OPTICAL AND THERMAL PROPERTIES OF NEODYMIUM DOPED TELLURITE NANOSTRUCTURED GLASS

NUR AMANINA BINTI HJ MAT JAN

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Science (Physics)

Faculty of Science
Universiti Teknologi Malaysia

MAY 2014

SPECIAL DEDICATED to

My Beloved Father and Mother

Hj. Mat Jan bin Hj. Abu Bakar

Hjh. Asiah bt Hj Hanapi

My Lovely Sisters

Nur Amirah

Nur Amalina

ACKNOWLEDGEMENT

Alhamdulillah, all praise to ALLAH S.W.T, the Almighty, the All Merciful and the All Compassionate for giving me the strength, courage and patience to complete this project. I would like to express my deepest gratitude to my supervisor, Prof. Dr. Md. Rahim Sahar for his vital encouragement, support and guide in my graduate program.

I would like to acknowledge and extend my heart felt gratitude to Assoc. Prof. Dr. Sib Krishna Goshal and Dr. Ramli for their help and inspiration.

I would like to acknowledge helpful and friendly support received from Mr. Mohamad Jaafar Raji and Mrs Anisah for helping me in preparing samples, Mrs. Radiah for helping me in optical analysis using UV-VIS-NIR spectrophotometer and luminescence analysis using Perkin Elmer LS 55 Luminescence spectrometer and Ms. Nurhidayah. Thanks also due to Mr Amin, a staff from Chemistry department, Faculty of Science, especially for helping me to analyse infrared spectroscopy using Perkin Elmer Fourier Transform Infra red, FTIR spectrometer.

Last but not least, I would like to express my heartly gratitude to my friends especially Firdaus, Kak Ezza, Siti, Hani, Hafizah, Yana and AOMRG members for their help and encouragement during my master's study in UTM.

May Allah repay all the kindness that you have given this far.

ABSTRACT

Neodymium doped tellurite nanostructured glass having a composition of $(75\text{-}x)TeO_2\text{-}15MgO\text{-}10Na_2O\text{-}(x)Nd_2O_3$, where $0 \leq x \leq 2.5$ mol% has successfully been prepared by melt-quenching technique. The amorphous nature of the glass was confirmed from the X-ray diffraction pattern. Thermal parameter of the glass was analyzed by using differential thermal analysis. It was found that the glass exhibits the transition temperature between 255 - 259 ^oC, crystallization temperature between 428 to 450 ^oC and melting temperature from 505 to 549 ^oC. The nanoparticles were obtained by applying heat treatment to the glass at near crystallisation temperature of 460 ^oC for 30 minutes. The existence of nanocrystalline nature of this glass was confirmed by X-ray diffraction and transmission electron microscopy. The vibrational study was conducted using Fourier transform infrared spectroscopy in the range 4000 - 400 cm^{-1}. It was found that there were three absorption peaks around 687 - 712 cm^{-1}, 624 - 632 cm^{-1} and 467 - 474 cm^{-1} which are due to the stretching of Te-O bending in TeO_3 trigonal pyramidal (tp) units, Te-O bands stretching vibration in TeO_4 trigonal bipyramidal (tbp) units and the bending vibrations of Te-O-Te or O-Te-O linkages, respectively. The optical absorption behaviour was studied using UV-Visible spectrophotometer. The values of indirect optical band gap are in the range 3.15 - 3.22 eV and for direct band gap the values are in the range 3.37 - 3.43 eV. The Urbach energy value for glass system was found to be in range 0.208 eV and 0.125 eV. The emission spectrum was recorded using photoluminescence spectrometer. The fluorescence spectra of Nd^{3+} ions exhibit emission transition of $^2P_{1/2} \rightarrow {}^4I_{9/2}$, $^2D_{3/2} \rightarrow {}^4I_{9/2}$ and $^4G_{7/2} \rightarrow {}^4I_{9/2}$ under 585 nm excitation wavelengths. It was found that the intensity is enhanced in the heat-treated glass compared to those of prepared glass.

ABSTRAK

Kaca tellurit berstruktur nano didopkan neodimium yang mempunyai komposisi (75-x)TeO_2-15MgO-10Na_2O-(x)Nd_2O_3, dengan $0 \leq x \leq 2.5$ mol% telah berjaya disediakan menggunakan teknik pelindapan leburan. Sifat amorfus kaca ditentukan daripada corak pembelauan sinar-X. Parameter terma kaca dianalisis menggunakan analisis perbezaan terma. Kaca ini didapati mempamerkan suhu peralihan antara 255 - 259 ^oC, suhu penghabluran kaca antara 428 - 450 ^oC dan suhu lebur kaca daripada 505 ke 549 ^oC. Zarah nano diperoleh dengan melakukan rawatan haba ke atas kaca pada suhu hampir dengan suhu penghabluran kaca pada 460 ^oC selama 30 minit. Kewujudan nanohablur kaca disahkan dengan pembelauan sinar-X dan mikroskopi penghantaran elektron. Kajian terhadap getaran telah dilakukan dengan menggunakan spektroskopi inframerah transformasi Fourier (FTIR) dalam julat 4000 - 400 cm^{-1}. Tiga puncak penyerapan yang ketara terdapat sekitar 687 - 712 cm^{-1}, 624 - 632 cm^{-1} dan 467 - 474 cm^{-1} masing-masing merujuk kepada regangan bengkokan Te-O dalam unit TeO_3 *piramid trigonal* (tp), getaran regangan jalur Te-O dalam unit TeO_4 *bipiramid trigonal* (tbp) dan getaran bengkokan Te-O-Te atau O-Te-O. Sifat serapan optik dikaji menggunakan spektrofotokopi ultralembayung-cahaya nampak. Nilai tenaga jurang optik tidak langsung ialah antara 3.15 - 3.22 eV dan tenaga jurang optik langsung ialah antara 3.37 - 3.43 eV. Tenaga Urbach bagi kaca adalah dalam julat 0.208 eV dan 0.125 eV. Spektrum pancaran telah direkod menggunakan spektrometer fotoluminesen. Spektra pendarcahaya Nd^{3+} menunjukkan peralihan pancaran $^2P_{1/2} \rightarrow {}^4I_{9/2}$, $^2D_{3/2} \rightarrow {}^4I_{9/2}$ dan $^4G_{7/2} \rightarrow {}^4I_{9/2}$ pada pengujaan 585 nm. Keamatan kaca rawatan haba didapati menunjukkan peningkatan keamatan berbanding kaca yang tiada rawatan haba.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	**ii**
	DEDICATION	**iii**
	ACKNOWLEDGEMENTS	**iv**
	ABSTRACT	**v**
	ABSTRAK	**vi**
	TABLE OF CONTENTS	**vii**
	LIST OF TABLES	**x**
	LIST OF FIGURES	**xii**
	LIST OF SYMBOLS	**xvi**
	LIST OF APPENDICES	**xx**
1	**BACKGROUND**	**1**
	1.1 Introduction	1
	1.2 Background of Study	1
	1.3 Problem Statement	5
	1.4 Objective of Study	5
	1.5 Scope of Study	6
	1.6 Significant of Study	6
2	**LITERATURE REVIEW**	**7**
	2.1 Introduction	7
	2.2 Glass	8
	2.3 Optical Properties	9
	2.3.1 Borate Glass	9

2.3.2 Phosphate Glass 11
2.3.3 Silicate Glass 13
2.3.4 Tellurite Glass 14
2.4 Nanostructured Glass 16
2.4.1 Synthesis of Nanostructured Glass 17
2.4.2 Optical Properties of Nanostructured Glass 18
2.5 Review on Characterizations for the Glass 20
2.5.1 X-ray Diffraction 21
2.5.2 Transmission Electron Microscope (TEM) 25
2.5.3 Nucleation and Growth of Nanostructured Glass 28
2.5.4 Differential Thermal Analysis (DTA) 29
2.5.5 Fourier Transform Infra Red (FTIR) Spectroscopy 32
2.5.6 UV-Vis Spectroscopy 35
2.5.7 Photoluminescence Spectroscopy 39

3 EXPERIMENTAL PROCEDURE 41
3.1 Introduction 41
3.2 Sample Preparation 41
3.3 Differential Thermal Analysis (DTA) 43
3.4 Heat Treatment 44
3.5 X-ray Diffraction (XRD) 44
3.6 Transmission Electron Microscopy (TEM) 44
3.7 Fourier Transform Infra-Red (FTIR) Spectroscopy 45
3.8 UV-Vis Spectroscopy 45
3.9 Photoluminescence Spectroscopy 46

4 RESULTS AND DISCUSSION 47
4.1 Introduction 47
4.2 Glass Composition 47
4.3 X-ray Diffraction Pattern 49
4.4 Differential Thermal Analysis (DTA) 49
4.5 Heat Treatment for Nucleation and Growth 55
4.5.1 X-ray Diffraction for Nanostructured Glass 55
4.5.2 Transmission Electron Microscopy 56

	4.6	Fourier Transform Infra Red Spectroscopy	58
	4.7	UV-Vis Spectroscopy	63
	4.8	Luminescence Properties	71
5	**CONCLUSION AND FUTURE OUTLOOK**		**78**
	5.1	Introduction	78
	5.2	Conclusion	78
	5.3	Future Outlook	80
REFERENCES			**81**
Appendices A - C			91

LIST OF TABLES

TABLE NO.	TITLE	PAGE
1.1	A comparison of selected properties for tellurite, silica, fluoride and chalcogenide glasses (Wang *et. al*,1994)	2
2.1	The factor affecting optical dispersion in borate glass systems (from Abdel-Baki M., *et al*., 2007)	10
2.2	The T_c and T_g for some Nd-doped tellurite glasses (Sahar *et al*., 2011)	31
2.3	DTA results of (90-x) TeO_2-10ZnO-xNa_2O (x = 0, 10, 20 and 30 mol%) tellurite glasses (Shaoxiong and Animesh, 2008)	32
2.4	Principal IR bands of TeO_2–RE glass system (from Sharaf El-Deen *et al*., 2008)	35
3.1	The composition of (75-x)TeO_2-15MgO-10Na_2O-(x)Nd_2O_3	42
4.1	The glass composition and appearance of (75-x)TeO_2-15MgO-10Na_2O-(x)Nd_2O_3 glass system with $0.0 \leq x \leq 2.5$ mol%.	48
4.2	DTA results of (75-x)TeO_2-15MgO-10Na_2O-(x)Nd_2O_3 glasses with $0.0 \leq x \leq 2.5$ mol%.	51

4.3	Glass thermal stability of (75-x)TeO_2-15MgO-10Na_2O-(x)Nd_2O_3 glasses with $0.0 \leq x \leq 2.5$ mol%.	51
4.4	IR peaks positions for (75-x)TeO_2-15MgO-10Na_2O-(x)Nd_2O_3 glass system where $0.0 \leq x \leq 2.5$ mol%.	59
4.5	FTIR absorption bands assignments	60
4.6	IR peaks positions for 2.5 mol% Nd_2O_3 glass system before and after heat treatment at 460 ^oC.	62
4.7	Electronic transitions from the optical spectra for (75-x)TeO_2-15MgO-10Na_2O-(x)Nd_2O_3 glass system with $0.0 \leq x \leq 2.5$ mol%	64
4.8	Optical band gap for direct and in direct in (75-x)TeO_2-15MgO-10Na_2O-(x)Nd_2O_3 glass system with $0.0 \leq x \leq 2.5$ mol%.	66
4.9	Urbach energy from (75-x)TeO_2-15MgO-10Na_2O-(x)Nd_2O_3 glass system between heat-treated and prepared glass with $0.0 \leq x \leq 2.5$ mol%.	68
4.10	Comparison of the value direct optical band gap, indirect optical band gap energy and Urbach energy from [75-x]TeO_2-15MgO-10Na_2O-xNd_2O_3 glass system between heat-treated and prepared glass.	71

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
2.1	Absorption spectra of Nd^{3+} ions in RTP glasses at room temperature (from Murthy *et al.*, 2011)	11
2.2	A typical emission spectra of phosphate glass after doped with 1 mol% of Sm_2O_3 excited at 403 nm (from Nurulhuda binti Mohammad Yusoff, 2011)	13
2.3	Model by Sakida *et al.* (From S. Sakida, S. Hayakawa, T. Yoko, J. Non-Cryst. Solids, 43, 13,1999a) showing a modification of TeO_2 glass by the addition of M_2O	15
2.4	(a) Optical absorption spectra and (b) PL of the SNAB + 2[CdS (bulk)+Nd_2O_3] (wt%) samples heated at 560 ^oC (from Sequeira *et. al,* 2011.)	19
2.5	Bragg diffraction from a cubic crystal lattice	21
2.6	FWHM for diffraction peak	23
2.7	XRD patterns for the $x$$Na_2O$-(100-$x$)$TeO_2$ ($0 \leq x \leq 33.3$ % mole fraction) crystallized glasses (from Ana Šantić *et al*., 2008)	24

2.8	Powder XRD pattern at room temperature for $10K_2O$-$4Na_2O$-$14Nb_2O_5$-$72TeO_2$ sample heat-treated at 375 ^oC for 1 h (from Jeong *et al*., 2007)	25
2.9	Schematic diagram of transmission electron microscope	26
2.10	((c), (d), (e)) shows the TEM images of the glass samples (from Amjad *et al*., 2013)	27
2.11	Dependence of growth rate on temperature (Ezza Syuhada Sazali, 2012)	29
2.12	A typical DTA curve for glass	30
2.13	Three region of IR Spectroscopy	32
2.14	The stretching vibrations mode	33
2.15	The bending vibrations mode	34
2.16	The components of a typical spectrometer	36
3.1	The melting schedule of the glass during the sample preparation	43
4.1	Glass samples of (75-x)TeO_2-15MgO-$10Na_2O$-(x)Nd_2O_3 glass	48
4.2	X-ray diffraction patterns of glass samples prepared with different compositions	49
4.3	The thermogram from differential thermal analysis (DTA) of the glass system	50
4.4	The dependences of T_g, T_c and T_m on the Nd_2O_3 concentration	52

4.5	The glass stability versus different Nd_2O_3 concentration	53
4.6	The Hruby criterion versus different Nd_2O_3 concentration	54
4.7	XRD pattern of the $72.5TeO_2$-$15MgO$-$10Na_2O$-$2.5Nd_2O_3$ glass system after heat treated at 460 ^oC	55
4.8	TEM micrograph obtained of the heat treated Nd_2O_3 doped tellurite glass above T_c	56
4.9	Gaussian fit obtained of the heat treated Nd_2O_3 doped tellurite glass above T_c	57
4.10	FTIR spectra of $(75-x)TeO_2$-$15MgO$-$10Na_2O$-$(x)Nd_2O_3$ glass system with $0.0 \leq x \leq 2.5$ mol%	58
4.11	FTIR spectra of the 2.5 mol% Nd_2O_3 glass system before and after heat treatment at 460 ^oC	62
4.12	Normalized optical absorption spectra of glasses with different mol % Nd_2O_3	63
4.13	Plot of $(\alpha\hbar\omega)^2$ versus $\hbar\omega$ for indirect band gap of $(75-x)TeO_2$-$15MgO$-$10Na_2O$-$(x)Nd_2O_3$ glass system with $0.0 \leq x \leq 2.5$ mol%	64
4.14	Plot of $(\alpha\hbar\omega)^{1/2}$ versus $\hbar\omega$ for indirect band gap of $(75-x)TeO_2$-$15MgO$-$10Na_2O$-$(x)Nd_2O_3$ glass system with $0.0 \leq x \leq 2.5$ mol%	65
4.15	Plot of direct and indirect band gap versus Nd_2O_3 concentration of $(75-x)TeO_2$-$15MgO$-$10Na_2O$-$(x)Nd_2O_3$ glass system with $0.0 \leq x \leq 2.5$ mol%	67

4.16	Plot of ln α versus $\hbar\omega$ for Urbach energy of $(75\text{-}x)TeO_2\text{-}15MgO\text{-}10Na_2O\text{-}(x)Nd_2O_3$ glass system with $0.0 \leq x \leq 2.5$ mol%	68
4.17	Plot of Urbach energy (eV) versus Nd_2O_3 concentration (mol%)	69
4.18	Comparison of the absorption spectra from $(75\text{-}x)TeO_2\text{-}15MgO\text{-}10Na_2O\text{-}(x)Nd_2O_3$ glass system containing 2.5 mol% Nd_2O_3 with heat-treated (460 ^oC) and prepared glass	70
4.19	Emission spectrum from the $(75\text{-}x)TeO_2\text{-}15MgO\text{-}10Na_2O\text{-}(x)Nd_2O_3$ glass system with excitation wavelength at 585 nm with $0.0 \leq x \leq 2.5$ mol%	72
4.20	Peak intensity as a function of concentration of Nd_2O_3	73
4.21	An emission spectra of glass at 2.5 mol% of Nd_2O_3 for prepared and heat-treated (460 ^oC) glass	74
4.22	Peak intensity as a function of different transitions level	75
4.23	Wavelength peaks versus concentration of Nd_2O_3	76
4.24	Schematic energy level diagram of the $(75\text{-}x)TeO_2\text{-}15MgO\text{-}10Na_2O\text{-}(x)Nd_2O_3$ glass system ($0.0 \leq x \leq 2.5$ mol%) with excitation wavelength at 585nm	77

LIST OF SYMBOLS

TeO_2	-	Tellurite oxide
Na_2O	-	Sodium oxide
PbO	-	Lead oxide
BaO	-	Barium Oxide
ZnO	-	Zinc Oxide
Nb_2O_5	-	Niobimium Oxide
WO_3	-	Tungsten trioxide
$Te\text{-}O_{ax}$	-	Te-O axial
Li_2O	-	Lithium Oxide
Mg	-	Magnesium
Zn	-	Zinc
Nd^{3+}	-	Trivalent Neodymium ion
OH^-	-	OH ion

SiO_2	-	Silicon Dioxide
GeO_2	-	Germanium Dioxide
P_2O_5	-	Phosphorus Pentoxide
B_2O_3	-	Boron Trioxide
$Al(PO_3)$	-	Aluminium Phosphate
$Ba(PO_3)$	-	Barium Phosphate
KH_2PO_4	-	Pottasium Phosphate
$Mg(PO_3)_2$	-	Magnesium Phosphate
Cr^{6+}	-	Chromium (VI) ion
NBO	-	Non-bridging oxygen
NPs	-	Nanoparticles
α_m	-	Molar polarizability
α_0^{2-}	-	Electric polarizability
Λ_{th}	-	Theoritical basicity
(N/V)	-	number of ions per unit volume
tp	-	trigonal pyramidal

tbp	-	trigonal bipyramidal
λ	-	Wavelength
E_a	-	Activation energy
$E_{direct\ opt}$	-	Optical direct band gap energy
$E_{indirect\ opt}$	-	Optical indirect band gap energy
E_{opt}	-	Optical band gap energy
ΔE_f	-	Free energy
ΔE	-	Urbach energy
E_F	-	Fermi energy level
U	-	Growth rate
T_d	-	Development temperature
T_n	-	Nucleated temperature
T_m	-	Melting temperature
T_c	-	Crystallization temperature
T_g	-	Glass transition temperature
H_R	-	Hruby criterion
S	-	Glass stability

ν_{as}	-	Asymmetric stretching vibration
ν_{s}	-	Symmetric stretching vibration
D	-	Crystal Size
θ	-	Bragg Angle
β	-	FWHM
I_0	-	Reference beam
I	-	Sample beam
A	-	Absorbance
T	-	Transmittance
$\alpha(\omega)$	-	Absorption coefficient
$\hbar\omega$	-	Photon energy

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	List Of Samples	91
B	Batch Calculation	92
C	Structure Unit in Tellurite Glass	94

CHAPTER 1

BACKGROUND

1.1 Introduction

In this chapter, the background, problem statement and the objective of this study will describe in details. The scope and the significant of this study will also be touch briefly.

1.2 Background of Study

Tellurite glasses have several advantages compared to silica, fluoride and chalcogenide glasses. They have wider transmission region (0.35 - 5 μm) than silicate glasses (0.2 - 3 μm). Tellurite glasses exhibit high non-linear refractive index compare to those of fluoride, phosphate and silicate glasses relatively.

They also have good glass stability and highly corrosion resistance compare to those of fluoride glasses. Their lower melting temperature and lower phonon energy make them attractive hosts for active medium. TeO_2-based glasses with lower

phonon energy could have higher quantum efficiencies and provide more fluorescent emissions than silica-based glasses. This implies that the tellurite glasses are suitable for nonlinear and laser applications.

Other than that, tellurite glasses are of interest due to better chemical durability and higher glass stability than halide glasses (Stanworth, 1962), and better compatibility when mix with other oxide glasses than the nonoxide glasses. From the data given in Table 1.1, it can be seen that the degree of covalence among the four glass family decreases in order of Chalcogenide > Tellurite > Silica > Fluoride glasses, which directly affects the wavelength of the transition peak (Wang *et al.*,1994).

Table 1.1: A comparison of selected properties for tellurite, silica, fluoride and chalcogenide glasses (Wang *et al.*,1994).

Property	Tellurite	Silica	Fluoride	Chalcogenide
Optical properties (typical values)				
Refractive index (n)	1.8–2.3	1.46	1.5	2.83
Abbe number (ν)	10–20	80	60–110	
Nonlinear refractive index (n_2, m^2/W)	2.5×10^{-19}	10^{-20}	10^{-21}	higher
Transmission range (μm)	0.4–5.0	0.2–2.5	0.2–7.0	0.8–16
Highest phonon energy (cm^{-1})	800	1000	500	300
Longest fluorescent wavelength (μm)	2.8	2.2	4.4	7.4
Bandgap (eV)	≈3	≈10		1–3
Acousto-optical figure of merit, $p^2n^6/\rho v^3$ (10^{-18} s^3/g)	24	1–19	–	
Physical properties (typical values)				
Glass transition (T_g, °C)	300	1000	300	300
Thermal expansion (10^{-7} °C)	120-170	5	150	140
Density (g/cm^3)	5.5	2.2	5.0	4.51
Dielectric constant (ϵ)	13–35	4.0	–	
Fiber loss	–	0.2 dB/km (1.5 μm)	15–25 dB/km (1.5–2.75 μm)	0.4 dB/km 6.5 μm
Bonding	covalent-ionic	ionic-covalent	ionic	covalent
Solubility in water	$<10^{-2}$	$<10^{-3}$	soluble	$<10^{-4}$

Since TeO_2 does not form glass by itself, it belongs to the intermediate class of glass-forming oxides usually, during glass preparation, metal oxides modifier such as Na_2O, PbO, BaO, ZnO, Nb_2O_5, WO_3 are added to it. Modifier molecules usually enhance the glass formation ability (GFA) in glass formers by breaking chains of structural units. It will cause changes in structural formation units (Stanworth, 1952; Suehara *et al.*, 1995; El-Mallawany, 2002; Narayanan and Zwanzinger, 2003). The structure of TeO_2 rich glasses have trigonal bipyramidal TeO_4, deformed TeO_4, TeO_{3+1} polyhedron and trigonal TeO_3 structural units. The network modifiers atoms can be easily attack two highly mobile axial bonds (Te-O_{ax}) in each TeO_4 unit. One of the Te-O_{ax} bonds in TeO_4 polyhedra elongates, the bond length increases and forms TeO_{3+1} structural unit when a network modifier like metal oxide is added into the glass matrix. Kaur *et al.* reported that the subscript 3+1 indicates that the fourth oxygen is nearby but is not within a true bonding range. Structural unit of TeO_3 may be defined when the Te-O bond length exceeds the average length (Singh, 1997). As for notation, TeO_4 can be labeled as Q_4^4, TeO_{3+1} as Q_4^3, and TeO_3 as $Q_3^{2,1,0}$ where the subscript represents the coordination number of oxygen around Te atom and the superscript is the number of bridging oxygens linked to a Te atom (Kaur *et al.*, 2010). However, this notation is not commonly been used except for phosphate glasses.

Modifier such as Na_2O or Li_2O is necessary to add to TeO_2 or otherwise the melted material quickly recrystalized. It is reported that the modifying elements such as Mg, Zn, and Ba are chosen for their ability to aid in the formation of stable tellurite glasses (Nishida *et al.*, 1990). The concentration of about 10 mol% of sodium is necessary to increase the glass forming stability of the mixtures is proven by Mc Laughlin in 2000. The combination of MgO with TeO_2 for example, will increase the glass transition temperature because of Mg-O bonds have much higher polarity than the Zn-O bonds due to the lower electronegative. Therefore, these bonds require energy to break. The existence polar bonds into the glass will result in the increase of glass the transition temperature (Sean Manning *et al.*, 2011). Other usage of those glasses includes potential application in pressure sensors or new laser host because of excellent infrared transmission (0.4 - 6.0 μm) (Singh *et al.*, 2007; Burger *et al.*, 1992).

Recently tellurite glasses doped with heavy metal and rare earth oxides have received significant attention because they can favorably change density, optical and thermal properties of tellurite glasses (Kaur *et al.*,2010). Tellurite glasses also promising applications for upconversion of infrared to visible light, ultra broadband fiber Raman amplifiers (Murugan *et al.*, 2005) and gas sensors (Chakraborty *et al.*, 1997).

Neodymium doped all-solid-state laser sources have been identified as the most efficient laser sources for numerous applications in the fields of high-resolution spectroscopy. The development of low threshold high gain host media for Nd^{3+} ion doping is encouraged by the applications in these areas. It is obvious that the enlargement of host material for Nd^{3+} ions requires optimum material properties. They are characterized by a low content of OH^- groups and a low frequency phonon spectrum. The low in OH^-content make it possible for the glass to reduce excitation losses due to the multiphonon relaxation. In addition, the OH^- free tellurite glasses which are used as host material for Nd^{3+}-doped laser glasses have been a subject of increasing interest for optoelectronic applications. It is because of their high refractive index and low phonon energies (Rajeswari, 2010).

According to Bogdanov, doping with larger rare earth ions concentration is need high pumping absorption in a short cavity length (Bogdanov, 1996). Then, Santa-Cruz *et al.* (1995) had further to this method to produce a glass system in which the local crystal field environment of the rare earth ions is the same as in the crystalline form. However, the homogeneity of the glass reduced by the formation of grain boundary thus producing some losses during pumping process (Santa-Cruz *et al.*, 1995).

1.3 Problem Statement

These nanostructered glasses have much technological interest especially because of their thermodynamic properties which show strong size dependence and can easily controlled by manufacturing processes. Lasing properties and capabilities of the glass can be made by controlling their structural development up to nanoscale. However, there is lack of information in the literature about the properties of Nd_2O_3 doped tellurite nanostructered glass. Furthermore, the method of producing the nanocrystal in the glass matrix using heat treatment is not well reported. Therefore, the aim of this study is to characterize the optical and thermal properties of Nd_2O_3 doped tellurite nanostructered glass.

1.4 Objective of Study

The objectives of this research are:

i. To prepare the glass based on $(75\text{-}x)TeO_2\text{-}15MgO\text{-}10Na_2O\text{-}(x)Nd_2O_3$ by using melt quenching technique.
ii. To determine the crystallization temperature of Nd^{3+} doped tellurite using Differential Thermal Analysis (DTA).
iii. To heat-treated the glass and determine the size of nanoparticles in the prepared sample using X-Ray Diffraction (XRD) and Transmission Electron Microscopy (TEM).
iv. To characterize the transmission behavior by using Fourier Transform Infra red (FTIR) spectroscopy.
v. To determine the optical band gap and Urbach energy by using UV-Vis spectroscopy.
vi. To characterize the emission properties by using photoluminescence spectroscopy.

1.5 Scope of Study

In sequence to achieve the above objectives the works have been focus on the preparation of glass based on the $(75\text{-}x)TeO_2\text{-}15MgO\text{-}10Na_2O\text{-}(x)Nd_2O_3$ system ($0 \leq x \leq 2.5$ mol%) using the melt quenching technique. The amorphous or crystalline phase present in the prepared sample will be identified. The thermal properties of the samples will be measured by using Differential Thermal Analysis (DTA). The feature of nanocrystalline phase will be observed by x-ray diffraction (XRD) and Transmission Electron Microscopy (TEM). The transmission spectra will be characterized by using Fourier Transform infrared (FTIR) spectrometer. The value of optical band gap and Urbach energy will be determined by using UV-VIS spectrophotometer. The emission of prepared glass will be characterized by using Photoluminescence Spectrometer.

1.6 Significant of Study

The reason why this study is being conducted is to find out the optical and thermal properties of $TeO_2\text{-}MgO\text{-}Na_2O$ nanostructured glass which is very promising development in optical technological applications. The obtained data can be used to enhance the glass capability to increase the possibility of the glass in laser emission.

REFERENCES

Abdel-Baki, M., Abdel Wahab, F. A. and El-Diasty, F. (2006). Optical Characterization of $xTiO_2$-(60-x)SiO_2-40Na_2O Glasses: I. Linear and Nonlinear Dispersion Properties. *Materials Chemistry and Physics*. 96, 201-210.

Abdel-Baki M., Abdel-Wahaba F. A., Radia A., El-Diasty F. (2007). Factors Affecting Optical Dispersion in Borate Glass Systems. *Journal of Physics and Chemistry of Solids*. 68, 1457–1470.

Abril, M., Me´ndez-Ramos, J., Martı´n, I.R., Rodrı´guez-Mendoza, U.R., Lavı´n, V., Delgado-Torres, A., Rodrı´guez, V.D., Nu´ n˜ez, P., and Lozano Gorrı´n, A.D. (2004). *J.Appl.Phys.* 95, 5271.

Almeida, R. M. (1988). Vibrational Spectroscopy of Glasses. *Journal of Non-Crystalline Solids*. 106, 37-358.

Akbari, B., Pirhadi Tavandashti, M. and Zandrahimi, M. (2011). Particle Size Characterization of Nanoparticles – A Practical Approach. Iranian. *Journal of Materials Science & Engineering*. 8(2), 49-56.

Amjad, Raja J., Sahar, M. R., Dousti, M. R., Ghoshal, S. K. and Jamaludin, M. N. A. (2013). Surface Enhanced Raman Scattering and Plasmon Enhanced Fluorescence in Zinc-Tellurite Glass. *Optics Express 14283*. 21(12), 1-9.

Amorim, H.T., Vermelho, M.V.D., Gouveia-Neto, A.S., Cassanjes, F.C., Ribeiro, S.J.L., and Messaddeq, Y. (2002). Energy Upconversion Luminescence In Neodymium-Doped Tellurite Glass. *J. of Alloys and Compounds.* 346, 282–284.

Annapurna, K., Dwivedi, R.N., Kundu, P. Buddhudu, S. (2003). NIR Emission and Upconversion Luminescence Spectra of Nd^{3+}:ZnO-SiO_2-B_2O_3 Glass. *Material Letters.* 57, 2095-2098.

Ana Šantić, Andrea Moguš-Milanković, Krešimir Furić, Maša Rajić-Linarić, Chandra S. Ray and Delbert E. Day. (2008). Structural Properties and Crystallization of Sodium Tellurite Glasses. *CROATICA CHEMICA ACTA*.**81** (4) 559-567.

Arshpreet Kaur, Atul Khanna, Carmen Pesquera, Fernando González, and Vasant Sathe. (2010). Preparation and Characterization of Lead and Zinc Tellurite Glasses. *Journal of Non-Crystalline Solids.* 356, 864–872.

Arnaudov, M., Dimitrov, V., Dimitriev, Y. and Markova, L. (1982). IR-spectral Investigation of Tellurites. *Mater. Res. Bull.* 1121.

Azlan Muhammad Noorazlan, Halimah Mohamed Kamari, Siti Shafinas Zulkefly, and Daud W. Mohamad. (2013). Effect of Erbium Nanoparticles on Optical Properties of Zinc Borotellurite Glass System. *Journal of Nanomaterials.* 940917, 1-8.

Azman, K., Sahar, M.R., and Rohani, M.S. (2010). The Upconversion of co-doped Nd^{3+}/Er^{3+} Tellurite Glass. *World Academy of Science, Engineering and Technology*. 64, 414-417.

Barady, G. (1957). Structure of Tellurium Oxide Glass. *J. Chem. Phys.* 27, 300.

Beall, G.H., and Pinckney, L.R. (1999). Nanophase Glass-ceramic. *J. Am. Ceram. Soc*. 82, 5-16.

Bengisu, M. (2001). Engineering Ceramics. Springer-Verlag Berlin Heidelberg, New York pp 9.

Bogdanov, V.K., Gibbs, W.E.K., Booth, D.J., Javorniczky, J.S., Newman, P.J. and MacFarlane, D.R. (1996) Fluorescence from Highly-doped Erbium Fluorozirconate Glasses Pumped at 800 nm. *Opt. Commun*. 132, 73-76.

Braglia, M., Brushi, C., Dai, G., Kraus, J., Mosso, S., Baricco, M., Battezzati, L., and Rossi, F. (1999). Glass Ceramics for Optical Amplifiers: Rheological, Thermal, and Optical Properties. *J. Non-Cryst Solids*. 256-257, 170-175.

Bruckner, R. (1970). Properties and Structure of Vitreous Silica. I. *J. Non-Cryst. Solids.* 5, 123–175.

Burger, H., Kneipp, K., Hobert, H., and Vogel, W. (1992). Glass Formation, Properties and Structural of Glass in the TeO_2-ZnO System. *Journal Non Crystalline Solids.* 151, 134-142.

Campbell, J.H. and Suratwala, T.I. (2000). Nd-doped Phosphate Glasses for High-Energy/High-Peak-Power Lasers. *J. Non-Cryst. Solids*. 263-264, 318-341.

Chakraborty,S., Satou,H., and Sakata,H. (1997).Direct Current Conductivity and Oxygen Gas-Sensing Properties of Iron–Antimony–Tellurite Glasses. *J. Appl. Phys*. 82, 5520.

Cotterill, R. (2008). *The Material World.* New York: Cambridge University Press.

Cummings, K. (1980). *The Technique of Glass Forming.* London: B T Batsford Ltd.

Doremus, R. H. (1973). *Glass Science*. New York: John Wiley & Sons.

Elahi, M. and Souri, D. (2006). Study of Optical Absorption and Optical Band Gap Determination of Thin Amorphous TeO_2-V_2O_5-MoO_3 Blown Films. *Indian Journal of Pure & Applied Physics*. 44, 468-472.

El-Mallawany,R. A. H. (2002).*Tellurite Glasses Handbook: Physical Properties and Data*. CRC Press, Boca Raton, Florida.

El-Mallawany,R.A.H. (2001).*Tellurite Glasses Handbook – Physical Properties and Data*.CRC Press, Boca Raton, Florida.

El-Mallawany, R. and Abbas Ahmed, I. (2008).Thermal Properties of Multicomponent Tellurite Glass.*J. Mater Sci*. 43, 5131-5138.

El-Mallawany, R., Dirar Abdalla, M., and Abbas Ahmed, I.(2008).New Tellurite Glass: Optical Properties. *Mater. Chem. and Phys*. 109, 291-296.

El-Sayed, S.M. Ashour, A.H. and Fares, S. A. (2001). Structural and Short Range Order Analysis of Glassy System. *Physica. B.* 406, 435-439.

Ezza Syuhada binti Sazali. (2012). Synthesis and Growth Dynamic Tellurite Doped Europium Nanoglass. *Thesis Msc*. Universiti Teknologi Malaysia.

Fox, M. (2001). *Optical Properties of Solids*. New York: Oxford University Press.

France, P. W.(1991).*Optical Fiber Lasers and Amplifiers*.CRC Press, Boca Raton, Florida.

Gayathri Pavani P., Sadhana K., Chandra Mouli V. (2011). Optical, Physical And Structural Studies Of Boro-Zinc Tellurite Glasses.*Physica B.* 406, 1242-1247.

Gonçalves, M.C., Santos, L. F., and Almeida, R. M. (2002). Rare-Earth-Doped Transparent Glass Ceramics.*C. R. Chimie* 5, 845–854.

Gontard, L.C., Dunin-Borkowski, R.E., Ozkaya, D., Hyde, T., Midgley P.A. and Ash P. (2006). Crystal Size and Shape Analysis of Pt Nanoparticles in Two and Three Dimensions. *Journal of Physics: Conference Series.* 26, 367–370

Hall, B. D., Zanchet, D., Ugarte, D.J. (2000). Estimating Nanoparticle Size from Diffraction Measurements. *J.Appl. Crystallogr*. 33, 1335-1341.

Hart, G. (1927). The Nomenclature of Silica. *Am. Mineral*. 12, 383–395.

Hayakawa, T., Selvan, S. T. and Nogami, M. (1999). Field Enhancement Effect of Small Ag Particles on the Fluorescence from Eu^{3+} -doped SiO_2 Glass. *Appl. Phys. Lett*. 74, 1513-1515.

Hetherington, G., Jack, K. H. and Ramsay, M. W. (1965). The High temperature Electrolysis of Vitreous Silica, Part I. Oxidation, Ultra-Violet Induced Fluorescence, and Irradiation Colour. *Phys. Chem. Glasses*. 6,6–15

Hirayama, C., and Lewis, D. (1964). *Phys. Chem. Glasses* 5, 44.

Hilling, W. B. and Turnbull, D. (1956).Theory of Crystal Growth in Undercooled Pure Liquids. *J. Chem. Phys.* 24, 914.

Hinna, H. (2007). *Infrared Spectrometry*. New Delhi: Jamia Hamdard Univrsity

Hirata, T. (2007).Evolution of the Inra-Red Vibrational Modes upon Thermal Oxidtion of Si Single Crystal.*Journal Physics Chemistry Solids* 58(10), 147-1501.

Huang, L. Jha, A. and Shen, S. (2008). Spectroscopic Properties of Sm^{3+} Doped Oxide and Fluoride Glasses for Efficient Visible Lasers (560–660 nm).*Optics Communications* 281, 4370–4373.

Hooi, M.O., Halimah, M.K. and Wan, M.D.W.Y. (2012). Optical Properties of Bismuth Tellurite Based Glass. *International Journal of Molecular Science*. 13: 4623-4631.

Hopper,R.W. (1985).Stochastic Theory of Scattering from Idealized Spinodal Structures: II. Scattering in General and for The Basic Late Stage Model.*J. Non-Cryst. Solids* 70, 111.

Hu L. and Jiang Z. (1996). Properties and Structures of TeO_2 based Glasses Containing Ferroelectric Components. *Phys. Chem. Glasses*. 371, 19-21.

Jeong E. D., Bae J. S., Ha M. G., Kim H. G., Pak H. K., Ryu B. K. , Komatsu T. (2007). Structure of a Nanocrystalline Phase with Second Harmonic Generation.*Journal of the Korean Physical Society*. 51. S32-S35.

Jia Liu, James M. O'Reilly, Thomas W. Smith and Paras N. Prasad (2005). Photo-Patterning Hybrid Sol-Gel Glass Materials Prepared from Ethylene Tellurite And Alkoxysilane. *J. Non-Cryst. Solids*, 351. 2440-2445.

Jurn, W., Schmelzer, P., Vladimir, M., Fokin, Alexander, S., and Abyzov (2010). How Do Crystal Form and Growi Glass-Forming Liquids: Ostwald's Rule Of Stages And Beyond. *International J. of App. Glass Sci.* 1(1), 16-26.

Johnson L. F., Guggenheim., H. (1971). Infrared-Pumped Visible Laser. *Appl. Phys .Lett.*19, 44.

Jones, G. O. (1971). *Glass*. Gateshead: Northumberland Press Ltd.

Jordan, W. G. and Jha, A. (1994) A Review of the Role of DSC Analysis in the Design of Fluorozirconate Glasses for Fibre Optic Applications.*J.Thermal Analysis*. 42, 759.

Joubert, M.F., (1999).Photon Avalanche Upconversion in Rare-Earth Laser Materials. *Opt. Mater.* 11, 181-203.

Kamalakar V., Upender G., Prasad M., Mouli M.C. (2010). Infrared, ESR and Optical Absorption Studies of Cu^{2+}ions Doped inTeO_2-ZnO-NaF Glass System. *Indian Journal of Pure &Appl. Phys*. 48, 709.

Kaur, G., Komatsu, T. and Thangara, R. (2000). Crystallization Kinetics of Bulk Amorphous

Se-Te-Sn System. *J. Mater. Sci*. 35,903-906.

Kumar, G. A., Lu, J., Kaminskii, A. A., Ken-Ichi Ueda, Yagi, H., Yanagitani, T., and Unnikrishnan, N. V.(2004). Spectroscopic and Simulated Emission Characteristics of Nd^{3+} in Transparent Y_2O_3 Ceramics.*J. Quantum Electron*. 40, 747-758.

Lakshminarayana, G. Yang, R. Mao, M. and Qiu, J. (2009).Spectral Analysis of RE^{3+} (RE=Sm, Dy, and Tm): P_2O_5-Al_2O_3-Na_2O Glasses. *Optical Materials* 31, 1506-1512.

Lambson, E., Saunders, S., Bridge, B., and El-Mallawany, R. (1984).*J. Non-Cryst. Solids*. 69,117.

Lipson, H., Burkmelter, J., and Dugyer, C. (1975).*J. Non Cryst. Solids*.17, 27.

Liu, C. and Heo.J. (2006).Up-conversion and photon avalanche in oxy-fluoride nano-structured glasses doped with Ho^{3+}.*J. Non-Cryst. Solids*.352, 5325.

MacFarlane, D.R., Javorniczky J.S., Newman, P.J., and Booth, D. J.(1999).Energy Exchange Processes in Er^{3+}-Doped Fluorozirconate Glasses. *J. Non-Cryst. Solids*.256 & 257.

Matthew, J., Dejneka and Alexander Streltsov (2002). Science and Technology Division,Corning Incorporated, Corning, NY 14831.

Mehl, R. F. (1939). *Trans Am. Inst. Min. Metal. Engs*.135, 416.

Mohamed, N. B., Yahya, A. K., Deni, M.S.M., Mohamed, S. N., Halimah, M. K.,and Sidek, H.A.A. (2010). Effects of concurrent TeO_2 reduction and ZnO addition on elastic and structural Properties of $(90-x)TeO_2–10Nb_2O_5–(x)ZnO$ glass. *J. Non-Cryst. Solids.*. 356, 1626–1630.

Mott, N.F and Davis, E.A. (1971). *Electronic Process in Non-Crystalline Materials*. Oxford University Press, London.

Murthy, D. V. R., Sasikala, T., Jamalaiah, B. C., Mohan Babu, A., Suresh Kumar, J., Jayasimhadri, M., and Rama Moorthy, L. (2011).Investigation on Luminescence Properties of Nd^{3+} Ions in Alkaline-Earth Titanium Phosphate Glasses.*Optics Communications*. 284, 603-607.

Murugan,G.S., Suzuki,T., and Ohishi,Y. (2005). Appl. Phys. Lett. 86. 161109.

McLaughlin, C., Tagg,S. L., Zwanziger,J. W., Haeffner,D. R. and Shastri, S. D. (2000).The Structure of TelluriteGlass: A Combined NMR, Neutron Diffraction, and X-Ray Diffraction Study. *J. Non-Cryst. Solids.* 274, 1–8.

Nath, P., Paul, A. and Douglas, R. W.(1965).*Phys. Chem. Glasses*.6,203.

Narayanan,R. A. and Zwanziger,J.W. (2003).The Glass Forming Ability of Tellurites: A Rigid Polytope Approach.*J. Non-Cryst. Solids*.316, 273.

Nazabal, V., Todoroki, S., Nukui, A., Matsumoto, T., Suehara, S., Hondo, T., Araki, T., Inoue, S., Rivero, C., and Cardinal, T.(2003). Oxyfluoride Tellurite Glasses Doped by Erbium: Thermal Analysis, Structural Organization and Spectral Properties.*J. Non-Cryst. Solids.*325, 85.

Nishida,T., Yamada,M., Ide,H. and Takashima,Y.(1990).Correlation between The Structure and GlassTransition Temperature of Potassium, Magnesium and Barium Tellurite Glasses.*J. Mater. Sci*. 25, 3546–3550.

Nurulhuda binti Mohammad Yusoff. (2011). *Optical Properties of Magnesium Phosphate Glass doped Samarium*. Thesis Msc. Universiti Teknologi Malaysia.

Oishi,H., Benino, Y. and Komatsu,T. (1999).Preparation and Optical Properties of Transparent Tellurite Based Glass Ceramics Doped by Er^{3+} and Eu^{3+}. *Phys. Chem. Glasses*. 40, 212.

Oliver. D. S. (1975). *The Use of Glass in Engineering*.Oxford University Press.

Oprea, I. –I., Hesse, H., and Betzler, K. (2004). *Opt. Mater*. 26, 235.

Oprea, I. –I., Hesse, H., and Betzler, K. (2005). Infrared-to-visible Upconversion Luminescence in Neodymium-doped Bismuth-Borate Glass. *Phys. Stat. Sol.(b).* 242(12), R109-R111.

Paul, A. (1982). *Chemistry of Glasses*, Chapman and Hall, London, New York.

Pavia, D. L. Lampman, G. M. and Kriz, G. S. (2001).*Introduction to Spectroscopy:A Guide for Students of Organic Chemistry*. London: Brooks Cole.

Pigeonneau, F. Martin, D. and Mario, O. (2010).Shrinkage of an Oxygen BubbleRising in a Molten Glass.*Chemical Engineering Science*. 65, 3158-3168.

Ping, D.H., Li, D. X. and Ye, H.Q. (1995). Characterization of the Microstructure in Nanocrystalline Materials. *J. Mater. Sci.Lett.*14, 1536.

Que, W., Sun, Z and Hu X.(2005).Yellow-to-Violet Up-Conversion Luminescence in Neodymium-Doped Sol-Gel GeO_2/γ-Glycidoxypropyltrimethoxysilane Hybrid Planar Waveguides. *J. Appl. Physis*. 98, 093-518.

Rada S., Culea E., Rada, M., Pascuta, P. and Maties, V. (2009).Structural and Electronic Properties of Tellurite Glasses.*J. Matter Sci*. 44, 3235-3240.

Rai, V. K., de Arau'jo C. B., Ledemi Y., Bureau B. and Poulain M., (2009). Optical Spectroscopy and Upconversion Luminescence in Nd^{3+} doped $Ga_{10}Ge_{25}S_{65}$Glass.*J. Appl. Phys.* 106, 103512.

Rajendran, V., Palanivelu, N., Chaudhuri, B. K.and Goswami, K.(2003). Characterisation of Semiconducting V_2O_5–Bi_2O_3–TeO_2Glasses Through Ultrasonic Measurements. *J. Non-Cryst. Solids*. 320, 195–209.

Rajeswari,R., Babu,S. S. and Jayasankar,C. K. (2010).Spectroscopic Characterization of Alkali Modified Zinc-Tellurite Glasses doped with Neodymium. *J. Spectrochimica Acta Part A.* 77, 135-140.

Rieker, T., Hanprasopwattana, A., Datye, A., Hubbard, P. (1999). Particle Size Distribution Inferred from Small-Angle X-ray Scattering and Transmission Electron Microscopy. *Langmuir*. 15, 638-641.

Reisfeld, R., and Jorhensen, C., (1977). *Lasers & Excited States of Rare Earth*. Springer, Berlin.

Reza Dousti, M., Sahar, M.R., Ghoshal, S. K., Amjad, Raja J. and Samavati, A.R.(2013). Effect of AgCl on Spectroscopic Properties of Erbium doped Zinc Tellurite Glass. *J. of Molecular Structure*. 1035, 6-12.

Rosmawati, S., Sidek, H.A.A., Zainal, A.T., and Mohd Zobir, H. (2007). IR and UV Spectral Studies of Zinc Tellurite Glasses. *Journal of Applied Sciences*. 7(20), 3051-3056.

Sahar, M. R. (1990). *A Study on Oxyhalide Glasses*.PhD Thesis, University of Warwick.

Sahar,M. R. (1998).*Sains Kaca Edisi Pertama*.Universiti Teknologi Malaysia,Johor.

Sahar, M. R. (2000). *Fizik Bahan Amorfus*. 1st Ed. UTM Skudai: DBP.

Sahar, M. R., Kassim, A. and Arifin, R. (2011). Synthesis and Optical Characterization of Nd^{3+} doped TeO_2-PbO-Li_2O. *Jurnal Fisika*.1, 1.

Sakida, S., Hayakawa, S. and Yoko, T., (1999). Part 2.^{125}Te NMR study of M_2O-TeO_2 (M = Li, Na, K, Rb and Cs) Glasses*J. Non-Cryst. Solids*.243, 1.

Santa-Cruz, P., Morin, D., Dexpert-Ghys,J., Sadoc,A. Glas,F., and Auzel,F. (1995).New Lanthanide-doped Fluoride-Based Vitreous Materials for Laser Applications.*J. Non-Cryst. Solids*.190, 238.

Sean Manning, Heike Ebendorff-Heidepriem, and Tanya M. Monro. (2011). Ternary Tellurite Glasses for The Fabrication of Nonlinear Optical Fibres. *Optical Materials Express*.2, 2.

Serqueira, E.O., Dantas, N.O., Anjos, V., Pereira-da-Silva, M.A., and BellM.J.V. (2011).Optical Spectroscopy of Nd^{3+}Ions in a Nanoglass Glass Matrix. *Journal of Luminescence*. 131, 1401-1406.

Sharaf El-Deen, L.M., Al Salhi, M.S., Meawad, M. Elkholy. (2008). IR and UV Spectral Studies for Rare-Earths doped Tellurite Glasses. *Journal of Alloys and Compounds.* 465, 333-339.

Shaltout I. (2000). Crystallization Kinetics and Structure of (TeO_2-TiO_2-Fe_2O_3) Glasses.*J. Mater Sci*. 35, 323.

Shaoxiong Shen and Animesh Jha. (2008). Raman Spectroscopic and DTA Studies of TeO_2-ZnO-Na_2O Tellurite Glasses. *Advanced Materials Research*. 39-20, 159-164.

Sherman Hsu C. P. (1997). *Handbook of Instrumental Techniques for Analytical Chemistry*, Prentice-Hall, NJ, p. 254.

Shimadzu Corporation. (1997). Instruction Manual Operation Guide UVPC Series Spectrophotometer. Kyoto: Shimadzu Co.

Sidek, H.A.A., Rosmawati, S., Talib, Z.A., Halimah, M.K., and Daud, W.M. (2009). Synthesis and Optical Properties of ZnO-TeO2 Glass System. *American Journal of Applied Sciences.* 6 (8), 1489-1494.

Silva, M.A.P., Messaddeq Y., Briois V., Poulain M., Villain F., and Ribeiro S.J.L. (2002). Synthesis and Structural Investigations on TeO_2-PbF_2-CdF_2 Glasses and Transparent Glass-Ceramics. *J. Phys. Chem. Solids*. 63(4), 605-612.

Singh, R. and Chakravarthi, J.S. (1997). Dc Conductivity of V_2O_5-Containing Zinc Tellurite Glasses.*Phys. Rev. B (Condensed Matter)*.55, 5550.

Sreekanth Cakradar,R.P., Sivaramaiah,G.,Lakshmana, R. andGopal,N.O. (2005).EPR and Optical Investigation of Manganese Ions in Alkali Lead Tetraborate Glasses.*SpectrochimicaActa Part A*. 62, 761.

Stanley, A.T.,Harris, E.A.,. Searle, T.M.,and Parker, J.M. (1993). Upconversion in Neodymium doped Fluoride Glasses.*J. Non-Crys. Solids*. 161, 235-240.

Stanworth, J. E. (1952). Tellurite Glasses. *J. of Nature*.169, 581.

Steele, F.N. and Douglas, R.W. (1965). Some Observations on the Absorption of Iron in Silicate and Borate Glasses. *Phys*. *Chem*. *Glasses.* 6, 246.

Su,G.J., Borrelli,N. U. and Miller,A.R. (1962).*Phys. Chem. Glasses* 3 (5) 167.

Subrahmanyam, K. and Salagram, M. (2000).*Opt. Mater*. 15, 181.

Suehara,S., Yamamoto,K., Hishita,S., Aizawa,T., Inoue,S., and Nukui,A. (1995). *Phys. Rev.B.*51, 14919.

Suhasini, T. Kumar, J. S. Sasikala, T. Jang, K. Lee, H. S. Jayasimhadri, M. Jeong, J.H. Yi, S. S. and Moorthy, L. R. (2009). Absorption and Fluorescence Properties of Sm^{3+} Ions in Fluoride Containing Phosphate Glasses.*Optical Materials* 31, 1167–1172.

Tanaka, K.,Mukai,T., Ishihara T., Hirao, K., Soga, N.,Sogo, S. Ashida, Mand Kato,.R.(1993).Preparation and Optical Properties of Transparent Glass-Ceramics Containing Cobalt(ll) Ions. *J. Am. Ceram. Soc.* 76, 2839.

Tanahashi, I., Yoshida, M., Manabe, Y. and Tohda, T. (1995) Effects of heat treatment on Ag particle growth and optical properties in Ag/SiO_2 glass composite thin films. *J. Mater. Res.* 10(2), 363-365.

Tauc, J. and Menth, A. (1972). States in The Gap. *J. Non-crystal Solids.* 8-10, 569-585.

Tirtha Som and Basudeb Karmakar (2009). Enhancement of Er^{3+} Upconverted Luminescence in Er^{3+}: Au-antimony Glass Dichroic Nanocomposites Containing Hexagonal Au Nanoparticles. *J. Opt. Soc. Am. B.* 26(12), B21-B27.

Vijaya Prakash, G., Narayan Rao, D. and Bhatnagar, A. K. (2001). Linear Optical Properties of Niobium-Based Tellurite Glasses. *Solid State Commun*. 119, 39.

Wang, J. S., Vogel, E. M., and Snitzer, E. (1994). Tellurite Glass: A New Candidate for Fiber Devices.*Opt. Mater*. 3, 187.

Watanabe, T., Benino,Y., Ishizaki, K., and Komatsu, T. (1999). Temperature Dependence of Vickers Hardness for TeO_2- based and Soda-Lime Silicate Glasses. *J. Ceram. Soc. Jpn*. 107, 1140.

Weber, M. J. (1980). Glass for Neodymium Fusion Lasers. *J. Non-Cryst. Solids*. 42(1-3), 189-196.

Wright, J. C. (1976). Up-Conversion and Excited State Energy Transfer in Rare-Earth Doped Materials. *Top. Appl. Phys*. 15, 239-295.

Xia, S. and Duan, C. K. (2007).The Simple Model and its Application to Interpretation and Assignment of 4f–5d Transition Spectra of Rare-Earth Ions in Solids.*Journal of Luminescence.* 122–123, 1–4.

Yano T., Kunimine N., Shibata S., Yamane M. (2003). Structural investigation of sodium borate glasses and melts by Raman spectroscopy. II. Conversion between BO_4 and BO_2O units at high temperature. *Journal of Non-Crystalline Solids.* 321, 147-156.

Yaru,N., Chunhua,L., Yan,Z., Qitu,Z. and Zhongzi,X. (2007). Study on Optical Properties and Structure of Sm_2O_3 Doped Boron-Aluminosilicate Glass.*Journal of Rare Earths* 25: 94-98.

Yen, W. M. and Selzer, P. M. (1981). *Laser Spectroscopy in Solids*. New York:Springer-Verlag, Berlin Heidelberg.

Zhou, B., Zhou, Y., Lam, Y. L., Chan, C. Y., Kam, C. H., Cheng, S. D. and Buddhudu, S. (2000). Up-Conversion Violet Emission in (Nd^{3+}+Ce^{3+}):SiO_2 – Al_2O_3 Sol–Gel Glasses.*Opt. Commun*. 182, 151.

Zhu, L. Zuo, C. Luo, Z. and Lu, A. (2010). Photoluminescence of Dy^{3+} and Sm^{3+}:SiO_2-Al_2O_3-LiF-CaF_2 Glasses. *Physica B* 405, 4401-4406.

Zmojda, J., Kochanowicz, M., Dorosz, D., and Swiderski, J. (2008). Luminescence Properties of Aluminosilicate Glasses Doped with Neodymium. *Proc. Of SPIE* 7124,712404-1.