OPTICAL PROPERTIES OF ERBIUM DOPED TELLURITE GLASS WITH DIFFERENT NaCl COMPOSITION

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To my late father

beloved family and friends

future husband

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ABSTRACT

A series of glasses based on (79.5-x)TeO_2-20Na_2O-(x)NaCl-0.5Er_2O_3 (where x = 0.0, 2.5, 5.0, 7.5 and 10.0 mol %) are successfully prepared by melt quenching technique. The amorphous nature of the glass have been characterized using X-ray Diffraction technique and the optical properties are characterized by means of UV-Vis-NIR and photoluminescence spectroscopy. The value of the optical band gap and the Urbach energy are calculated from the absorption edge data. The value of optical band gap lies between 2.99 eV and 3.13 eV for the indirect transition whereas the value of Urbach energy varies from 0.17 eV to 0.27 eV. From the luminescence spectrum, it is found that the luminescence emission spectra centered at 435 nm, 475 nm and 563 nm which assigned to the transition of $^2H_{11/2}$, $^4S_{3/2}$ and $^4F_{9/2}$ to $^4I_{15/2}$ respectively under 375 nm of excitation wavelength. Most properties observed to be dependent in a systematic manner on the NaCl content.

ABSTRAK

Satu siri kaca pada komposisi (79.5-*x*)TeO_2-20Na_2O-(*x*)NaCl-0.5Er_2O_3 (dengan *x* = 0.0, 2.5, 5.0, 7.5 and 10.0 mol%) telah berjaya dihasilkan dengan menggunakan teknik pelindapan leburan. Sifat amorfus kaca tersebut telah ditentukan dengan kaedah pembelauan sinar-X dan sifat sifat optic kaca tersebut ditentukan dengan menggunakan spektroskopi ultra unggu dan cahaya nampak dan spektroskopi fotoluminesen. Nilai jurang tenaga optik dan tenaga Urbach diperolehi daripada kiraan data serapan pinggir. Jurang tenaga Eg berada pada julat 2.99 eV sehingga 3.8 eV untuk peralihan tidak lansung manakala nilai tenaga Urbach pula berada pada julat 0.17 eV sehingg 0.27 eV. Daripada spectrum luminesen, dapat diperhatikan bahawa spektra rencatan luminesen berpusat pada 435 nm, 475 nm dan 563 nm, masing-masing dikaitkan dengan transisi $^2H_{11/2}$, $^4S_{3/2}$ and $^4F_{9/2}$ to $^4I_{15/2}$ dengan pengujaan gelombang pada 375 nm. Kebanyakkan ciri yang diperoleh bergantung pada kandungan sistematik NaCl.

ABSTRACT

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Satu siri kaca pada komposisi (79.5-x)TeO_2-20Na_2O-(x)NaCl-0.5Er_2O_3 (dengan x = 0.0, 2.5, 5.0, 7.5 and 10.0 mol%) telah berjaya dihasilkan dengan menggunakan teknik pelindapan leburan. Sifat amorfus kaca tersebut telah ditentukan dengan kaedah pembelauan sinar-X dan sifat sifat optic kaca tersebut ditentukan dengan menggunakan spektroskopi ultra unggu dan cahaya nampak dan spektroskopi fotoluminesen. Nilai jurang tenaga optik dan tenaga Urbach diperolehi daripada kiraan data serapan pinggir. Jurang tenaga Eg berada pada julat 2.99 eV sehingga 3.8 eV untuk peralihan tidak lansung manakala nilai tenaga Urbach pula berada pada julat 0.17 eV sehingg 0.27 eV. Daripada spectrum luminesen, dapat diperhatikan bahawa spektra rencatan luminesen berpusat pada 435 nm, 475 nm dan 563 nm, masing-masing dikaitkan dengan transisi $^2H_{11/2}$, $^4S_{3/2}$ and $^4F_{9/2}$ to $^4I_{15/2}$ dengan pengujaan gelombang pada 375 nm. Kebanyakkan ciri yang diperoleh bergantung pada kandungan sistematik NaCl.

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LIST OF SYMBOLS

α	-	Absorption coefficient
C	-	Constant
d	-	Sample thickness
ΔE	-	Width of the band tail
E_g	-	Band gap energy
E_{opt}	-	Optical energy gap
$\hbar$	-	Planck constant
λ	-	Wavelength
ω	-	Angular frequency
T_m	-	Glass melting temperature
T_g	-	Glass transition temperature
T_c	-	Crystallization temperature
θ		Diffracted angle

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CHAPTER 1

INTRODUCTION

1.0 Introduction

In this chapter, the general information about this study will be described in details. This study is about modifier variation assisted optical response in erbium tellurite glass. The background of study, objectives of the study, statement of problem and scope of the study will be explained in this chapter.

1.1 Background of Study

In general, glass is a transparent, hard and brittle material. Glass is very unique material and has many special properties compared with other material such as plastic or metal. All glass is an amorphous solid but not all amorphous solid is a glass. The amorphous (non-crystalline) term can be understood as the arrangement of atoms in the materials. The arrangement of atoms in amorphous materials is short range order which is the arrangement are not in periodic manner. In contrast with amorphous structure, a crystal structure has a long range order and periodic arrangement of atoms. Glass usually formed by solidification of melt without occur any crystallization. In other words, it is formed by cooling from the molten state of higher temperature to stable state of low temperature. The cooling should be fast enough so that the melt of right viscosity does not form into crystal.

Tellurite glasses are known to be very suitable hosts for doping with rare-earth element. They show good properties in chemical durability, mechanical stability and also superior transparency in a wide spectral range of 3-18μm. These properties make the tellurite glasses a better candidate for practical laser application (Weber *et.al*., 1981; Nii *et.al*., 1998). Researcher has interest in tellurite glass because of their low transition temperature and also their excellent infrared transmission. Thus this glass is a potential for various longer-wavelength applications (Sahar and Noordin., 1995).

The erbium-doped tellurite glasses also have shown chemical and optical properties that suitable for optical application such as laser light modulator (Uhlmann and Kreidl., 1983) and thermally stable for fiber drawing (Neindre *et.al*, 1999). The determination of the optical parameters such as refractive index, extinction coefficient, band gap energy, material dispersion of glass, and their nonlinear aspects is fundamental topic and important in a sector of technology (Jlassi *et.al*., 2011).

1.2 Problem Statement

Research shows that, tellurite glass have been studied almost decade, with highlight generally on their synthesis and properties (El-Mallawany, 2002). The application of the tellurite glass is important especially in the industrial application in laser glass technology. Er^{3+} doped tellurite glass is one of the excellent candidates for optical communication materials due to their high refractive index, high solubility of rare earth, large resistance against corrosion and good transparency in the region from visible to infrared (0.35-6μm) (Chen et.al., 2003; Lin et.al., 2003). Tellurite glasses modified by halides and oxide-halides of the non transition metal ions have already been investigate by previous researchers. Most of these researchers focused on the glass formation range of the oxyhalide tellurite glass. Moreover, the modifier used are mostly $PbCl_2$ or ZnCl (Wang et.al, 1988; Kostka et.al, 2003; Fortes et.al, 2003; Sahar et.al, 2012) but few have used the NaCl (Ivanova, 1990). However, there are no systematic study has been made so far on the glass system of (79.5-x)TeO_2-20Na_2O-(x)NaCl-0.5Er_2O_3. Therefore, an investigation of the optical properties of erbium doped tellurite glass with NaCl variation was carried out and the results of this study are presented in this thesis.

1.3 Objectives of the Study

In order to achieve more information on the glass properties, the objectives of this study as follow:

a) To prepare (79.5-x)TeO_2-20Na_2O-(x)NaCl-0.5Er_2O_3 glass system by using melt quenching technique.
b) To determine the amorphous nature of (79.5-x)TeO_2-20Na_2O-(x)NaCl-0.5Er_2O_3 glass system.
c) To determine the optical band gap energy and Urbach energy of (79.5-x)TeO_2-20Na_2O-(x)NaCl-0.5Er_2O_3 glass system.
d) To determine the luminescence properties of (79.5-x)TeO_2-20Na_2O-(x)NaCl-0.5Er_2O_3 glass system.

1.4 Scope of Study

In order to achieve the objectives, the study has been divided into several scopes as follow;

a) Preparation of tellurite glass doped with Erbium (79.5-x)TeO_2-20Na_2O-(x)NaCl-0.5Er_2O_3 (where x = 0.0, 2.5, 5.0, 7.5 and 10.0 mol%) using conventional melt quenching technique.
b) Determination of the amorphous nature of glass system using X-ray Diffraction.
c) To determine the optical band gap energy and Urbach energy of the glass system using UV-VIS-NIR spectrophotometer.
d) Determination of emission spectra of glass system using photoluminescence spectrophotometer.

REFERENCES

Aitken B.G. and Youngman R.E., NMR Studies Of Aluminum Speciation In Tellurite Glasses, *Journal of Non-Crystalline Solids,* 2001. 284; 9-15.

Amjad. R.J., Sahar. M.R., Goshal. S.K., Dousti. M.R., Riaz. S., Samavati. A.R., Ariffin. R., Naseem. S., Annealing Time Dependent Up-Conversion Luminescence Enhancement In Magnesium-Tellurite Glass, *Journal Of Luminescence*, 2013. 136; 145-149.

Chen. D. D., Liu. Y. H., Zhang. Q. Y., Deng. Z. D., Jiang. Z. H., Thermal Stability And Spectroscopic Properties Of Er^{3+}-Doped Niobium Tellurite Glasses For Broadband Amplifiers, *Material Chemistry Physics*, 2005. 90; 78-82.

Chen, D. Wang, Y. Bao, F and Yu, Y., Broadband Near-infrared Emission from Tm^{3+}/Er^{3+} Co-Doped Nano-structured Glass Ceramics, *Journal Applied Physics*, 2007. 1001: 113511.

Dimitrivev. J., Arnaudov. M. and Dimitrov. V., Phase diagram and Infrared-Spectral Investigation of the $2TeO_2$-V_2O_5-Na_2O System. *Journal of Solid State Chemistry*, 1981. 38; 55-61.

Dousti. M.R., Sahar. M.R., Goshal. S.K., Amjad. R.J., and Arifin. R, Plasmonic Enhanced Luminescence in Er^{3+}: Ag Co-doped Tellurite Glass. *Journal of Molecular Structure,* 2013. 1033; 79-83.

Dousti. M. R, Sahar. M.R., Ghoshal. S.K., Amjad. R J., Samavati. A.R., Effect of AgCl on Spectroscopic Properties of Erbium Doped Zinc Tellurite Glass, *Journal of Molecular Structure*, 2013. 1035; 6-12.

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

El-Mallawany. R., Tellurite glasses Part 1: Elastic properties, *Materials Chemistry and Physics*, 1998. 53(2); 93-120.

El-Mallawany. R., *Tellurite Glasses Handbook: Physical Properties and Data*, CRC Press LLC. 2002.

El-Mallawany. R., Abdalla. M. D., Ahmed. I. A., New Tellurite Glass: Optical Properties, *Journal Materials Chemistry and Physics*, 2008. 109; 291-296.

Fares. H., Jlassi. I., Elhouichet. H., Férid. M., Investigations of Thermal, Structural And Optical Properties Of Tellurite Glass With WO_3 Adding, *Journal Non Crystalline Solid*, 2014. 396–397; 1–7.

Fortes. L. M., Santos. L. F., Goncalves. M. C., Almeida. R. M., Mattarellib. M., Montagna. M., Chiasera. A., Ferrari. M., Monteil. A., Chaussedent. S., Righini. G. C., Er^{3+} Ion Dispersion In Tellurium Oxychloride Glasses, *Optical Materials*, 2007. 29; 503–509.

Fortes. L. M., Santos. L. F., Goncalves. M. C., Almeida. R. M., The Effects of $Zncl_2$ And $ErCl_3$on The Vibrational Spectra and Structure of Tellurite Glasses, *Journal Non Crystalline Solid*, 2006. 352; 690-694.

Fortes. L. M., Santos. L. F., Goncalves. M. C., Almeida. R. M., Preparation And Characterization of Er^{3+}-doped TeO_2-Based Oxyhalide Glasses, *Journal Non Crystalline Solid*, 2003. 324; 150-158.

Hou. Z., Xue. Z., Wang. S., Hu. X,. Lu. H., Niu. C., Wang. H., Wang. C. and Zhou. Y., Thermal Stability and Structure of Tellurite Glass. *Key Engineering Materials*, 2012. 512-515; 994-997.

Ivanova. I., Glass Formation in Oxide-Halide System, *Journal of Material Science,* 1990. 25; 2087-2090

Jihong. Z., Haizheng. T., Yu. C., Xiujian. Z., Structure, Upconversion and Fluorescence Properties of Er^{3+}-Doped TeO_2-TiO_2-La_2O_3 Tellurite glass, *Journal of Rare Earths*, 2007. 25(1); 108-112.

Jlassi. I., Elhouichet. H., Ferid. M., Chtourou. R., Oueslati. M., Study of Photoluminescence Quenching in Er^{3+}-Doped Tellurite Glasses, *Optical Materials*, 2010. 32; 743–747.

Jlassi. I., Elhouichet. H., Ferid. M., Thermal and Optical Properties of Tellurite Glasses Doped Erbium, *Journal Material Science*, 2011. 46; 806-812.

Kostka. P., Lezal. D., Poulain. M., Pedlikova. J., Novotna. M., Glass Formation in The PbCl2-Sb2O3-TeO2 System, *Solid State Phenomena*, 2003. 90-91; 235-240.

Kumar. G.A., De la Rosa. E., Desirena. H., Radiative And Non Radiative Spectroscopic Properties Of Er^{3+} Ion In Tellurite Glass, *Optics Communications,* 2006. 260(2); 601-606.

Lin. H., Meredith. G., Jiang. S. B., Peng. X., Luo. T., Peyghambarian. N. and Pun. E. Y., Optical Transitions and Visible Upconversion In Er3+ Doped Niobic Tellurite Glass, *J. Appl. Phys*, 2003. 93; 186.

Liu. Y. H., Chen. H., Chen. D. D., Zhang. Q. Y. and Jiang. Z. H., Infrared -to-Visible Upconversion Emissions in Er^{3+} doped TeO_2-based Oxyhalide Glasses, *Key Engineering Materials*, 2005. 280-283; 953-956.

Malik. M. S. and Hogarth. C. A., Control of Electrical Conductivity With The Admixture of Chlorine In Copper Tellurite Glasses, *Journal of Materials Science*, 1990. 25; 116.

Marjanovic. S., Toulouse. J., Jain. H., Sandmann. C., Dierolf. V., Kortan. A. R., Kopylov. N., Ahrens. R. G., Characterization Of New Erbium-Doped Tellurite Glasses And Fibers, *Journal of Non-Crystalline Solids*, 2003. 322; 311–318.

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

Neindre. L. L., Jiang. S., Hwan. B. C., Luo. T., Watson. J., Peyghambarian. N., Effect of Relative Alkali Content on Absorption Line Width In Erbium-Doped Tellurite Glasses, *Journal Non-Crystalline Solids*, 1999. 255; 97-102.

Nii. H., Ozaki. K., Herren. M., and Morita M., Up-Conversion Flourescence of Er^{3+}- and Yb^{3+}- Doped TeO_2 Based Oxide Glass and Single Crystals, *Journal Luminescence*, 1998. 76-77, 116-119.

Rosmawati, S. Sidek, H.A.A. Zainal, A.T. and Zobir, H. M.. IR and UV Spectral Studies of Zinc Tellurite Glasses, *J. Appllied Sci*, 2007. 7 (20). 3051-3056.

Sahar M.R. 'Sains Kaca". Universiti Teknologi Malaysia Skudai. 1998.

Sahar,M., and Noordin, N.. Oxychloride Glasses on the TeO2-ZnO-ZnCl2 System, *J. Non-Crsyst. Solids*, 1995. 184, 137-140.

Sahar. M.R., Arifin. R., Ghosal. S.K., Effects of Chloride Ion inTeO2-ZnO-ZnCl2-Li2O-Eu2O3 Glass System, *Solid State Phenomena*, 2012. 181-182; 383-387.

Shen. X., Nie. Q., Xu. T., Dai. S., Wang. X., Investigation on Energy Transfer From Er^{3+} to Nd^{3+} in Tellurite Glass, *Journal of Rare Earths*, 2008. 26; 899-903.

Shen. X., Nie. Q., Xu. T., Dai. S., Li. G., Wang. X. Effect of Ce^{3+} on The Spectroscopic Properties in Er^{3+} Doped TeO_2–GeO_2–Nb_2O_5–Li_2O Glasses, *Journal of Luminescence*, 2007. 126: 273.

Sudo. S., *Optical Fiber Amplifiers—Materials, Devices, and Applications*, Artech House.1997.

Sreekanth C. R. P., Sivaramaiah. G., Lakshmana R. J., Gopal. N. O., EPR and Optical Investigations Of Manganese Ions In Alkali Lead Tetraborate Glasses, *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, 2005. 62; 761-768.

Stambouli. W., Elhouichet. H., Ferid. M., Study Of Thermal, Structural and Optical Properties of Tellurite Glass With Different TiO_2 Composition, *Journal of Molecular Structure*, 2012. 1028; 39-43.

Tincher. B., Massera. J., Petit. L., Richardson. K., Viscosity Properties of Tellurite-Based Glasses, *Materials Research Bulletin*, (2010). 45(12), 1861-1865.

Uhlmann. D. R. and Kreidl. N. J., *Glass: science and technology*, Academic Press: New York,, vol 1; 1983.

Upender. G. and Mouli. V. C., Optical, Thermal and Electrical Properties of Ternary TeO_2–WO_3–PbO Glasses, *Journal of Molecular Structure*, 2011. 1006; 159-165.

Upender, G., Ramesh, S., Prasad, M., Sathe, V. G., Mouli, V. C., Optical Band Gap, Glass Transition Temperature and Structural Studies of (100-2x)TeO_2-xAg_2O-xWO_3 glass system, *Journal of Alloys and Compounds*, 2010. 504; 468-474.

Wang. Y.H., Osaka. A., Miura. Y., Takada. J., Oda. K. and Takahashi. K., Glass Forming Range and Properties of New Oxyhalide Glasses in The System TeO_2-PbO-$PbCl_2$, *Material Science Forum*, 1988. 32-33; 161-166.

Weber. M. J., Myers. J. D., and Blackburn. D. H., Optical Properties of Nd^{3+} In Tellurite and Phosphotellurite Glasses, *Journal Applied Physics*, 1981. 52, 2944.

Zhang. J., Tao. H., Cheng. Y., Zhao X., Structure, Upconversion and Flourescence Properties of Er^{3+} -Doped TeO_2-TiO_2-La_2O_3 Tellurite Glass, *Journal of Rare Earth*, 2007. 25; 108.