SPECTROSCOPIC PROPERTIES OF ERBIUM DOPED TELLURITE GLASS

SITI FATIMAH BINTI ISMAIL

UNIVERSITI TEKNOLOGI MALAYSIA

SPECTROSCOPIC PROPERTIES OF EBIUM DOPED TELLURITE GLASS

SITI FATIMAH BINTI ISMAIL

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

JANUARY 2014

This thesis is specially dedicated to:

my beloved father (Ismail bin Mamat)
and my mother (Latipah binti Abdul Rahman),
my siblings (Adam bin Ismail, Zaini Arif bin Ismail, Sulaiman bin Ismail),
and my beloved friend (Allahyarham Nik Ahmad Irham bin Nik Rusli)

Thank you for being with me all along.

ACKNOWLEDGEMENT

Alhamdulillah, all praise to Allah SWT, the Almighty, for giving me the courage, strength, and patience to complete this master study. First and foremost, I would like to express my deepest gratitude to my supervisor, Prof Dr. Md. Rahim Sahar for the encouragement, assistance and advice during the work.

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

My sincere thanks and appreciation extend to the lab assistants, Mr. Mohamad Jaafar for helping me in preparing samples, Mr. Abd. Rahman Bin Abdullah for helping in thermal analysis using DTA,. Also thanks to Mrs. Radiah Hassan for helping in using Shimadzu UV-VIS-NIR spectrophotometer, Mr. Zainal for samples analysis by X-ray Diffraction spectrometer and Mr. Amin for helping in using Perkin-Elmer spectrum FTIR spectrometer.

I wish to express my warm thanks to all my fellow lab mates in Optical Crystal Research Group, for their guidance, motivating dialogue, glittering idea and the restless time we were struggling together, also for all the moment we have shared.

I also would like to express my gratitude to Kementerian Pengajian Tinggi (KPT) for supporting scholarship for four semesters under MyMaster.

ABSTRACT

Er^{3+} doped tellurite glasses of composition (75-x)TeO_2-25ZnO-5Na_2O-xEr_2O_3 with x = 0, 0.2, 0.4, 0.7, 0.9, 1.1 and 1.4 mol% were successfully prepared by melt quenching technique. No definite peaks were found from the X-ray diffraction pattern, thus verified the amorphous nature of glass. However, the X-ray diffraction pattern for heat treated glass showed a wide peak which indicated the occurrence of nanocrystallite particle in the sample. The crystallite size was determined by Scherrer equation and confirmed by the image obtained from transmission electron microscopy technique. The vibrational study was conducted using Fourier transform infrared (FTIR) spectroscopy in the range of 4000 cm^{-1} – 400 cm^{-1}. It was observed that, four absorption peaks occur around 1600 cm^{-1} – 3400 cm^{-1}, 666 cm^{-1} – 755 cm^{-1}, 546 cm^{-1} – 684 cm^{-1} and 465 cm^{-1} which were due to the stretching mode vibration of OH bond, TeO_4 trigonal bipyramids and TeO_3 trigonal pyramids, Er-O bond and Zn-O tetrahedral bond, respectively. The FTIR spectra for heat treated samples generated a higher intensity absorption band located at 564 cm^{-1}, 573 cm^{-1}, 669 cm^{-1} and 688 cm^{-1}. The thermal stability of the glass was investigated using differential thermal analyzer. The thermal parameters, such as the glass transition temperature (T_g), crystalline temperature (T_c), melting temperature (T_m) and thermal stability (T_c-T_g) were determined. It was found that, this glass system has glass formation range around 51.47°C - 99.35°C. The emission spectrum was recorded using photoluminescence spectrometer at room temperature. From the luminescence spectra, blue and green emission bands associated with Er^{3+} transition at (382 nm) $^4G_{11/2}\rightarrow{}^4I_{15/2}$, (465 nm) $^4F_{5/2}\rightarrow{}^4I_{15/2}$, (501 nm) $^2H_{11/2}\rightarrow{}^4I_{15/2}$ and (550 nm) $^4S_{3/2}\rightarrow{}^4I_{15/2}$ with an excitation wavelength λ_{exci} = 786 nm were observed. Meanwhile, the luminescence intensity for heat treated samples was slightly higher. The absorption characteristic was determined using ultra violet-visible spectroscopy. It was observed that, the optical band gap (E_g) and the Urbach energy (ΔE) was in the range 2.89 eV - 2.18 eV and 0.59 eV - 0.15 eV, respectively depending on the Er_2O_3 concentration. For the heat treated samples, the optical band gap (E_g) and the Urbach energy (ΔE) was in the range of 2.72 eV - 2.68 eV and 0.54 eV - 0.21 eV, respectively.

ABSTRAK

Kaca tellurite berdop Er^{3+} dengan komposisi (75-x)TeO_2-25ZnO-5Na_2O-xEr_2O_3 dengan x = 0, 0.2, 0.4, 0.7, 0.9, 1.1 dan 1.4 % mol telah berjaya disediakan menggunakan teknik pelindapan leburan. Corak pembelauan sinar- X tidak menemui puncak yang pasti, ini mengesahkan bahawa kaca tersebut adalah amorfus. Walau bagaimanapun, corak pembelauan sinar- X bagi kaca yang diberi rawatan haba menunjukkan puncak yang lebar menandakan adanya zarah nano kristalit dalam sampel. Saiz kristalit telah ditentukan daripada persamaan Scherrer dan ditentusahkan dari imej mikroskop transmisi elektron. Kajian getaran dijalankan menggunakan spektroskopi Fourier transformasi infra-merah (FTIR) dalam julat 4000 cm^{-1} - 400 cm^{-1}. Empat puncak penyerapan berlaku di sekitar 1600 cm^{-1} - 3400 cm^{-1}, 666 cm^{-1} - 755 cm^{-1}, 546 cm^{-1} - 684 cm^{-1} dan 465 cm^{-1} yang masing-masing disebabkan oleh mod getaran regangan OH, TeO_4 *trigonal bipyramids* dan TeO_3 *trigonal pyramids*, Er-O and Zn-O *tetrahedral bond*. Spektrum FTIR bagi sampel yang terawat haba menghasilkan keamatan tinggi di jalur penyerapan pada 564 cm^{-1}, 573 cm^{-1}, 669 cm^{-1} and 688 cm^{-1}. Kestabilan terma kaca telah dikaji menggunakan analisis pembezaan terma. Parameter terma seperti suhu transisi (T_g), suhu penghabluran (T_c), suhu lebur (T_m) dan kestabilan terma (T_c-T_g) telah ditentukan. Sistem kaca ini didapati mempunyai julat pembentukan kaca di sekitar 51.47 ^oC - 99.35 ^oC. Spektrum pancaran telah direkod menggunakan spektrometer fotoluminesen pada suhu bilik. Dari spektra fotoluminesen, jalur biru dan hijau yang dikaitkan dengan peralihan Er^{3+} di (382 nm) $^4G_{11/2}\rightarrow{}^4I_{15/2}$, (465 nm), $^4F_{5/2}\rightarrow{}^4I_{15/2}$, (501 nm) $^2H_{11/2}\rightarrow{}^4I_{15/2}$ dan (550 nm) $^4S_{3/2}\rightarrow{}^4I_{15/2}$ dengan jarak gelombang pengujaan λ_{exci} = 786 nm telah diperoleh. Sementara itu, keamatan untuk sampel terawat haba adalah lebih tinggi berbanding sampel asas. Ciri penyerapan telah ditentukan menggunakan spektroskopi ultralembayung cahaya nampak. Jurang jalur optik (E_g) dan tenaga Urbach (ΔE) masing-masing adalah dalam julat 2.89 eV - 2.18 eV dan 0.59 eV - 0.15 eV, bergantung kepada kepekatan Er_2O_3. Jurang jalur optik (E_g) dan tenaga Urbach (ΔE) bagi sampel terawat haba masing-masing adalah dalam julat 2.72 eV - 2.68 eV and 0.54 eV - 0.21 eV.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

4fn	-	Shell configuration belong to lanthanide series
4f	-	Orbital belong to lanthanide series
α	-	Absorption coefficient
A	-	Absorption intensity
CB	-	Conduction band
d	-	Sample thickness
E_g	-	Optical energy gap
Er^{3+}	-	Trivalent erbium ion
Er_2O_3	-	Erbium oxide
ESA	-	Excited state absorption
eV	-	Electron volt
FTIR	-	Fourier transformed infrared
ΔE	-	Width of the band tails
hkl	-	Crystal plane orientation index
IR	-	Infrared
Na_2O	-	Sodium oxide
NBO	-	Non-bridging oxygen
n	-	Integer number, called the order of reflection
nm	-	nanometer
RE	-	Rare earth
θ	-	Bragg angle
Δt	-	Differential temperature
T	-	Temperature
T_c	-	Crystallization temperature
T_g	-	Glass transition temperature

T_m	-	Glass melting temperature
TeO_2	-	Tellurium oxide
UV	-	Ultraviolet
Vis	-	Visible
$\bar{\nu}$	-	Wavenumber
ω	-	Frequency
θ	-	Angle
λ	-	Wavelength
XRD	-	X-ray diffraction
ZnO	-	Zinc oxide

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

Glass is an amorphous material and has a degree of short range. Glass also known as a hard, brittle, corrosion resistant, inert and transparent material. Glass is defined as the mixture of inorganic material that has been cooled to a rigid condition without be a crystal. Glass also defined as a material produced as a result of cooling of the material from the liquid state to a condition in which the mass is rigid and the viscosity increases. Glass is generally defined as a product of inorganic material produced by the combustion process (melting), then cooled to a rigid solid state without crystallization (Sahar,1998). Glass has excellent features in a wide range of fields such as optically homogenous, transmits light well, excellent solid solvent into which nearly all elements can be melted to produce diverse materials and various shapes can be easily formed.

There a several types of glass found such as silicate glass, borate, phosphate and telluride. Tellurite glasses contain tellurium oxide (TeO_2) as the main component. Tellurite glasses have numerous favorable optical properties such as a wide transmission range from ultraviolet to mid-infrared (0.35-5.0 µm), lower phonon energy (700-750 cm^{-1}) than other known glass hosts such as borates or silicates, high linear and nonlinear refractive index, good stability and resistance to moisture. Tellurite glasses are of particular interest because of not only their low transition temperature but also their excellent infrared transmission (Sahar,1995).

In this production of tellurite based glass, zinc oxide (ZnO) and erbium (III) oxide (Er_2O_3) added to strengthen the glass structure. Zinc telluride is one of the more common semiconducting materials used in optoelectronics. Zinc telluride is one of the II-VI compound and which have special electrical and optical properties. This special properties make ZnTe is important for development of various seminconductor devices such as photodetectors, light emitting diode, laser diodes, and solar cells. Zinc telluride is a direct band gap material with band gap of 2.23-2.25 eV. It is usually a p-type semiconductor. Zinc telluride typically has a cubic crystal structure but can be also prepared as hexagonal crystals. Zinc telluride glasses are reported to be suitable host for optically active rare earth ions. The structure of TeO_2-based glasses is also of interest because there are two types of basic structure unit, namely TeO_4 trigonal bipyramids (tbp) and TeO_3 trigonal pyramid (tp) (Aida *et al.*, 2000). Water in glass influences a variety of glass properties such as reduces the viscosity and increases the rates of structural relaxation and phase separation of glass. It has been reported elsewhere that IR absorption in TeO_2-ZnO glasses is very much depend on the ZnO content. As the amount of ZnO content became higher, the absorption peak due to the Te-O bond vibration decreases, while the position absorption peak due to the Te-O bonds increases. Structural measurements in telluride glasses are very essential to interpret their physical and chemical properties.

Erbium (III) oxide is one of the rare earth in lanthanide series and it pink solid. Erbium sometimes used as a colouring for glasses and a dopant for optical fibers and optical amplifiers. Melting and boiling points of the Erbium (III) oxide is very high at 2344 ^oC and 3290 ^oC. Erbium (III) oxide has high density of 8.64 gcm^{-3} and molar weight 382.56 g/mol. It has a strong ionic bond and can increase mechanical properties of glass. The main application of erbium is as an activator in the manufacture of laser glass because the glass containing erbium laser will emit radiation when given the appropriate energy.

1.2 Research background

Nowadays, rare earth doped tellurite nanoglass had become more explore in the research due great application on the optical telecommunication. Nanoglass or nanocrystalline materials are characterized by a microstructure length or grain size of up to about 100 nm. Method of fabricating useful nanoglass through the controlled nucleation of glass has stimulated a broad research effort in the field of glass nucleation in 1957 by Stookey.

Glasses would crystallize spontaneously if they were brought to thermodynamics equilibrium at room temperature. Why glasses remain amorphous when they are undercooled below the equilibrium melting temperatures of their crystalline phases and this situation is necessary to understand the principles of catalyzed crystallization. There are two possible reasons either the nucleation rate or the growth rate is negligibly small at all temperatures. The extremely slow nucleation rate is the critical factor preventing crystallization of glasses. Once growth has started, crystals grow sizable rates in many glasses at suitable temperatures. Evidently, there are no nucleation in the conventional glass melt and prevent from homogenous nucleation. Solution to induce nucleation and crystal growth is by using concept of heat treatment.

A lot of work have been done on rare-earth doped glass ceramic materials with active ions embedded in the crystalline phase (Mattarelli *et al.*,2004). The rare-earths, especially Er^{3+} which are optically active ions commonly embedded in tellurite crystalline phase and several extraordinary advantages have been observed for optical properties of rare earth ions in tellurite nanocrystals. It was also found that the intensity of the frequency up-conversion luminescence of transparent Er^{3+} -doped tellurite based crystallized glasses at around 550 nm is strong compared with their precursor glass (Sakai *et al.,* 2000; Hirano et al. 2001) .

In this study, Er^{3+} doped tellurite glass will be prepared by using conventional melt quenching technique with various concentration of erbium. In characterizing the samples, the spectroscopic studies of the tellurite glass will be measured. As a result, more information will be collected about erbium doped tellurite glass.

1.3 Statement of problem

Tellurite glasses have excellent optical and chemical properties. Tellurite glasses are promising candidates for optical fiber laser and optical amplifier application. It has been reported that tellurite glasses are good for hosting rare earth ions since they provide a low phonon energy environment to minimize the nonradiative losses. Erbium doped tellurite glass exhibit more good optical quality, stability and also have been used in many optical applications. However, to our knowledge not many spectroscopic properties of tellurite glass doped Er^{3+} have been reported. It is therefore the aims of this study to prepare and characterizes the spectroscopic properties in term of absorption, transmission, structural and emission in order to obtain clear understanding of the relationship between structural and optical properties of Er^{3+} doped tellurite glass.

1.4 Objectives

The objectives of this research are:

i. To prepare TeO_2-ZnO-Na_2O-Er_2O_3 with different Er_2O_3 content by using melt quenching technique.
ii. To characterize the structural properties by using x-ray diffraction, transmission electron microscopy (TEM) and fourier transform infra red (FTIR) spectroscopy.
iii. To characterize the thermal properties by using differential thermal analyzer (DTA).
iv. To characterize the optical properties by using photoluminescence and UV-Visible spectroscopy.

1.5 Scope of study

In order to achieve the above objectives the works have been focused on the given scope:

i. The preparation of the glass based on (75-x) TeO_2-25ZnO-5Na_2O-xEr_2O_3 (x = 0. 0.2, 0.4, 0.7, 0.9, 1.1, 1.4 mol %) glass system will be provided through the melt quenching technique.
ii. Determination of crystallite particles size by Scherrer equation.
iii. Characterization of transmission spectra by using Fourier Transform Infra Red (FTIR) spectroscopy.
iv. Characterization of absorption in the UV and visible region using UV-VIS spectrophotometer.

v. Characterization of emission using photoluminescence spectroscopy.

1.6 Significant of research

Research on tellurite glass doped erbium is very important because of the possible photonic applications. From this research the information about spectroscopic properties of TeO_2-ZnO-Er_2O_3 will be found out and as well as glass will be enhanced the development of new optical technology in glass science and engineering in last century.

REFERENCES

A. Santana-Alonso, A. C. Yanes, J. M´endez-Ramos, J. del-Castillo1, and V. D. Rodr´ıguez (2009). Sol–gel transparent nano-glassceramics comprising rare earth-doped $NaYF_4$ nanocrystals. *Physica Status Solidi A* 10: 2249–2254.

Abdel-Baki, M. and El-Disty, F. (2006). Optical Properties of Oxide Glasses Containig Transition Metals: Case of Titanium and Chromium-Containing Glasses. *Current Opinion in Solid State and Material Science*. 10: 217-229.

Abd El-Moneim (2002), Structural and Optical Properties of Glasses, *Material Chemistry Physics*. 73 318-322.

Aida K., Benino Y., Dimitrov V., Komatsu T., Sato R., (2000). Kinetics of Enthalpy Relaxation At The Glass Transition In Ternary Tellurite Glasses. *Journal Amorphous Ceramics Society*. 83: 1192-1198.

Ali, A.A (2009). Characterization and Electrical Properties of V_2O_5-CuO-P_2O_5 Glasses. *Physica*. B 403: 2684-2689.

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

Alpert, N.L. Keise, W.E and Szymanski, H.A (1970). IR: Theory and Practice of Infrared Spectroscopy. New York: Plenum Press.

Budi, A.S. (2003). A Study on the Mechanical, Electrical and Vibrational Spectroscopy Behavior of Neodymium Phosphate Glasses. Universiti Teknologi Malaysia: Ph.D. Thesis.

Burger, H. Kneipp, K. Hobert, H., Vogel W. (1992). Glass Formation, Properties and Structural of Glass in the TeO_2-0ZnO system. *Journal Non Crystalline Solids* 151: 134-142.

Chaudhry, M.A and Altaf, M. (1998). Optical Absorption Studies of Sodium Cadmium Phosphate Glasses. *Material Letters*. 34: 213-216.

Chunlei Yu, Junjie Zhang, Lei Wei, Zhonghong Jiang, (2006), New Transparent Er^{3+} Doped Oxyfluoride Tellurite Glass Ceramic With Improved Near Infrared and Up-Conversion Fluorescence Properties. *Materials Letter*. 61: 3644-3646.

Cullity. B. D., Elements of X-Ray Diffraction. USA: Massachusetts. Addison Wesely. 1978.

D. W. Hall, M. J. Weber, in: M. J. Weber (Ed) (1991), CRC Handbook of Laser Science and Technology, Supplement 1: Lasers, Boca Raton, CRC Press, 137.

El-Mallawany, R. Patra, A. Friend, C.S. Kapoor, R. and Prasad, P.N. (2004). Study Luminescence Properties of Er^{3+} ions in New Tellurite Glasses. *Optical Material*. 26:267-270.

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.

F.F.Bently, L.D. Smithson, A.L. Rozek. (1968). Infrared Spectra and Characteristics Frequencies 700-300 cm^{-1}. *Interscience Publication New York*. 103.

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

He, B.B.(2009). Two-Dimensional X-Ray Diffraction. New Jersey: John Wiley & Sons, Inc

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): 1497-1501

Hu, L. and Jiang Z. (1996). Properties and Structures of TeO_2 Based Glasses Containing Ferroelectric Component. *Physics Chemistry Glasses* 37(1): 19-21.

Jlassi, H. Elhouicher, M. Ferid, R. Chtourou, M. Oueslati (2010). Thermal and optical properties of Er^{3+} doped tellurite glasses. *Optical Materials*. 32: 743-747.

Jlassi, H. Elhouichet, M. Ferid, C. Barthou, J. Lumin (2010).Judd-Ofelt Analysis an Improvement of Thermal and Optical Properties of Tellurite Glasses by Adding P_2O_5. *Journal of Luminescence*.130: 2394-2401.

J. A. Caird, S. A. Payne, M. J. Weber (Eds.) (1991), CRC Handbook of Laser Science and Technology, Supplement 1, Lasers, Boca Raton, CRC Press. 3.

Kader, A.A. El-Mallawany, R. and Elkholy, M.M. (1993). Network Structure of Tellurite Phosphate Glasses: Optical and Infrared Spectra. *Journal Applied Physics*. 73(1): 71-74.

Kassab, L.R.P., Camilo, M.E., Amancio, C.T., Silva, D.M., Martinelli, J.R (2008). Effects of gold nanoparticles in the green and red emission of TeO_2- PbO-GeO_2 glasses doped with Er^{3+}- Yb^{3+}. *Optical Materials*. 33: 1948-1951.

Kawasaki, S.Honma, T. Benino, Y.Pujiwara, T.Sato, R. and Komatsu, T.(2003). Writing of Crystal-Dots and Lines by YAG Laer Irradiation and Their Morphologies in Samarium Tellurite Glasses. *Journal Non-Crystal Solids* 325:61-69.

K. Hirano, Y. Benino, T. Komatsu (2001), *Journal Physics Chemistry Solids* 62, 2075.

K.Shioya, T. Komatsu, H. Kim, R.Sato and K. Matusita (1995), *Journal Non Crystalline Solids*.144:128-144.

Lin, H. Pun, E.Y.B. and Liu, X.R. (2001). Er^{3+} Doped $Na_2O.Cd_3Al2Si_3O_{12}$ Glass for Infrared and Upconversion Applications. *Journal Non-Crystalline* 283: 27-33.

M. Braglia, C. Brushi, G.Dai, J. Kraus, S.Mosso, M. Baricco, L. Battezzati, F. Rossi (1999). *Journal Non-Crystalline Solids*. 170: 256-257.

M. J. Weber (1979), Non-Metallic Compound II, in: K. A. Gschneidner Jr, L. R. Eyring (Eds), Handbook on the physics and chemistry of Rare Earths, Amsterdam, North-Holland Physics Publishing, Vol 37, 275.

M. J. Weber (1990) The Structural of Non-Crystalline Materials.*Journal Non Crystalline Solids*. 123: 208-222.

M. Mortier, A. Montevillie, G. Patriarche, G.Maze, F. auzel (2001). Glass and Other Amorphous Materials.*Optical Material*. 16: 255.

M. Mortier, P. Goldner, C. Chateau, M. Genotelle (2001). Erbium Doped Glass Ceramics: Concentration Effect On Crystal Strcuture and Energy Transfer Between Active ions. *Journal of Alloys and Compound*. 323-324: 245-249.

M.Mattarelli, V.K. Tikihomiv, A.B.Seddon, et al (2004). *Journal Non-Crystalline Solids* 345&346,354.

Marjanore S. Toulouse J, Jain H, Sandman C, Dierolf V, Kortan AR, Kopylou N, Ahrens RG (2003). *Journal Non-Crystalline Solids* 322:311.

Md. Rahim Sahar (1998). Sains Kaca Edisi Pertama.Universiti Teknologi Malaysia, Johor.

M.R. Dousti, M.R. Sahar, R.J. Amjad, S.K. Ghoshal, A. Khorramnazari, A. Dordizadeh Basirabad and A. Samavati: (2012) Spectroscopic Investigation of Rare Earth Doped of Phosphate Glasses Containing Silver Nanoparticle.*European Physics. Journal*. Vol. 66, 237.

Nakanishi, K. and Solomon, P.H. (1977). Infrared Absorption Spectrosopy. Second Edition. San Francisco: Holen-Day Inc.

N. Mott, E. Davis. Electronic Process in Non-Crystalline Materials, Scond Edition. UK, Clarendon Press, Oxford, 1979.

Pan Z, Morgan S. H. (1997) . Optical transition of Er^{3+} in Lead-Tellerium-Germenate Glasses. *Journal Luminescence*.75: 301-308.

P. Gayathri Pavani, K. Sadhana, V. Chandra Mouli. (2011). Optical, Physical and Structural Studies of Boro-Zinc Tellurite Glases. *Physica*. 406: 1242-1247.

P. Scherrer (1918), “Bestimmung der Grösse und der inneren Struktur von Kolloidteilchen mittels Röntgenstrahlen,” Nachr. Ges. Wiss. Göttingen 26 pp 98-100.

Perkin Elmer (2000). Spectrum GX User's Guide. United Kingdom: Perkin Elmer Co.

Rao. C. N. R., Materials for Solid State Battery. Singapore, World Scientific Publishing company. 1963.

R. El-Mallawany, M.Dirar Abdalla, I. Abbas Ahmed, Materials Chemistry and Physics 109 (2008) 291-296.

R. J. Amjad, M.R. Sahar, S.K. Ghoshal, M.R. Dousti, S. Riaz and B.A. Tahir: (2012). Plasmon-Enhanced Upconversion Fluorescence in Er^{3+}: Ag Phosphate Glass: The Effect of Heat Treatment. *Chinese Physics Letter*. 29: 087-304.

R. Reisfeld, Y. Eckstein.(1974).Optcial Transitions Of Er^{3+} ions in $ZnCl_2$-Based Glass.*Journal Non-Crystalline. Solids* 15: 1-25.

R. Sakai, Y. Benino, T. Komatsu (2000). Enhanced Second Harmonic Generation At Surface In Transparent Nanocrystalline TeO_2-Based Glass Ceramics *Applied Physics Letters*. 77: 2118.

S. D. Stookey(1959),Corning Glass Works, Catalyzed Crystallinization of Glass in Theory and Practice, Vol. 51, 805-808.

Sahar M.R., Noordin N (1995). Effect of AlF_3 on the Density and Elastic Properties of Zinc Tellurite Glass Systems. *Journal Non-Crystalline Solids.*184: 137 140.

Sahar, M.R. (1998). *Sains Kaca*. Penerbit Universiti Teknologi Malaysia.

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

Sidebottom DL, Hruschka MA, Potter BG, Brow RK (1997), Structure and Optical Properties of Rare Earth-Doped Zinc Oxyhalide Tellurite Glasses. *Journal Non Crystalline Solids* 9: 222-282.

Som, Tirtha., and Karmakar, Basudeb (2009). Ehancement of Er^{3+} Upconverted luminescence in Er^{3+}: Antimony glass dichroic nanocamposites containing hexagonal Au nanoparticles. *Journal Optical Science*. 26:12.

Sreekanth Chakradar R.P., Sivaramaiah G., Lakshmana R., Gopal N.O. (2005). EPR and Optical Investigation of Manganese Ions in Alkali Lead Tetraborate Glasses. *Spectrochimica Acta Part A*, 62: 761-768.

Sun K (1988) In: Preparation and characterization of rare earth glasses, Thesis, Brown University.

Talib, Z. A. Daud, W.M. Tarmizi, E. Z. M. Sidek, H. A. A. and Yunus, W. M. M. (2008). Optical Absorption Spectrum of Cu_2O-CaO-P_2O_5 Glasses. *Journal of Physics and Chemistry of Solids.* 69: 1969-1973.

Tastumisago, M. Minami, T. Kowaa, Y. and Adachi, H. (1994). Structural Change of Rapidly Queched Binary Tellurite Glasses With Composition and Temperature. *Physics Chemistry Glasses* 35: 84-89.

V. Nazabal, S. Todoroki, A. Nukui, T. Matsumato, S. Suehara, T. Hondo, T. Araki, S. Inove, C. Rivero, T. Cardinal (2003), Spectral Properties of Er3+ Doped Oxyfluoride Tellurite Glassses. *Journal Non-Crystlline Solids* 325 85.

W. Holand, G. Bell (2002), Glass Ceramic Technology, The American Ceramic Society.

Xia, H. Nie, Q.Zhang, J. and Wang, J.(2003). Preparation and Optical Spectroscopy of Na_2-TeO_2-ZnO Glasses Containig Divalent Europium Ions. *Materials Letters*. 57: 3895-3898.

Zengda Pan, Akira Ueda, Steven H Morgan, Richard Mu, (2006). Luminescence of Er^{3+} in Oxyfluoride Transparent Glass-Ceramics. *Journal Rare Earth.* 24: 299-705.