_g and the crystallization temperature, T_c were determined using differential thermal analyser, DTA. Meanwhile, the density and molar volume of the glass were determined by using Archemedes technique. The glass durability was determined by the measurement of its corrosion rate in acidic solution, alkaline solution and in distilled water. It was found that the glass was amorphous as no peak existed in the X-ray diffraction spectra. It was also found that the T_g and T_c increased as the Yb^{3+} content was increased. It was observed that the glass density increased while molar volume decreased with increasing Yb^{3+} content. The corrosion rate in acidic solution, alkaline solution and distilled water were in the range of (2.46 to 52.04) $\times 10^{-7}$ gmm^{-2} day^{-1}, (0.90 to 2.87) $\times 10^{-7}$ $gmm^{-2}day^{-1}$ and (1.13 to 2.59) $\times 10^{-7}$ $gmm^{-2}day^{-1}$, respectively. It was generally expected that the degradation of glass was due to the ion exchange mechanism and diffusion controlled process.

ABSTRAK

Satu siri kaca tellurit yang berasaskan (80-x)TeO_2-10PbO-10$PbCl_2$-xYb_2O_3 di mana $0 \leq x \leq 3$ mol% telah berjaya disediakan dengan teknik sepuhlindap konvensional. Kaca tersebut adalah stabil dalam udara dan struktur fasanya telah ditentukan dangan teknik pembelauan sinar X. Suhu transisi, T_g dan suhu penghabluran T_c ditentukan menggunakan analisis pembezaan terma, DTA. Manakala ketumpatan kaca serta isipadu molar kaca telah ditentukan dengan teknik Archemedes. Ketahanan kaca telah ditentukan dengan mengira kadar kakisan di dalam larutan asid, larutan alkali dan air suling. Didapati, kaca adalah amorfus di mana tiada puncak yang muncul dalam spektra pembelauan sinar X. T_g dan T_c juga meningkat apabila kandungan Yb^{3+} bertambah di dalam kaca. Dapat dicerap yang ketumpatan kaca meningkat manakala isipadu molar pula semakin berkurang dengan penambahan Yb^{3+}. Kadar kakisan di dalam larutan asid, larutan alkali dan air suling setiap satu dalam lingkungan (2.46 hingga 52.04) $\times 10^{-7}$ $gmm^{-2}hari^{-1}$, (0.90 hingga 2.87) $\times$ 10^{-7} gmm^{-2} $hari^{-1}$ dan (1.13 hingga 2.59) $\times$ 10^{-7} $gmm^{-2}hari^{-1}$. Secara umumnya, dijangkakan kemusnahan kaca yang berlaku adalah disebabkan oleh mekanisme pertukaran ion dan proses kawalan resapan.

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LIST OF SYMBOLS

T_c	-	Crystallization temperature
T_m	-	Melting point
T_g	-	Transition temperature
µm	-	micrometer
nm	-	nanometer
G	-	gram
cm	-	centimeter
mm	-	milimeter
°C	-	Degree celcius
d	-	Surface layer thickness
b	-	Corrosion constant
T	-	Time
S	-	Surface area
V	-	Volume
C	-	Concentration of solution
w, W	-	Molecular weight
m, w	-	Mass

N	-	Order of reflection
Λ	-	Wavelength
d	-	Interplanar spacing of the crystal
Θ	-	Angle of incidence
ρ	-	Density
V_m	-	Molar volume
M	-	Molar mass of glass
A	-	Total surface area

LIST OF ABBREVIATIONS

tbps	-	Trigonal bypiramidal
NBO	-	Non-bridging oxygen
BAP	-	Borate aluminum phosphate
XRD	-	X-ray diffraction
FTIR	-	Fourier transformation infrared spectrometer
ICP-MS	-	Inductively coupled plasma mass spectroscopy
EDX	-	Energy Dispersive Analysis by X-ray
FESEM	-	Field emission scanning electron microscope
DSC	-	Differential Scanning Calorimetry
DTA	-	Differential Thermal Analysis

CHAPTER 1

INTRODUCTION

1.1 Background

Heavy metal and rare earth oxides doped tellurite glasses are of scientific and technological interest. Kumar *et al*. (1997), Yousef *et al*. (2006), Verma *et al*. (2009) and Ozdanova *et al*. (2007) have conducted their study and find out that this type of glass has very suitable properties for stated purposes such as the density, optical and thermal properties and can be favorably changed. Heavy metal oxide tellurite glasses including the lead tellurite glasses are one of the suitable materials for the slow light generation via stimulated Raman Scattering (Qin *et al*., 1997).

One of the important factors in material selection is their chemical durability. This characteristic will determine the quality of the material. Corrosion can be defined as the chemical or electrochemical reaction between a material and its environment that produces deterioration of the material and its properties.

Glass is an amorphous material which has very high resistance to corrosion. This property makes it a very suitable material in so many applications besides of its strength and other excellent characteristics. However, corrosion can still occur to the glass when it is exposed to some conditions such as the glass composition, temperature and pH of the aqueous media (Rana *et al*., 1961).

There are many studies conducted by a lot of researchers on the optical properties of tellurite glasses but very few reports have been written on the corrosion behaviors of these glasses, especially when they are added with rare-earth materials which will be further discussed in the next chapter. In this study, the corrosion behavior of the tellurite based glass will be determined at different compositions under pH of 2, 4, 9, 11 and distilled water. The PbO and the $PbCl_2$ will be added as the modifier. A rare earth element which is Yb_2O_3 will be added as the doping material. Such materials are selected because of their excellent characteristics based on previous research (Wang *et al*., 2005a, Xu *et al*., 2004).

1.2 Problem statements

It is impossible to stop corrosion from being happened since the chemical reactions of materials and environment is always unavoidable. However, corrosion rate can be reduced so that the material can last longer in its original form. Glass is actually very resistant to corrosion compared to other materials (Shen *et al*., 2002). However, there is a lack of report on the study of chemical durability of tellurite glass. This is probably due to only few researches that have been conducted as compare to those of study in optical properties. Thus, it is the aim of this study to evaluate the corrosion behavior of tellurite glass and to contribute more information in this area.

1.3 Objectives of study

The objectives of this study are:

i. to prepare the samples of Yb_2O_3 mixed lead tellurite glass with composition of (80-x)TeO_2-10PbO-10$PbCl_2$-xYb_2O_3 using melt quenching technique.

ii. to determine the physical properties of the glass.

iii. to determine the thermal parameter of the glass.

iv. to determine the corrosion rate of the glass.

v. to examine the corrosion mechanism of the glass.

1.4 Scope of study

In this research, the samples of lead tellurite glass will be prepared with different compositions. The study of thermal properties of the glass is carried out by determining the transition temperature and crystallization temperature of the glass. The physical properties of the glass will be covered by determining the density and the molar volume of the glass. The mechanism of the corrosion on the samples will be studied by immersing the samples in aqueous solution of pH 2, pH 4, distilled water, pH 9 and pH 11 and the rate of the corrosion attack will be determined for each composition of lead tellurite glass. The composition is varied by varying the amount of Yb_2O_3 from 0 to 3 mol%.

1.5 Significance of study

The discovery of unique characteristics of tellurite glass has contributed so much in developing new technology. For example, the study of spectroscopy of rare earth in tellurite glass has helped to design an amplifier that operates in 1330 – 1370 nm regions. The measurement of fiber loss for this research showed that the Er-doped fibres had less than 880 $dBkm^{-1}$ attenuation in the range of 1200 to 1400 nm which also concluded that the Er-doped tellurite fibers was highly suitable in designing broadband amplifiers (Shen *et al*., 2002)**.**

Tellurite glass also finds applications for up conversion of infrared to visible light, optical amplifiers and gas sensor. Heavy metal oxide tellurite glasses are promising materials for slow light generation via stimulated Raman scattering. The lead tellurite glasses are of interest in non-linear optics for second and third harmonic generation.

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