TITANIUM DIOXIDE NANOPARTICLES MEDIATED SURFACE PLASMON RESONANCE ASSISTED OPTICAL PROPERTIES OF ERBIUM-DOPED TELLURITE GLASS

NUR NABIHAH BINTI YUSOF

UNIVERSITI TEKNOLOGI MALAYSIA

TITANIUM DIOXIDE NANOPARTICLES MEDIATED SURFACE PLASMON RESONANCE ASSISTED OPTICAL PROPERTIES OF ERBIUM-DOPED TELLURITE GLASS

NUR NABIHAH BINTI YUSOF

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Philosophy

Faculty of Science
Universiti Teknologi Malaysia

.

JULY 2016

To my beloved parents (Kelsom binti Taib and Assoc. Prof. Dr. Yusof bin Munajat), supportive and kind brother (Mohd. Adli bin Yusof), helpful sister (Nur Dalila binti Yusof) and also the AOMRG members who always assist me throughout my research. I could never complete this work without your support and guidance. Thank you.

ACKNOWLEDGEMENT

Alhamdulilah, all praised to Allah S.W.T, for giving me strength, courage and patience to complete this work.

My sincere gratitude goes to my supervisor, Assoc. Prof. Dr. Sib Krishna Ghoshal for his guidance, encouragement and enthusiasm throughout these years. I am really honoured to be given opportunity to investigate such new challenging issue under knowledgeable supervisor. My appreciation also goes to my co-supervisors, Dr. Ramli Arifin for his assistance in entire course. I also like to thank Prof. Hadi Nur and Prof. Nishiyama Norikazu for selecting me for a research attachment to Japan.

I am also indebted to Ministry of Education for sponsored me through My Master programme and sponsoring for research attachment in Japan. I am also grateful to UTM by providing fund through GUP/RU grants (Vot. 05H36, 12H42, and 4F424). Sincere appreciation also goes to laboratory assistance at Faculty of Science UTM, Universiti Sains Malaysia and laboratory members in Osaka University. Without their help, I could not proceed any experimental work.

Last but not least, my beloved senior and AOMRG members who continuous helping me for my research project. Their view, tips and knowledge are useful indeed. Thank you.

ABSTRACT

Low emission and absorption cross-section of rare earth (RE) ion doped tellurite glasses that limit them from making solid state lasers needs further improvement. Combination of metal nanoparticles (NPs) with RE ions in the glass is proven to be prospective for overcoming such limitations. Via tuneable surface plasmon resonance (SPR) of metal NPs, an alteration in the optical properties of such glasses is feasible. In this view, present thesis takes an attempt to determine the mechanism of metal NPs SPR mediated modification in the optical properties of Erbium (Er^{3+}) ions by embedding Titanium dioxide (TiO_2) NPs into the tellurite glass. Five glass samples are prepared using melt-quenching technique with the composition (69-x)TeO_2-20ZnO-10Na_2O-1Er_2O_3-$x$$TiO_2$, where x = 0.1, 0.2, 0.3, 0.4 mol%. Prepared samples are thoroughly characterized using X-ray diffraction (XRD), transmission electron microscope (TEM), energy dispersive X-ray (EDX), Fourier transform infrared (FTIR), Raman, ultraviolet-visible-near infrared (UV-Vis-NIR) and photoluminescence (PL) measurements. XRD pattern of achieved transparent glass samples confirmed their amorphous nature and TEM images revealed the existence of TiO_2 NPs with average size between 16 to 22 nm. EDX spectra displayed the presence of Ti element in the sample together with other appropriate elemental traces. FTIR and Raman spectra showed different vibration modes of Te-O bond (bending, asymmetric and symmetric stretching) in the structural unit of TeO_4 and TeO_3. Glass containing 0.4 mol% of TiO_2 NPs displayed an enhancement in the Raman signal by a factor of 1.56 to 3.58 for the bands centered at 388, 495, 673, 758 and 845 cm^{-1}. This intensity enhancement is mainly attributed to the TiO_2 NPs SPR assisted effects. Meanwhile, UV-Vis-NIR spectra exhibited ten absorption bands centred at 407, 444, 452, 489, 522, 552, 653, 800, 976 and 1532 nm. Absorption spectra of TiO_2 NPs manifested two plasmon bands at 552 (transverse mode) and 580 nm (longitudinal mode). PL spectra demonstrated three prominent bands centred at 525, 545 and 660 nm, which are allocated to the Er^{3+} ion transition from the excited levels ($^2H_{11/2}$, $^4S_{3/2}$ and $^4F_{9/2}$) to the ground level ($^4I_{15/2}$). Furthermore, glass containing 0.2 mol% of TiO_2 NPs revealed PL intensity enhancement by a factor of 30.00, 28.57 (for green bands) and 19.60 (for red band). This observation is ascribed to the SPR effect of TiO_2 NPs which created strong local electric field in the vicinity of Er^{3+} ion. Green emission showed the highest enhancement due to its appearance in the immediate proximity of plasmon band. It is asserted that the incorporation of TiO_2 NPs in the glass produced plasmonic effect and thereby altered the UV-Vis-NIR absorbance and improved the emission intensity of the samples. A correlation between SPR effect and surface enhance Raman scattering (SERS) is established. Present functional glass composition may be useful for device applications especially in photovoltaic and solid state laser.

ABSTRAK

Keratan rentas penyerapan dan pancaran yang rendah bagi kaca tellurite didop dengan ion nadir bumi (RE) telah membataskannya daripada menjadi laser keadaan pepejal dan memerlukan penambahbaikan seterusnya. Gabungan zarah nano logam (NPs) dengan ion RE dalam kaca telah terbukti mampu menangani keterbatasan masalah ini. Melalui resonans plasmon permukaan (SPR) boleh tala bagi logam NPs, pengubahsuaian sifat optik kaca tersebut barangkali mampu dilaksanakan. Berdasarkan pandangan ini, tesis ini cuba untuk menentukan mekanisma SPR logam NPs yang telah menjadi pengantaraan pengubsuaian terhadap perubahan sifat optik dopan Erbium (Er^{3+}) dengan mencampurkan zarah nano Titanium dioksida (TiO_2) ke dalam kaca tellurite. Lima sampel kaca telah disediakan menggunakan teknik perlindapan leburan dengan komposisi (69-x)TeO_2-20ZnO-10Na_2O-1Er_2O_3-$x$$TiO_2$, dengan x = 0.1, 0.2, 0.3, 0.4 % mol. Sampel yang disediakan telah menjalani pencirian menggunakan pengukuran pembelauan sinar-X (XRD), mikroskop elektron transmisi (TEM), serakan tenaga sinar-X (EDX), inframerah transformasi Fourier (FTIR), Raman, ultra ungu-cahaya nampak-inframerah dekat (UV-Vis-NIR) dan kefotopendarcahayaan (PL). Corak XRD bagi sampel kaca lutsinar yang dihasil mengesahkan ia adalah bersifat amorfus dan imej TEM pula telah mendedahkan kewujudan NPs TiO_2 dengan saiz purata antara 16 hingga 22 nm. Spektrum EDX memaparkan kehadiran unsur Ti dalam sampel bersama unsur lain yang berpadanan. Spektrum FTIR dan Raman menunjukkan mod getaran berbeza bagi ikatan Te-O (pelenturan, regangan tidak simetri dan simetri) pada struktur unit TeO_4 dan TeO_3. Kaca yang mengandungi 0.4 % mol NPs TiO_2 memaparkan peningkatan isyarat Raman sebanyak 1.56 hingga 3.58 kali ganda bagi jalur berpusat disekitar 388, 495, 673, 758 dan 845 cm^{-1}. Peningkatan isyarat ini adalah disebabkan kesan bantuan SPR NPs TiO_2. Manakala, spektrum UV-Vis-NIR mempamerkan sepuluh jalur penyerapan berpusat di 407, 444, 452, 489, 522, 552, 653, 800, 976 dan 1532 nm. Spektrum penyerapan NPs TiO_2 adalah manifestasi dua jalur plasmon pada 552 (mod melintang) dan 580 (mod membujur). Spektrum PL mempamerkan tiga jalur utama berpusat pada 525, 545 dan 660 nm berpadanan dengan peralihan ion Er^{3+} dari keadaan teruja ($^2H_{11/2}$, $^4S_{3/2}$ dan $^4F_{9/2}$) ke keadaan dasar ($^4I_{15/2}$). Malahan, kaca yang mengandungi 0.2 % mol NPs TiO_2 mendedahkan peningkatan keamatan PL sebanyak 30.00, 28.57 kali ganda (bagi jalur hijau) dan 19.60 kali ganda (bagi jalur merah). Cerapan ini berpunca daripada kesan SPR dari NPs TiO_2 yang menghasilkan medan elektrik setempat yang kuat disekitar ion Er^{3+}. Pancaran cahaya hijau menunjukkan peningkatan tertinggi kerana kejadiannya berhampiran dengan jalur plasmon. Perlu ditegasankan bahawa kemasukan NPs TiO_2 ke dalam kaca menghasilkan kesan plasma yang mengubah penyerapan UV-Vis-NIR dan meningkatkan keamatan pancaran sampel. Hubungkait antara SPR dan peningkatan permukaan penyerakan Raman (SERS) telah dikenalpasti. Fungsi komposisi kaca semasa dalam kajian ini berkemungkinan berguna untuk aplikasi peralatan terutamanya dalam fotovolta dan laser keadaan pepejal.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	**ii**
	DEDICATION	**iii**
	ACKNOWLEDGEMENT	**iv**
	ABSTRACT	**v**
	ABSTRAK	**vi**
	TABLE OF CONTENTS	**vii**
	LIST OF TABLES	**xi**
	LIST OF FIGURES	**xiii**
	LIST OF ABBREVATIONS	**xvii**
	LIST OF APPENDICES	**xx**
1	**INTRODUCTION**	**1**
	1.1 Introduction	1
	1.2 Problem Statement	3
	1.3 Objectives	5
	1.4 Scope of Study	5
	1.5 Research Significance	6
	1.6 Thesis Outline	7

2	**LITERATURE REVIEW**	**9**
	2.1 Introduction	9
	2.2 Tellurite Glass	9
	2.2.1 General Properties	9
	2.2.2 Structural Properties	10
	2.2.3 Effect of Modifier to Tellurite Glass	12
	2.3 Rare Earth Ions	13
	2.3.1 Rare Earth as Dopant	13
	2.3.2 Erbium Ions	15
	2.4 Nanoparticles	16
	2.4.1 General Properties	16
	2.4.2 Titanium Dioxide Nanoparticles	17
	2.4.3 Nanoparticles Embedded Rare-Earth-Doped Glass	19
	2.5 Theory	22
	2.5.1 Interaction of Light with Metal Nanoparticles	22
	2.5.2 Surface Plasmon Resonance	23
	2.5.3 Energy Transfer	24
	2.5.4 Up and Down Conversion Phenomena	26
	2.5.5 Radiative and Non-Radiative Decay	30
	2.5.6 Oswald Ripening and Digestive Ripening Process	31
	2.5.7 Surface Enhanced Raman Scattering (SERS)	32
	2.5.8 Physical Properties of Tellurite Glass	33
	2.5.9 X-ray Diffraction	36
	2.5.10 Transmission Electron Microscopy	39
	2.5.11 Energy Disperse X-ray Spectroscopy	42

	2.5.12 Fourier Transform Infrared Spectroscopy	45
	2.5.13 Raman Spectroscopy	49
	2.5.14 UV-Vis-NIR Absorption Spectroscopy	54
	2.5.15 Photoluminescence Spectroscopy	59
3	**METHODOLOGY**	**64**
	3.1 Introduction	64
	3.2 Materials	64
	3.3 Mixing Glass Constituent	65
	3.4 Preparation of Glass	65
	3.5 Sample Characterization	67
	3.5.1 Physical Properties	68
	3.5.2 Structural Properties	68
	3.5.2.1 X-ray Diffractometer	68
	3.5.2.2 Transmission Electron Microscope	69
	3.5.2.3 Energy Dispersive X-ray Spectrometer	70
	3.5.2.4 Fourier Transform Infrared Spectrophotometer	71
	3.5.2.5 Raman Spectrometer	72
	3.5.3 Optical Properties	73
	3.5.3.1 UV-Vis-NIR Spectrophotometer	73
	3.5.3.2 Photoluminescence Spectrophotometer	74
4	**RESULTS AND DISCUSSIONS**	**76**
	4.1 Introduction	76
	4.2 Physical Properties	76
	4.3 Structural Properties	81

	4.3.1	XRD Pattern	81
	4.3.2	EDX Spectra	84
	4.3.3	TEM Micrograph	86
	4.3.4	Raman Spectral Analyses	86
	4.3.5	FTIR Analysis	90
	4.4	Optical Properties	93
	4.4.1	Surface Plasmon Resonance Band	93
	4.4.2	Absorption Spectra	94
	4.4.3	Photoluminescence Spectra	96
5		**CONCLUSION AND FURTHER OUTLOOK**	**106**
	5.1	Conclusions	106
	5.2	Further Outlook	108
		REFERENCES	**109**
		APPENDICES	**127**

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.1	Absorption band of TiO_2 in different glass system	19
2.2	Previous studies on metal NPs embedded RE-doped glass	21
2.3	Physical properties of Au NPs embedded Er^{3+}-doped tellurite glass	36
2.4	Main luminescence excitation bands and lines in REs	61
3.1	Compositions (in mol%) of TiO_2 NPs embedded Er^{3+}doped Zn-Na tellurite glass samples with their codes	65
4.1	Compositions (in mol %) of synthesized glass samples with their codes and physical appearances	77
4.2	(a) Glass code, average molecular weights, $M_v\left(g.mol^{-1}\right)$, refractive indices, n, densities, $\rho\left(g.cm^{-3}\right)$, molar volumes, $V_M\left(cm^3.mol^{-1}\right)$ and polarizabilities, $\alpha_e\left(\times 10^{-23} cm^3\right)$ and (b) direct E_{dir} and indirect E_{indir} $\left(eV\right)$ band gap and Urbach energy ΔE $\left(eV\right)$of respective glass samples	80
4.3	Weight and atomic percentage of element in TZNE0.4Ti	83
4.4	Band assignments of Raman Spectra for TZNE04.Ti	87
4.5	IR band assignment of prepared glass	93
4.6	Glass code, TiO_2 NPs concentration and maximum DC enhancement factor of respective glass samples	100

4.7 Glass code, TiO_2 NPs concentration, maximum UC enhancement factor (η_{max}) 103

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
2.1	Structure units in tellurite glass	11
2.2	Energy diagram of trivalent RE ions	14
2.3	Possible spectroscopic response between light and metal NPs	22
2.4	Schematic diagram of LSPR phenomenon	23
2.5	Schematic diagram (a) direct excitation of the activator and (b) indirect excitation followed by energy transfer from the sensitizer or host to the activator	25
2.6	Energy transfer process between NPs and RE ions	26
2.7	Schematic representations for (a) the typical down-conversion process (b) a simple up-conversion process	27
2.8	Principal up-conversion processes for RE-doped glass : (a) excited state absorption, (b) energy transfer up-conversion, (c) photon avalanche	28
2.9	Radiative and non-radiative decay process in two-level system	31

2.10	Schematic illustration of (a) Oswald ripening and (b) Digestive ripening process	32
2.11	Variation colour of erbium-doped tellurite glass	34
2.12	Schematic diagram of Bragg's diffraction from lattice planes	37
2.13	Schematic diagram of X-Ray Diffractometer	38
2.14	Typical XRD pattern of tellurite glass	39
2.15	Schematic diagram of TEM as electron beam pass through sample	41
2.16	TEM micrograph of glass matrix cointaining Au NPs	42
2.17	Schematic of electron transition	43
2.18	Schematic of Energy Dispersive X-ray Spectrometer (EDX)	44
2.19	EDX spectra of glass containing Au	45
2.20	Types of vibration	46
2.21	Michelson interferometer	48
2.22	FTIR spectra of erbium-doped tellurite glass containing Au NPs	49
2.23	Energy states of IR and Raman spectroscopy	52
2.24	Optical diagram of Raman spectrometer	53
2.25	Raman spectra at various concentration of Au NPs embedded in Er^{3+}-doped tellurite glass	53
2.26	Interaction of light on matter include absorbance, transmission and reflection	54
2.27	Schematic diagram of UV-Vis-NIR spectroscopy	58
2.28	Typical absorption spectra of erbium-doped tellurite glass embedded with various Au NPs concentration	59
2.29	Schematic diagram of fluorescence process	60

2.30	Essential component in fluorescence spectrometer	62
2.31	Luminescence spectra of Er-doped tellurite glass embedded with Au NPs	63
3.1	Graphical representation of melt-quenching technique in terms of cooling processes	66
3.2	Appearance of prepared glass sample	66
3.3	Flow chart of glass characterization	67
3.4	Analytical balance	68
3.5	XRD Diffractometer	69
3.6	TEM microscope	70
3.7	EDX spectrometer	71
3.8	FTIR spectrophotometer	72
3.9	Raman spectrophotometer	73
3.10	UV-Vis-NIR spectrophotometer	74
3.11	PL spectrophotometer	75
4.1	Variation colour of seven prepared samples	77
4.2	Tauc's plot for sample TZNE0.4Ti	80
4.3	Typical XRD pattern of the Er-doped tellurite glass for all prepared glass	82
4.4	EDX Spectra for TZNE0.4Ti with presence Ti element	83
4.5	TEM micrograph of TZNE0.2Ti and the average size distribution of TiO_2 NPs	84
4.6	TEM micrograph of TZNE0.3Ti and the average size distribution of TiO_2 NPs	85
4.7	TEM micrograph of TZNE0.4Ti and the average size distribution of TiO_2 NPs	85
4.8	Raman spectra of prepared glass samples	86
4.9	De-convoluted Raman spectra of Er-doped tellurite glass with 0.4 mol% of TiO2 NPs	87

4.10	Ratio of [TeO3]/[TeO4] against TiO2 NPs concentrations	89
4.11	Raman enhancement factor for all selected prepared glass	90
4.12	FTIR spectra of prepared glass in range 450-4000 cm^{-1}	91
4.13	SPR band of TZN0.4Ti glass at range 540-600 nm	94
4.14	UV-Vis-NIR absorption spectra of glass samples (a) in range 400-600 nm (b) in range 400-1600 nm	95
4.15	Excitation spectra of prepared glasses in the range of (a) 350-550 nm and (b) 550-800 nm	97
4.16	Luminescence spectra for (70-x)TeO_2-20ZnO-10Na_2O-Er_2O_3- xTiO_2 glass system under 490 nm excitation	99
4.17	Integrated luminescence intensity against TiO_2 NPs concentration for DC system	99
4.18	Emission spectra of Er^{3+} ion of all samples under the excitation wavelength 800 nm	101
4.19	De-convoluted fluorescence spectra of sample TZNE0.4Ti using Gaussian fit	101
4.20	TiO_2 NPs concentration dependent integrated PL intensity for UC system	103
4.21	Partial energy level diagram of Er^{3+} ion	105

LIST OF ABBREVATIONS

Au	-	Gold
Ag	-	Silver
BO	-	Bridging oxygen
CCD	-	Charge-coupled device
Ce	-	Cerium
CXA	-	Computer-assisted X-ray analyzer
CCD	-	Charge-coupled device
DC	-	Down-Conversion
Dy	-	Dysprosium
Er^{3+}	-	Erbium
EDX	-	Energy dispersive X-ray
ET	-	Energy transfer
Eu	-	Europium
ESA	-	Excited state absorption
ETU	-	Energy transfer up-conversion
eV		Electron volt
FTIR	-	Fourier transform infrared
FET	-	Field effect transistor

FFT	-	Fast Fourier transform
Gd	-	Gadolinium
GSA	-	Ground-state absorption
HRTEM	-	High resolution transmission electron microscopy
HST	-	Hypersensitive transition
Ho	-	Holmium
IR	-	Infrared
IUPAC	-	International union of pure and applied chemistry
KBr	-	Potassium bromide
LFE	-	Local field effect
La	-	Lanthanum
Lu	-	Lutetium
LPE	-	Lone pair electron
LSP	-	Localised surface plasmon
LSPR	-	Localised surface plasmon resonance
MRP	-	Multiphonon
MEF	-	Metal enhanced fluorescence
MCA	-	Multichannel analyzer
Na	-	Sodium
NPs	-	Nanoparticles
NIR	-	Near-Infrared
NBO	-	Non-bridging oxygen
Nd	-	Neodymium
NR	-	Non-radiative
Nd-YAG	-	Neodymium-doped yttrium aluminum garnet
OH-		Hydroxyl group
Pt	-	Platinum
PL	-	Photoluminescence
Pr	-	Praseodymium

Pm	-	Promethium
PA	-	Photon avalanche
RE	-	Rare earth
R	-	Radiative decay
SEM	-	Scanning electron microscope
SPR	-	Surface plasmon resonance
SERS	-	Surface enhance Raman scattering
Sc	-	Scandium
Sm	-	Samarium
SAXS	-	Small-angle X-ray scattering spectroscopy
Te	-	Tellurite
TiO_2	-	Titanium dioxide
TEM	-	Transmission electron microscope
Tbp	-	Trigonal bipyramid
Tp	-	Trigonal pyramid
Tb	-	Terbium
Tm	-	Thulium
UTM	-	Universiti Teknologi Malaysia
UV-Vis-NIR	-	Ultra violet-visible-near infrared
UC	-	Up-conversion
Vis	-	Visible
Xe	-	Xenon
XRD	-	X-ray diffraction
XRF	-	Fluorescence
XPS	-	X-Ray photoelectron spectroscopy
Y	-	Yttrium
Yb	-	Ytterbium
Zn	-	Zinc

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	List of Publication	127
B	Batch Glass Calculation	128
C	Uncertainty Calculation for Physical Properties	130
D	UV-Vis-NIR Absorption Properties of Prepared Glass	133
E	Calculations of Weight and Atomic Percentage of Atoms in Glass	135
F	EDX Measurement	139
G	De-convoluted Raman Spectra of all Glass Sample	142

CHAPTER 1

INTRODUCTION

1.1 Introduction

Glass represent one of the most important inorganic material in infrared photonic system due to its high-transparency and superior optical properties (Sun, 2013). Recently, RE-doped glasses attract much attention due to their high emission efficiencies as luminescence material in which the RE ions are capable to emits intense radiations in visible, IR and NIR region using suitable excitation wavelength (Ravi *et al.*, 2014). These beneficial features are useful for optical devices application such as infrared lasers and fibre amplifiers (Nogami *et al.*, 2000).

First solid-state lasers: Nd-doped glass was demonstrated in 1961 (Righini and Ferrari, 2005) and found to be efficient candidates for photonic devices such as fibre and microchip lasers, include planar waveguide as well (Raju *et al.*, 2013). Since then, glass doped with other REs like Er^{3+} receive great attention especially when transition wavelength of Er^{3+} ion at 1500nm is close to operational wavelength of optical communication. Remarkable result has been achieved by intense research on RE-doped glass to develop efficient laser host for photonic and optical devices (Righini and Ferrari, 2005).

Interest in Er^{3+}-doped glass has grown due to its potential in providing the up-converted visible fluorescence for varies optical application. Thus, enhancement of fluorescence in visible region is an important issue. Tellurite glass has been label as excellent hosts for Er^{3+} ions that has low phonon frequency cut-off compare to silica glass (Kishi and Tanabe, 2006; Peng *et al.*, 2014). It suppress non-radiative loss and subsequently increase the luminescence intensity of Er^{3+} ion in the glass (Sidebottom *et al.*, 1997). In fact, tellurite glass has non-hygroscopic properties which limit the usage of other glass such as phosphate and borate glass (Sidek *et al.*, 2009). However, high doping of Er^{3+} ions can cause luminescence quenching in tellurite glass. This phenomenon is attributed by interaction of Er^{3+} ions with hydroxyl (OH^-) groups (Dai *et al.*, 2006). Accordingly, these shortcoming need to be overcome to enhance the optical response of glass system.

Presently, vitreous materials with combination of RE ions and metallic NPs become a fruitful method to overcome these limitations. Interestingly, the presence of metal NPs in glass matrix is capable to intensify the luminescence intensity and enhance nonlinear optical properties of material. SPR effect is proven responsible to such significant enhancement of the optical properties of the material (de Almeida *et al.*, 2008). Au and Ag NPs are common plasmonic material used as second doping material in glass to increase luminescence properties of host glass based on their SPR effect. (Eichelbaum *et al.*, 2008; Eichelbaum and Rademann, 2009). In addition, they are really stable and hardly oxidised compare to other metal NPs. However, due to wide range of parameters for separate applications, it is impossible to address all the requirements using noble metals. Therefore, alternative materials are needed to optimize the performance (Guler *et al.*, 2015). Literature revealed that titanium dioxide (TiO_2) NPs also exhibit SPR properties (Abdulhalim *et al.*, 2008). However no literature reported the incorporation of pure TiO_2 NPs as sensitizer in RE ions doped tellurite glass. Other than that, TiO_2 NPs also considered as abundant low cost material with high chemical stability and photo-catalytic activity that safe towards both human and environment (Gupta and Tripathi, 2011).

Enhancement of Raman signal to several orders of magnitude due to molecule polarization is known as Surface Enhance Raman Scattering (SERS). Previous research have establish correlations between SPR and SERS enhancement by tuning SPR band using different NPs size and structure (Fleger and Rosenbluh, 2009). SPR is thought responsible for localised field enhancement to stimulate SERS (Darvill *et al.*, 2013). Of late, the SPR effects and SERS of titanium dioxide NPs (TiO_2 NPs) embedded erbium-tellurite glasses have not been explored. In addition, there is an insufficient systematic experimental and specific study particularly on SERS to explain the role of TiO_2 NPs embedded in Er^{3+}-doped tellurite glasses. Therefore, the present study focus on determine the role of TiO_2 NPs mediated SPR assisted electromagnetic interaction which is responsible in enhancing the optical properties of tellurite glasses containing low-concentration of Er^{3+} ions. Furthermore, the mechanism of SPR and SERS will be addressed in accordance for their potential in nanophotonics device applications.

1.2 Problem Statement

Emission of erbium ion in tellurite glass requires high intensity and gain enhancement for diverse applications. Embedment of metallic NPs in erbium doped tellurite glass is believed able to enhance the optical response via SPR effects (Reza Dousti *et al.*, 2013a). Unlike Au and Ag NPs, a detail studies on the mechanism of SPR enhanced optical properties mediated by pure TiO_2 NPs with varying concentration in tellurite-based glass materials is not fully understood (Awang *et al.*, 2013; Reza Dousti *et al*., 2013). Glass composition optimization due to the embedment of NPs in the glass matrix is pre-requisite to determine the modified properties. Therefore, optimization of TiO_2 NPs concentration inside erbium-doped tellurite glass need to be carried out.

Size, shape and distribution of metal NPs inside the glass significantly change the optical properties of the glass (Rivera *et al*., 2011). The variations of metal NPs size and shape in the glass matrix containing Er^{3+} ions able to modified the luminescence properties of Er^{3+} ions by altering its local symmetries through amplification of electric field intensity and efficient energy transfer from metal NPs to Er^{3+} ions (Awang *et al*., 2014). However no further investigations has been done to overlook the effect of changing TiO_2 NPs size and shape inside the glass containing Er^{3+} ions on the enhancement of local electric field and luminescence properties. Thus, further investigate is needed to identify the effect of different TiO_2 NPs size and shape on the optical properties of the glass in term of SPR effect.

There has been correlation between SERS and SPR effect of metal NPs with its different shape and size inside erbium-doped tellurite glass (Awang *et al*., 2013; Reza Dousti *et al*., 2013). Yet the relationship between the SPR effects and SERS of TiO_2 NPs in erbium-doped tellurite glasses has not been further studied. In addition, evolution of structural and optical properties in the presence of TiO_2 NPs and the role of SPR effects on overall glass properties have not reported yet. Therefore, the present study will provide new information regarding the structural and optical properties of tellurite glass doped at lower concentration of Er^{3+} ions embedded with varying concentrations of TiO_2 NPs. Correlation between SERS and SPR effect with presence TiO_2 NPs inside the Er^{3+}-doped tellurite glass will be establish. Overall, this study will provide the fundamental underlying physics of SPR in tellurite glass which useful for widespread applications.

1.3 Objectives

The objectives of this study are as follows:

i. To synthesize a series of glass by melt quenching technique with composition (69-*x*)TeO_2-20ZnO-10Na_2O-1Er_2O_3-(*x*)TiO_2, where x = 0, 0.1, 0.2, 0.3 and 0.4 mol%.
ii. To identify the existence of TiO_2 NPs and distinguish for different sizes and shapes in glass matrix using transmission electron microscopic (TEM) and energy dispersive X-ray (EDX) measurements.
iii. To determine the effect of different TiO_2 NPs concentration on structural properties of the glass include SERS effect using Infrared spectroscopy and Raman spectroscopy.
iv. To determine the role of TiO_2 NPs on absorption and emission properties of glass using ultra-violet-visible-near infrared (UV-Vis-NIR) spectroscopy and photoluminescence (PL) spectroscopy.

1.4 Scope of Study

Series of glass with composition of (69-*x*)TeO_2-20ZnO-10Na_2O-1Er_2O_3-(*x*)TiO_2 are prepared by melt-quenching technique. The composition of 70TeO_2–20ZnO–10Na_2O has been identified as promising Er^{3+} host matrix for photonic application (Souza *et al.*, 2002). Therefore, this glass composition is chosen due to its optimal performance. Tellurite has remarkable characteristic as host glass. Furthermore, ZnO will be added as modifier for better glass forming ability and reduce crystallization rates of tellurite network (Said Mahraz *et al.*, 2013). The addition of

Na_2O increase the solubility of RE ions in glass (Baki *et al.*, 2014). Metal oxide is chosen due to its chemical and mechanical stabilities (Clara Gonçalves *et al.*, 2002). Awang *et al.*, (2013) proposed that using 1.0 mol% of Er_2O_3 show the most intense UC luminescence for all spectral range in tellurite-zinc-sodium based glass system. Further addition of Er_2O_3 cause quenching effect on UC emission. Thus, 1.0 mol% concentration of Er_2O_3 is used in this glass system to avoid fluorescence quenching and to obtain optimum luminescence spectra. Accordingly, TiO_2 NPs with different concentration are incorporate into glass system to examine the SPR effect on the optical properties of the glass especially.

The amorphous nature of glass is determined using XRD. TEM is used to obtain the micrograph of NPs distribute in glass matrix and EDX analysis are performed to affirm the existence of TiO_2 NPs by tracing Ti element inside the sample. Vibrational structure of glass are determined using FTIR and Raman spectroscopy. The enhancement in Raman signal is determined to verify the correlation between SERS and SPR effect in tailoring the structural properties of glass. Meanwhile the absorption and emission spectra of glass are analyzed using UV-Vis-NIR and PL spectroscopy.

1.5 Research Significance

The relevance of present study leads to the improvement in fundamental understanding regarding mechanism of enhanced nonlinear optical properties of glass material. The systematic and controlled synthesis method is useful for large scale production of glasses at industrial level. The utilization of TiO_2 NPs instead of Au and Ag NPs is probable to extend a new knowledge regarding the effect of SPR and its relation with SERS on modification in optical properties of Er^{3+}-doped ZnO-Na_2O

tellurite glasses. This beneficial knowledge contributes to the fabrication of functional materials for various applications in the field of nanophotonics, photovoltaics and biology in general meanwhile plasmonic solar cells, lasers and self-cleaning glasses, in particular. The present study is also useful to bring new insight of the plasmonic nanoglass research with desired properties for industrial application in Malaysia.

1.6 Thesis Outline

This thesis consists of five chapters and describes the modification of optical properties in Er^{3+}-doped ZnO-Na_2O tellurite glass in the presence of TiO_2 NPs mediated the SPR effect. This study offers a systematic way of preparing glass using melt-quenching technique with selected glass composition and subsequent thorough characterizations in term of physical, structural and optical properties.

Chapter 1 provides brief introduction and motivation of this research. Problem statement and objective are included to show the research gap and ways to tackle such problem. The scope and significance of this research are also written in this chapter.

Chapter 2 offers general information regarding structure of tellurite glass including the role of Er^{3+} and TiO_2 NPs in glass network. The mechanism associated with SPR and SERS effect from TiO_2 NPs mediated modification in optical properties of the glass are also discussed. Theory relate to this work are included. Working principle and basic concept of instrument used in this work are presented and some overview of previous studies also attached.

Chapter 3 underscores the methodology of sample preparation and procedure executed to obtain results from instrument used. In addition, the in depth information regarding characterization in terms of physical properties, structural and optical properties of samples are emphasized.

Chapter 4 presents all the results of different characterizations include the discussion on the data analyses towards the fulfilment of the proposed objectives. The mechanisms responsible for enhancement or quenching of the sample are explained. The correlation between NPs size and spectroscopic modification are established.

Chapter 5 concludes the entire research to ensure research objectives are fulfilled. Many aspects has not fully explored due time restriction. However, the information gather from this research may beneficial for future directions.

Certain important calculations involving the methodology and the results that are not included in Chapter 4 are attached in the appendix.

REFERENCES

Abdelghany, A.M. and El-batal, H.A. (2013) Effect of TiO_2 doping and Gamma Ray Irradiation on the Properties of $SrO–B_2O_3$ Glasses. *Journal of Non-Crystalline Solids*, 379, 214–219.

Abdulhalim, I., Zourob, M., and Lakhtakia, A. (2008) Surface Plasmon Resonance for Biosensing: A Mini-Review. *Electromagnetics*, 28, 214–242.

Abdel-Baki, M., El-Diasty, F., and Wahab, F.A.A. (2006) Optical Characterization of $xTiO_2–(60−x)SiO_2–40Na_2O$ glasses: II. Absorption edge, Fermi level, Electronic Polarizability and Optical Basicity. *Optics Communications*, 261, 65–70.

Affatigato, M. (2015) Modern Glass Characterization. Wiley, New Jersey. 89.

Ahmmad, S.K., Samee, M.A., Edukondalu, A., and Rahman, S. (2012) Physical and Optical Properties of Zinc Arsenic Tellurite Glasses. *Results in Physics*, 2, 175–181.

Al-rawi, S.S., Jassim, A.H., and Al-hilli, H.A. (2006) FTIR Spectra of Molybdenum Tellurite Glasses. *Iraqi Journal of Appllied Physics*, 2, 23–25.

Alvarez-Ordóñez, A. and Prieto, M. (2012) *Fourier Transform Infrared Spectroscopy in Food Microbiology*. Springer, New York. 1-7.

Alim, K.A., Fonoberov, V.A., Shamsa, M., and Balandin, A.A. (2005) Micro-Raman Investigation of Optical Phonons in ZnO Nanocrystals. *Journal of Applied Physics*, 97.

Amjad, R.J., Sahar, M.R., Ghoshal, S.K., Dousti, M.R., Riaz, S., Samavati, A.R., Arifin, R., and Naseem, S. (2013a) Annealing Time Dependent Up-Conversion Luminescence Enhancement in Magnesium-Tellurite Glass. *Journal of Luminescence*, 136, 145–149.

Amjad, R.J., Sahar, M.R., Dousti, M.R., Ghoshal, S.K., and Jamaludin, M.N.A. (2013b) Surface Enhanced Raman Scattering and Plasmon Enhanced Fluorescence in Zinc-Tellurite Glass. *Optics Express*, 21, 14282–14290.

Amjad, R.J., Dousti, M.R., and Sahar, M.R. (2015) Spectroscopic Investigation and Judd–Ofelt Analysis of Silver Nanoparticles embedded Er^{3+}-doped Tellurite Glass. *Current Applied Physics*, 15, 1–7.

Arifin, R., Sahar, M. R., and Sulhadi, S. (2007) FTIR Spectroscopy Study on Tellurite doped Eu_2O_3 Glass. *Springer*, 15, 122–126.

Atwood, D.A. (2013) *The Rare Earth Elements: Fundamentals and Applications*. Wiley, Lexington, 390.

Awang, A., Ghoshal, S.K., Sahar, M.R., Reza Dousti, M., Amjad, R.J., and Nawaz, F. (2013) Enhanced Spectroscopic Properties and Judd–Ofelt Parameters of Er-doped Tellurite Glass: Effect of Gold Nanoparticles. *Current Applied Physics*, 13, 1813–1818.

Awang, A., Ghoshal, S.K., Sahar, M.R., Arifin, R., and Nawaz, F. (2014) Non-Spherical Gold Nanoparticles Mediated Surface Plasmon Resonance in Er^{3+} Doped Zinc-Sodium Tellurite Glasses: Role of Heat Treatment. *Journal of Luminescence*, 149, 138–143.

Awang, A., Ghoshal, S.K., Sahar, M.R., and Arifin, R. (2015) Gold Nanoparticles assisted Structural and Spectroscopic Modification in Er^{3+}-doped Zinc Sodium Tellurite Glass. *Optical Materials*, 42, 495–505.

Azmi, S.A.M. and Sahar, M.R. (2015) Optical Response and Magnetic Characteristic of Samarium doped Zinc Phosphate Glasses containing Nickel Nanoparticles. *Journal of Magnetism and Magnetic Materials*, 393, 341–346.

Azlan, M.N., Halimah, M.K., Shafinas, S.Z., and Daud, W.M. (2015) Electronic Polarizability of Zinc Borotellurite Glass System Containing Erbium Nanoparticles. *Materials Express*, 5, 211–218.

Badr, Y., Battisha, I.K., and Salem, M. A. (2008) Up-conversion Luminescence Application in Er^{3+}: TiO_2 Thin Film Prepared by Dip Coating Sol-Gel Route. *Indian Journal of Pure and Applied Physics*, 46, 706–711.

Baki, S.O., Tan, L.S., Kan, C.S., Kamari, H.M., Noor, A.S.M., and Mahdi, M.A. (2014) Spectroscopic Studies of Er^{3+}-Yb^{3+} codoped Multicomposition Tellurite Oxide Glass. *Advanced Materials Research*, 895, 323–333.

Barmina, E.V., Stratakis, E., Fotakis, K., and Shafeev, G.A. (2010) Generation of Nanostructures on Metals by Laser Ablation in Liquids: New Results. *Quantum Electronics*, 40, 1012.

Baynton, P.L. (1955) Colour of Tellurite Glasses. *Nature*, 691–692.

Burns, G. (1962) Shielding and Crystal Fields at Rare-Earth Ions. *Physical Review*, 128, 2121–2130.

Burlakov, V.M., Bootharaju, M.S., Besong, T.M.D., Bakar, O.M., and Goriely, A. (2014) Reversing Ostwald Ripening. *Cornell University Library*, Oxford. 1-15.

Callister, W.D. and Rethwisch, D.G. (2009) *Materials Science and Engineering: An Introduction, 8th Edition*. Wiley, Versailles. 75-78 .

Cao, G. and Wang, Y. (2011) *Nanostructures and Nanomaterials: Synthesis, Properties, and Applications*. World Scientific Series in Nanoscience and Nanotechnology, World Scientific, Danvers. 444-448.

Chen, Z., Dinh, H.N., and Miller, E. (2013) *Photoelectrochemical Water Splitting Standards, Experimental Methods, and Protocols*. Springer, New York. 49-52.

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

Dai, S., Yu, C., Zhou, G., Zhang, J., Wang, G., and Hu, L. (2006) Concentration Quenching in Erbium-doped Tellurite Glasses. *Journal of Luminescence*, 117, 39–45.

Daley, R. (2005) *Organic Chemistry, part 2 of 3*. Lulu.com, Southampton. 394-401.

Damak, K., Yousef, E., AlFaify, S., Rüssel, C., and Maâlej, R. (2014) Raman, Green and Infrared Emission Cross-Sections of Er^{3+} doped TZPPN Tellurite Glass. *Optical Materials Express*, 4, 597.

Dan, H.K., Zhou, D., Wang, R., Jiao, Q., Yang, Z., Song, Z., Yu, X., and Qiu, J. (2015) Effect of Copper Nanoparticles on the Enhancement of Upconversion in the Tb^{3+}/Yb^{3+} Co-Doped Transparent Glass–Ceramics. *Optical Materials*, 39, 160–166.

Darvill, D., Centeno, A., and Xie, F. (2013) Plasmonic Fluorescence Enhancement by Metal Nanostructures: Shaping the Future of Bionanotechnology. *Physical Chemistry Chemical Physics : PCCP*, 15, 15709–15726.

De Graef, M. (2003) *Introduction to Conventional Transmission Electron Microscopy*. Cambridge University Press, Cambridge. 1-3.

De Almeida, R., da Silva, D.M., Kassab, L.R.P., and de Araujo, C.B. (2008) Eu^{3+} Luminescence in Tellurite Glasses with Gold Nanostructures. *Optics Communications*, 281, 108–112.

Devi, N.B. (2015) *Fabrication of Nanostructures using Modified Dense Plasma Focus and their Characterization including Surface Plasmon Resonance*. Ph.D Thesis, University of Delhi. 154-155.

Di Bartolo, B. and Chen, X. (2001) Advances in Energy Transfer Processes: Proceedings of the 16th Course of the International School of Atomic and Molecular Spectroscopy. *World Scientific*, Erice Sicily. 261-272.

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

Dimitrov, V. and Sakka, S. (1996) Linear and Nonlinear Optical Properties Of Simple Oxides. II. *Journal of Applied Physics*, 79, 1741.

Dimitriev, Y., Dimitrov, V., and Arnaudov, M. (1983) IR Spectra and Structures of Tellurite Glasses. *Journal of Materials Science*, 18, 1353–1358.

Dousti, M.R., Sahar, M.R., Ghoshal, S.K., Amjad, R.J., and Arifin, R. (2012) Up-conversion Enhancement in Er^{3+}-Ag Co-Doped Zinc Tellurite Glass: Effect of Heat Treatment. *Journal of Non-Crystalline Solids*, 358, 2939–2942.

Dong, S., Dong, S., Zhou, D., Zhou, X., Ma, D., and Du, Y. (2015) Synthesis of Er^{3+}:Al_2O_3-doped and Rutile-Dominant TiO_2 Composite with Increased Responsive Wavelength Range and Enhanced Photocatalytic Performance Under Visible Light Irradiation. *Journal of Molecular Catalysis A: Chemical*, 407, 38–46.

Dousti, M.R., Sahar, M.R., Amjad, R.J., Ghoshal, S.K., and Awang, A. (2013) Surface Enhanced Raman Scattering and Up-conversion Emission by Silver Nanoparticles in Erbium–Zinc–Tellurite Glass. *Journal of Luminescence*, 143, 368–373.

Durhn, A. and Navarro, J.M.F. (1990) Characterization of Titanium Induced Optical Absorption Bands in Phosphate Glasses. *Jounal of Non-Cyrstalline Solids*, 127, 267–272.

Eichelbaum, M. and Rademann, K. (2009) Plasmonic Enhancement or Energy Transfer on the Luminescence of Gold-, Silver-, and Lanthanide-Doped Silicate Glasses and its Potential for Light-Emitting Devices. *Advanced Functional Materials*, 19, 2045–2052.

Eichelbaum, M., Rademann, K., Hoell, A., Tatchev, D.M., Weigel, W., Stößer, R., and Pacchioni, G. (2008) Photoluminescence of Atomic Gold and Silver Particles in Soda-Lime Silicate Glasses. *Nanotechnology*, 19, 135701.

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

El-mallawany, R. (2002) *Tellurite Glasses Handbook*. CRC Press, New York. 1-3.

Farouk, M. (2014) Effect Of TiO_2 on the Structural, Thermal and Optical Properties of BaO–Li_2O–Diborate Glasses. *Journal of Non-Crystalline Solids*, 402, 74–78.

Fedlheim, D.L. and Foss, C.A. (2001) *Metal Nanoparticles: Synthesis, Characterization, And Applications*. CRC Press, New York. 3-5.

Fleger, Y. and Rosenbluh, M. (2009) Surface Plasmons and Surface Enhanced Raman Spectra of Aggregated and Alloyed Gold-Silver Nanoparticles. *Advances in Nonlinear Optics*. 1–5.

Fuxi Gan. (1995) *Laser Materials*. World Scientific, Singapore. 286-296.

Gaft, M., Reisfeld, R., and Panczer, G. (2015) *Modern Luminescence Spectroscopy of Minerals and Materials*. Springer, Germany. 15-16.

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

Ghoshal, S.K., Awang, A., Sahar, M.R., Amjad, R.J., and Dousti, M.R. (2013) Spectroscopic and Structural Properties of TeO_2-ZnO-Na_2O-Er_2O_3-Au Glasses. *Chalcogenide Letters*, 10, 411–420.

Ghoshal, S.K., Awang, A., Sahar, M.R., and Arifin, R. (2015) Gold Nanoparticles assisted Surface Enhanced Raman Scattering and Luminescence of Er^{3+} Doped Zinc–Sodium Tellurite Glass. *Journal of Luminescence*, 159, 265–273.

Ghribi, N., Dutreilh-Colas, M., Duclère, J.-R., Hayakawa, T., Carreaud, J., Karray, R., Kabadou, A., and Thomas, P. (2015) Thermal, Optical and Structural Properties of Glasses within the TeO_2-TiO_2-ZnO System. *Journal of Alloys and Compounds*, 622, 333–340.

Ghoneim, N.A., Abdelghany, A.M., Abo-Naf, S.M., Moustafa, F.A., and Elbadry, K.M. (2013) Spectroscopic Studies of Lithium Phosphate, Lead Phosphate and Zinc Phosphate Glasses containing TiO_2: Effect Of Gamma Irradiation. *Journal of Molecular Structure*, 1035, 209–217.

Griffiths, P.R. and De Haseth, J.A. (2007) *Fourier Transform Infrared Spectrometry*. Wiley, New Jersey.19-20.

Grundmann, M. (2010) *Graduate Texts in Physics.* Springer, Cambridge. *59-61.*

Guery, G., Fargues, A., Cardinal, T., Dussauze, M., Adamietz, F., Rodriguez, V., Musgraves, J.D., Richardson, K., and Thomas, P. (2012) Impact Of Tellurite-Based Glass Structure on Raman Gain. *Chemical Physics Letters*, 554, 123–127.

Guglielmi, M., Kickelbick, G., and Martucci, A. (2014) *Sol-Gel Nanocomposites*. Springer, New York. 93-108

Guler, U., Shalaev, V.M., and Boltasseva, A. (2014) Nanoparticle Plasmonics : Going Practical with Transition Metal Nitrides. *Biochemical Pharmacology*, 1–11.

Gupta, S.M. and Tripathi, M. (2011) A Review of TiO_2 Nanoparticles. *Chinese Science Bulletin*, 56, 1639–1657.

Halimah, M.K., Daud, W.M., Sidek, H.A.A., Zaidan, A.W., and Zainal, A.S. (2010) Optical Properties of Ternary Tellurite Glasses. *Material Science Polymer*, 28, 173–180.

Health, J. (2014) *Energy dispersive spectroscopy*. Wiley, Chichester. 1-29.

Heitmann, J., Schmidt, M., Zacharias, M., Timoshenko, V.Y., Lisachenko, M.G., and Kashkarov, P.K. (2003) Fabrication and Photoluminescence Properties of Erbium doped Size-Controlled Silicon Nanocrystals. *Materials Science and Engineering B: Solid-State Materials for Advanced Technology*, 105, 214–220.

Hu, M., Chen, J., Li, Z.-Y., Au, L., Hartland, G. V, Li, X., Marquez, M., and Xia, Y. (2006) Gold Nanostructures: Engineering their Plasmonic Properties for Biomedical Applications. *Chemical Society reviews*, 35, 1084–1094.

Hu, Y., Qiu, J., Song, Z., Yang, Z., Yang, Y., Zhou, D., Jiao, Q., and Ma, C. (2014) Spectroscopic Properties of $Tm^{3+}/Er^{3+}/Yb^{3+}$ co-doped Oxyfluorogermanate Glasses Containing Silver Nanoparticles. *Journal of Luminescence*, 145, 512–517.

Huang, B., Zhou, Y., Yang, F., Wu, L., Qi, Y., and Li, J. (2016) The 1.53μm Spectroscopic Properties of $Er^{3+}/Ce^{3+}/Yb^{3+}$ tri-doped Tellurite Glasses Containing Silver Nanoparticles. *Optical Materials*, 51, 9–17.

Huang, Q., Chen, J., Zhao, J., Pan, J., Lei, W., and Zhang, Z. (2015) Enhanced Photoluminescence Property for Quantum Dot-Gold Nanoparticle *Hybrid. Nanoscale Research Letters*, 10, 1–6.

Hussein, N.S. and da Silva Santos, J.D. (2008) *Physics and Chemistry of Rare-earth Ions Doped Glasses*, Trans Tech, Switzerland. 6–7.

Islam, A., Haither, M.J., Khan, I., and Islam, M. (2012) Optical and Structural Characterization of TiO_2 Nanoparticles. *IOSR Journal*. 3, 18–24.

Ismail, S.F., Sahar, M.R., and Ghoshal, S.K. (2016a) Effects of Titanium Nanoparticles on Self-Cleaning and Structural Features of Zinc-Magnesium-Phosphate Glass. *Materials Research Bulletin*, 74, 502–506.

Ismail, S.F., Sahar, M.R., and Ghoshal, S.K. (2016b) Physical and Absorption Properties of Titanium Nanoparticles Incorporated into Zinc Magnesium Phosphate Glass. *Materials Characterization*, 111, 177–182.

Jha, A., Richards, B., Jose, G., Teddy-Fernandez, T., Joshi, P., Jiang, X., and Lousteau, J. (2012) Rare-earth ion doped TeO_2 and GeO_2 Glasses as Laser Materials. *Progress in Materials Science*, 57, 1426–1491.

Jian Hua Yao, K. R. Elder, Hong Guo, M.G. (1993) Theory and Stimulation of Ostwald Rippening. *Physical Review B, 47, 14110-14125*.

Jiang, Z., Wen, G., Luo, Y., Zhang, X., Liu, Q., and Liang, A. (2014) A New Silver Nanorod SPR Probe for Detection of Trace Benzoyl Peroxide. *Scientific Reports*, 4.

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

Jlassi, I., Elhouichet, H., and Ferid, M. (2011) Thermal and Optical Properties of Tellurite Glasses doped Erbium. *Journal of Materials Science*, 46, 806–812.

Jones, M., Fosbery, R., Gregory, J., and Taylor, D. (2014) *Cambridge International As and A Level Biology Coursebook.* Cambridge International Examinations, Cambridge University Press, Cambridge. 11-12.

Jose, R., Arai, Y., and Ohishi, Y. (2007) Raman Scattering Characteristics of the TBSN-Based Tellurite Glass System as a New Raman Gain Medium. *Journal of the Optical Society of America B*, 24, 1517.

Kafizas, A., Kellici, S., Darr, J. A., and Parkin, I.P. (2009) Titanium Dioxide and Composite Metal/Metal Oxide Titania Thin Films on Glass: A Comparative Study of Photocatalytic Activity. *Journal of Photochemistry and Photobiology A: Chemistry*, 204, 183–190.

Kalampounias, A.G., Papatheodorou, G.N., and Yannopoulos, S.N. (2006) A Temperature Dependence Raman Study of the $0.1Nb_2O_5$-$0.9TeO_2$ Glass-Forming System. *Journal of Physics and Chemistry of Solids*, 67, 725–731.

Kalampounias, A.G., Papatheodorou, G.N., and Yannopoulos, S.N. (2007) A Temperature-Dependent Raman Study of the *x*LiCl-(1-*x*)TeO2 Glasses and Melts. *Journal of Physics and Chemistry of Solids*, 68, 1029–1034.

Kalampounias, A.G., Nasikas, N.K., and Papatheodorou, G.N. (2011) Structural Investigations of the $xTeO_2(1-x)GeO_2$ (x=0, 0.2, 0.4, 0.6, 0.8 and 1.0) Tellurite Glasses: A Composition Dependent Raman Spectroscopic Study. *Journal of Physics and Chemistry of Solids*, 72, 1052–1056.

Kassab, L.R.P., Da Silva, D.S., and De Araújo, C.B. (2010) Influence of Metallic Nanoparticles on Electric-Dipole and Magnetic-Dipole Transitions of Eu^{3+} doped Germanate Glasses. *Journal of Applied Physics*, 107, 1–5.

Kaur, M., Singh, A., Thakur, V., and Singh, L. (2015) Effect of TiO_2 Substitution on Optical and Structural Aspects of Phosphate Glasses. *Journal of Molecular Structure*, 1089, 95–101.

Kaur, G., Kumar, M., Arora, A., Pandey, O.P., and Singh, K. (2011) Influence of Y_2O_3 on Structural and Optical Properties of SiO_2–BaO–ZnO–xB_2O_3–(10−x) Y_2O_3 Glasses and Glass Ceramics. *Journal of Non-Crystalline Solids*, 357, 858–863.

Kaviany, M. (2014) *Heat Transfer Physics*. Cambridge University Press, Cambridge. 577.

Kenyon, A.J. (2002) Recent Developments in Rare-Earth doped Materials for Optoelectronics. *Progress in Quantum Electronics*, 26, 225–284.

Khopkar, S.M. (1998) *Basic Concepts of Analytical Chemistry*. New Age International Publishers, Daryagaj. 248.

Kishi, Y. and Tanabe, S. (2006) Properties of Tm^{3+}-doped Germanotellurite Glasses for S-Band Amplifier. *Journal of the American Ceramic Society*, 89, 236–240.

Koechner, W. (1999) *Solid-State Laser Engineering: 5th edition*. Springer, New York. 21-22.

Kumar, C.S.S.R. (2013) *UV-VIS and Photoluminescence Spectroscopy for Nanomaterials Characterization*. Springer, New York. 1-60.

Kundu, R.S., Dhankhar, S., Punia, R., Nanda, K., and Kishore, N. (2014) Bismuth Modified Physical, Structural and Optical Properties of Mid-IR Transparent Zinc Boro-Tellurite Glasses. *Journal of Alloys and Compounds*, 587, 66–73.

Kneipp, K., Kneipp, H., Itzkan, I., Dasari, R.R., and Feld, M.S. (2002) Surface-Enhanced Raman Scattering and Biophysics. *Journal of Physics: Condensed Matter Matter*, 14, 597–624.

Kwaadgras, B.W., Verdult, M., Dijkstra, M., and Van Roij, R. (2011) Polarizability and Alignment of Dielectric Nanoparticles in an External Electric Field: Bowls, Dumbbells, and Cuboids. *Journal of Chemical Physics*, 135, 1–15.

Lakowicz, J.R. (2013) *Principles of Fluorescence Spectroscopy*. Springer, New York. 1-20.

Lakshmanan, A. (2008) *Luminescence and Display Phosphors: Phenomena and Applications*, Nova Science, 233.

Le Ru, E. and Etchegoin, P. (2008) Principles of Surface-Enhanced Raman Spectroscopy: And Related Plasmonic Effects. Elsevier, Oxord. 1-18.

Leng, Y. (2009) *Materials Characterization: Introduction to Microscopic and Spectroscopic Methods*. Wile, Hong Kong. 3-29.

Lewis, I.R. and Edwards, H. (2001) *Handbook of Raman Spectroscopy: From the Research Laboratory to the Process Line*. Practical Spectroscopy, CRC Press. New York. 1-2.

Lin-Vien, D., Colthup, N.B., Fateley, W.G., and Grasselli, J.G. (1991) *The Handbook of Infrared and Raman Characteristic Frequencies of Organic Molecules*. Academic Press, California. 1-7.

Liu, G. and Jacquier, B. (2005) *Spectroscopic Properties of Rare Earths in Optical Materials*. Materials Science, New York. 23-25.

Loehman, R.E. (2010) *Characterization of Ceramics*. Material Characterization Series: Surfaces, Interfaces and Thin Films, Momentum Press, New York. 51-52.

Long, Y.T. and Jing, C. (2014) *Localized Surface Plasmon Resonance Based Nanobiosensors*. Springer, New York. 3-6.

Lorentz, H.A. (1881) Concerning the Application of the Principle of Virial in the Kinetic Theory of Gases. *Annals of Physics*, 248, 127–136.

Lorenz, L. (1881) On the Thermal and Electrical Conductivities Of Metals. *Annals of Physics*, 249, 422–447.

Louis, C. and Pluchery, O. (2012) *Gold Nanoparticles for Physics, Chemistry and Biology*. Imperial College Press, Covent Garden. 47-50.

Luo, Z., Huang, Y., and Chen, X. (2007) *Spectroscopy of Solid-state Laser and Luminescent Materials*. Nova Science Publishers, New York. 209-225.

Luther, J.M., Jain, P.K., Ewers, T., and Alivisatos, A.P. (2011) Localized Surface Plasmon Resonances Arising from Free Carriers in Doped Quantum Dots. *Nature Material* 10, 361–366.

Madhusudan Reddy, K., Baruwati, B., Jayalakshmi, M., Mohan Rao, M., and Manorama, S. V. (2005) S-, N- and C-doped Titanium Dioxide Nanoparticles: Synthesis, Characterization and Redox Charge Transfer Study. *Journal of Solid State Chemistry*, 178, 3352–3358.

Manning, S., Ebendorff-Heidepriem, H., and Monro, T.M. (2012) Ternary Tellurite Glasses for the Fabrication of Nonlinear Optical Fibres. *Optical Materials Express*, 2, 140.

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

Mitome, M. (2006) Visibility of Si Nanoparticles Embedded in an Amorphous SiO_2 Matrix. *Journal of Electron Microscopy*, 55, 201–7.

Moawat, H.M., Toulouse, J., Jain, H., Latinovic, O., and Kortan, A.R. (2006). *Optoelectronic Materials and Technology in the Information Age*. The American Ceramic Society, Indianapolis. 45-50.

Mohamed, E.A., Ahmad, F., and Aly, K.A. (2012) Effect of Lithium Addition on Thermal and Optical Properties of Zinc–Tellurite Glass. *Journal of Alloys and Compounds*, 538, 230–236.

Mott, N.F. and Davis, E.A. (1979) *Electronic Processes in Non Crystalline Materials. Second Edition*. Clarendon Press, Oxford, 7. 273–284.

Murugan, G.S., Suzuki, T., and Ohishi, Y. (2006) Raman Characteristics and Nonlinear Optical Properties Of Tellurite and Phosphotellurite Glasses Containing Heavy Metal Oxides with Ultrabroad Raman Bands. *Journal of Applied Physics*, 100, 1–6.

Mustafa, I.S., Kamari, H.M., Yusoff, W.M.D.W., Aziz, S.A., and Rahman, A.A. (2013) Structural and Optical Properties of Lead-Boro-Tellurrite Glasses Induced by Gamma-Ray. *International Journal Of Molecular Sciences*, 14, 3201–3214.

Nandyala Sooraj Hussain and Jose Domingos Da Santos. (2015) *Physics and Chemistry of Rare-Earth Ions Doped Glasses*. Trans Tech Publications, Switzerland. 5-8.

Nawaz, F., Sahar, M.R., Ghoshal, S.K., Awang, A., and Amjad, R.J. (2014) Judd-Ofelt Analysis of Spectroscopic Properties of Sm^{3+} doped Sodium Tellurite Glasses co-doped with Yb^{3+}. *Journal of Luminescence*, 147, 90–96.

Ngo, Y.H., Li, D., Simon, G.P., and Garnier, G. (2011) Paper Surfaces Functionalized by Nanoparticles. *Advances in Colloid and Interface Science*, 163, 23–38.

Nogami, M., Nagakura, T., and Hayakawa, T. (2000) Site-Dependent Fluorescence and Hole-Burning Spectra of Eu^{3+}-Doped Al_2O_3-SiO_2 Glasses. *Journal of Luminescence*, 86, 117–123.

Noguez, C. (2007) Surface Plasmons on Metal Nanoparticles: The Influence of Shape and Physical Environment. *Journal Physical Chemistry C*, 111, 3806–3819.

Obadina, V.O. and Reddy, B.R. (2013) Investigation of Silver Nanostructures and Their Influence on the Fluorescence Spectrum of Erbium-Doped Glasses. *Optics and Photonics Journal*. 3, 45–50.

O’Donnell, M.D., Richardson, K., Stolen, R., Seddon, A. B., Furniss, D., Tikhomirov, V.K., Rivero, C., Ramme, M., Stegeman, R., Stegeman, G., Couzi, M., and Cardinal, T. (2007) Tellurite and Fluorotellurite Glasses For Fiberoptic Raman Amplifiers: Glass Characterization, Optical Properties, Raman Gain, Preliminary Fiberization, and Fiber Characterization. *Journal of the American Ceramic Society*, 90, 1448–1457.

Owen, A. (1996) *Fundamentals of UV-Visible Spectroscopy*. Agilent Technologies, Germany. 1, 1–136.

Ozin, G.A., Arsenault, A.C., Cademartiri, L., and Britain, R.S. (2009) *Nanochemistry: A Chemical Approach to Nanomaterials*. Royal Society of Chemistry, Great Britain. 226-227.

Pan, Z., Ueda, A., Aga, R., Burger, A., Mu, R., and Morgan, S.H. (2010) Spectroscopic Studies of Er^{3+} doped Ge-Ga-S Glass Containing Silver Nanoparticles. *Journal of Non-Crystalline Solids*, 356, 1097–1101.

Paramesh, G. and Varma, K.B.R. (2013) Mechanical Properties of Glasses and TiO_2 Nanocrystal Glass Composites in BaO-TiO_2-B_2O_3 System. *Journal of Non-Crystalline Solids*, 380, 128–134.

Patoka, P. (2011) Tunable Plasmonic Properties of Nanostructures Fabricated by Shadow Nanosphere Lithography. *Naturwissenschaften*. 8-11.

Pelant, I. and Valenta, J. (2012) *Luminescence Spectroscopy of Semiconductors*. Luminescence Spectroscopy of Semiconductors. Oxford University Press, New York. 148-153

Peña-Rodríguez, O. and Pal, U. (2011) Effects of Surface Oxidation on the Linear Optical Properties of Cu Nanoparticles. *Journal of the Optical Society of America B*, 28, 2735.

Peng, Y.P., Yuan, X., Zhang, J., and Zhang, L. (2014) The Effect of La_2O_3 in Tm^{3+}-Doped Germanate-Tellurite Glasses for ~2 μm Emission. *Scientific Reports*, 4, 1–5.

Petryayeva, E. and Krull, U.J. (2011) Localized Surface Plasmon Resonance: Nanostructures, Bioassays and Biosensing-A Review. *Analytica Chimica Acta*, 706, 8–24.

Pi, X.X., Cao, X.H., Fu, Z.X., Zhang, L., Han, P. De, Wang, L.X., and Zhang, Q.T. (2015) Application of Te-Based Glass in Silicon Solar Cells. *Acta Metallurgica Sinica (English Letters)*, 28, 223–229.

Polfer, N.C. and Dugourd, P. (2013) *Laser Photodissociation and Spectroscopy of Mass-separated Biomolecular Ions*. Lecture Notes in Chemistry, Springer International Publishing.

Polman, A. (2001) Erbium as a Probe of Everything? *Physica B: Condensed Matter*, 300, 78–90.

Prakash, G.V., Reddy, A.A., and Babu, S.S. (2011) *Optical Amplifiers from Rare-Earth co-doped Glass Waveguides*. Intech Open Access Publisher. 1-23.

Pukhov, K.K. and Sekatskii, S.K. (2014) Enhancement of Hypersensitive Transitions of Rare-Earth Ions in the Near Field of Nano-objects. *Optics and Spectroscopy*, 116, 712–714.

Quinten, M. (2010) *Optical Properties of Nanoparticle Systems: Mie and Beyond*. Wiley, Weinheim. 94-97.

Raju, C.N., Reddy, C.A., Sailaja, S., Seo, H.J., and Reddy, B.S. (2012) Judd–Ofelt Theory: Optical Absorption and NIR Emission Spectral Studies of Nd^{3+}:CdO–Bi_2O_3–B_2O_3 Glasses for Laser Applications. *Journal of Materials Science*, 47, 772–778.

Raju, K.V., Raju, C.N., Sailaja, S., and Reddy, B.S. (2013) Judd-Ofelt Analysis and Photoluminescence Properties Of RE^{3+} (RE = Er & Nd): Cadmium Lithium Boro Tellurite Glasses. *Solid State Sciences*, 15, 102–109.

Ramamoorthy, R.K., Bhatnagar, A K., Rocca, F., Mattarelli, M., and Montagna, M. (2012) Structural and Optical Characterization of the Local Environment of Er^{3+} Ions in PbO-ZnO Tellurite Glasses. *Journal of Physics. Condensed Matter : An Institute of Physics Journal*, 24, 1-8.

Rastar, A., Yazdanshenas, M.E., Rashidi, A., and Bidoki, S.M. (2013) Theoretical Review of Optical Properties of Nanoparticles. *Journal of Engineered Fabrics & Fibers (JEFF)*, 8, 85-96.

Ravi, O., Reddy, C.M., Reddy, B.S., and Prasad, B.D. (2014) Judd – Ofelt Analysis and Spectral Properties of Dy^{3+} Ions doped Niobium Containing Tellurium Calcium Zinc Borate Glasses. *Optics Communications*, 312, 263–268.

Ray, C.S. and Day, D.E. (2008) Structural Properties and Crystallization of Sodium Tellurite Glasses. *Croatica Chemica Acta*, 81, 9–16.

Reddy, M.S., Reddy, M.R., Nagarjuna, M., and Rao, P.R. (2009) Influence of Titanium ions on Spectroscopic and Dielectric Properties of PbO-Bi_2O_3-As_2O_3 Glasses. *IOP Conference Series: Materials Science and Engineering*. 1-4.

Reza Dousti, M. and Raheleh Hosseinian, S. (2014) Enhanced Upconversion Emission of Dy^{3+}-doped Tellurite Glass by Heat-Treated Silver Nanoparticles. *Journal of Luminescence*, 154, 218–223.

Reza Dousti, M., Sahar, M.R., Amjad, R.J., Ghoshal, S.K., Khorramnazari, A., Dordizadeh Basirabad, A., and Samavati, A. (2012) Enhanced Frequency Upconversion in Er^{3+}-doped Sodium Lead Tellurite Glass Containing Silver Nanoparticles. *The European Physical Journal D*, 66, 1–6.

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

Reza Dousti, M., Sahar, M.R., Rohani, M.S., Samavati, A., Mahraz, Z.A., Amjad, R.J., Awang, A., and Arifin, R. (2014) Nano-Silver Enhanced Luminescence of Eu^{3+}-doped Lead Tellurite Glass. *Journal of Molecular Structure*, 1065-1066, 39–42.

Righini, G.C. and Ferrari, M. (2005) Photoluminescence of Rare-Earth-doped Glasses. *Rivista del Nuovo Cimento*, 28, 1–53.

Rivera, V.A.G., Osorio, S.P.A., Manzani, D., Messaddeq, Y., Nunes, L.A.O., and Marega, E. (2011) Growth of Silver Nano-particle Embedded in Tellurite Glass: Interaction Between Localized Surface Plasmon Resonance and Er^{3+} ions. *Optical Materials*, 33, 888–892.

Rivera, V.A.G., Ledemi, Y., Osorio, S.P.A., Manzani, D., Messaddeq, Y., Nunes, L.A.O., and Marega, E. (2012) Efficient Plasmonic Coupling between Er^{3+}:(Ag/Au) in Tellurite Glasses. *Journal of Non-Crystalline Solids*, 358, 399–405.

Rolli, R., Wachtler, K., Wachtler, M., Bettinelli, M., Speghini, A., and Ajò, D. (2001) Optical Spectroscopy of Lanthanide Ions in ZnO-TeO_2 Glasses. *Spectrochimica Acta. Part A, Molecular And Biomolecular Spectroscopy*, 57, 2009–2017.

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, 3051–3056.

Rosmawati, S., Sidek, H.A.A., Zainal, A.T., and Mohd Zobir, H. (2008) Effect of Zinc on the Physical Properties of Tellurite Glass. *Journal of Applied Sciences*, 8, 1956–1961.

Said Mahraz, Z.A., Sahar, M.R., Ghoshal, S.K., and Reza Dousti, M. (2013) Concentration Dependent Luminescence Quenching of Er^{3+}-doped Zinc Boro-Tellurite Glass. *Journal of Luminescence*, 144, 139–145.

Sathyanarayana, D.N. (2001) *Electronic Absorption Spectroscopy and Related Techniques*. Universities Press,Mumbai. 9-12.

Sazali, E.S., Sahar, M.R., Ghoshal, S.K., Arifin, R., Rohani, M.S., and Awang, A. (2014) Optical Properties of Gold Nanoparticle embedded Er^{3+} doped Lead–Tellurite Glasses. *Journal of Alloys and Compounds*, 607, 85–90.

Schasfoort, R.B.M. and Tudos, A.J. (2008) *Handbook of Surface Plasmon Resonance*. Royal Society of Chemistry, Cambridge. 1-2.

Sekiya, T., Mochida, N., Ohtsuka, A., and Tonokawa, M. (1989) Normal Vibrations of Two Polymorphic forms of TeO_2 Crystals and Assignments of Raman Peaks of Pure TeO_2 Glass. *Journal of the Ceramic Society of Japan*, 97, 1435–1440.

Sekiya, T., Mochida, N., Ohtsuka, A., and Tonokawa, M. (1992) Raman Spectra of $MO_{1/2}TeO_2$ (M = Li, Na, K, Rb, Cs and Tl) Glasses. *Journal of Non-Crystalline Solids*, 144, 128–144.

Sekiya, T., Mochida, N., and Ohtsuka, A. (1994) Raman Spectra of MO-TeO_2 (M = Mg, Sr, Ba and Zn) Glasses. *Journal of Non-Crystalline Solids*, 168, 106–114.

Sharma, A. and Schulman, S.G. (1999) *Introduction to Fluorescence Spectroscopy*. Wiley, New York. 63-64.

Sharma, H., Agarwal, D.C., Shukla, A. K., Avasthi, D.K., and Vankar, V.D. (2013) Surface-Enhanced Raman Scattering and Fluorescence Emission of Gold Nanoparticle-Multiwalled Carbon Nanotube Hybrids. *Journal of Raman Spectroscopy*, 44, 12–20.

Shen, C., Wang, Y.J., Xu, J.H., and Luo, G.S. (2012) Facile Synthesis and Photocatalytic Properties of TiO_2 Nanoparticles Supported on Porous Glass Beads. *Chemical Engineering Journal*, 209, 478–485.

Shi, H., Magaye, R., Castranova, V., and Zhao, J. (2013) Titanium Dioxide Nanoparticles: A Review of Current Toxicological Data. *Particle and Fibre Toxicology*, 10, 15.

Shinde, K.N., Dhoble, S.J., Swart, H.C., and Park, K. (2012) Phosphate Phosphors for Solid-State Lighting. *Phosphate Phosphors for Solid-State Lighting*, 174, 41–60.

Sidebottom, D.L., Hruschka, M. A., Potter, B.G., and Brow, R.K. (1997) Structure and Optical Properties of Rare Earth-doped Zinc Oxyhalide Tellurite Glasses. *Journal of Non-Crystalline Solids*, 222, 282–289.

Sidek, H., El-Mallawany, R., Badaron, S., Kamari, H., and Matori, K. (2015) Optical Properties of Erbium Zinc Tellurite Glass System. *Advance in Material Science and Engineering*, 5.

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

Siesler, H.W., Ozaki, Y., Kawata, S., and Heise, H.M. (2008) *Near-Infrared Spectroscopy: Principles, Instruments, Applications*. Wiley, British. 27-28.

Da Silva, D.M., Kassab, L.R.P., Lüthi, S.R., de Araújo, C.B., Gomes, A.S.L., and Bell, M.J.V. (2007) Frequency Upconversion in Er^{3+} doped $PbO–GeO_2$ Glasses Containing Metallic Nanoparticles. *Applied Physics Letters*, 90, 081913.

Singh, S.K., Giri, N.K., Rai, D.K., and Rai, S.B. (2010) Enhanced Upconversion Emission in E^{r3+}-Doped Tellurite Glass Containing Silver Nanoparticles. *Solid State Sciences*, 12, 1480–1483.

Skoog, D.A., Holler, F.J., and Crouch, S.R. (2007) *Principles of Instrumental Analysis*. Cengage Learning, California. 314-315.

Smith, B.C. (1995) *Fundamentals of Fourier Transform Infrared Spectroscopy*. Taylor & Francis, Florida, 1-19.

Soltani, I., Hraiech, S., Horchani-naifer, K., Elhouichet, H., and Férid, M. (2015) Effect of Silver Nanoparticles on Spectroscopic Properties of Er^{3+} Doped Phosphate Glass. *Optical Materials*, 46, 1–7.

Som, T. and Karmakar, B. (2009) Nanosilver Enhanced Up-conversion Fluorescence of Erbium Ions in Er^{3+}: Ag-Antimony Glass Nanocomposites. *Journal of Applied Physics*, 105.

Souza, N.M., Ramos, A.Y., and Barbosa, L.C. (2002) Er^{3+} Environment in TeO_2–ZnO–Na_2O Glasses. *Journal of Non-Crystalline Solids*, 304, 195–199.

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

Stuart, B.H. (2004) *Infrared Spectroscopy: Fundamentals and Applications*. Analytical Techniques in the Sciences, Wiley, Chichester.18-38.

Subrahmanyam, N., Lal, B., and Avadhanulu, M.N. (2004) *A Text Book of Optics (m.e.)*. S. Chand Limited, New Delhi. 611-620.

Sun, D.W. (2009) *Infrared Spectroscopy for Food Quality Analysis and Control*. Academic Press, Ireland. 146-176.

Sun, H.T. (2013) Inorganic Photonic Materials for Lasers and Biomedicine in the Infrared. *Cornell University Library*. 1-5.

Tanko, Y.A., Sahar, M.R., and Ghoshal, S.K. (2016) Prominent Spectral Features Of Sm^{3+} Ion In Disordered Zinc Tellurite Glass. *Results in Physics*, 6, 7–11.

Tadros, T. (2013) Ostwald Ripening. *Encyclopedia of Colloid and Interface Science*. Springer, Berkshire. 819-820.

Thanh, N.T.K., Maclean, N., and Mahiddine, S. (2014) Mechanisms of Nucleation and Growth of Nanoparticles in Solution. *Chemical Reviews*, 114, 7610–30.

Thakur, V.K. and Singha, A.S. (2015) *Surface Modification of Biopolymers*. Wiley, New Jersey. 335-339.

Theivasanthi.T and Alagar.M. (2013) Titanium dioxide (TiO_2) Nanoparticles XRD Analyses: An Insight. *Cornell University Library. 1-10.*

Toma, H.E., Zamarion, V.M., Toma, S.H., and Araki, K. (2010) The Coordination Chemistry at Gold Nanoparticles. *Journal of The Brazilian Chemical Society*, 21, 1158–1176.

Turrell, G. and Corset, J. (1996) *Raman Microscopy: Developments and Applications*.Academic Press, California. 27-28.

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

Vaughan, D. (1999) *Energy-Dispersive X-Ray Microanalysis: An Introduction*. Kevex Instruments, Sunnyvale.1-10.

Wang, J.S., Vogel, E.M., and Snitzer, E. (1994) Tellurite Glass: A New Candidate For Fiber Devices. *Optical Materials*, 3, 187–203.

Wang, R.P. (2014) *Amorphous Chalcogenides: Advances and Applications*. CRC Press, Boca Raton. 273-275.

Watt, I.M. (1997) *The Principles and Practice of Electron Microscopy*. Cambridge University Press, Cambridge. 60-65.

West, P.R., Ishii, S., Naik, G. V, Emani, N.K., Shalaev, V.M., and Boltasseva, A. (2010) Searching for Better Plasmonic Materials. *Laser & Photonics Reviews*, 4, 795–808.

Widanarto, W., Sahar, M.R., Ghoshal, S.K., Arifin, R., Rohani, M.S., Hamzah, K., and Jandra, M. (2013) Natural Fe_3O_4 Nanoparticles embedded Zinc-Tellurite Glasses: Polarizability and Optical Properties. *Materials Chemistry and Physics*, 138, 174–178.

Willets, K. A and Van Duyne, R.P. (2007) Localized Surface Plasmon Resonance Spectroscopy and Sensing. *Annual Review of Physical Chemistry*, 58, 267–97.

Wu, Y., Shen, X., Dai, S., Xu, Y., Chen, F., Lin, C., and Xu, T. (2011) Silver Nanoparticles Enhanced Up-conversion Luminescence in Er $^{3+}$ / Yb $^{3+}$ co-doped Bismuth-Germanate Glasses. *Journal of Physical Chemistry*, 25040–25045.

Xu, S., Liu, Y., Li, H., and Xu, W. (2011) Surface-Enhanced Raman scattering (SERS) based on Surface Plasmon Resonance Coupling Techniques. *Frontiers of Chemistry in China*, 6, 341–354.

Zhang, J., Wu, Y., Xing, M., Leghari, S.A.K., and Sajjad, S. (2010) Development of Modified N-Doped TiO_2 Photocatalyst with Metals, Nonmetals and Metal Oxides. *Energy & Environmental Science*, 3, 715.

Zhang, L. and Hu, H. (2003) The Fluorescence Properties of Highly-doped Erbium Fluoroaluminate Glass Pumped at 800 and 980 nm. *Journal of Non-Crystalline Solids*, 326-327, 353–358.

Zhang, W., Lin, J., Cheng, M., Zhang, S., Jia, Y., and Zhao, J. (2015) Radiative Transition, Local Field Enhancement and Energy Transfer Microcosmic Mechanism of Tellurite Glasses Containing Er^{3+}, Yb^{3+} Ions and Ag Nanoparticles. *Journal of Quantitative Spectroscopy and Radiative Transfer*, 159, 39–52.