PHYSICAL, STRUCTURAL, ELASTIC AND OPTICAL PROPERTIES OF NEODYMIUM OXIDE DOPED ZINC TELLURITE GLASS SYSTEM WITH SILVER INCORPORATION

ABDULBASET A. ABDULLA AWSHAH

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

May 2019

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DEDICATION

This work is dedicated to my parents Al-Hadi and Fatimah. May Almighty Allah bless and ease their ways.

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Chairman : Professor Halimah Mohamed Kamari, PhD
Faculty : Science

Four series of zinc tellurite glasses doped with neodymium oxide and neodymium oxide nanoparticles with chemical composition equations $[(TeO_2)_{0.7}(ZnO)_{0.3}]_{(1-x)}(Nd_2O_3)_{(x)}$ (TZN), $[(TeO_2)_{0.7}(ZnO)_{0.3}]_{(1-x)}(Nd_2O_3NPs)_{(x)}$(TZNnPs), $\{[(TeO_2)_{0.7}(ZnO)_{0.3}]_{(1-x)}(Nd_2O_3)_{(x)}\}_{(0.99)}$ $(Ag_2O)_{(0.01)}$ (TZAN), $\{[(TeO_2)_{0.7}(ZnO)_{0.3}]_{(1-x)}(Nd_2O_3\ NPs)_{(x)}\}_{(0.99)}(Ag_2O)_{0.01}$ (TZANnPs) have been prepared using the melt-quenching method. The aim of the work was to study the physical, structural, elastic and optical properties of the glasses with the view of achieving an improved application potential for the glasses. The choice of the glass composition was for high refractive index, easy glass formation as well as excellent absorption/emission in the infrared region. Density and molar volume measurement, X-ray diffraction (XRD), Fourier transform infrared (FTIR) and Transmission electron microscopy (TEM) were employed for these studies. Over the last few decades, the study of tellurite glasses and their applications in the areas of scientific, technological and industrial applications have been given a great deal of attention by glass scientists and technologists. Since TeO_2 alone does not form glass, it must be combined with one or more another oxide to form a glass. Structural, optical, electrical and elastic properties of tellurium oxide-based glasses have been and are still under study.

The XRD analyses patterns of all the four glass series showed a broad hump around 20-30^o, confirming the glassy and amorphous nature of the glasses. The FTIR spectral analysis and the deconvolution of the spectra showed the presence and concentration of TeO_3 and TeO_4 structural units against the Nd_2O_3 molar concentration. The TeO_4 concentration variation with Nd_2O_3 was used as the determinant of the variations in bridging and non-bridging oxygen concentrations. Density for all the series of glasses studied showed an increasing pattern from 5346 to 5580, 5346 to 5580, 5345 to 5954, 5410 to 5580 kg cm^{-3} with increase in Nd_2O_3/Nd_2O_3 NPs concentration in TZN,

TZNnPs, TZAN and TZANnPs respectively. The TEM morphological structures for the two Nd_2O_3 NPs doped series revealed the NPs were agglomerated in the glass structure. The ultrasonic velocities and the elastic moduli for the glasses showed different patterns of non-linear variations against both the Nd_2O_3 micro particles and nanoparticles. Other elastic parameters studied include the microhardness, Poisson's ratio, softening temperature, Debye temperature, fractal bond connectivity and fugacity. Theoretical data sets for the elastic properties of the glass systems were obtained using the Makishima and Mackenzie model, Rocherulle model, bond compression and ring deformation models. The values obtained for the elastic moduli using the Makishima and Mackenzie model and Rocherulle model are in excellent agreement with the corresponding experimental set of data. The bond compression model set of data for all the four series of glasses studied presented much higher values of the elastic moduli when compared with the corresponding experimental values of the elastic moduli and thus the model is not suitable for these systems of glasses.

The UV-Vis spectra for all the glass series showed cut-off wavelengths that are not sharp (showing amorphous nature), with absorptions peaks due to Nd^{3+} ions around 435, 460, 478.5, 507.5, 530, 601.5, 635, 685.5 and 752.5 nm wavelengths, corresponding to transitions from $^4I_{9/2}$ to $^2P_{1/2}$, $^4I_{9/2}$ to $^4G_{11/2}$, $^4I_{9/2}$ to ($^2K_{15/2}$ + $^2G_{9/2}$ + $^2D_{3/2}$), $^4I_{9/2}$ to $^4G_{9/2}$, $^4I_{9/2}$ to ($^4G_{7/2}$+$^4G_{9/2}$), $^4I_{9/2}$ to ($^4G_{5/2}$+$^2G_{7/2}$), $^4I_{9/2}$ to $^2H_{11/2}$, $^4I_{9/2}$ to $F_{9/2}$, $^4I_{9/2}$ to ($^4F_{7/2}$+$^4S_{3/2}$) respectively. The optical energy band gaps in all the glass series showed non-linear relationships against the Nd_2O_3 concentration showing a clear dependence on the TeO_4 concentration. The refractive index value ranges for TZN, TZNnPs, TZAN and TZANnPs glass systems are 2.5331 - 2.6371, 2.54695 - 2.60927, 2.5440 - 2.6184 and 2.5567 - 2.6240 respectively. High refractive index values (Higher than conventional silicate/phosphate/other glasses currently in use), polarizability, optical basicity as well as favorable metallization criterion values ($0.3 < M < 0.45$) suggests the glasses have good potential for application in areas of the laser and non-linear optical applications. Other optical parameters studied include the reflection loss, transmission coefficient, dielectric constant and the polaron radius. The values of the refractive index, metallization criterion, optical basicity, dielectric constant and polarizability showed that the glasses studied can be used for optical fiber and laser applications.

Considering their high refractive indices, all the four series have shown advantage against other glasses conventionally used in the fiber and amplifier technology such as tellurite (2.0 - 2.3) , silicate (1.5 - 1.8), , sulfide (around 2.2) and Phosphate (around 1.65) glasses. Putting their elastic (Elastic Moduli, Microhardness, Softening temperature) and optical properties (UV-Vis intensity/effective bandwidth, refractive index, metallization criterion, optical basicity, transmission coefficient) together into consideration, the TZANnPs glass system appeared to have more overall advantage over the other three glass systems for application in both photonics and amplifier technology.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

SIFAT FIZIKAL, STRUKTUR, KENYAL DAN OPTIK SISTEM KACA NEODIMIUM OKSIDA TERDOP DENGAN ZINK TELURIT YANG TELAH DITAMBAHKAN DENGAN ARGENTUM OKSIDA

Oleh

ABDULBASET A. ABDULLA AWSHAH

Mei 2019

Pengerusi : Profesor Halimah Mohamed Kamari, PhD
Fakulti : Sains

Empat siri kaca zink tellurit yang telah didopkan dengan neodimium oksida dan nanozarah neodimium yang mempunyai komposisi kimia $[(TeO_2)_{0.7}(ZnO)_{0.3}]_{(1-x)}(Nd_2O_3)_{(x)}$ (TZN), $[(TeO_2)_{0.7}(ZnO)_{0.3}]_{(1-x)}(Nd_2O_3NPs)_{(x)}$(TZNnPs), $\{[(TeO_2)_{0.7}(ZnO)_{0.3}]_{(1-x)}(Nd_2O_3)_{(x)}\}_{(0.99)}(Ag_2O)_{(0.01)}$ (TZAN), $\{[(TeO_2)_{0.7}(ZnO)_{0.3}]_{(1-x)}(Nd_2O_3\ NPs)_{(x)}\}_{(0.99)}(Ag_2O)_{0.01}$ (TZANnPs) telah disediakan menggunakan kaedah sepuh lindap. Tujuan penyelidikan ini adalah untuk mengkaji sifat-sifat fizikal, struktur, kenyal dan optik bahan kaca dengan harapan untuk meningkat potensi aplikasi bahan kaca. Komposisi kaca bagi penyelidikan ini telah dipilih untuk mendapatkan kaca dengan indeks biasan yang tinggi, pembentukan kaca yang mudah serta penyerapan/pemancaran yang sangat baik di kawasan inframerah. Pengukuran ketumpatan dan isipadu molar, belauan sinar (XRD), mikroskopi penghantaran elektron (TEM) dan (FTIR) telah digunakan dalam kajian ini.

Sejak beberapa dekad yang lalu, kajian bagi kaca tellurit dan penggunaannya di dalam bidang saintifik, teknologi dan aplikasi industri telah diberikan banyak perhatian oleh saintis dan ahli teknologi kaca. Oleh kerana TeO_2 sahaja tidak dapat membentuk kaca, ia mesti digabungkan dengan satu atau lebih oksida lain untuk menbentuk kaca. Sifat stuktur, optik, elektrik dan kekenyalan kaca berasaskan tellurium oksida telah dan masih dalam kajian.

Corak analisis XRD bagi semua keempat-empat siri kaca menunjukkan kewujudan satu bonggol yang luas di sekitar 20-30^o yang telah mengesahkan sifat hablur dan amorfus kaca. Analisis dan dekonvolusi atas spektrum FTIR telah menunjukkan kehadiran serta bilangan unit-unit struktur TeO_3 dan TeO_4 berbanding dengan

kepekatan molekul Nd_2O_3. Perubahan dalam bilangan TeO_4 selari dengan Nd_2O_3 telah digunakan sebagai penentu variasi dalam bilangan oksigen penitian serta oksigen bukan penitian. Ketumpatan untuk semua siri kaca yang telah dikaji menunjukkan corak peningkatan dari 5346 ke 5580, 5346 ke 5580, 5345 ke 5954, 5410 sehingga 5580 kg cm^{-3} dengan peningkatan kepekatan Nd_2O_3/Nd_2O_3 NPs dalam sistem kaca TZN, TZNnPs, TZAN and TZANnPs masing-masing. Struktur morfologi TEM untuk kedua-dua siri yang telah didopkan dengan Nd_2O_3 NPs menunjukkan bahawa nanozarah telah aglomerat di dalam struktur kaca. Halaju ultrasonik dan moduli kenyal untuk kaca yang telah disediakan menunjukkan corak variasi bukan linear yang berbeza terhadap kedua-dua mikro dan nanozarah Nd_2O_3. Parameter kenyal lain yang juga dikaji termasuk mikrokekerasan, nisbah, Poisson, suhu pelembutan, suhu Debye, penyambungan ikatan fraktal dan fugasiti. Data teori bagi ciri-ciri kenyal sistem kaca juga boleh diperolehi menggunakan model Makishima dan Mackenzie, model Rocherulle, ikatan kemampatan dan model pengugahan cincin. Nilai-nilai yang diperolehi bagi modulus kenyal yang menggunakan model Makishima dan Mackenzie dan model Rocherulle adalah sangat baik serta sepadan dengan set data eksperimen. Data dari model kemampatan ikatan bagi semua keempat-empat siri kaca yang telah dikaji membentangkan nilai yang lebih tinggi daripada moduli kenyal apabila dibandingkan dengan nilai eksperimen yang sepadan dengan moduli elastik dan oleh itu, model tersebut tidak sesuai untuk sistem kaca ini.

Spektrum (UV-Vis) untuk semua siri kaca menunjukkan gelombang terpotong yang tidak tajam (menunjukkan sifat amorfus), dengan puncak serapan yang disebabkan oleh ion Nd^{3+} sekitar 435, 460, 478.5, 507.5, 530, 601.5, 635, 685.5 dan 752.5 nm yang sepadan dengan peralihan dari $^4I_{9/2}$ to $^2P_{1/2}$, $^4I_{9/2}$ to $^4G_{11/2}$, $^4I_{9/2}$ to ($^2K_{15/2}$ + $^2G_{9/2}$ + $^2D_{3/2}$), $^4I_{9/2}$ to $^4G_{9/2}$, $^4I_{9/2}$ to ($^4G_{7/2}$+$^4G_{9/2}$), $^4I_{9/2}$ to ($^4G_{5/2}$+$^2G_{7/2}$), $^4I_{9/2}$ to $^2H_{11/2}$, $^4I_{9/2}$ to $F_{9/2}$, $^4I_{9/2}$ to ($^4F_{7/2}$+$^4S_{3/2}$) masing-masing. Jurang jalur optik dalam semua siri kaca menunjukkan hubungan yang tidak linear terhadap kepekatan Nd_2O_3 yang menunjukkan kebergantungan yang jelas terhadap bilangan TeO_4. Nilai indeks biasan untuk sistem kaca TZN, TZNnPs, TZAN and TZANnPs adalah 2.5331 - 2.6371, 2.54695 - 2.60927, 2.5440 - 2.6184 dan 2.5567 - 2.6240 masing-masing. Nilai index pembiasan yang tinggi (lebih tinggi dari silika/ phospat/ kaca konventional lain yang digunakan masa kini), kebolehkutuban, kebesan optik dan juga nilai kriteria metalisasi yang sesuai ($0.3 < M < 0.45$)), mencadangkan kaca ini mempunyai potensi yang baik untuk aplikasi di dalam bidang laser dan optik taklinear. Parameter optik lain yang dikaji termasuk kehilangan pantulan, pekali pemancaran, pemalar dielektrik dan jejari polaron. Nilai indeks pembiasan, kriteria metalisasi, kebesan optik, pemalar dielektrik dan kebolehkutuban menunjukkan kaca yang dikaji ini boleh digunakan untuk aplikasi fiber optik dan laser.

Memandang keempat-empat siri sample kaca mempunyai nilai indeks pembiasan yang tinggi, ia mempunyai kelebihan berbanding dengan kaca konventional lain yang digunakan didalam teknologi fiber dan amplifier seperti kaca telurit (2.0- 2.3), silikat (1.5-1.8), sulfida (sekitar 2.2) dan fosfat (sekitar 1.65). Menggabungkan bersama nilai bagi sifat- sifat kenyal (modulus-modulus kenyal, mikrokekerasan, suhu pelembutan) dan sifat-sifat optik (keamatan/ jalur lebar berkesan UV-Vis, indeks biasan, kriteria metalisasi, kebesan optik, pemalar pemancaran) di dalam pertimbangan, sistem kaca TZANnPs dilihat mempunyai kelebihan keseluruhan mengatasi tiga siri kaca yang lain untuk aplikasi di dalam kedua-dua bidang teknologi fotonik dan amplifier.

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Declaration by graduate student

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LIST OF ABBREVIATIONS

TeO_2-ZnO	Tellurite - Zinc Oxide (Zinc Tellurite)
Nd_2O_3	Neodymium oxide
Ag_2O	Silver oxide
TZN	Neodymium oxide doped zinc-tellurite
TZNnPs	Neodymium oxide nanoparticles doped zinc-tellurite
TZAN	Neodymium oxide doped zinc-tellurite incorporated with silver oxide
TZANnPs	Neodymium oxide nanoparticles doped zinc-tellurite incorporated with silver oxide
TeO_3	trigonal pyramid
TeO_4	trigonal bipyramid
BO	bridging oxygen
NBO	non bridging oxygen
XRD	X-ray diffraction
IR	Infrared
FTIR	fourier transforms infrared spectroscopy
TEM	Transmission Electron Microscopy
ρ	density
V_m	Molar volume
V_L	longitudinal velocity
V_S	shear velocity
E	Young's modulus
K	bulk modulus
L	longitudinal modulus
G	shear modulus

θ_D	Debye temperature
Ts	softening temperature
H	microhardness
σ	poisson's ratio
λ	Wavelength
N_A	Avogadro's number
Vis	Visible
V_B	Valence Band
α	absorption coefficient
C_B	Conduction Band
A	absorbance
E_{opt}	optical band gap energy
$\hbar\omega$	photon energy
$E^{1/2}$	Indirect Band Gap
E^2	Direct Band Gap
∆E	Urbach Energy
(n)	Refractive Index
OPD	Oxygen Packing Density
R_m	Molar Refractive Index
l	Atomic ring size
V_t	Packing density
α_m	Molar Polarizability
G	Dissociation energy
α_e	Electronic polarizability
T	Transmission Coefficient
R_L	Reflection Loss

ε	Dielectric constants
M	Metallization Criterion
N	Nd Ion Concentration
R_p	Polaron Radius
R_i	Nd Inter-Ionic Distance
F	Field Strength of Nd ion Yield
Λ_{th}	Optical Basicity
χ	Linear Dielectric Susceptibility

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The glass is a material made from a mixture of inorganic metal oxides through high temperature fusion of the oxides, which solidifies into a rigid, clear and non-crystalline state. Glasses are versatile materials that are known all over the world (Çelikbilek et al., 2012; Yamane & Ashara, 2000). Glass formation is made possible by the presence of a sufficient amount of a glass former (such as SiO_2, B_2O_3, TeO_2, P_2O_5) composition (Bourhis et al., 2015; El-Moneim, 2001; Nishara Begum & Rajendran, 2007; Mahraz et al., 2014). Glass property is altered to favour some specific applications purposes. Oxide ions such as Pb^{2+}, Zn^{2+}, Ba^{2+}, Bi^{2+}, Na^{+}, K^{+} are incorporated in the glass network to modify both the structure and the properties for a given desired application. For specific luminesces applications, different rare earth ions (such as Er^{3+}, Nd^{3+}, Ho^{3+}, Eu^{3+}) are identified for addition as impurities (doping) which gives them the required property for the desired applications (Chen et al., 2015; Dias, et al., 2016; Kaky et al., 2017; Walas et al., 2017).

Tellurite glasses have shown some greater advantages when compared with other oxide glasses considering their malleability, the low temperature of processing and mechanical strength as well (Hesham et al., 2003). The tellurium atoms in a tellurite-based glasses possess a lone pair of 5s orbit electron with a high hyper polarity which makes them excellent for nonlinear optical glasses applications. In the tellurite based glasses, the weak Te-O bond that is broken easily during the process of glass formation provides for them their heavy metal and rare earth ions accommodation ability (Maheshvaran et al., 2011).

The investigations of tellurite-based glasses have been very comprehensive over the last decades due to their mid infrared transparency, refractive index, low-phonon energy, chemical and thermal stability, rare earth ions solubility, high dielectric constant, high glass stability and high resistance to corrosion (Saddeek, 2005). Tellurite based glasses found to have some great potential in the areas of laser technology, high performance optics, planar waveguides and optical fibres production, sensing, detection, and transmission.

Tellurite glasses have found many applications in non-linear optical devices such as high speed optical- switches, up-conversion frequency systems and others like the production of optical fibres and planar waveguides, high performance optics, laser technology and in optical data transmission, detection and sensing (Joshi et al., 2012). Because of their high third order nonlinear susceptibility, tellurium oxides glasses are considered excellent for optical amplifiers (Pavani et al., 2011). Their applications in fields of science, technology and even industrial are informed by their high linear and non-linear refractive indices as well as their physical, chemical and mechanical qualities (Linda et al., 2013).

Because tellurium oxide (TeO_2) alone does not form glass and is considered a conditional glass former, another oxide is required to form a tellurite based glasses (Gaafar et al., 2014). Previous researches have proven boron oxide (B_2O_3), another glass former to be the best candidate for combination with tellurium oxide. Normally, borate glasses are considered in glass science and technology because of their high transparency, relatively high thermal stability, good rare earth (RE) ions solubility, low melting point and variable coordination numbers (Kesavulu et al., 2016) .

Rare earth oxides are used sometimes in high concentrations (depending on the need and application) in oxide glasses for a wide range of applications from optical data transmission, detection, sensing to laser technologies and many others (El-Mallawany, 2000). The choice of the RE ions depends on the relationship between the radiative or non-radiative RE ions and the host glass composition (Mahraz et al., 2014). Hence, the phonon energy must be low to attend high efficiency in terms of luminescence, and the tunability between the host and the dopant ions is necessary. Of the rare earth metal oxide ions, erbium ions were found to be excellent for doping in borotellurite glasses due to their high solubility in the network and unique properties they possess (Azlan et al., 2017).

Combination utilized by different researchers for its good glass forming ability and good stability is the zinc tellurite glass system. Zinc tellurite glasses are reported to be a suitable host for optically active rare earth ions because of the wide glass-formation range which is close to the extremum for binary tellurite glasses. In these cases, the ZnO-TeO_2 system was utilized as the basic foundational network for the synthesis of optical glasses for application in an ultra-low loss optical fibres in the 3500-400 nm wavelength (Rosmawati et al., 2008; Sayyed, 2016). The composition has also been considered in recent years for applications in the areas super heavy glasses in optical flint. Glasses with the ZnO-TeO_2 composition are known for their high refractive index with is mostly proportional with the TeO_2 composition in the glass network (Pavani et al., 2011; Rosmawati et al., 2008). Interestingly, the role of ZnO in the combination is for the improvement of the thermal stability and the glass transition temperature. Apart from the thermal property enhancement, the ZnO-TeO_2 composition provides an attractive optical nonlinearity of second order to the (Linda et al., 2013; Veeraiah, 1997). Zinc tellurite combination has also been useful in transparent electrodes, gas sensors, and catalysts. ZnO plays both the roles of network modifier and network former in glass systems (Usman et al., 2018).

Because of their technological importance, rare-earth doped glasses in recent years had been given great deal attention in the light converting and optoelectronic devices, optical fibres and amplifiers, and white light emitting diodes. Selection of the structural. The choice of the environmental structure around which the dopant ions get themselves situated is of great importance for their behaviour and for optimum performance (Abdelghany et al., 2016).

1.2 Problem Statement

Over the last few decades, the study of tellurite glasses and their applications in the areas of scientific, technological and industrial applications have been given a great deal of attention by glass scientists and technologists (Sayyed, 2016). Since TeO_2 alone does not form glass, it must be combined with one or more other oxides to form a glass (El-Mallawany, 2002). Structural, optical, electrical and elastic properties of tellurium oxide-based glasses have been and are still under study (Pavani et al., 2011; Hasnimulyati et al., 2017). Interestingly, the role of ZnO in the combination is for the improvement of the optical band gap and elastic properties of the glass system. The incorporation of Ag_2O into the glass composition enhances the optical emission and as well reduces the energy band gap.

The work of Halimah et al., (2005) studied the ultrasonic and physical properties of borotellurite glass. From work, the study was made of the proportion of tellurium oxide and boron oxide combination in terms physical and mechanical properties for the various scientific, technological and industrial applications of the glasses (Halimah et al., 2005).

For their properties that made them promising materials in various applications for photonics and opto-electronics, tellurite based glasses has been given special research attention (Poor et al., 2013). Applications, particularly in the fabrication of both active and passive optical fibres as well as high-gain optical amplifiers used in the communication technology, have made TeO_2 based glasses of high research interest (Chillcce et al., 2011).

In the report of Damas et al., (2012), tellurium oxide as a host material in glasses have the lowest phonon energy of around 780 cm^{-1} with high transparency in the visible, near and mid infrared spectral region. Having refractive indices that are larger than those of quartz, phosphate glasses or borosilicate glasses, they appeared to be better in terms of losses due scattering and absorption and possesses higher chemical durability (Damas et al., 2012).

However, there is a lack of adequate information on elastic and optical properties of neodymium-doped zinc tellurite glasses.

Therefore, this research focuses on effects of silver incorporated neodymium oxide and neodymium oxide nanoparticles doped zinc tellurite glass, with the expectation of enhancing the optical and elastic properties of zinc tellurite glass and add new knowledge about these glasses.

1.3 Objectives

The main objective of this research is to study the structural, physical, elastic and optical properties of neodymium doped zinc tellurite glass. Three objectives were designed in order to achieve this,

1. To fabricate Nd_2O_3 and Nd_2O_3 NPs doped $[(TeO_2)_{0.7}(ZnO)_{0.3}]_{(1-x)}(Nd_2O_3)_{(x)}$ glass systems and Nd_2O_3 and Nd_2O_3 NPs doped Ag_2O incorporated $\{[(TeO_2)_{0.7}(ZnO)_{0.3}]_{(1-x)} (Nd_2O_3)_{(x)}\}_{(0.99)} (Ag_2O)_{0.01}$ glass system.
2. To investigate and determine the physical, structural, elastic and optical properties of Nd_2O_3 doped zinc tellurite glass system.
3. To study the effect of Ag_2O on physical, structural, elastic and optical properties of Nd_2O_3 and Nd_2O_3 NPs doped zinc tellurite glass system.

1.4 Hypothesis

1- The density of the glass is expected to increase with the increase in dopants concentration as a result of higher molecular weight of the dopants when compared to the tellurite and zinc oxides.
2- The addition of Nd_2O_3 and Nd_2O_3 NPs and Ag_2O are likely to enhance the elastic and optical properties of the zinc tellurite glass system.
3- Incorporation of Ag_2O into the zinc tellurite glass is expected to increase the number of non-bridging oxygen by converting the TeO_4 to TeO_3 in the glass composition.

1.5 Significance of the Study

Tellurite glasses have been under study in the last few decades. They are studied for different scientific, industrial and technological application interests. In this study, tellurium oxide had been selected for its contribution in terms of its low phonon energy, high refractive index and high optical transmission in the infrared region. The choice of zinc oxide was to improve the glasses' optical properties. The combination of $ZnO-TeO_2$ provides a very wonderful environment for rare-earth ions for effective and excellent optical and photonic applications (Azlan et al., 2015; Hajer et al., 2014; Tagiara et al., 2017). In all glass-based lasers, trivalent lanthanides are the as the active ions used. Over the years, glasses doped with Nd_2O_3 have been the most thoroughly investigated of all. The host glass is usually silicates, fluorides, and phosphates glass systems. For bulk laser glass applications, phosphate glasses have been mostly considered (Baesso et al., 1999).

In other to improve glass's optical, structural properties and electrical conductivity, Ag_2O is incorporated in the glass network matrix. The expectation is that both the optical emission, transmission, refractive index quality of glasses can be improved with appropriate Ag^+ ions concentration incorporation in a glass network structure (Halimah et al., 2010b; Moawad et al., 2004; Prátula et al., 2017).

In this work, tellurite-based glasses are considered with the incorporation of both ZnO and Ag_2O with Nd_2O_3 for the enhancement of the optical, elastic and structural properties for laser and optical fibre amplifier application.

1.6 Thesis Organization

The thesis consists of six chapters, with each chapter describing the sequence of study as described as follows;

Chapter 1 introduces the background of tellurite glasses, zinc tellurite and neodymium doped glasses and their applications. The chapter also presents the problem statement, aim and objectives, scope of the study as well as the organization of the thesis. **Chapter 2** presents the related literature' overview of the glass, glass formation, tellurite, zinc tellurite and neodymium doped glasses and their applications. The chapter also discussed previous literature that studied optical, structural and elastic (theoretical and experimental) properties of different glasses. **Chapter 3** describes the theories and principles employed in the study. The theories applied in density and molar volume and the characterizations which include the FTIR, XRD, photoluminescence, UV-Vis spectroscopes and ultrasonic non-destructive. The chapter also showed the theories on which the Makishima and Mackenzie, Rocherulle, bond compression and ring deformation models. **Chapter 4** describes the experimental techniques, materials, and methods employed in the study. The section also described the glass fabrication and all the characterization methods, equipment and the chemicals employed. **Chapter 5** presents and discusses the results of density and molar volume measurements, XRD, UV-Vis, TEM, photoluminescence spectroscopy. The section also presents and discusses the results of calculated optical and elastic parameters in the study. **Chapter 6** presents the overall conclusion based on the obtained results and gives recommendations on some future study in the field.

REFERENCES

Abd El-Moneim, A., Youssof, I. M., & Shoaib, M. M. (1998). Elastic moduli prediction and correlation in SiO_2-based glasses. *Materials Chemistry and Physics*, *52*(3), 258–262.

Abdelghany, A. M., Zeyada, H. M., Elbatal, H. A., & Fetouh, R. (2016). Synthesis and Spectral Properties of Nd_2O_3-Doped Sodium Silicophosphate Glass. *Silicon*, *8*(2), 325–330.

Afef, B., Alqahtani, M. M., Hegazy, H. H., Yousef, E., Damak, K., & Maâlej, R. (2018). Green and near infrared emission of Er^{3+}doped PZS and PZC glasses. *Journal of Luminescence*, *194*(January 2017), 706–712.

Afifi, H., & Marzouk, S. (2003). Ultrasonic velocity and elastic moduli of heavy metal tellurite glasses. *Materials Chemistry and Physics*, *80*(2), 517–523.

Agbaoye, R. O., Adebambo, P. O., Akinlami, J. O., Afolabi, T. A., Karazhanov, S. Z., Ceresoli, D., & Adebayo, G. A. (2017). Elastic constants and mechanical properties of PEDOT from first principles calculations. *Computational Materials Science*, *139*, 234–242.

Alazoumi, S. H., Sidek, H. A. A., Halimah, M. K., Matori, K. A., Zaid, M. H. M., & Abdulbaset, A. A. (2017). Synthesis and elastic properties of ternary ZnO-PbO-TeO_2 glasses. *Chalcogenide Letters*, *14*(8), 303–320.

Aliyu, U. S., Kamari, H. M., Hamza, A. M., & Awshah, A. A. (2018). The Structural, Physical and Optical Properties of Borotellurite Glasses Incorporated with Silica from Rice Husk. *Journal of Science and Mathematics Letters*, *6*, 32-46.

Aly, K. A., Afify, N., Saddeek, Y. B., & Abousehly, A. M. (2016). Elastic and optical properties of Ge x Se 2 Sb 1− x (0.0≤ x≤ 1.0) glasses. *Bulletin of Materials Science*, *39*(2), 491-498.

Annapoorani, K., Basavapoornima, C., Suriya Murthy, N., & Marimuthu, K. (2016). Investigations on structural and luminescence behavior of Er^{3+} doped Lithium Zinc borate glasses for lasers and optical amplifier applications. *Journal of Non-Crystalline Solids*, *447*, 273–282.

Annapoorani, K., Murthy, N. S., Ravindran, T. R., & Marimuthu, K. (2016). Influence of Er^{3+} ion concentration on spectroscopic properties and luminescence behavior in Er^{3+} doped Strontium telluroborate glasses. *Journal of Luminescence*, *171*, 19–26.

Azlan, M. N., & Halimah, M. K. (2018). Role of Nd^{3+} nanoparticles on enhanced optical efficiency in borotellurite glass for optical fiber. *Results in Physics*, *11*, 58-64.

Azlan, M. N., Halimah, M. K., Baki, S. O., & Daud, W. M. (2016). Effect of Neodymium Concentration on Structural and Optical Properties of Tellurite Based Glass System. *Journal of Materials Science Forum*, *846*(May), 183–188.

Azlan, M. N., Halimah, M. K., Shafinas, S. Z., & Daud, W. M. (2014a). Polarizability and optical basicity of Er^{3+} ions doped tellurite based glasses. *Chalcogenide Letters*, *11*(7), 319–335.

Azlan, M. N., Halimah, M. K., Shafinas, S. Z., Daud, W. M., & Sidek, H. A. A. (2014b). Influence of erbium concentration on spectroscopic properties of tellurite based glass. Solid State Science And Technology, 22(1-2), 148-156.

Azlan, M. N., Halimah, M. K., Shafinas, S. Z., & Daud, W. M. (2015). Electronic polarizability of zinc borotellurite glass system containing erbium nanoparticles. *Materials Express*, *5*(3), 211–218.

Azlan, M. N., Halimah, M. K., & Sidek, H. A. A. (2017). Linear and nonlinear optical properties of erbium doped zinc borotellurite glass system. *Journal of Luminescence*, *181*, 400–406.

Azuraida, A., Halimah, M. K., Sidek, A. A., Azurahanim, C. A. C., Iskandar, S. M., Ishak, M., & Nurazlin, A. (2015). Comparative studies of bismuth and barium boro-tellurite glass system: Structural and optical properties. *Chalcogenide Letters*, *12*(10), 497–503.

Baesso, M. L., Bento, A. C., Duarte, A. R., Neto, A. M., Miranda, L. C. M., Sampaio, J. A., Gandra, F. C. G. (1999). Nd_2O_3 doped low silica calcium aluminosilicate glasses: Thermomechanical properties. *Journal of Applied Physics*, *85*(12), 8112–8118.

Basavapoornima, C., Linganna, K., Kesavulu, C. R., Ju, S., Kim, B. H., Han, W.-T., & Jayasankar, C. K. (2017). Spectroscopic and pump power dependent upconversion studies of Er^{3+}-doped lead phosphate glasses for photonic applications. *Journal of Alloys and Compounds*, *699*, 959–968.

Benmadani, Y., Kermaoui, A., Chalal, M., Khemici, W., Kellou, A., & Pellé, F. (2013). Erbium doped tellurite glasses with improved thermal properties as promising candidates for laser action and amplification. *Optical Materials*, *35*(12), 2234–2240.

Berwal, N., Dhankhar, S., Sharma, P., Kundu, R. S., Punia, R., & Kishore, N. (2017). Physical , structural and optical characterization of silicate modi fi ed bismuth-borate-tellurite glasses. *Journal of Molecular Structure*, *1127*, 636–644.

Bhatia, B., Meena, S. L., Parihar, V., & Poonia, M. (2015). Optical Basicity and Polarizability of Nd^{3+} -Doped Bismuth Borate Glasses, *New Journal of Glass and Ceramics*, 5(03), 44–52.

Bolundut, L., Pop, L., Bosca, M., Tothazan, N., Borodi, G., Culea, E., Culea & Stefan, R. (2017). Structural, spectroscopic and magnetic properties of Nd^{3+} doped lead tellurite glass ceramics containing silver. *Journal of Alloys and Compounds*, *692*, 934-940.

Bootjomchai, C. (2015). Comparative studies between theoretical and experimental of elastic properties and irradiation effects of soda lime glasses doped with neodymium oxide. *Radiation Physics and Chemistry*, *110*, 96–104.

Bounakhla, M., & Tahri, M. (2014). X-ray fluorescence analytical techniques. *National Center for Energy Sciences and Nuclear Techniques* (CNESTEN), Rabat, Morocco.

Bourhis, K., Massera, J., Petit, L., Koponen, J., Fargues, A., Cardinal, T., Ferraris, M. (2015). Erbium-doped borosilicate glasses containing various amounts of P_2O_5 and Al_2O_3: Influence of the silica content on the structure and thermal, physical, optical and luminescence properties. *Materials Research Bulletin*, *70*, 47-54.

Byrnes, S. J. F. (2008). *Basic theory and phenomenology of polarons*. Berkeley.

Çelikbilek, M., Ersundu, A. E., & Ayd, S. (2012). Crystallization Kinetics of Amorphous Materials. In *Advances in Crystallization Processes* (p. 648). Rijeka, Croatia: InTech.

Chen, R., Tian, Y., Li, B., Wang, F., Jing, X., Zhang, J., & Xu, S. (2015). 2 lm fluorescence of Ho^{3+}:5I7 5I8 transition sensitized by Er^{3+} in tellurite germanate glasses. *Optical Materials*, *49*, 116–122.

Chillcce, E. F., Mazali, I. O., Alves, O. L., & Barbosa, L. C. (2011). Optical and physical properties of Er^{3+} -doped oxy-fluoride tellurite glasses. *Optical Materials*, *33*, 389–396.

Chimalawong, P., Kaewkhao, J., Kedkaew, C., & Limsuwan, P. (2010). Optical and electronic polarizability investigation of Nd^{3+}-doped soda-lime silicate glasses. *Journal of Physics and Chemistry of Solids*, *71*(7), 965–970.

Chimalawong, P., Kaewkhao, J., Kittiauchawal, T., Kedkaew, C., & Limsuwan, P. (2010). Optical Properties of the SiO_2 -Na_2O-CaO-Nd_2O_3 Glasses. *American Journal of Applied Sciences 7*, *7*(4), 584–589.

Chinnamat, W., Laopaiboon, R., Laopaiboon, J., Pencharee, S., & Bootjomchai, C. (2017). Influence of ionic radius modifying oxides on the elastic properties of glasses using ultrasonic techniques and FTIR spectroscopy. *Physics and Chemistry of Glasses: European Journal of Glass Science and Technology Part B*, *58*(5), 207–216.

Christian, G. (1996). Principles of Spectroscopy. In *Analytical Chemistry* (6th ed., p. 104). wiley.

Damas, P., Coelho, J., Hungerford, G., & Hussain, N. S. (2012). Structural studies of lithium boro tellurite glasses doped with praseodymium and samarium oxides. *Materials Research Bulletin*, *47*(11), 3489–3494.

De Araújo, C. B., Kassab, L. R. P., Kobayashi, R. A., Naranjo, L. P., & Santa Cruz, P. A. (2006). Luminescence enhancement of Pb^{2+} ions in TeO_2-PbO- GeO_2 glasses containing silver nanostructures. *Journal of Applied Physics*, *99*(12), 1–5.

Devreese, J. T. (2000). Polarons. *Encyclopedia of Applied Physics*, 383–409.

Dhara, A., Mishra, R. K., Shukla, R., Valsala, T. P., Sudarsan, V., Tyagi, A. K., & Kaushik, C. P. (2016). A comparative study on the structural aspects of sodium borosilicate glasses and barium borosilicate glasses : Effect of Al_2O_3 addition. *Journal of Non-Crystalline Solids*, *447*, 283–289.

Dharma, J., & Pisal, A. (2012). Simple Method of Measuring the Band Gap Energy Value of TiO_2 in the Powder Form using a UV / Vis / NIR Spectrometer. *PerkinElmer, Inc.* Shelton, CT USA.

Dias, J. D. M., Melo, G. H. A., Lodi, T. A., Carvalho, J. O., Filho, P. F. F., & Barboza, M. J. (2016). Thermal and structural properties of Nd_2O_3 -doped calcium boroaluminate glasses. *Journal of Rare Earths*, *34*(5), 521–528.

Dimitrov, V., & Komatsu, T. (2010). An Interpretation Of Optical Properties Of Oxides And Oxide Glasses In Terms Of The Electronic Ion Polarizability And Average Single Bond Strength. *Journal of the University of Chemical Technology and Metallurgy*, *45*(3), 219–250.

Dimitrov, V., Komatsu, T., & Sato, R. (1999). Optical Basicity and O1s Binding Energy of Simple Oxides. *Journal of the Ceramic Society of Japan*, *107*(1), 21–26.

Dimitrov, V., & Takayuki, K. (2005). Classification of oxide glasses : A polarizability approach. *Journal of Solid State Chemistry*, *178*, 831–846.

Dousti, M. R. (2017). Enhanced luminescence properties of Nd^{3+} doped boro-tellurite glasses via silver additive. *Optik*, *136*, 553–557.

Dousti, M. R., Amjad, M., Hussain, A., Amjad, R. J., Shaukat, S. F., Carlos, F. D. S., Branch, T. (2015). Enhanced Near-Infrared Emission Of Er^{3+} -Doped Tellurite. *Chalcogenide Letters*, *12*(3), 123–128.

Dresselhaus, M. S. (1966). Solid State Physics Part II: Optical Properties of Solids. *Proceedins of the International School of Physics*, 198.

Edukondalu, A., Sathe, V., Rahman, S., & Siva Kumar, K. (2014). Thermal, mechanical and Raman studies on mixed alkali borotungstate glasses. *Physica B: Condensed Matter*, *438*, 120–126.

Eevon, C., Halimah, M. K., Azmi, Z., & Azurahanim, C. (2016a). Elastic Properties Of TeO_2-B_2O_3—ZnO-Gd_2O_3 Glasses Using Non-Destructive Ultrasonic Technique. *Chalcogenide Letters*, *13*(6), 281–289.

Eevon, C., Halimah, M. K., Zakaria, A., Azurahanim, C. A. C., Azlan, M. N., & Faznny, M. F. (2016b). Linear and nonlinear optical properties of Gd^{3+} doped zinc borotellurite glasses for all-optical switching applications. *Results in Physics*, *6*, 761-766.

El-Mallawany, R. (2000). Structural Interpretations on tellurite glasses. *Materials Chemistry and Physics*, *63*, 109–115.

El-Mallawany, R. A. H. (2002). *Tellurite Glasses Handbook: Physical Properties and Data*. Florida: CRC Press LLC, 2000 N.W. Corporate Blvd., Boca Raton, Florida 33431.

El-Mallawany, R., Abdalla, M. D., Ahmed, I. A., Dirar Abdalla, M., Ahmed, I. A., Abdalla, M. D., & Ahmed, I. A. (2008). New tellurite glass: Optical properties. *Materials Chemistry and Physics*, *109*(2–3), 291–296.

El-Mallawany, R., Afifi, H. A., El-Gazery, M., & Ali, A. A. (2018). Effect of Bi_2O_3addition on the ultrasonic properties of pentaternary borate glasses. *Measurement: Journal of the International Measurement Confederation*, *116*(November 2017), 314–317.

El-Mallawany, R., Gaafar, M. S., & Veeraiah, N. (2015). Evaluation of bulk modulus and ring diameter of some tellurite glass systems. *Chalcogenide Letters*, *12*(2), 67–74.

El-Mallwany, R. A., & Saunders, G. A. (1988). Elastic properties of binary , ternary and quaternary rare earth tellu rite glasses. *Journal of Materials Science Letters*, *7*, 870–874.

El-moneim, A. A. (2016a). Phosphate-based glasses : Prediction of acoustical properties. *Physica B: Physics of Condensed Matter*, *487*, 53–60.

El-Moneim, A. A. (2001). Bond compression bulk modulus and Poisson’s ratio of the polycomponent silicate glasses. *Materials Chemistry and Physics*, *70*(3), 340–343.

El-Moneim, A. A. (2016b). Correlation between acoustical and structural properties of glasses: Extension of Abd El-Moneim model for bioactive silica based glasses. *Materials Chemistry and Physics*, *173*, 372–378.

El-Moneim, A. A. (2017). Theoretical analysis for ultrasonic properties of vanadate-phosphate glasses over an extended range of composition: Part II. *Journal of Non-Crystalline Solids*, *465*, 49–54.

El-Moneim, A. A., & Hassan, Y. A. (2018). Approach to dissociation energy and elastic properties of vanadate and V_2O_5 -contained glasses from single bond strength: Part I. *Materials Chemistry and Physics*, *207*, 271–281.

El-Moneim, A., Youssof, I. M., & Abd El-Latif, L. (2006). Structural role of RO and Al_2O_3in borate glasses using an ultrasonic technique. *Acta Materialia*, *54*(14), 3811–3819.

Elazoumi, S. H., Sidek, H. A. A., Rammah, Y. S., El-Mallawany, R., Halimah, M. K., Matori, K. A., & Zaid, M. H. M. (2018). Effect of PbO on optical properties of tellurite glass. *Results in Physics*, *8*, 16–25.

Elbashar, Y. H., & Rayan, D. A. (2016). Thermal analysis of B_2O_3-Na_2O-ZnO glass doped Nd_2O_3. *International Journal of Applied Engineering Research*, *11*(11074203), 5791–5796.

Elkhoshkhany, N. (2014). Optical Properties of WO_3 -PbO Tellurite Glasses Doped with Rare Earths. *Journal of Chemical Engineering*, *8*, 11–20.

Elkhoshkhany, N., & Syala, E. (2017). Kinetic characterization of TeO_2–Bi_2O_3 –V_2O_5 –Na_2O –TiO_2 glass system. *Ceramics International*, *43*(8), 6156–6162.

Eniu, D., Gruian, C., Vanea, E., Patcas, L., & Simon, V. (2015). FTIR and EPR spectroscopic investigation of calcium-silicate glasses with iron and dysprosium. *Journal of Molecular Structure*, *1084*, 23–27.

Eraiah, B. (2010). Optical properties of lead-tellurite glasses doped with samarium trioxide. *Bulletin of Materials Science*, *33*(4), 391–394.

Ersundu, M. C., & Ersundu, A. E. (2016). Structure and crystallization kinetics of lithium tellurite glasses. *Journal of Non-Crystalline Solids*, *453*, 150–157.

Faznny, M. F., Halimah, M. K., & Azlan, M. N. (2016). Effect Of Lanthanum Oxide On Optical Properties Of Zinc Borotellurite Glass System. *Materials Science Forum*, *846*(March), 63–68.

Ferrer, N. (2007). Applications of Fourier transform infrared spectroscopy. Barcelona, Spain.

Fiocco, L., Ferroni, L., Gardin, C., Zavan, B., Secco, M., Matthews, S., & Bernardo, E. (2016). Wollastonite-diopside glass-ceramic foams from supercritical carbon dioxide-assisted extrusion of a silicone resin and inorganic fi llers. *Journal of Non-Crystalline Solids*, *443*, 33–38.

Gaafar, M. S., Abdeen, M. A. M., & Marzouk, S. Y. (2011). Structural investigation and simulation of acoustic properties of some tellurite glasses using artificial intelligence technique. *Journal of Alloys and Compounds*, *509*(8), 3566–3575.

Gaafar, M. S., & El-aal, N. S. A. (2012). Ultrasonic relaxation in Zinc - Borate glasses. *Current Applied Physics*, *12*(2), 589–596.

Gaafar, M. S., & Marzouk, S. Y. (2007). Mechanical and structural studies on sodium borosilicate glasses doped with Er_2O_3 using ultrasonic velocity and FTIR spectroscopy. *Physica B*, *388*, 294–302.

Gaafar, M. S., Marzouk, S. Y., Zayed, H. A., Soliman, L. I., & El-deen, A. H. S. (2013). Structural studies and mechanical properties of some borate glasses doped with different alkali and cobalt oxides. *Current Applied Physics*, *13*(1), 152–158.

Gaafar, M. S., Shaarany, I., & Alharbi, T. (2014). Structural investigations on some cadmium-borotellurate glasses using ultrasonic, FT-IR and X-ray techniques. *Journal of Alloys and Compounds*, *616*, 625–632.

Ghribi, N., Dutreilh-Colas, M., Duclère, J. R., Gouraud, F., Chotard, T., Karray, R., … Thomas, P. (2015). Structural, mechanical and optical investigations in the TeO_2-rich part of the TeO_2-GeO_2-ZnO ternary glass system. *Solid State Sciences*, *40*, 20–30.

Gomes, J. F., Lima, A. M. O., Sandrini, M., Medina, A. N., Steimacher, A., Pedrochi, F., & Barboza, M. J. (2017). Optical and spectroscopic study of erbium doped calcium borotellurite glasses. *Optical Materials*, *66*, 211–219.

Guo, H., Wang, Y., Gong, Y., Yin, H., Mo, Z., Tang, Y., & Chi, L. (2016). Optical band gap and photoluminescence in heavily Tb^{3+} doped GeO_2-B_2O_3-SiO_2-Ga_2O_3 magneto-optical glasses. *Journal of Alloys and Compounds*, *686*, 635-640.

Gupta, P., & Ramrakhiani, M. (2009). Influence of the particle size on the optical properties of CdSe nanoparticles. *The Open Nanoscience Journal,* 3(1).

Hajer, S. S., Halimah, M. K., Zakaria, A., & Azlan, M. N. (2016, March). Effect of samarium nanoparticles on optical properties of zinc borotellurite glass system. *In Materials Science Forum (Vol. 846)*, 63-68.

Hajer, S. S., Halimah, M. K., Azmi, Z., & Azlan, M. N. (2014). Optical properties of Zinc-Borotellurite doped samarium. *Chalcogenide Letters*, *11*(11), 553–566.

Halimah, M. K., Daud, W. M., & Sidek, H. A. A. (2010a). Effect of AgI addition on elastic properties of quaternary tellurite glass systems. *Chalcogenide Letters*, *7*(11), 613–620.

Halimah, M. K., Daud, W. M., & Sidek, H. A. A. (2010b). Elastic properties of TeO_2-B_2O_3-Ag_2O glasses. *Ionics*, *16*(9), 807–813.

Halimah, M. K., Daud, W. M., Sidek, H. A. A., Zaidan, A. W., & Zainal, A. S. (2010c). Optical properties of ternary tellurite glasses. *Material Science-Poland*, *28*(1) 173.

Halimah, M. K., Faznny, M. F., Azlan, M. N., & Sidek, H. A. A. (2017). Optical basicity and electronic polarizability of zinc borotellurite glass doped La^{3+} ions. *Results in Physics*, *7,* 581-589.

Halimah, M. K., Hasnimulyati, L., Zakaria, A., Halim, S. A., Ishak, M., Azuraida, A., & Al-Hada, N. M. (2017). Influence of gamma radiation on the structural and optical properties of thulium-doped glass. *Materials Science and Engineering B: Solid-State Materials for Advanced Technology*, *226*(September), 158–163.

Halimah, M., Sidek, H., Daud, W., Zainul, H., Talib, Z., Zaidan, A.,Mansor, H. (2005). Ultrasonic Study and Physical Properties of Borotellurite Glasses. *American Journal of Applied Sciences*, *2*(11), 1541–1546.

Hasnimulyati, L., Halimah, M. K., Zakaria, A., Halim, S. A., & Ishak, M. (2017). A comparative study of the experimental and the theoretical elastic data of Tm^{3+} doped zinc borotellurite glass. *Materials Chemistry and Physics*, *192*, 228–234.

Hamezan, M., Sidek, H. A. A., Zaidan, A. W., Kaida, K., & Zainal, A. T. (2006). Elastic constants and thermal properties of lead-bismuth borate glasses. *Journal of Applied Sci*ence, *6*(4), 943-949.

Hamza A. M, M. K. Halimah, F. D. Muhammad, and K. T. Chan, "Physical properties , ligand fi eld and Judd-Ofelt intensity parameters of bio- silicate borotellurite glass system doped with erbium oxide," J. Lumin., vol. 207, no. May 2018, pp. 497–506, 2019

Hesham, A., & Samier, M. (2003). Ultrasonic velocity and elastic moduli of heavy metal tellurite glasses. *Material Chemistry and Physics*, *80*, 517–523.

Herzfeld, K. F. (1927). On Atomic Properties which make an Element a Metal. *Phys. Rev. Physical Review, 29*(5), 701–705.

Homes, C. C., Vogt, T., Shapiro, S. M., Wakimoto, S., & Ramirez, A. P. (2001). Optical Response of Perovskite-Related Oxide, *293*(July), 673–676.

Honma, T., Sato, R., Benino, Y., Komatsu, T., & Dimitrov, V. (2000). Electronic polarizability, optical basicity and XPS spectra of Sb_2O_3–B_2O_3 glasses. *Journal of Non-Crystalline Solids*, *272*(1), 1–13.

Hooi M. O., Mohamed-Kamari, H & Wan-Yusoff, W. M. D. (2012). Optical properties of bismuth tellurite based glass. Int. J. Mol. Sci. 2012, 13(4), 4623–4631.

Hraiech, S., Bouzidi, C., & Férid, M. (2017). Luminescence properties of Er^{3+}-doped phosphate glasses. *Physica B: Condensed Matter*, *522*(July), 15–21.

Hwa, L. G., Hsieh, K. J., & Liu, L. C. (2003). Elastic moduli of low-silica calcium alumino-silicate glasses. *Materials Chemistry and Physics*, *78*(1), 105–110.

Hwa, L. G., Lu, C. L., & Liu, L. C. (2000). Elastic moduli of calcium alumino-silicate glasses studied by Brillouin scattering. *Materials Research Bulletin*, *35*(8), 1285–1292.

Iaea. (1988). Ultrasonic Testing of Materials At Level 2. In *A Technical Document Issued By The Internal Atomic Energy Agency, Vienna* (p. 278). Vienna.

Irimpan, L., Krishnan, B., Nampoori, V. P. N., & Radhakrishnan, P. (2008). Linear and nonlinear optical characteristics of ZnO-SiO_2 nanocomposites. *Applied Optics, 47*(24), 4345–4351.

Isakandar, S. M., Halimah, M. K., Daud, W. M., Sidek, H. A. A., & Khairul Zaman, M. D. (2012). Thermal Stability and Physical Properties of PbO-B_2O_3-TeO_2 Glass System. *Solid State Science and Technology*, *20*(1), 48–55.

Janek, J., So, M., Zur, L., Pietrasik, E., Pisarska, J., & Pisarski, W. A. (2016). Luminescence investigations of rare earth doped lead-free borate glasses modi fi ed by MO (M ¼ Ca , Sr , Ba), *180*, 237–243.

Jlassi, I., Fares, H., & Elhouichet, H. (2018). Enhancement of spectroscopic and luminescence properties of Er^{3+}doped tellurite glasses by adding $P_2O_5$for lasing materials. *Journal of Luminescence, 194*(August 2017), 569–578.

Joshi, C., Rai, R. N., & Rai, S. B. (2012). Structural, thermal, and optical properties of Er^{3+} /Yb^{3+} co-doped oxyhalide tellurite glasses, glass-ceramics and ceramics. *Journal of Quantitative Spectroscopy and Radiative Transfer, 113*, 397–404.

Kaky, K. M., Lakshminarayana, G., Baki, S. O., Lira, A., Caldiño, U., Meza-Rocha, A. N., Mahdi, M. A. (2017). Structural and optical studies of Er^{3+}-doped alkali/alkaline oxide containing zinc boro-aluminosilicate glasses for 1.5 μm optical amplifier applications. *Optical Materials*, *69*, 401–419.

Kashif, I., El-Maboud, A. A., & Ratep, A. (2014). Effect of Nd_2O_3 addition on structure and characterization of lead bismuth borate glass. *Results in Physics*, *4*, 1-5.

Kassab, L. R. P., Courrol, L. C., Seragioli, R., Wetter, N. U., Tatumi, S. H., & Gomes, L. (2004). Er^{3+} laser transition in PbO-PbF_2-B_2O_3 glasses. *Journal of Non-Crystalline Solids*, *348*, 94–97.

Kaur, A., Khanna, A., & Aleksandrov, L. I. (2017). Structural, thermal, optical and photo-luminescent properties of barium tellurite glasses doped with rare-earth ions. *Journal of Non-Crystalline Solids*, *476*(August), 67–74.

Kaur, A., Khanna, A., González, F., Pesquera, C., & Chen, B. (2016). Structural , optical , dielectric and thermal properties of molybdenum tellurite and borotellurite glasses. *Journal of Non-Crystalline Solids, 444*, 1–10.

Kek, B., & Grum, T. (2016). Pulse-Echo Ultrasonic Testing of Adhesively Bonded Joints in Glass Façades, *62*, 147–153.

Kesavulu, C. R., Kim, H. J., Lee, S. W., Kaewkhao, J., Wantana, N., Kaewnuam, E., Kaewjaeng, S. (2017). Spectroscopic investigations of Nd^{3+}doped gadolinium calcium silica borate glasses for the NIR emission at 1059 nm. *Journal of Alloys and Compounds*, *695*, 590–598

Kesavulu, C. R., Kim, H. J., Lee, S. W., Kaewkhao, J., Wantana, N., Kothan, S., & Kaewjaeng, S. (2016). Influence of Er^{3+} ion concentration on optical and photoluminescence properties of Er^{3+} -doped gadolinium-calcium silica borate glasses. *Journal of Alloys and Compounds*, *683*, 590–598.

Khan, A. A. (1999). Ultrasonic Testing of Materials at Level 2 (10th ed.). Vienna: Internatinal Atomic Energy Agency.

King, P. L., Ramsey, M. S., McMillan, P. F., & Swayze, G. (2004). Laboratory Fourier transform infrared spectroscopy methods for geologic samples. *Infrared spectroscopy in geochemistry, exploration geochemistry, and remote sensing, 33*, 57-91.

Komatsu, T., Ito, N., Honma, T., & Dimitrov, V. (2012). Temperature dependence of refractive index and electronic polarizability of RO–TeO_2 glasses (R= Mg, Ba, Zn). *Solid State Sciences, 14(10)*, 1419-1425.

Kumar, A. (2010). Preparation of Apatite-Wollastonite and Phlogophite Glass Ceramic and Study of Its Properties. *National Institute Of Technology Rourkela.*

Kundu, R. S., Dhankhar, S., Punia, R., Nanda, K., & Kishore, N. (2014). Bismuth modified physical , structural and optical properties of mid-IR transparent zinc boro-tellurite glasses. *Journal Of Alloys And Compounds*, *587*, 66–73.

Lambson, E. F., Saunders, G. A., Bridge, B., & El-Mallawany, R. A. (1984). The Elastic Behaviour of TeO_2 Glass Under Uniaxial And Hydrostatic Pressure. *Journal of Non-Crystalline Solids*, *69*, 117–133.

Landau, L. D., & Pekar, S. I. (1948). Effective Mass of Polarons. *Journal of Physics*, *18*(5), 71–74.

Laopaiboon, R., & Bootjomchai, C. (2015). Physical properties and thermoluminescence of glasses designed for radiation dosimetry measurements. *Materials and Design*, *80*, 20–27.

Laopaiboon, R., Laopaiboon, J., Pencharee, S., Nontachat, S., & Bootjomchai, C. (2016). The effects of gamma irradiation on the elastic properties of soda lime glass doped with cerium oxide. *Journal of Alloys and Compounds*, *666*, 292–300.

Li, Q., Xing, M., Chen, Z., Wang, X., Zhao, C., Qiu, J., Yu J., & Chang, J. (2016). Er^{3+}/Yb^{3+} co-doped bioactive glasses with up-conversion luminescence prepared by containerless processing. *Ceramics International*, *42*(11), 13168-13175.

Lide, D. R. (2003). CRC Handbook of Chemistry and Physics, 84th Edition, 2003-2004. *Handbook of Chemistry and Physics*, *53*, 2616.

Lim, T. Y., Wagiran, H., Hussin, R., Hashim, S., & Saeed, M. A. (2014). Physical and optical properties of dysprosium ion doped strontium borate glasses. *Physica B: Condensed Matter*, *451*, 63-67.

Linda, D., Duclère, J.-R., Hayakawa, T., Dutreilh-Colas, M., Cardinal, T., Mirgorodsky, A., Thomas, P. (2013). Optical properties of tellurite glasses elaborated within the TeO_2 –Tl_2O–Ag_2O and TeO_2 –ZnO–Ag_2O ternary systems. *Journal of Alloys and Compounds*, *561*, 151–160.

Linganna, K., Agawane, G. L., & Choi, J. H. (2017). Longer lifetime of Er3+/Yb3+co-doped fluorophosphate glasses for optical amplifier applications. *Journal of Non-Crystalline Solids*, *471*(May), 65–71.

Lisiecki, R., Czerska, E., Żelechower, M., Swadźba, R., & Ryba-Romanowski, W. (2017). Oxyfluoride silicate glasses and glass-ceramics doped with erbium and ytterbium - An examination of luminescence properties and up-conversion phenomena. *Materials and Design*, *126*, 174–182.

Ma, Y., Huang, F., Hu, L., & Zhang, J. (2013). Er^{3+}/Ho^{3+}-Codoped Fluorotellurite Glasses for 2.7 µm Fiber Laser Materials. *Fibers*, *1*(2), 11–20.

Macdougall, S. K. W., Ivaturi, A., Marques-Hueso, J., Krämer, K. W., & Richards, B. S. (2014). Broadband photoluminescent quantum yield optimisation of Er^{3+}-doped β-NaYF4for upconversion in silicon solar cells. *Solar Energy Materials and Solar Cells*, *128*, 18–26.

Maheshvaran, K., Linganna, K., & Marimuthu, K. (2011). Composition dependent structural and optical properties of Sm^{3+} doped boro-tellurite glasses. *Journal of Luminescence*, *131*(12), 2746–2753.

Maheshvaran, K., Veeran, P. K., & Marimuthu, K. (2013). Structural and optical studies on Eu^{3+} doped boro-tellurite glasses. *Solid State Sciences*, *17*, 54–62.

Mahraz, Z. A. S. (2016). Effect of Silver Nanoparticles on Spectral Features of Erbium Doped Zinc-boro-tellurite Glass (Doctoral dissertation, Universiti Teknologi Malaysia).

Mahraz, Z. A. S., Sahar, M. R., & Ghoshal, S. K. (2014). Band gap and polarizability of boro-tellurite glass: influence of erbium ions. *Journal of Molecular Structure*, *1072*, 238-241.

Makishima, A., & Mackenzie, J. D. (1975). Calculation of bulk modulus, shear modulus and Poisson's ratio of glass. *Journal of Non-Crystalline Solids*, *17*(2), 147–157.

Mansour, E. (2012). FTIR spectra of pseudo-binary sodium borate glasses containing TeO_2. *Journal of Molecular Structure, 1014*, 1–6.

Marzouk, S. Y. (2009). Ultrasonic and infrared measurements of copper-doped sodium phosphate glasses. *Materials Chemistry and Physics*, *114*(1), 188–193.

Marzouk, S. Y., & Gaafar, M. S. (2007). Ultrasonic study on some borosilicate glasses doped with different transition metal oxides. *Solid State Communications*, *144*, 478–483.

Matori, K. A., Sayyed, M. I., Sidek, H. A. A., Zaid, M. H. M., & Singh, V. P. (2017). Comprehensive study on physical, elastic and shielding properties of lead zinc phosphate glasses. *Journal of Non-Crystalline Solids*, *457*, 97–103.

Mauro, J. C. (2011). Topological constraint theory of glass. *American Ceramic Society Bulletin*, *90*(4), 31–37.

Meena, S. L., & Bhatia, B. (2016). Polarizability and Optical Basicity of Er^{3+} Ions Doped Zinc Lithium Bismuth Borate Glasses. *Journal of Pure Applied and Industrial Physics*, *6*(10), 175–183.

Mhareb, M. H. A., Hashim, S., Ghoshal, S. K., Alajerami, Y. S. M., Saleh, M. A., Maqableh, M. M. A., & Tamchek, N. (2015). Optical and erbium ion concentration correlation in lithium magnesium borate glass. *Optik*, *126*(23), 3638–3643.

Michalina, W., Tomasz, L., Anna, S., Marcin, Ł., Wojciech, S., Barbara, K., … Kościelska, B. (2017). Eu^{3+} doped tellurite glass ceramics containing SrF_2 nanocrystals: Preparation, structure and luminescence properties. *Journal of Alloys and Compounds*, *696*, 619–626.

Mo, Z. X., Guo, H. W., Liu, P., Shen, Y. D., & Gao, D. N. (2016). Luminescence properties of magneto-optical glasses containing Tb^{3+} ions. *Journal of Alloys and Compounds*, *658*, 967–972.

Moawad, H. M. M., Jain, H., El-Mallawany, R., Ramadan, T., El-Sharbiny, M., El-Mallawany, R.,El- Sharbiny, M. (2004). Electrical Conductivity of Silver Vanadium Tellurite Glasses. *Journal of the American Ceramic Society*, *85*(11), 2655–2659.

Mohamed, E. A., Ahmad, F., & Aly, K. A. (2012). Effect of lithium addition on thermal and optical properties of zinc-tellurite glass. *Journal of Alloys and Compounds, 538*, 230–236.

Mostafa, A. G., Sayed, M. A., Saddeek, Y. B., Hassaan, M. Y., Aly, K. A., City, N., Arabia, S. (2015). Studying the Elastic Properties of Glasses Based on Ckd Using Ultrasonic Technique, *10*(3), 935–940.

Mustafa, I. S., Ain, N., Razali, N., Ibrahim, A. R., Yahaya, Z., & Kamari, H. M. (2015). From Rice Husk to Transparent Radiation Protection Material. *Jurnal Intelek*, *9*(2), 1–6.

Mustafa, I. S., Kamari, H. M., Wan Yusoff, W. M. D., Aziz, S. A., & Rahman, A. A. (2013). Structural and optical properties of lead-boro-tellurrite glasses induced by Gamma-ray. *International Journal of Molecular Sciences*, *14*(2), 3201–3214.

Narayanan, M. K., & Shashikala, H. D. (2015). Thermal and optical properties of BaO–CaF_2 –P_2O_5 glasses. *Journal of Non-Crystalline Solids*, *422*, 6–11.

Nishara Begum, A., & Rajendran, V. (2007). Structure investigation of TeO_2-BaO glass employing ultrasonic study. *Materials Letters*, *61*(11–12), 2143–2146.

Nobarzad, A. E. K., Masoumi, K. M., & Heirdari, K. (2014). *Phase Identification by X-ray diffraction*.

Noorazlan, A. M., Kamari, H. M., Zulkefly, S. S., & Mohamad, D. W. (2013). Effect of erbium nanoparticles on optical properties of zinc borotellurite glass system. Journal of Nanomaterials, 8(2),49–59.

Noorazlan, A. M., Kamari, H. M., Baki, S. O., & Mohamad, D. W. (2015). Green Emission of Tellurite Based Glass Containing Erbium Oxide Nanoparticles. *Journal of Nanomaterials*, *2015*(October).

Owen, T. (1996). *Principles and applications of UV-visible spectroscopy*. Copyright Hewlett-Packard Company.

Pandarinath, M. A., Upender, G., Rao, K. N., & Babu, D. S. (2016). Thermal, optical and spectroscopic studies of boro-tellurite glass system containing ZnO. *Journal of Non-Crystalline Solids*, *433*, 60–67.

Pavani, P. G., Sadhana, K., & Mouli, V. C. (2011). Optical, physical and structural studies of boro-zinc tellurite glasses. *Physica B: Physics of Condensed Matter*, *406*, 1242–1247.

Pawar, P. P., Munishwar, S. R., Gautam, S., & Gedam, R. S. (2017). Physical , thermal , structural and optical properties of Dy 3 þ doped lithium alumino-borate glasses for bright W-LED. *Journal of Luminescence*, *183*, 79–88.

Pereira, C., Barbosa, J., Cassanjes, F. C., Gonçalves, R. R., Ribeiro, S. J. L., & Poirier, G. (2016). Thermal , structural and optical properties of new TeO_2 e Sb_2O_3 e GeO_2 ternary glasses. *Optical Materials*, *62*, 95–103.

Pönitzsch, A., Nofz, M., Wondraczek, L., & Deubener, J. (2016). Bulk elastic properties , hardness and fatigue of calcium aluminosilicate glasses in the intermediate-silica range. *Journal of Non-Crystalline Solids*, *434*, 1–12.

Pontuschka, W. M., Giehl, J. M., Miranda, A. R., Costa, Z. M. Da, & Alencar, A. M. (2016). Effect of the Al_2O_3 addition on the formation of silver nanoparticles in heat treated soda-lime silicate glasses. *Journal of Non-Crystalline Solids*, *453*, 74–83.

Poor, H. B., Aziz, H. A., & Zamiri, R. (2013). Ultrasonic and optical properties and emission of Er^{3+} / Yb^{3+} doped lead bismuth-germanate glass affected by Bi^{+} / Bi^{2+} ions. *Journal of Luminescence*, *143*, 526–533.

Prátula, P. E., Terny, S., Sola, M. E., & Frechero, M. A. (2017). Ionic conductivity enhancement achieved by the incorporation of ZnO in a lithium tellurite glass. *Journal of Non-Crystalline Solids*, *461*, 18–23.

Rajesh, S., Saravanan, S., & Palani, R. (2015). Structural and Elastic Properties of Li^{+} and W^{6+} Metal Ions Doped With Sodium Borate Glass Using Pulser – Receiver Technique. *International Journal of Science and Research (IJRS)*, (January), 22–24.

Ramadevudu, G., & Chary, M. N. (2017). Physical and spectroscopic studies of Cr^{3+} doped mixed alkaline earth oxide borate glasses. *Materials Chemistry and Physics*, *186*, 382–389.

Rao, V. H., Prasad, P. S., Rao, P. V., Santos, L. F., & Veeraiah, N. (2016). Influence of Sb_2O_3 on tellurite based glasses for photonic applications. *Journal of Alloys and Compounds*, *687*, 898–905.

Rao, Y. R., Goud, K. K., Kumar, E. R., Reddy, M. C. S., Rao, B. A., Chandra, M., Rao, B. A. (2014). Upconversion Luminescence in Er^{3+} / Yb^{3+} Codoped Lead Bismuth Indium Borate Glasses. *International Journal of Recent Development in Engineering and Technology*, *3*(1), 2347–6435.

Rasool, S. N., Jamalaiah, B. C., Suresh, K., Moorthy, L. R., & Jayasankar, C. K. (2017). Spectroscopic properties of Er^{3+}-doped phosphate based glasses for broadband 1.54 μm emission. *Journal of Molecular Structure*, *1130*, 837–843.

Reddy, R. R., Ahammed, Y. N., Azeem, P. A., Gopal, K. R., & Rao, T. V. R. (2001). Electronic Polarizability and Optical Basicity Properties of Oxide Glasses Through Average Electronegativity. *Journal of Non-Crystalline Solids*, *286*, 169–180.

Reza Dousti, M., & Amjad, R. J. (2017). Effect of silver nanoparticles on the upconversion and near-infrared emissions of Er^{3+}:Yb^{3+}co-doped zinc tellurite glasses. *Measurement: Journal of the International Measurement Confederation*, *105*, 114–119.

Rocherulle, J., Ecolivet, C., Poulain, M., Verdier, P., & Laurent, Y. (1989). Elastic moduli of oxynitride glasses. Extension of Makishima and Mackenzie's theory. *Journal of Non-Crystalline Solids*, *108*(2), 187–193.

Rosmawati, S., Sidek, H. A. A., Zainal, A. T., & Zobir, H. M. (2008). Effect of zinc on the physical properties of tellurite glass. *Journal of Applied Sciences, 8(10)*, 1956–1961.

Rojek, M., Stabik, J., & Sokół, S. (2007). Fatigue and ultrasonic testing of epoxy-glass composites. *Journal of Achievements in Material and Manufacturing Engineering*, *20*(1–2), 183–186.

Rolli, R., Montagna, M., Chaussedent, S., Monteil, A., Tikhomirov, V. K., & Ferrari, M. (2003). Erbium-doped tellurite glasses with high quantum efficiency and broadband stimulated emission cross section at 1.5 lm. *Optical Materials*, *21*, 743–748.

Saddeek, Y. B. (2004a). Structural analysis of alkali borate glasses. *Physica B: Condensed Matter, 344*(1-4), 163-175.

Saddeek, Y. B. (2004b). Ultrasonic study and physical properties of some borate glasses. *Materials Chemistry and Physics*, *83*, 222–228.

Saddeek, Y. B. (2005a). Elastic properties of Gd^{3+} -doped tellurovanadate glasses using pulse-echo technique. *Materials Chemistry and Physics*, *91*, 146–153.

Saddeek, Y. B. (2009). Structural and acoustical studies of lead sodium borate glasses. *Journal of Alloys and Compounds*, *467*, 14–21.

Saddeek, Y. B. (2011). Study of elastic moduli of lithium borobismuthate glasses using ultrasonic technique. *Journal of Non-Crystalline Solids*, *357*(15), 2920–2925.

Saddeek, Y. B., Azooz, M. A., & Kenawy, S. H. (2005b). Constants of elasticity of Li_2O-B_2O_3-fly ash: Structural study by ultrasonic technique. *Materials Chemistry and Physics*, *94*(2–3), 213–220.

Saddeek, Y. B., Elsayed, N. Z., Y.B., S., & N.Z., E. (2015). Structural and mechanical features of some lanthanum tellurite glasses. *Canadian Journal of Physics*, *93*(4), 460–465.

Saddeek, Y. B., & Latif, L. A. El. (2004c). Effect of TeO_2 on the elastic moduli of sodium borate glasses. *Physica B: Condensed Matter*, *348*(1–4), 475–484.

Salah, H. A., Sidek, A. A., El-Mallawany, R., Umar, S. Al., Halimah, M. K., Hafiz, M. M. Z., Ushah, A. (2018). Optical Properties of Zinc Lead Tellurite Glasses. *Results in Physics*, *9*, 1371-1376.

Samanta, B., Dutta, D., & Ghosh, S. (2017). Synthesis and different Optical properties of Gd_2O_3 doped sodium zinc tellurite glasses. *Physica B: Condensed Matter*, *515*(82–88), 12.

Sayyed, M. I. (2016). Bismuth modi fi ed shielding properties of zinc boro-tellurite glasses. *Journal of Alloys and Compounds*, *688*, 111–117.

Schmitt, J., & Flemming, H. (1998). FTIR-spectroscopy in microbial and material analysis. *International Biodeterioration & Biodegradation*, *41*, 1–11.

Shelby, J. E. (2005). Introduction to Glass Science and Technology. *And TechnologyIntroduction to Glass Science*, *208*(Part_1_2), X001–X002.

Sidek, H. A. A., Badaron, S. S., Kamari, H. M., & Matori, K. A. (2015). Optical Properties of Erbium Zinc Tellurite Glass System. *Advances in Materials Science and Engineering*, *2015*(1155), 5.

Sidek, H. A. A., El-Mallawany, R. A., Hariharan, K., & Rosmawati, S. (2014). Effect of concurrent ZnO addition and AlF_3 reduction on the elastic properties of tellurite based glass system. *Advances in Condensed Matter Physics*, *2014*.

Sidek, H. A. A., El-Mallawany, R., Matori, K. A., & Halimah, M. K. (2016). Effect of PbO on the elastic behavior of $ZnO–P_2O_5$ glass systems. *Results in Physics*, *6*, 449-455.

Sklepić, K., Vorokhta, M., Mošner, P., Koudelka, L., & Moguš-Milanković, A. (2014). Electrical mobility of silver ion in $Ag_2O–B_2O_3–P_2O_5–TeO_2$ glasses. *The Journal of Physical Chemistry B*, *118*(41), 12050-12058.

Soltani, I., Hraiech, S., Horchani-Naifer, K., Elhouichet, H., Gelloz, B., & Férid, M. (2016). Growth of silver nanoparticles stimulate spectroscopic properties of Er^{3+}doped phosphate glasses: Heat treatment effect. *Journal of Alloys and Compounds*, *686*, 556–563.

Stanek, S., Nekvindova, P., Svecova, B., Vytykacova, S., Mika, M., Oswald, J.,Spirkova, J. (2016). The influence of silver-ion doping using ion implantation on the luminescence properties of Er-Yb silicate glasses. *Nuclear Instruments and Methods in Physics Research, Section B: Beam Interactions with Materials and Atoms*, *371*, 350–354.

Stanek, S., Nekvindova, P., Svecova, B., Vytykacova, S., Mika, M., Oswald, J.,Spirkova, J. (2017). The influence of silver ion exchange on the luminescence properties of Er-Yb silicate glasses. *Optical Materials*, *72*, 183–189.

Stuart, B. (2005). *Infrared Spectroscopy: Fundamentals and Applications*. Chichester, UK.: Spinger.

Sudevan, S., Tilak, T., Mukherjee, R., Rajiv, A., & Reddy, M. S. (2015). Optical properties of lithium-zinc–boro-molybdate glass doped with rare earth oxides. *Int. J. Chem. Phys. Sci.*, *4*(6), 28-36.

Swapna, K., Mahamuda, S., Venkateswarlu, M., Rao, A. S., Jayasimhadri, M., Shakya, S., & Prakash, G. V. (2015). Visible, up-conversion and NIR (~ 1.5 µm) luminescence studies of Er^{3+} doped zinc alumino bismuth borate glasses. *Journal of Luminescence*, *163*, 55-63.

Tagiara, N. S., Palles, D., Simandiras, E. D., Psycharis, V., Kyritsis, A., & Kamitsos, E. I. (2017). Synthesis, thermal and structural properties of pure TeO_2 glass and zinc-tellurite glasses. *Journal of Non-Crystalline Solids*, *457*, 116–125.

Tanner, D. B. (2013). Optical effects in solids. *Department of Physics, University of Florida*.

Thirumaran, S., & Karthikeyan, N. (2013). Structural Elucidation of Some Borate Glass Specimen by Employing Ultrasonic and Spectroscopic Studies. *Journal of Ceramics*, *2013*, 1–10.

Thombre, D. B. (2014). The Estimation of Oxide Polarizability using the Electronegativity for $Li_2O : B_2O_3 : SiO_2$ Glass System. *International Journal of Scientific Engineering and Technology*, *3*(8), 1047–1050.

Tijani, S. A., Kamal, S. M., Al-Hadeethi, Y., Arib, M., Hussein, M. A., Wageh, S., & Dim, L. A. (2018). Radiation shielding properties of transparent erbium zinc tellurite glass system determined at medical diagnostic energies. *Journal of Alloys and Compounds*, *471*, 293–299.

Tuyen, V. P. (2016). Optical Properties of Dy^{3+} Doped Boro-tellurite Glasses. *VNU Journal of Science: Mathematics – Physics*, *32*(2), 1–7.

Umar, S. A., Halimah, M. K., Chan, K. T., & Latif, A. A. (2017). Physical, structural and optical properties of erbium doped rice husk silicate borotellurite (Er-doped RHSBT) glasses. *Journal of Non-Crystalline Solids*, *472*(July), 31–38.

Umar, S. A., Ibrahim, G. G., Ibrahim, I. E., Najib, M. U., & Liman, M. S. (2015). Simulation of heating in space plasma. *Pelagia Research Library*, *6*(6), 103–113.

Upender, G., Ramesh, S., Prasad, M., Sathe, V. G., & Mouli, V. C. (2010). Optical band gap, glass transition temperature and structural studies of (100− 2x) TeO_2–xAg_2O–xWO_3 glass system. *Journal of Alloys and Compounds*, *504*(2), 468-474.

Usman, A., Halimah, M. K., Latif, A. A., Diana, F., & Abubakar, A. I. (2018). Influence of Ho^{3+} ions on structural and optical properties of zinc borotellurite glass system. *Journal of Non-Crystalline Solids*, *483*(December 2017), 18–25.

Veeraiah, N. (1997). Elastic properties of ZnF / -PbO-TeO_2 glasses doped with certain rare earth ions. *Bulletin of Materials Science*, *20*(5), 667–675.

Veit, U., & Rüssel, C. (2016). Density and Young ' s Modulus of ternary glasses close to the eutectic composition in the CaO – Al_2O_3 – SiO_2 -system. *Ceramics International*, *42*(5), 5810–5822.

Vijayalakshmi, L., Naveen Kumar, K., Rao, K. S., & Hwang, P. (2018). Bright up-conversion white light emission from Er^{3+}doped lithium fluoro zinc borate glasses for photonic applications. *Journal of Molecular Structure*, *1155*, 394–402.

Walas, M., Lewandowski, T., Synak, A., Łapiński, M., Sadowski, W., & Kościelska, B. (2017). Eu^{3+} doped tellurite glass ceramics containing SrF_2 nanocrystals: Preparation, structure and luminescence properties. *Journal of Alloys and Compounds*, *696*, 619–626.

Wang, Q., Dahal, R., Feng, I. W., Lin, J. Y., Jiang, H. X., & Hui, R. (2011). Emission and absorption cross-sections of an Er:GaN waveguide prepared with metal organic chemical vapor deposition. *Applied Physics Letters*, *99*(12), 1–4.

Wang, Y., Dai, S., Chen, F., Xu, T., & Nie, Q. (2009). Physical properties and optical band gap of new tellurite glasses within the TeO_2-Nb_2O_5-Bi_2O_3 system. *Materials Chemistry and Physics*, *113*(1), 407–411.

Yamane, M., & Ashara, Y. (2000). *Glasses for Photonics*. *Cambridge University Press*. Cambridge, New York, Port Melbourne, Madrid, Cape Town Yinnon,: Cambridge University Press.

Yousef, E. S. (2013). Er^{3+} ions doped tellurite glasses with high thermal stability, elasticity, absorption intensity, emission cross section and their optical application. *Journal of Alloys and Compounds Journal*, *561*, 234–240.

Yousef, E. S., El-Adawy, A., & El-KheshKhany, N. (2006). Effect of rare earth (Pr_2O_3, Nd_2O_3, Sm_2O_3, Eu_2O_3, $Gd_2O_3$and Er_2O_3) on the acoustic properties of glass belonging to bismuth-borate system. *Solid State Communications*, *139*(3), 108–113.

Yousef, E. S., Elokr, M. M., & Aboudeif, Y. M. (2016). Optical, elastic properties and DTA of TNZP host tellurite glasses doped with Er^{3+} ions. *Journal of Molecular Structure*, *1108*, 257–262.

Yu, K., Qiu, X., Xu, X., Wei, W., Peng, B., & Zhou, Z. (2007). Enhanced photoluminescence of Nd2O3 nanoparticles modified with silane-coupling agent: Fluorescent resonance energy transfer analysis. *Applied Physics Letters*, *90*(9), 091916.

Yusof, N. N., Ghoshal, S. K., Arifin, R., Awang, A., Tewari, H. S., & Hamzah, K. (2018). Self-cleaning and spectral attributes of erbium doped sodium-zinc-tellurite glass: Role of titania nanoparticles. *Journal of Non-Crystalline Solids*, *481*, 225–238.

Zaid, M. H. M., Matori, K. A., Abdul Aziz, S. H., Zakaria, A., & Ghazali, M. S. M. (2012). Effect of ZnO on the physical properties and optical band gap of soda lime silicate glass. *International Journal of Molecular Sciences*, *13*(6), 7550–7558.