UNIVERSITI PUTRA MALAYSIA

OPTICAL AND ELECTRICAL PROPERTIES OF TELLURITE BASE GLASS ADDED WITH BISMUTH AND HOLMIUM OXIDES

OO HOOI MING

FS 2013 82

OPTICAL AND ELECTRICAL PROPERTIES OF TELLURITE BASE GLASS ADDED WITH BISMUTH AND HOLMIUM OXIDES

By

OO HOOI MING

Thesis is Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

July 2013

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in Fulfilment of the requirement for the degree of Master of Science.

OPTICAL AND ELECTRICAL PROPERTIES OF TELLURITE BASE GLASS ADDED WITH BISMUTH AND HOLMIUM OXIDES

By

OO HOOI MING

July 2013

Chair: Halimah Mohamed Kamari, PhD

Faculty: Science

Tellurite glasses are good material in non-linear, photonic and communication application because these glasses are stable and provide low photon energy in room temperature. When other metal oxides are added in the tellurite glass system, it can enhance the optical and electrical behaviour. For this research, two series of binary tellurite based glasses: bismuth and holmium tellurite were successfully synthesized using a conventional melt quenching method. XRD results for both binary tellurite glass system show that the glasses are in amorphous phase. The glass samples are transparency, yellow colour for bismuth tellurite glass, orange colour holmium tellurite glass when there is no sunlight and yellow colour when sunlight is present. The optical and electrical properties measurements were investigated for both binary tellurite glasses system.

For bismuth tellurite glass system, the density, molar volume and refractive index increase when bismuth ions Bi^{3+} increases. This is due to the increase in the

polarization of the ions Bi^{3+}. FTIR results show that it slightly shifted to the low wavenumber and this due to formation of TeO_3 units and non-bridging oxygen. When formation TeO_3 units and non-bridging oxygen increase, the optical band gap, E_{opt} decreases. The conductivity and the resistance in electric properties depend on the network modifier present in the sample. As ion Bi^{3+} content increases, the formation of non-bridging oxygen in the sample increase leads to an increase in the conductivity of the sample.

For holmium tellurite glasses, as the holmium content increases, the density increasing while the molar volume decreases. Besides, the refractive index increases when the holmium content increases. FTIR results show that it slightly shifted to the low wavenumber and this also due to formation of TeO_3 units and non-bridging oxygen. For electrical properties, the increase of ion Ho^{3+} content will increase the formation of holmium (iii) oxide quasi-molecular complexes in tellurite glass matrix which causes the conductivity of the sample to decrease.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

SIFAT-SIFAT OPTIK DAN ELEKTRIK DALAM KACA BERASASKAN TELURIT DENGAN PENAMBAHAN BISMUT DAN HOLMIUM OKSIDA

By

OO HOOI MING

Julai 2013

Pengerusi: Halimah Mohamed Kamari, PhD

Fakulti: Sains

Kaca telurit adalah bahan yang berguna dalam aplikasi bukan linear, fotonik dan komunikasi. Ini disebabkan kaca ini stabil dan juga dapat menyediakan tenaga foton rendah dalam keadaan suhu bilik. Apabila oksida logam lain ditambah dalam sistem kaca telurit, ini boleh meningkatkan sifat optik dan elektrik. Untuk kajian ini, dua siri kaca binary teluriti berasaskan: bismut telurit dan holmium telurit telah disediakan dengan kaedah sepuh lindap. Keputusan XRD bagi kedua-dua sistem kaca telurit binari telah menunjukkan bahawa sampel kaca bagi kedua-dua sistem ini adalah dalam fasa amorfus. Sampel kaca dalam kedua-dua sistem kaca telurit binari adalah lutcahaya dan kaca bismut telurit berwarna kuning manakala bagi kaca holmium telurit berwarna oren dalam keadaan tanpa cahaya matahari dan berwarna kuning dengan kehadiran cahaya matahari. Pengukuran sifat optik dan elektrik telah dilakukan untuk kedua-dua sistem kaca telurit binari.

Bagi sistem kaca bismut telurit, apabila Bi^{3+} ion meningkat, ketumpatan, isipadu molar dan indeks biasan meningkat. Keadaan ini berlaku disebabkan pengutuban ion

Bi^{3+} meningkat.Keputusan FTIR menunjukkan bahawa ia beralih sedikit kepada nombor gelombang rendah dan ini adalah disebabkan oleh pembentukan unit-unit TeO_3 dan oksigen tak bersambungan. Apabila pembentukan unit TeO_3 dan oksigen tak bersambungan meningkat, jurang jalur optik, E_{opt} berkurang. Kekonduksian dan rintangan dalam sifat elektrik bergantung kepada kehadiran pengubahsuai rangkaian dalam sampel. Kandungan ions Bi^{3+} meningkat, pembentukan oksigen tak bersambungan dalam sampel meningkat dan kekonduksian dalam sampel juga meningkat.

Bagi sampel kaca holmium tellurite, ketumpatan meningkat manakala isipadu molar berkurang semasa kandungan holmium meningkat. Disamping itu, indeks biasan meningkat apabila kandungan holmium meningkat. Keputusan FTIR menunjukkan bahawa ia beralih sedikit kepada nombor gelombang rendah dan ini adalah disebabkan oleh pembentukan unit-unit TeO_3 dan oksigen tak bersambungan. Bagi sifat elektrik, kandungan ion Ho^{3+} meningkat akan meningkatkan pembentukan molekul kompleks kuasi holmium (iii) oksida dalam matriks kaca yang menyebabkan kekonduksian sampel berkurang.

ACKNOWLEDGEMENTS

Firstly, I would like to dedicate my sincere appreciation and gratitude to all the parties who have supported me in this final year project, especially my project supervisor, Dr. Halimah, for all her support, unlimited guidance and invaluable advice throughout the period of preparing this thesis.

Apart from that, I would also like to express special thanks to my seniors, especially Abang Iskandar , for their continuous assistance and tolerance. They often offer help when necessary and generously shared their valuable knowledge in my process of completing this project.

I would also like to extend my appreciation to my family members especially my parents and sisters for their understanding, support and tolerance. They are always by my side no matter what happen to me.

Last but not least, I would like to express my gratitude to my course-mates and friends, who shared my happiness and sadness as well as giving their generous assistance towards the success of my project. I am very grateful to have them as my friends and I could hardly express my gratitude in words. Thank you.

APPROVAL

I certify that a Thesis Examination Committee has met on 1 July 2013 to conduct the final examination of Oo Hooi Ming on her thesis entitled "Optical and Electrical Properties of Tellurite Base Glass added with Bismuth and Holmium Oxides" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998, The Committee recommends that the student be awarded the Master of Science.

Members of the Thesis Examination Committee were as follows:

Zainal Abidin Sulaiman, PhD
Associate Professor
Centre of Foundation Studies for Agricultural Science
Universiti Putra Malaysia
(Chaiman)

Zaidan Abdul Wahab, PhD
Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Internal Examiner)

Chen Soo Kien, PhD
Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Internal Examiner)

Muhamad Deraman, PhD
Professor
Faculty Science and Technology
Universiti Kebangsaan Malaysia
(External Examiner)

(SEOW HENG FONG, PhD)
Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia
Date:

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Halimah Mohamed Kamari, PhD
Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Chairman)

Wan Mohamad Daud Wan Yusoff, PhD
Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Member)

BUJANG BIN KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

DECLARATION

Declaration by graduate student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any other institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and Innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012.The thesis has undergone plagiarism detection software

Signature: _____ Date: 1 JULY 2013

Name and Matric No.: _____

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- 47 supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

Signature :_____

Name of Chairman of Supervisory Committee:_____

Signature: :_____

Name of Member of Supervisory Committee:_____

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

TeO_2	Tellurite oxide	-
Bi_2O_3	Bismuth (iii) oxide	-
NBO	Non-bridging oxygen	-
BO	Bridging oxygen	-
XRD	X-ray diffraction	-
FTIR	Fourier transmission infrared	-
λ	Wavelength	m
d	Interplanar distance	m
θ	Scattering angle	^{o}
α	Absorption coefficient	cm^{-1}
$h\nu$	Incident photon energy	eV
A	Constant	-
E_{opt}	Optical band gap	eV
E_g	Urbach energy	eV
B	Constant	-
ΔE	Width of the band tail of the electron states	eV
Q	Charge	C
C	Stored charge	C
V	Voltage	V
V_o	Amplitude	V
ω	Angular frequency	rad s^{-1}
t	Time	s
ε^*	Dielectric constant	-
ε'	Real permittivity	-
ε''	Loss factor	-

σ	Conductivity	Scm^{-1}
Z	Impedance	Ω
X_c	Capacitive reactance	Ω
ρ_s	Density of sample	g/cm^3
ρ_{water}	Density of distill water	g/cm^3
M_{air}	Mass in air	g
V_s	Volume of sample	cm^3
M	Molar mass	g/mol
A	Area	m^2
d	Thickness	m

CHAPTER 1

INTRODUCTION

1.1 Overview

Tellurite glasses are good material in lasers and nonlinear applications, photonic application and communication applications. These glasses often use because they are stable in room temperature, good thermal properties and good optical and electrical properties (Prakash, 2001). It can also be used in photorefractive materials, non-linear devices, up-conversion lasers and optical amplifier because these glasses have low photon energy, high linear and non-linear refractive index (Marko, 2004). Metal oxide such as Bi_2O_3, Sb_2O_3, MoO_3 and Nb_2O_5 have been added in the tellurite glass system to enhance the optical behaviour (Hidetsugu, 1994). Many studies in tertiary tellurite based glasses have been reported by various authors (Ayuni, 2011). For example, Tiefeng et al. (2011) studies the optical non linear properties of TeO_2-Bi_2O_3-BaO glass, it was found that an increase of the ion bismuth content and a decrease of ion barium content will lead to an increase of the non linear properties of glass because bismuth dissolves in tellurite glass matrix .

Bismuth (iii) oxide is used in optical fiber material and ceramic material because it can provide high refractive index and low in temperature. In addition, it is also used in the electronic field due to the high valence cation of low field strength and high polarizability (El-Mallawany, 2002).

Holmium (iii) oxide, known as rare earth material and used for study in optical properties because it can be used as efficient visible lasers for the applications in the fields of telecommunication and medical diagnostic (Xudong, 2008). Nowadays, rare earth ions such as Er^{3+}, Tm^{3+} and Ho^{3+} with certain glasses convert IR to ultraviolet

or visible light through upconversion process to successfully obtain the optimum wavelength of the sample provided.

1.2 Problem statement

Nowadays many researchers study the optical properties and electric properties of bismuth glasses and holmium glasses. For optical properties, most of researchers study the optical transitions and upconversion properties but the optical energy band gap and Urbach energy have not been analyzed. For electrical properties, some researchers study on dielectric properties but the resistance and impedance have not been analyzed. For this research, there was less information to refer.

1.3 Objective of research

The objectives of this research are to

a. Determine optical band gap and refractive index of the telllurite based glass with added bismuth oxide and holmium oxide.

b. Study electrical properties of the telllurite based glass with added bismuth oxide and holmium oxide.

1.4 Outline of the thesis

This thesis consists five chapters: first chapter is the introduction of this research. Second chapter consists of the literature review that some of the researcher study and analysis in glass material related to this research. Third chapter is methodology, which is the process of preparing glass sample and the equipment used in this experiment. Fourth chapter is the result and discussion. The fifth chapter includes the conclusion and future research.

REFERENCES

Alcock, N. W., 1990. Bonding and Structure. *Crystal Research and Technology* 27: 891-1012

Ayuni, J. N., Halimah, M. K., Talib, Z. A., Sidek, H. A. A., Daud, W. M., Zaidan, A. W., Khamirul, A. M., 2011**.** Optical Properties of Ternary TeO_2-B_2O_3-ZnO Glass System. *Materials Science and Engineering* 17: 012027.

Boris L. S., Todor P., Hitoki Y., 2009. Synthesis and nonlinear optical properties of TeO_2–Bi_2O_3–GeO_2 glasses. *Scripta Materialia* 61: 493–496.

Boyer, J. C., Vetrone, F., Capobianco, J. A., 2003. Optical transitions and upconversion properties of Ho^{3+} doped ZnO-TeO_2 glass. *Journal of Applied Physics* 93: 12.

Chagraoui A., Tairi A., Ajebli K., Bensaid H., Moussaoui A. 2010. New tellurite glasses and crystalline phases in the Bi_2O_3–CaO–TeO_2 system: Synthesis and characterization. *Journal of Alloys and Compounds* 495: 67–71

Durga, D. K., Yadagiri Reddy, P., Veeraiah, N., 2002. Optical absorption and thermoluminescence properties of ZnF_2–MO–TeO_2 (MO=As_2O_3, Bi_2O_3 and P_2O_5) glasses doped with chromium ions. *Journal of Luminescence* 99: 53–60

Durga, D. K., Veeraiah, N., 2001. Dielectric dispersion in ZnF_2-Bi_2O_3-TeO_2 glass system. *Journal of Materials Science* 36: 5625 – 5632.

Doweidar, H., Saddeek, Y.B., 2009. FTIR and ultrasonic investigations on modified bismuth borate glasses. *Journal of Non-Crystalline Solids* 355: 348–354.

El-Mallawany, R.A. *Tellurite Glasses Handbook.* Boca Raton: CRC Press Inc., 2002.

El-Mallawany, R., Dirar Abdalla, M., Abbas Ahmed, I., 2008. New tellurite glass:Optical properties. *Materials Chemistry and Physics* 109: 291–296.

Gorur G. R., *Dielectrics in Electric Fields*. New York Basel: Marcel Dekker, Inc, 2003.

Guonian, W., Junjie, Z., Shixun, D., Lei, W., Jianhu, Y., Zhonghong, J., 2005. Structural investigation on TeO_2–$BiCl_3$ glassy system. *Journal of Molecular Structure* 750: 1–6.

Hidetsugu, M., Takashi, K., Hironobu, S., 1994. Electrical conductivity of W_2O_5-Sb_2O_3-TeO_2 glasses. *Journal of Non-Crystalline Solids* 168: 157-166.

Halimah, M.K., Sidek, H. A. A., Daud, W.M., Zainal, A. S., Mansor H., Kamirul, A.M., 2010. Physical Properties Of Binary Tellurite Glass System. *Solid State Science and Technology 18* 1: 364-370.

Halimah, M.K., Daud, W.M., Sidek, H.A.A., Zaidan, A.W., Zainal, A.S., 2010. Optical properties of ternary tellurite glasses. *Materials Science-Poland* 28: 1

Kang, O.M., Bhuvanesh, N. S. P., Halasyamani, P.S., 2001. Bi_2TeO_5: Synthesis, Structure, and Powder Second Harmonic Generation Properties. *Inorg. Chem.* 40: 1978-1980.

Marko, U., Matjaz, V., Danilo, S., 2004. Phase Formation and Dielectric Characterization of the Bi_2O_3–TeO_2 System Prepared in an Oxygen Atmosphere. *J. Am. Ceram. Soc.* 87: 591-97.

Mohamed, N.B., Yahya, A.K., Deni, M.S.M., Mohamed, S.N., Halimah, M.K., 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. *Journal of Non-Crystalline Solids* 1626-1630.

Munoz-Martín, D., Villegas, M.A., Gonzalo, J., Fernández-Navarro, J.M., 2009. Characterisation of glasses in the TeO_2–WO_3–PbO system. *Journal of the European Ceramic Society* 29: 2903–2913.

Petru, P., Eugen, C., 2008. FTIR spectroscopic study of some bismuth germanate glasses containing gadolinium ions. *Materials Letters* 62: 4127–4129.

Prakash, G.V., Rao, D.N., Bhatnagar, A.K., 2001. Linear optical properties of niobium based tellurite glasses. *Solid State Communications* 119: 39-44.

Rai, S.B., Singh, A.K., Singh, S.K., 2003. Spectroscopic properties of Ho^{3+} ions doped in tellurite glass. *Spectrochimica Acta Part A* 59: 3221-3226

Rajendran, V., Palanivelu, N., Chaudhuri, B.K., Goswami, K., 2003. Characterisation of semiconducting V_2O_5–Bi_2O_3–TeO_2 glasses through ultrasonic measurements. *Journal of Non-Crystalline Solids* 320: 195–209.

Reisfeld, R., Hormadaly, J., Muranevich, A., 1978. Absorption and Emission of Ho^{3+} in Germanate Glasses. *Journal of Non-Crystalline Solids* 29: 323-332

Reisfeld, R., Hormadaly, 1976. Optical intensities of holmium in tellurite, calibo, and phosphate glasses. *Journal of Chemical Physics*, 64: 3207- 3212

Saddeeka, Y. B., Afifi, H.A.; Abd El-Aal, N.S., 2007. Interpretation of mechanical properties and structure of TeO_2–Li_2O–B_2O_3 glasses. *Physica B* 398: 1–7.

Senthil, G.M., Fargin, E., Rodriguez, V., Adamietz, F., Couzi, M., Buffeteau, T., Le Coustumer, P., 2004. Temperature-assisted electrical poling of TeO_2–Bi_2O_3–ZnO glasses for non-linear optical applications. *Journal of Non-Crystalline Solids* 344: 158–166.

Shaaban, M.H., Ali, A.A., El-Nimr, M.K., 2006. AC conductivity of tellurite glasses doped with Ho_2O_3. *Materials Chemistry and Physics* 96: 433–438

Sidek, H.A.A., Rosmawati, S., Talib, Z.A., Halimah, M.K., Daud, W.M., 2009. Synthesis and Optical Properties of ZnO-TeO_2 Glass System. *American Journal of Applied Sciences 6* 8: 1489-1494.

Tauc, J., 1974. *.Amorphous and Liquid Semiconductors.* New York: Plenum

Teja, P.M.V., Rajyasree, Ch., Rao, P.S., Babu, A.R., Tirupataiah, Ch., Rao, D.K., 2011. Structural and electrical properties of ZnF_2–Bi_2O_3–GeO_2 glasses doped with CoO. *Journal of Molecular Structure* 1014: 119–125.

Tiefeng, X., Feifei, C., Shixun, D., Xiang, S., Xunsi, W., Qiuhua, N, Chao, L., 2011. Glass formation and third-order optical nonlinear properties within TeO_2–Bi_2O_3–BaO pseudo-ternary system. *Journal of Non-Crystalline Solids* 357: 2219–2222.

Xudong, Z., Tiefeng, X., Shixun, D., Qiuhua, N., Xiang, S., Longjun, L., Xianghua, Z., 2008. Investigation of energy transfer and frequency upconversion in Er^{3+}/Ho^{3+} co-doped tellurite glasses. *Journal of Alloys and Compoundss* 450: 306-309.

Yanfei, C., Qiuhua, N., Tiefeng, X., Shixun, D., Xunshi, W., Xiang, S., 2008. A study of nonlinear optical properties in Bi_2O_3–WO_3–TeO_2 glasses. *Journal of Non-Crystalline Solids* 354: 3468–3472.

Yanling, W., Shixun, D., Feifei, C., Tiefeng, X., Qiuhua, N.., 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: 407–411.

Yousef, El Sayed, S., 2005. Characterization of oxyfluoride tellurite glasses through thermal, optical and ultrasonic measurements. *J. Phys. D: Appl. Phys.* 38: 3970–3975.