



UNIVERSITI PUTRA MALAYSIA

***PHYSICAL AND RADIATION SHIELDING PROPERTIES OF TELLURITE
BASED GLASS***

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**PHYSICAL AND RADIATION SHIELDING PROPERTIES OF TELLURITE BASED
GLASS**

By

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**Thesis Submitted to the Department of Physics, Faculty of Science, Universiti Putra
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Bachelor of Science in Materials Science with Honours**

FEBRUARY 2022

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DEDICATION

Firstly, this thesis is dedicated to my project supervisor, Dr Sharudin Bin Omar Baki who helps me a lot in my studies and for the guidance for the whole final year project. Next, I would like to thank my project co-supervisor, Dr Muhammad Khalis Abdul Karim for his helps in this project. On this occasion, I also would like to say thank you to my parents, Noorzain Bin Mohd Isa and Rohaya Binti Majid for their invaluable support throughout my studies in University Putra Malaysia. Not to be forgotten either, I would like to thank all my lecturers, my siblings, my friends and others that help me throughout completion of the thesis. Thank you for the supports, encouragements and help.

ABSTRACT

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FEBRUARY 2022

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Faculty: Faculty of Science

Tellurium (TeO_2) is a conditional glassmaker and using a twin roller method to quickly cool down has reduced glass production. TeO_2 does not form glass on its own and it must be combined with one or more other oxides to form glass. The structural, optical, electrical, and elastic properties of tellurium oxide-based glasses have been studied and continue to be studied. The simulations were conducted using Photon Shielding and Dosimetry (PSD) software. As a result of this study, output generated in the form of value of density, Half Value Layer (HVL), Mean Free Path (MFP) and Mass attenuation coefficient (MAC).

ABSTRAK

SIFAT-SIFAT PERISAI FIZIKAL DAN SINARAN KACA BERASASKAN

TELLURITE

Oleh

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Tellurium (TeO_2) ialah pembuat kaca bersyarat dan menggunakan kaedah pengelek berkembar untuk menyejukkan dengan cepat telah mengurangkan pengeluaran kaca. TeO_2 tidak membentuk kaca dengan sendirinya dan ia mesti digabungkan dengan satu atau lebih oksida lain untuk membentuk kaca. Ciri-ciri struktur, optik, elektrik, dan keanjalan bagi cermin mata berasaskan telurium oksida telah dikaji dan terus dikaji Simulasi dijalankan menggunakan perisian Photon Shielding and Dosimetry (PSD). Hasil daripada kajian ini, output yang dihasilkan dalam bentuk nilai ketumpatan, Lapisan Nilai Separuh (HVL), Laluan Bebas Min (MFP) dan pekali pengecilan jisim (MAC) .

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DECLARATION

Declaration by student

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LIST OF ABBREVIATIONS

nm	Nanometer
PSD	Photon Shielding and Dosimetry
°C	Degree celcius
cm ³	Cubic centimeter
HMO	Heavy metal oxides
HVL	Half Value Layer
MAC	Mass attenuation coefficient
MFP	Mean Free Path
MeV	Mega electron volt
AKR	Air kerma rate

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The history of glass is extensive, but it is still fascinating to learn about and comprehend. Furthermore, glasses are known as both the oldest and most recent materials in the world, where they are used for a wide range of applications in everyday life. Glasses formed using melt-quenching processes may experience certain thermal effects, which will impact their stability, diffusivity, relaxation time, and position of the glass transition temperature (Hilden & Morris, 2004). Tellurite glasses have been studied for over 150 years, but more recent versions have purities greater than 98.5 percent. Because of their low melting point and lack of hygroscopic properties, tellurite glasses have limited the application of phosphate and borate glasses while arousing widespread interest in the field of photonics and related technologies. Tellurite dianion is pyramidal, like selenite and sulfite. Tellurite glasses are continuing to attract attention for their nonlinear applications, and they have been used to fabricate microstructured fibers with a core diameter as small as 400nm. This is shown by the fact that the TeO₂ composition of glasses is used to achieve a high refractive index, ease of production, high transmittance in the infrared region, strong optical nonlinearity, and low phonon energies (Sio et al., 1997).

1.2 Problem Statements

Tellurium (TeO_2) is a conditional glassmaker and using a twin roller method to quickly cool down has reduced glass production. The majority of glass-forming oxides have an entire number and a glass-like structure that is similar to the crystalline structure. Glass scientists and technologists have paid close attention to the study of tellurite glasses and their applications in scientific, technological, and industrial applications over the last few decades.

TeO_2 does not form glass on its own and it must be combined with one or more other oxides to form glass. The structural, optical, electrical, and elastic properties of tellurium oxide-based glasses have been studied and continue to be studied. Tellurite-based glasses have received special research attention due to their properties that make them promising materials in a variety of photonics and optoelectronics applications. Moreover, TeO_2 -based glasses are highly research interest due to their applications, particularly in the fabrication of both active and passive optical fibres, as well as high-gain optical amplifiers used in communication technology.

1.3 Thesis Objectives

The goals of this research are to:

- 1) To understand the role of heavy metal oxides in tellurite based glass.
- 2) Simulate and optimize the effect of Tm_2O_3 and Bi_2O_3 to tellurite based glass.

3) To study optical and radiation shielding properties of tellurite based glass.

1.4 Scope of Study

There are some scope of study as follows :-

- 1) Glass preparation using some raw material such as TiO_2 , Bi_2O_3 , Er_2O_3 , Tm_2O_3 and TeO_2 powder based using empirical formula $85\text{TeO}_2-10\text{TiO}_2-(4.8-y)\text{Bi}_2\text{O}_3-0.2(\text{Er}_2\text{O}_3)-y(\text{Tm}_2\text{O}_3)$ in mol% which $y = 0.2, 0.5, 0.9$ and $60\text{TeO}_2-35\text{PbO}-(4.8-y)\text{Bi}_2\text{O}_3-0.2(\text{Er}_2\text{O}_3)-y(\text{Tm}_2\text{O}_3)$ in mol% which $y = 0.5, 0.9$ by melt-quenching technique.
- 2) Analyze physical and radiation shielding properties of tellurite based glass samples based on result obtained from density meter and Photon Shielding and Dosimetry (PSD) software.

1.5 Outline of thesis

Each chapter has a well-organized sequence of research. First chapter has revealed about the introduction of this study which is about glass and followed by the problem statements, the objective of the thesis and the scope of study. Those subtopic above are presented as a general explanation for the next chapter which there are more detail that will be explained about tellurite based glass. Next, chapter 3 will be included the methodological step by step of glass making. For chapter 4 will be the discussion of optical and radiation shielding properties of the glass. Lastly, chapter 5 outlined the conclusion.

CHAPTER 2

LITERATURE REVIEW

2.1 Introductions

This part includes the study's literature review that provides an in-depth examination of glass. Additionally, tellurite glass was examined. Besides, all the information about tellurite based glass will be revealed in this chapter.

2.2 Glass

Glass is an inorganic material that is frequently transparent or translucent, as well as hard, brittle, and weather-resistant (The Editors of Encyclopaedia Britannica, 2021). Glass was originally manufactured in antiquity, but its exact beginnings are unknown. Egyptian glass beads, originating from around 2500 BCE, are the earliest glass items discovered. A sort of glass with feathery or zigzag patterns of coloured threads on the surface of the glass vessel was developed later in Egyptian civilisation. Glass has been used to make utilitarian and ornamental products since antiquity, and it continues to play a significant role in industries as diverse as construction, housewares, and telecommunications. It's manufactured by chilling molten components like silica sand quickly enough to prevent visible crystals from forming. Normally, glass is transparent to the visible portion of the electromagnetic spectrum. Glass, on the other hand, scatters or reflects light, is brittle, chemically resistant,

pourable, mouldable, moulded, moulded, and extruded, and has the potential for high tensile strength (Anne Marie Helmenstine, 2019).

2.2.1 Glass former

Glass's properties are determined by its composition. The network former, the glass's fundamental unit, is one of the most important compositional changes that can be made. The former can be thought of as the glass's backbone, and changing this element or compound has a significant impact on the final material's properties. Glass formers are introduced into the bulk material to improve the development of a glass and to create the linked backbone of the glass network. Boron, silicone, germanium, and phosphorus are all common cations in network formers. The majority of the glass is made up of network formers, which form a highly cross-linked network of chemical bonds. Although silicon oxide is the most common network-forming constituent of glass, other oxides such as boron and germanium are also widely used. Tellurium dioxide (TeO_2) is a conditional glass former, and rapid cooling via the twin roller method allowed for limited glass formation (Hauke et al., 2020).

2.2.2 Glass intermediate

Intermediate glasses have nearly constant elastic moduli as a function of temperature and/or pressure. These glasses would be useful in the development of thermal optical fibres for improved telecommunications and fibre sensing applications, as well as in the development of glass products for applications involving a wide range of thermal and mechanical stimulation. (Jaccani et al., 2018).

Intermediates, which include titanium, aluminium, and zinc, are chemicals that, depending on the glass composition, can act as network-formers or modifiers. (Kienzler, B, 2012). Glasses are naturally highly disordered, and preventing the formation of ordered crystallites within the material necessitates a finely tuned balance of network formers, intermediates, and modifiers.

2.2.3 Glass modifier

Modifiers are substances that can be added to glass in trace amounts to change its properties. These elements include lithium, sodium, potassium, and calcium, and they exist as charged single atoms (ions) within the cross-linked network formers, reducing the glass's relative number of strong bonds and thus its melting point and viscosity. Glass modifiers disrupt the usual bonding between glass-forming components and oxygen by weakly interacting with oxygen atoms. This causes the formation of "non-bridging oxygens" and a reduction in the amount of strong bonding within the glass. As a result, glass modifiers have a noticeable effect on the properties of glass and as a result of the material's overall bonding being weaker, these include a decrease in melting temperature, surface tension, and viscosity (Grayson, 2020).

2.3 Tellurite glass

Tellurium oxide (TeO_2) is the primary constituent of tellurite glasses. Tellurium dioxide is referred to be a conditional glass former, and as such requires a modifier to create the glassy state readily (Mustafa et al., 2013). Tellurium (TeO_2) glass is an excellent solvent for heavy metal oxide (HMO) and has a high atomic number these

glasses have demonstrated remarkable results in a variety of fields. Furthermore, it has a number of distinguishing characteristics that allow it to be used in a variety of applications such as radiation shielding, pressure sensors, laser hosts, and so on. Tellurium is superior on phosphate and silicate glasses due to several physical properties such as good infrared transmissivity, high dielectric constant, low melting point, and high refractive indices. Tellurium dioxide (TeO_2), with a melting point of 733°C , is the most stable oxide of tellurium (Te). The stability properties of tellurium oxides were demonstrated to be transferable to their glass derivatives, allowing for experimentation with a broader range of components in the composition of tellurite glasses and thus better control over performance characteristic variation (El-Mallawany & El-Mallawany, 2014).



Figure 2.1 : Tellurium Dioxide Powder

2.4 Titanium dioxide (TiO_2)

Titanium dioxide, also known as titanium(IV) oxide, is a chemical compound with the formula TiO_2 . Although mineral forms can appear black, it is a white, water-insoluble solid. It has a wide range of applications as a pigment, including paint, sunscreen, and food colouring. Titanium dioxide, which was first mass-produced in 1916, is the most

widely used white pigment due to its brightness and extremely high refractive index, which is only surpassed by a few other materials. (St. Clair, Kassia , 2016). Titanium dioxide has been used in porcelain enamels as a bleaching and opacifying agent, giving them brightness, hardness, and acid resistance. It has an extremely high melting point of 1,843°C and boiling point of 2,972°C, so occurs naturally as a solid, and, even in its particle form, it is insoluble in water. Titanium dioxide is now used in cosmetics, such as skin care products and sunscreen lotions, with claims that it protects the skin from ultraviolet radiation due to its ability to absorb ultraviolet light.



Figure 2.2 : Titanium Dioxide Powder

2.5 Bismuth (III) oxide (Bi_2O_3)

Bismuth(III) oxide is a yellow nanoparticulate powder with a melting point of 817 °C and a boiling point of 1980 °C. It provides the same high gloss, flow, 'healing' and 'bubble clearance' characteristics, refractive index, surface tension and viscosity. When examining probable applications for solid electrolytes, thermal expansion qualities are just as significant as electrical properties. High thermal expansion coefficients indicate considerable dimensional changes when heated and cooled, which would limit an electrolyte's performance. The transition from high-

temperature Bi₂O₃ to intermediate-temperature Bi₂O₃ is accompanied by a considerable volume change and, as a result, a worsening of the material's mechanical characteristics. This, paired with the β -phase's highly narrow stability range (727–824 °C), has prompted research into its stabilisation at ambient temperature.



Figure 2.3 : Bismuth (III) Oxide Powder

2.6 Erbium(III) oxide (Er_2O_3)

Erbium(III) oxide is made from erbium, a lanthanide metal. Carl Gustaf Mosander partially isolated it in 1843, while Georges Urbain and Charles James were the first to acquire it in pure form in 1905 (Aaron John, 1984). The colour of erbium oxide is pink and has a cubic crystal structure. It has a melting point of 2344 °C and a boiling point of 3290 °C. Erbium oxide can take on a hexagonal shape under certain conditions. Erbium oxide is insoluble in water and soluble in mineral acids. Er₂O₃ readily absorbs moisture and carbon dioxide from the atmosphere (Singh et al., 2003). Due to its electrical, optical, and photoluminescence capabilities, Er₂O₃ has a wide range of uses. Because of their unique particle-size-dependent optical and electrical characteristics, nanoscale materials doped with Er³⁺ are of great interest.



Figure 2.4 : Erbium(III) Oxide Powder

2.7 Thulium(III) oxide (Tm_2O_3)

Thulium(III) oxide is a pale green solid compound, with the formula Tm_2O_3 . The powder of thulium oxide (Tm_2O_3) has a greenish-white colour. The structure of this rare earth sesquioxide is cubic. This material's melting point is around $2341^\circ C$. In water, Tm_2O_3 is insoluble, but in acidic situations, it is slightly soluble. Because of its promise in catalytic, electrical, optical, and electrochemical applications, Tm_2O_3 is currently attracting a lot of attention. The dielectric constant of Tm_2O_3 is 12–13, and the energy band gap is 5 eV. These intriguing features have drawn interest as a gate dielectric oxide or an interfacial layer for preventing EOT formation during heat treatments. Other uses for Tm_2O_3 include pH-sensing membranes, reversible hydrogen absorption and desorption in $NaAlH_4$ due to its catalytic activity, electrochemical sensors, ceramics, fuel cells, X-ray equipment, active agents of phosphors, control materials of atomic reactors, luminescent materials, lasers, and medical applications.



Figure 2.5 : Thulium(III) Oxide Powder

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will go through the procedure to prepare the tellurite based glass. The glass was prepared by using melt-quenching technique that is traditionally used in glass making . Besides, mixing the ingredients and quenching the glass melt to create a glass are few of the procedure and will be discussed more on next subtopics.

3.2 Preparation of the glass

Glass with composition $TeO_2-TiO_2-Bi_2O_3-Er_2O_3-Tm_2O_3$ and $TeO_2-PbO-Bi_2O_3-Er_2O_3-Tm_2O_3$ were synthesized by conventional melt quenching technique using high purity chemical powders. Firstly, each chemical powders had been weigh by using electronic balance in order to get 0.1mg for 10g batch. The composition of synthesized $85TeO_2-10TiO_2-(4.8-y)Bi_2O_3-0.2(Er_2O_3)-y(Tm_2O_3)$ in mol% which $y = 0.2, 0.5, 0.9$ and $60TeO_2-35PbO-(4.8-y)Bi_2O_3-0.2(Er_2O_3)-y(Tm_2O_3)$ in mol% which $y = 0.5, 0.9$. Mix the chemical powder in an alumina crucible and stir thoroughly until it well mixed. The composition of the samples in mol% has been tabulated in Table 3.1 and Table 3.1.2 . After that , the mixture were then placed in electric furnace and pre-heated for 1 hour at 300° C. This is because pre-heating is really important as a role to remove any access water that could contaminate the mixture. After one hour of pre-heat, the mixture were then heated to 1100° C for the melting process and to ensure it undergo homogenous melting. Then after 3 hours, the mixture will melt completely and be poured into a stainless-steel mold that also be pre-heated at 250° C in the microwave in ordered to prevent the sample from thermal shock and to reduce the glass cracking due to its mechanical stress. After that , it were annealed in a muffle furnace for 1 hour to remove any air bubbles and it also increase mechanical strength of the samples. After it was completed, glass sample was left overnight for cooling process under room temperature. Lastly, Sic Abrasive Paper Highgrade 1000 was used to polish all the samples.

TTB	Sample-ID	TeO ₂ /mol. %	TiO ₂ /mol. %	Bi ₂ O ₃ /mol. %	Er ₂ O ₃ /mol. % doped	Tm ₂ O ₃ /mol. % Doped y
TTB-Er ³⁺ /Tm ³⁺ 85TeO ₂ -10TiO ₂ - (4.8-y)Bi ₂ O ₃ - 0.2(Er ₂ O ₃)- y(Tm ₂ O ₃)	TTB26	85	10	4.6	0.2	0.2
	TTB27	85	10	4.3	0.2	0.5
	TTB28	85	10	3.9	0.2	0.9

Table 3.1 : Composition samples in mol%

TPB-Er ³⁺ /Tm ³⁺	Sample-ID	TeO ₂ /mol. %	PbO /mol. %	Bi ₂ O ₃ /mol. %	Er ₂ O ₃ /mol. % doped	Tm ₂ O ₃ /mol. % Doped y
60TeO ₂ -35PbO- (4.8-y)Bi ₂ O ₃ - 0.2(Er ₂ O ₃)- y(Tm ₂ O ₃)	TPB27	60	35	4.3	0.2	0.5
	TPB28	60	35	3.9	0.2	0.9

Table 3.1.2 : Composition samples in mol%

3.3 Density

The density (more precisely, the volumetric mass density; also known as specific mass), of a substance is its mass per unit volume but a bit different for glass density (ρ) which is a parameter that can be used to determine how compact construction of a glass. In this study, Alfa Mirage MD-300S was used to determine the density of the glass sample which shown in Figure 3.1. The densimeter's operating are using Archimedes principle by calculating the density using the buoyancy force of the water, where the space it occupied is filled by fluid having some weight. This weight is supported by the surrounding fluid, and the buoyant force must equal to the weight of te fluid displaced by the object. The densimeter are highly precise, general purpose model with density resolution of 0.001g/cm³; measurable weight 0.01~300g and capable of measuring specific gravity of solids and liquids.



Figure 3.1 : Alfa Mirage MD-300S

3.4 Radiation shielding

Radiation shielding is defined as an interaction between particles and matter that occurs as a result of collisions and atom capture. Considerations for radiation shielding are multifaceted. In most cases, radioactive materials used in radiochemical processes must be delivered in some manner from the reactor to a processing facility. The shielding wall design must be thick enough to allow for dose rate attenuation and compliance with the safety standards. Glass is an essential radiation barrier for applications that require line-of-sight, such as nuclear fuel processing and medical radiography, due to its unique set of features. Radiation shielding is defined as an interaction between particles and matter that occurs as a result of collisions and atom capture. In steel, one neutron with 1 Mev of energy travels an average distance of 4 cm between collisions. After 200 collisions with steel and 40 collisions with polymeric neutron shielding material, it comes to a halt. In steel, a 1 Mev gamma ray travels an average of 2 cm and is halted after 10 encounters.

3.5 Half-value layer (HVL)

The half-value layer (HVL) of a material, also known as half-value thickness, is the thickness at which the intensity of radiation entering it is reduced by half. Instead of intensity, HVL can be described in terms of air kerma rate (AKR). The half-value layer is the thickness of a specific material that reduces the AKR to one-half of its original value by attenuating the radiation beam. The contribution of all scattered radiation, other than those contained initially in the beam, is regarded to be omitted. Measurements of air kerma, exposure, or exposure rate, rather than AKR, can be used

to determine half value layer if they are specified in the description. The first half-value layer is referred to as a half-value layer, whereas subsequent half-value layers refer to the amount of specified material that will reduce the air kerma rate by one-half after material equal to the sum of all previous half-value layers has been inserted into the beam. The mean free path is linked to HVL, however the mean free path is the average distance a unit of radiation can travel in a material before being absorbed, whereas HVL is the average amount of material required to absorb 50% of all radiation.

3.6 Mean free path (MFP)

Mean free path is moving particle such as an atom, a molecule, or a photon considerably alters its direction or energy or, in a given context, other attributes over an average distance, usually as a result of one or more repeated collisions with other particles. As a result, the average distance between these encounters is a measure of a given interaction's probability. The mean free path, as well as the cross section and density of the material, are inversely related to this distance. The mean free path is defined differently depending on the type of cross section utilised in the calculation. The mean free path has a dependence on the energy distribution of the particles relative to the medium.

3.7 Mass attenuation coefficient (MAC)

The mass attenuation coefficient, also known as the mass narrow beam attenuation coefficient, describes how easily a beam of light, sound, particles, or other energy or matter may pass through a material's volume. Other electromagnetic radiation such as X-rays, sound, or any other beam that can be attenuated can all have mass attenuation coefficients defined in addition to visible light. The square metre per kilogramme (m²/kg) is a SI measure for mass attenuation coefficient. cm²/g which is the most often used measure for X-ray mass attenuation coefficients. The mass attenuation coefficient is a type of absorption cross section in which the effective area is calculated per unit mass rather than per particle. Mass attenuation coefficient is defined as :

$$\frac{\mu}{\rho_m},$$

where μ is the attenuation coefficient (linear attenuation coefficient) and ρ_m is the mass density.

3.8 Photon Shielding and Dosimetry (PSD) software

For the calculation of parameters related to shielding and dosimetry, a user-friendly online Photon Shielding and Dosimetry (PSD) software has been developed. These characteristics include linear and mass attenuation coefficients (LAC, MAC), half and tenth value layers (HVL, TVL), mean free path (MFP), effective atomic number and electron density (Z_{eff} , N_{eff}), energy absorption and exposure accumulation factors

(Ceff), and effective conductivity (Ceff) (EABF, EBF). In the continuous energy zone, the software can create data on shielding properties (1 keV-100 GeV). In addition, the software includes certain well-known radioactive sources (^{22}Na , ^{55}Fe , ^{60}Co , ^{109}Cd , ^{131}I , ^{133}Ba , ^{137}Cs , ^{152}Eu , and ^{241}Am) as well as some distinctive (K-shell) X-ray energies of Cu, Rb, Mo, Ag, Ba, and Tb elements that can be selected by the user. As a result, the shielding parameters for photon energies accessible for the predefined energies can be obtained. This software may also calculate another important shielding metric, the fast neutron removal cross section (FNRCs), for a molecule or a combination.



Figure 3.2 : PSD Online Software

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter will be included the simulation for the result of physical properties and radiation shielding properties of $TeO_2-TiO_2-Bi_2O_3-Er_2O_3-Tm_2O_3$ and $TeO_2-PbO-Bi_2O_3-Er_2O_3-Tm_2O_3$ glass. For the physical properties will be discussed about density and molar volume while for the radiation shielding properties will be discussed about Half Value Layer (HVL), Mean Free Path (MFP) and Mass attenuation coefficient (MAC).

4.2 Physical properties

4.2.1 Density

Density is one of the most important measurement that gives an initial impression of the change in the internal structure of the material. Methodology to calculate the density had been stated before that Alfa Mirage MD-300S been used which it applied Archimedes' principle. Table 4.1 shows that as the content of Tm_2O_3 increase, the density of the sample will be increasing perpendicularly with the mol% of the composition that shown in Table 3.1 and Table 3.1.2.

Sample	Density (g/cm ³)
TTB 26	5.164
TTB 27	5.084
TTB 28	4.781
TPB 27	6.500
TPB 28	6.700

Table 4.1 : Density of the samples

4.2.2 Molar volume

The following equation was used to calculate the molar volume of the glass sample:

$$V_m = \frac{M}{\rho}$$

Where M is the molecular weight of the sample glass, and p is the density of the sample glass. Table 4.2 shows the result of calculation that gives molar volume.

Physical properties	Glass Sample				
	TTB26	TTB27	TTB28	TPB27	TPB28
Density (g/cm ³)	5.164	5.084	4.781	6.500	6.700
Molecular weight (g/mol)	166.616	166.376	166.056	146.443	146.123
Molar volume (cm ³ /mol)	32.256	32.725	34.732	22.530	21.809

Table 4.2 : molar volume of the samples (cm³/mol)

4.3 Optical Properties (transparency)

As shown in Figure 4.1 , Figure 4.2 , Figure 4.3, Figure 4.4 and Figure 4.5 below shows that all of the sample can be concluded and can be considered as transparent tellurite based glass.



Figure 4.1 : TTB 26



Figure 4.2 : TTB 27



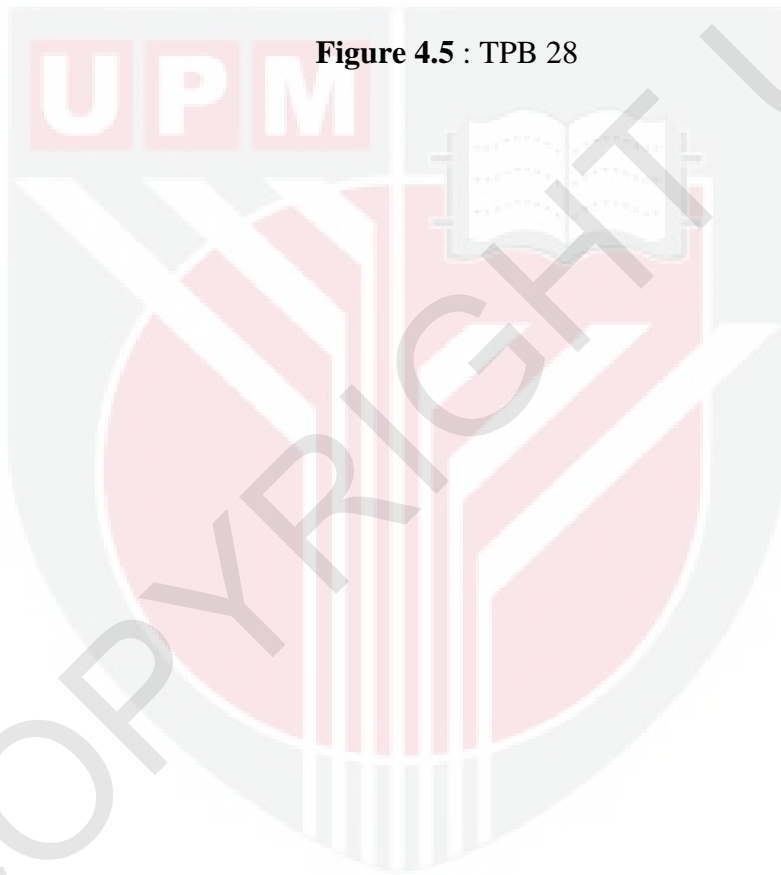
Figure 4.3 : TTB 28



Figure 4.4 : TPB 27



Figure 4.5 : TPB 28



4.4 Half Value Layer

The half-value layer is a very important measure for studying gamma-ray shielding qualities and estimating gamma radiation penetrating power inside a material. HVL refers to the thickness that reduces the incident photon intensity by half and reflects the photons' ability to penetrate as energy increases. The following formula was used to compute HVL values for the current glasses. (Sayyed 2017, 2016)

$$HVL = \frac{\ln(2)}{\mu}$$

Energy (MeV)	TTB26	TTB27	TTB28	TPB27	TPB28
0.015	0.003	0.003	0.003	0.002	0.002
0.02	0.005	0.005	0.006	0.004	0.004
0.03	0.015	0.015	0.016	0.012	0.012
0.04	0.009	0.009	0.009	0.008	0.008
0.05	0.016	0.016	0.017	0.015	0.014
0.06	0.025	0.025	0.026	0.023	0.022
0.08	0.054	0.054	0.056	0.048	0.046
0.1	0.071	0.072	0.078	0.060	0.059
0.15	0.190	0.195	0.210	0.160	0.158
0.2	0.357	0.366	0.394	0.297	0.292
0.2835 <i>Cs (137)</i>	0.670	0.686	0.736	0.547	0.536
0.3	0.731	0.747	0.801	0.595	0.583
0.4	1.064	1.086	1.162	0.855	0.835
0.5	1.337	1.363	1.456	1.066	1.040
0.6	1.564	1.593	1.700	1.241	1.209
0.6617 <i>Cs (137)</i>	1.688	1.718	1.832	1.336	1.301
0.8	1.933	1.967	2.096	1.526	1.484
1	2.238	2.276	2.424	1.762	1.712
1.5	2.826	2.873	3.057	2.221	2.157
2	3.211	3.264	3.473	2.530	2.457
3	3.645	3.705	3.944	2.896	2.813
4	3.838	3.902	4.153	3.075	2.987
5	3.907	3.972	4.229	3.153	3.063
6	3.913	3.979	4.237	3.176	3.086
8	3.833	3.897	4.151	3.139	3.051
10	3.709	3.772	4.017	3.057	2.971
15	3.406	3.464	3.691	2.834	2.756

Table 4.3 : Half value layer of each sample

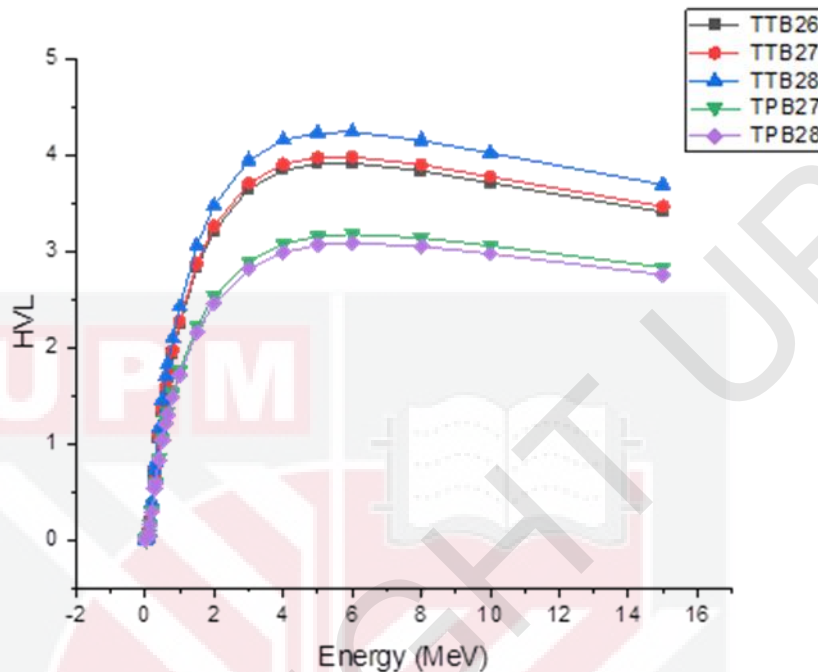


Figure 4.6 : Half value layer against energy

Based on Table 4.3 and Figure 4.6, half value layer has a peak at interval energy between 0.2835 MeV and 0.6627 for every samples. TTB28 glass exhibits the highest value of half value layer among the glass samples and varied between 0.736cm and 1.832cam while, TPB28 glass posses the lowest value of half value layer among the glass sample and varied between 0.536cm and 1.301cm for energy interval between 0.015 MeV and 15 MeV. From this data, we can conclude that the lowest half value layer indicates the highest shielding capability because the lower the value of half value layer means more interaction of photons energies with the glass. Therefore, TPB28 has better shielding properties compared to other glass samples. Reported that

the addition content of Tm₂O₃ and Bi₂O₃ affected the density of the samples where half value layer value depends on the density of the sample.

4.5 Mean free path (MFP)

The mean free path is the average distance between two successive collisions by the photons and can be obtained according to the equation :

$$MFP = \frac{1}{\mu}$$

Energy (MeV)	S1	S2	S3	S1	S2
0.015	0.004	0.004	0.004	0.003	0.003
0.02	0.007	0.007	0.008	0.006	0.006
0.03	0.021	0.022	0.024	0.017	0.017
0.04	0.013	0.013	0.014	0.012	0.011
0.05	0.023	0.023	0.025	0.021	0.021
0.06	0.036	0.036	0.038	0.033	0.031
0.08	0.077	0.078	0.081	0.070	0.067
0.1	0.102	0.104	0.112	0.087	0.086
0.15	0.275	0.282	0.303	0.231	0.228
0.2	0.515	0.528	0.568	0.428	0.421
0.2835 Cs (137)	0.967	0.989	1.061	0.789	0.774
0.3	1.055	1.078	1.156	0.858	0.841
0.4	1.535	1.567	1.676	1.233	1.205
0.5	1.929	1.966	2.100	1.538	1.500
0.6	2.257	2.298	2.452	1.790	1.744
0.6617 Cs (137)	2.435	2.479	2.643	1.928	1.877
0.8	2.789	2.837	3.023	2.201	2.141
1	3.229	3.283	3.497	2.542	2.470
1.5	4.077	4.144	4.411	3.205	3.112
2	4.633	4.708	5.011	3.650	3.545
3	5.259	5.346	5.690	4.178	4.058
4	5.537	5.629	5.992	4.436	4.309
5	5.637	5.731	6.101	4.548	4.419
6	5.645	5.740	6.112	4.582	4.452
8	5.529	5.623	5.988	4.528	4.401
10	5.350	5.441	5.796	4.410	4.287
15	4.913	4.998	5.325	4.089	3.976

Table 4.4 : Mean free path value of each sample

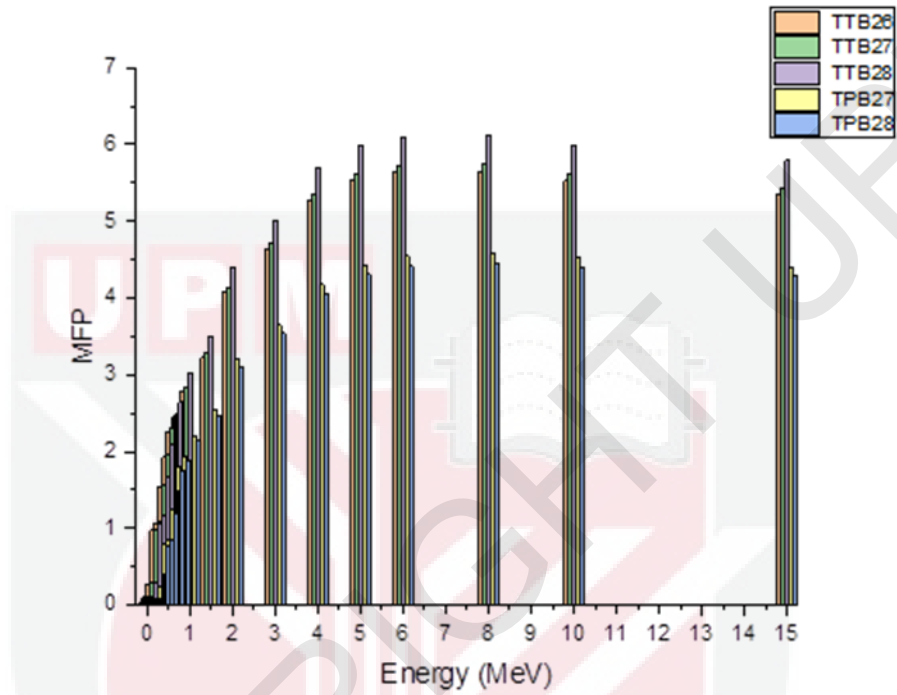


Figure 4.7 : Mean free path against energy

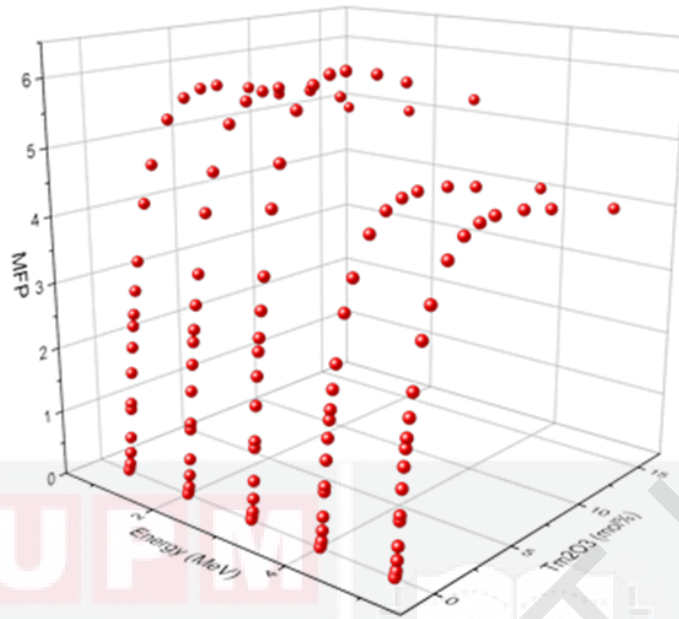


Figure 4.7.2 : Mean free path against energy (3D)

Based on Table 4.4 , Figure 4.7 and Figure 4.7.2 , mean free path has a peak at interval energy between 0.2835 MeV and 0.6627 for every samples. Mean free path inversely with the value of density of the sample, where if the density of the samples increases, the value of mean free path will be decreasing. From the Figure 4.7 shows that at highest energy which is 15 MeV, TPB28 has the lowest value of mean free path which is 3.976cm while TTB28 has the highest value of mean free path which is 5.325 cm for energy interval between 0.015 MeV and 15 MeV. From this data , we can conclude that the lower the value of mean free path, the greater the shielding effectiveness of sample, where we are avoiding for value of mean free path to be high as photon are able to penetrate the glass more deeply. Therefore, TPB28 has better shielding properties among others glass samples.

4.6 Mass attenuation coefficient (MAC)

The μ_m values have been calculated by applying mixture rule and μ_m are the weight fraction and the mass attenuation coefficient of the constituent element obtained by using Photon Shielding and Dosimetry (PSD) software. The geometry of the present simulation consists of monoenergetic gamma ray source and slab representing one of the studied glasses. The mass fraction and the density parameters of the samples. The glass sample was placed between the source and the detector. The μ_m values were determined by dividing the linear attenuation coefficient by the density of the glass sample.

Energy (MeV)		TTB26	TTB27	TTB28	TPB27	TPB28
0.015		48.739	48.641	48.508	47.132	46.979
0.02		26.624	26.320	25.913	26.099	25.636
0.03		9.130	9.019	8.871	8.937	8.769
0.04		15.348	15.311	15.261	13.079	13.017
0.05		8.535	8.514	8.486	7.278	7.243
0.06		5.358	5.412	5.485	4.678	4.759
0.08		2.508	2.534	2.568	2.202	2.241
0.1		1.903	1.885	1.862	1.772	1.745
0.15		0.705	0.699	0.690	0.666	0.656
0.2		0.376	0.373	0.368	0.359	0.355
0.2835	<i>Cs (137)</i>	0.200	0.199	0.197	0.195	0.193
0.3		0.184	0.182	0.181	0.179	0.177
0.4		0.126	0.126	0.125	0.125	0.124
0.5		0.100	0.100	0.100	0.100	0.100
0.6		0.086	0.086	0.085	0.086	0.086
0.6617	<i>Cs (137)</i>	0.080	0.079	0.079	0.080	0.080
0.8		0.069	0.069	0.069	0.070	0.070
1		0.060	0.060	0.060	0.061	0.060
1.5		0.047	0.047	0.047	0.048	0.048
2		0.042	0.042	0.042	0.042	0.042
3		0.037	0.037	0.037	0.037	0.037
4		0.035	0.035	0.035	0.035	0.035
5		0.034	0.034	0.034	0.034	0.034
6		0.034	0.034	0.034	0.034	0.034
8		0.035	0.035	0.035	0.034	0.034
10		0.036	0.036	0.036	0.035	0.035
15		0.039	0.039	0.039	0.038	0.038

Table 4.5 : Mass attenuation coefficient value of each sample

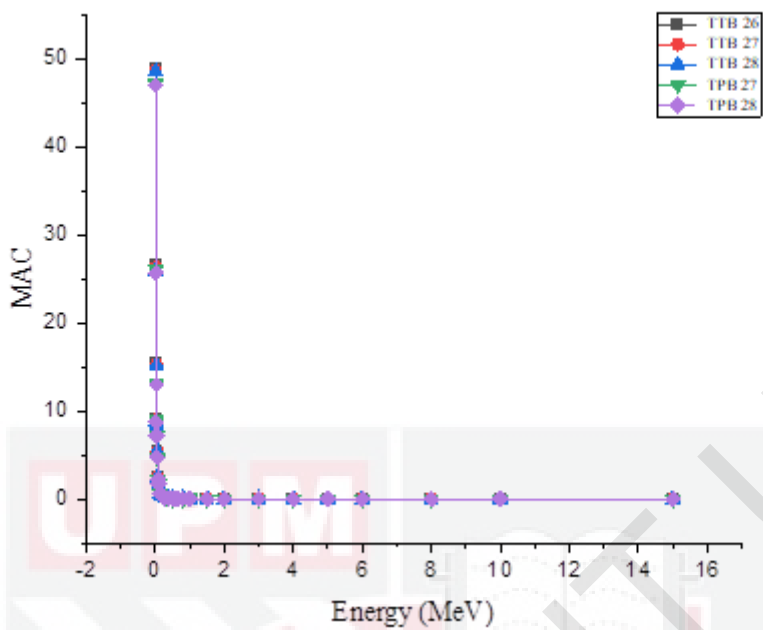


Figure 4.8 : Mass attenuation coefficient against energy

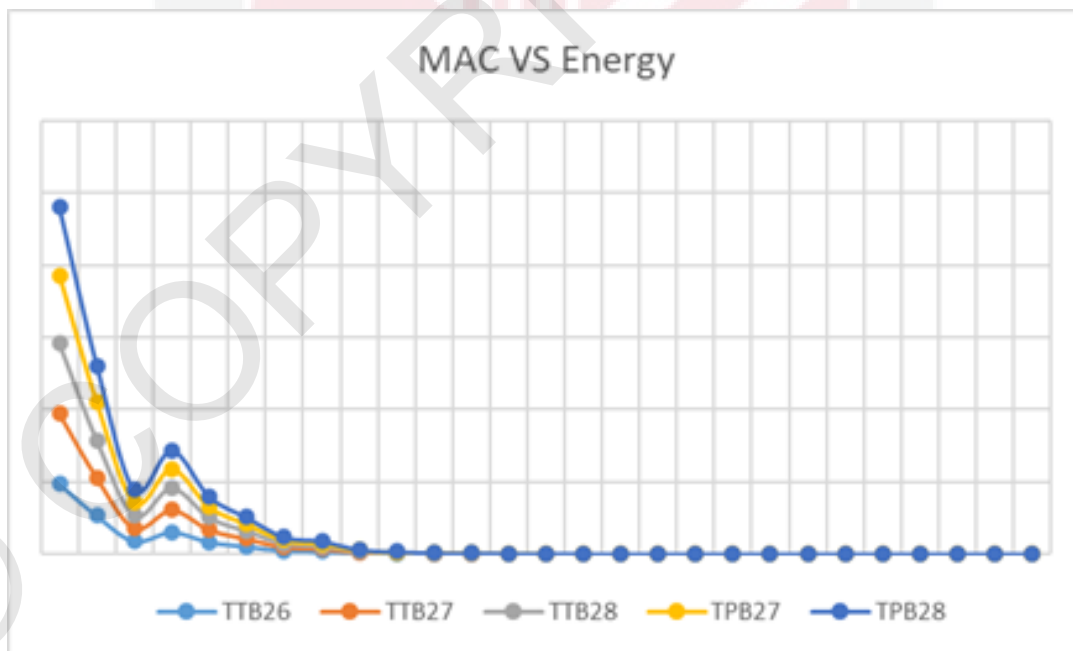


Figure 4.8.2 : Mass attenuation coefficient against energy

Based on Table 4.5 and Figure 4.8, mass attenuation coefficient value has a peak at interval energy between 0.2835 MeV and 0.6627 for every samples. For mass attenuation coefficient, we commonly investigate the capability of radiation shielding properties at the lowest energy which TPB28 has the highest value of mass attenuation coefficient which is 46.979 cm at 0.015 MeV while TTB28 has the lowest value of mass attenuation coefficient which is 48.508 cm at 0.015 MeV. In this case , Mass attenuation coefficient decreases as photon energy increase and decreases as the weight fraction of tellurium oxide (TeO_2) decrease in the sample. From this data we can conclude that, the higher the value of mass attenuation coefficient, the greater the shielding effectiveness of the glass sample, where the better a particular materials attenuates more photons. Therefore, TPB28 has better radiation shielding properties compared to other glass samples.



CHAPTER 5

CONCLUSION

5.1 Introduction

This chapter discusses the overall finding of this study.



5.2 Conclusion

This study has been covered about physical properties and radiation shielding properties of tellurite based glass and the result that obtained from the densimeter and Photon Shielding and Dosimetry (PSD) software as shown above . There are many studies that revealed the properties of the sample such as density , molar volume ,

Half Value Layer (HVL), Mean Free Path (MFP) and Mass attenuation coefficient (MAC). Structural properties of the glass samples has been shown by the density, molar volume and the transparency where the density and molar volume affected every increases and decreases of radiation shielding studies. For the transparency , we can concluded from Figure 4.1, Figure 4.2, Figure 4.3, Figure 4.4 and Figure 4.5 that all the glass sample is transparent amorphous glass especially TPB27 and TPB28. For the radiation shielding properties, there are three type of shielding properties which is Half Value Layer, Mean Free Path and Mass Attenuation Coefficient. First is Half value layer which depending on the density of the sample and lowest half value layer values indicates the highest shielding capability. Next is Mean Free Path which is inversely with the value of density of the sample and the lowest value of Mean Free Path indicates the greatest shielding effectiveness of sample. Lastly is Mass Attenuation Coefficient where the higher the value of Mass Attenuation Coefficient, the greater the shielding effectiveness of sample. In conclusion, TPB28 has the best radiation shielding properties compared to TTB26, TTB27,TTB28 and TPB27 due to its radiation shielding properties. Radiation has the ability to shift atoms in the human body, causing harm to the affected tissues and organs. Radiation shielding considerations are becoming increasingly important for both present and long-term development. As a result, looking for non-toxic and transparent radiation shielding materials is intriguing. These materials can be used to monitor and manage radiation exposure in a variety of radiation-related applications, including medical, industry, and nuclear power.

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