OPTICAL PROPERTIES AND EMISSION CROSS-SECTION OF NEODYMIUM NANOPARTICLES DOPED TELLURITE GLASS COATED WITH GRAPHENE OXIDE/ REDUCED GRAPHENE OXIDE

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UNIVERSITI PENDIDIKAN SULTAN IDRIS

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HAFIZAH RAJAA BINTI SHAARI

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ABSTRACT

This study investigated the optical properties of neodymium nanoparticles (NPs) doped tellurite glass coated with graphene oxide (GO)/ reduced graphene oxide (rGO). Two series of glasses were prepared and coated using melt-quenching and spray-coating methods. The X-ray diffractograms proved the amorphous structure of the glass series. The presence of non-bridging oxygens in the glass network were proven via FTIR analysis. Meanwhile, the existence of neodymium nanoparticles in the tellurite glass network were confirmed using TEM analysis. FESEM and EDX analysis showed the morphologies of GO and rGO on the glass surface and their chemical elements, respectively. From UV-Vis spectroscopy analysis, the optical band gaps of ZBTNd (NPs)-GO and ZBTNd (NPs)-rGO were found in the range 2.355-2.998 eV and 2.770-3.125 eV, respectively. Meanwhile, the refractive index of ZBTNd (NPs)-GO and ZBTNd (NPs)-rGO were 2.041-2.194 and 2.339-2.657, respectively. Furthermore, the oxide ion polarizability ($\alpha_{o^{2-}}$) of ZBTNd (NPs)-GO and ZBTNd (NPs)-rGO were 3.453-3.854 Å and 3.360-3.664 Å, respectively. The optical basicity (Λ) values for ZBTNd (NPs)-GO and ZBTNd (NPs)-rGO were 1.220 to 1.262 and 1.174 to 1.214, respectively. The metallization criteria (M) for both glass series demonstrate that the glass system has acceptable optical nonlinearity in the range of $0.3 < M < 0.4$. The nephelauxetic ratio (β) and bonding parameter (δ) indicate the covalency nature in both glass series. The emission cross-section spectra and gains of the neodymium ions (Nd^{3+}) at the transitions of $^4F_{3/2} \rightarrow {}^4I_{15/2}$ and $^4F_{3/2} \rightarrow {}^4I_{13/2}$ were examined using the McCumber theory. All glass series indicate a positive increase of more than 60% in population inversion. In conclusion, the coating of GO and rGO on the tellurite glass surface gives significant effects on the overall optical properties. Implication of this study is it can offer new advancements in the glass coating field for laser glass.

SIFAT OPTIK DAN KERATAN RENTAS PELEPASAN BAGI KACA TELURIT DIDOP NEODIMIUM NANOZARAH DISALUT DENGAN GRAFIN OKSIDA/GRAFIN OKSIDA TERTURUN

ABSTRAK

Kajian ini menyiasat sifat optik kaca telurit didopkan nanozarah (NPs) neodimium bersalut dengan grafin oksida (GO)/ grafin oksida terturun (rGO). Dua siri kaca disediakan dan disalut menggunakan kaedah sepuh lindap dan semburan salutan. Difraktogram sinar-X membuktikan bahawa siri kaca ini mempunyai sifat amorfus. Kehadiran oksigen tidak bersambungan dalam rangkaian kaca telah dibuktikan melalui analisis FTIR. Manakala, kewujudan nanozarah neodimium dalam rangkaian kaca telurit telah disahkan menggunakan analisis TEM. Analisis FESEM dan EDX masing-masing menunjukkan morfologi GO dan rGO pada permukaan kaca dan unsur kimianya. Daripada analisis spectroskopi UV-Vis, jurang jalur tenaga optik ZBTNd (NPs)-GO dan ZBTNd (NPs)-rGO masing-masing didapati dalam julat 2.355-2.998 eV dan 2.770-3.125 eV. Sementara itu, indeks biasan ZBTNd (NPs)-GO dan ZBTNd (NPs)-rGO masing-masing ditentukan dalam julat 2.041-2.194 dan 2.339-2.657. Tambahan pula, kebolehpolaran ion oksida ($\alpha_{o^{2-}}$) ZBTNd (NPs) - GO dan ZBTNd (NPs) - rGO masing-masing ialah 3.453-3.854 Å dan 3.360-3.664 Å. Nilai kebesan optik (Λ) untuk ZBTNd (NPs)-GO dan ZBTNd (NPs)-rGO masing-masing ialah 1.220 hingga 1.262 dan 1.174 hingga 1.214. Kriteria perlogaman (M) untuk kedua-dua siri kaca menunjukkan bahawa sistem kaca mempunyai ketidaklinearan optik yang boleh diterima dalam julat $0.3 < M < 0.4$. Nisbah nefelauksetik (β) dan parameter ikatan (δ) menunjukkan sifat kovalen dalam kedua-dua siri kaca. Spektrum keratan rentas pelepasan dan perolehan peralihan ion neodimium Nd^{3+} pada transisi $^4F_{3/2} \rightarrow {^4I_{15/2}}$ dan $^4F_{3/2} \rightarrow {^4I_{13/2}}$ diuji berasaskan teori McCumber. Semua siri kaca ini menunjukkan peningkatan positif lebih daripada 60% dalam penyongsangan populasi. Kesimpulannya, salutan GO dan rGO pada permukaan kaca tellurit memberikan kesan yang signifikan kepada sifat optik secara keseluruhan. Implikasi kajian ini adalah ia dapat menawarkan kemajuan yang baru dalam bidang salutan kaca dalam kaca laser.

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LIST OF ABBREVIATION

ΔE	Energy	joule (J)
ΔEu	Urbach Energy	Joule (J)/eV
ΔEu	Urbach Energy	Joule (J)/eV
A	Area	m^2
Ag	silver	-
Au	gold	-
B_2O_3	Borate oxide	-
BO	bridging oxygen	-
d	Thickness	m
EDX	Energy Dispersive X-ray	-
E_{opt}	Optical energy gap	Joule (J)/eV
FESEM	Field Emission Scanning Electron Microscope	-
FTIR	Fourier Transform Infrared	-
GO	Graphene Oxide	-
K_B	Boltzmann constant	-
M	Metallization criterion	-
n	Refractive index	-
N_A	Avogadro number	mol^{-1}

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NBO	Non Bridging Oxygen	-
Nd_2O_3	Neodymium oxide	-
Nd^{3+}	Neodymium Ion	-
Nps	Nanoparticles	-
RE	Rare-earth	-
REIs	Rare-earth ions	-
rGO	Reduced Graphene Oxide (rGO)	-
T	Temperature	degree celcius
TEM	Transmission Electron Microscopy	-
TeO_3	Trigonal Pyramid	-
TeO_4	Trigonal Bipyramid	-
Vm	Molar volume	m^3/mol
XRD	X-Ray Diffraction	-
ZBTNd (NPs)	Neodymium Nanoparticles Doped Zincborotellurite	
ZBTNd (NPs)-GO	Graphene Oxide Coated Neodymium Nanoparticles Doped Zincborotellurite	
ZBTNd (NPs)-rGO	Reduced Graphene Oxide Coated Neodymium Nanoparticles Doped Zincborotellurite	
ZnO	Zinc Oxide	
α_e	Electronic Polarizability	$Å^3$
α_o^{2-}	Oxide Ion Polarizability	$Å^3$
β	Nephelauxetic ratio	-

δ	Bonding parameter	-
Λ	Optical basicity	-
λ	Wavelength	m
ρ	Density	kg/m^3
υ_a	Wavenumber aquo-ion	cm^{-1}
υ_c	Wavenumber host matrix	cm^{-1}
ω	Radian Frequency	Fm^{-1}
$\hbar\omega$	Photon energy	Joule (J)/eV

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter describes a brief introduction to the research background, research problems and objectives. The significance of the studies, scopes and limitations of the study are presented in this chapter. In addition, the explanation overview of the research work is presented in Figure 1.1. The last part of this chapter ended with a summary of the thesis outline.

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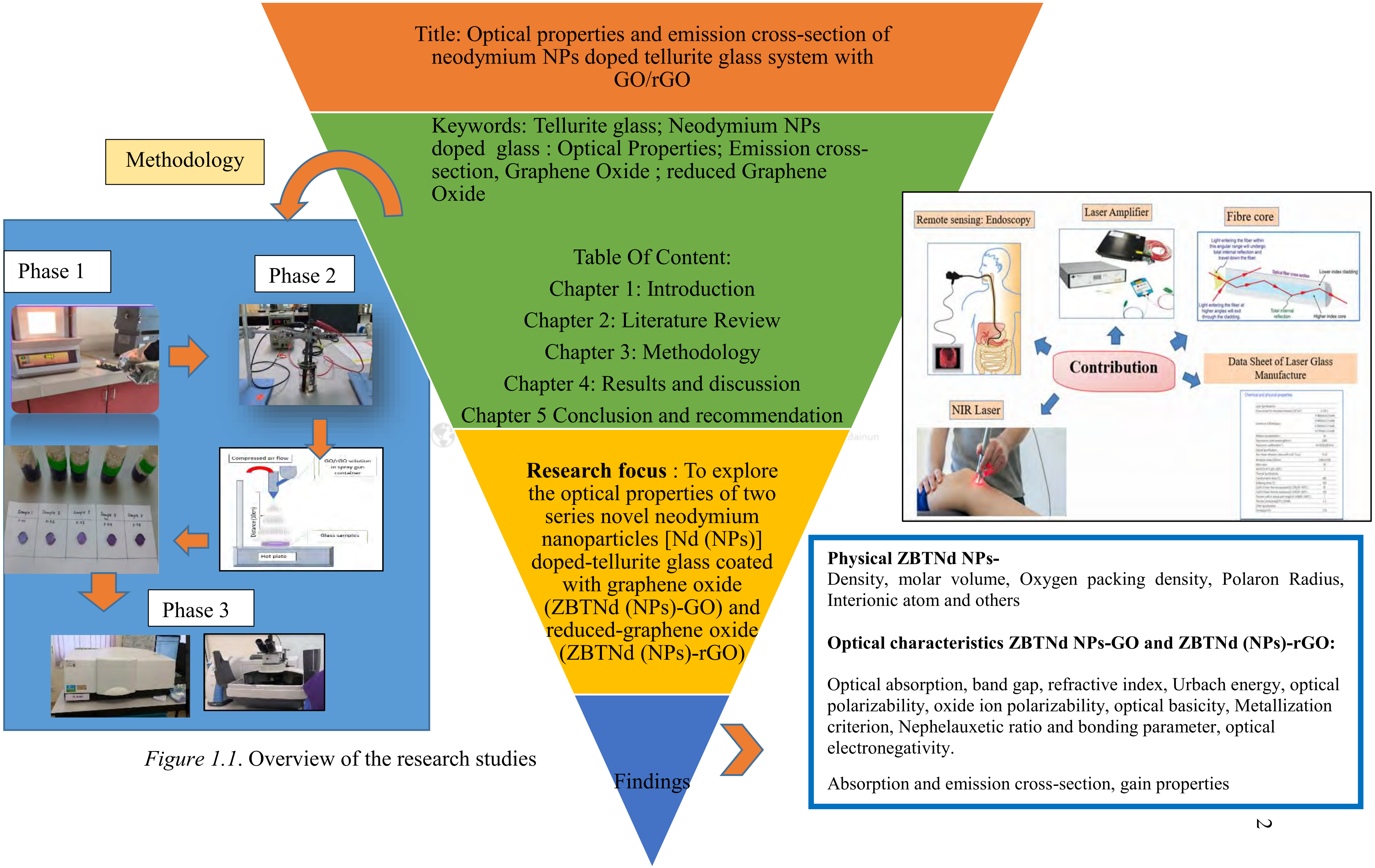

Figure 1.1. Overview of the research studies

1.2 Research Background

Glass is a multipurpose material that is used frequently in many applications. Glass can be a stiff, brittle, and transparent solid. This characteristic demonstrates that glass has exceptional qualities for technological and decorative applications. Furthermore, glass has the advantages of being recyclable, chemically resistant, and durable in a wide range of temperatures. These characteristics demonstrates the importance of glass in technological applications, including architecture, packaging, glassware, photovoltaics, and the most cutting-edge fields of microelectronics and photonics (Sidek, 2011).

In the context of photonics applications, particularly telecommunications and laser applications, advanced glass materials are used to manufacture glass optical fibres and optical components (Righini, 2022). Thus, further research is required to produce optical fibre glass materials that can transmit more signals in telecommunications systems and serve as fibre and laser amplifiers (Azlan, 2016). Some researchers, for instance, have enhanced the performance of existing glass by incorporating rare earth elements such as erbium, ytterbium, neodymium, thullium, samarium, gadolinium and others (Kaewkhao et al., 2022; Manzani et al., 2012; Su et al., 2018; Tafida et al., 2023; Eevon et al., 2016) particularly those pertaining to its structure and optical quality. In order to avoid issues such as high production, instability in glass properties, and the tendency for glass to break, it is crucial to minimise defects during glass production (Azlan et al., 2019). Furthermore, replacing existing glass optical materials necessitates the selection of glass materials with superior optical quality and exceptional stability. Thus, several drawbacks must be overcome to manufacture better optical materials for glass fibre optics and laser technology.

According to El-Mallawany (2011), tellurite glasses have scientific and technological significance due to their physical and optical properties. Tellurite oxide is the most stable oxide and its properties inspired scientists to conduct research. This substance possesses chemical resistance, a higher normal index, thermal resistance, and non-hygroscopic properties (Pandarinath et al., 2016). Moreover, tellurite-based glass possesses a high third-order nonlinear susceptibility, making it suitable for use in optical amplifiers (Gayathri Pavani et al., 2011). In addition, tellurite glass has a lower phonon energy than host glasses containing borate, phosphate, silicate, and germanate. Table 1.1 lists the categories of glass and their respective phonon energies. According to Tarafdeer et al., (2016) glass with a high phonon energy would show weak optical absorption cross sections, large non-radiative energy loss, and reduced upconversion luminescence performance. Table 1.2 compares the tellurite in chalcogenide, fluoride, and silica glasses. The exceptional optical and physical characteristics of tellurite-based glass make it the ideal substrate for photonic applications (Wang et al., 1994).

Meanwhile, Stambouli et al., (2012) stated that tellurite glass is widely recognised to be a potential host for photonic glass owing to its exceptional stability with rare-earth (RE) ions, a wide-reaching radiation window, and its ability to function well as a laser host, among other things. This glass has a high refractive index of 2.0 and is chemically stable, making it a superior choice compared to other glasses like borate, germinate, silicate, and phosphate glasses (Azlan et al., 2019; Sharma et al., 2022).

Table 1.1

Phonon energy of different glass hosts

Glass hosts	Phonon Energy (cm^{-1})
Borate	1400
Phosphate	1200
Silica	1100
Germanate	900
Tellurite	700

Adapted from Tarafder et al., 2016

Table 1.2

Comparing tellurite, silica, fluoride, and chalcogenide glasses.

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

Adapted from Wang et., al 1994

Ternary tellurite-based glass systems are stable due to the combination of the glass modifier and glass former. Due to its instability and propensity to crystallise, pure TeO_2 cannot by itself produce glass (Azlan, 2016; Hasim, 2014). TeO_2 must be modified with substances like alkali, alkali earth, and transition metal oxide to improve its capacity to form glass. In particular, the physical features, density, optical qualities, and mechanical durability of glass systems may change as a result of the inclusion of these modifiers (Effendy et al., 2021).

Tellurium oxide (TeO_2), borate oxide and zinc oxide are regarded as the optimal choices for modifying tellurite-based glass systems. According to reports, incorporating borate into TeO_2 glass increases infrared transmission and reduces hygroscopicity. (Azlan et al., 2017). Some researchers believe that B_2O_3 is an exceptional glass-forming element because it can exist with three or four coordinates and produce stable glasses. It has tremendous potential as a novel optical device. Due to its highly soluble with rare-earth ions and strong B-O covalent bonds. Furthermore, incorporation of a small quantity of TeO_2 to the borate glass matrix enhances both the transparency and refractive index of the glass, thereby augmenting its overall quality.(Ami Hazlin et al., 2017; Faznny et al., 2017; Gayathri Pavani et al., 2011; Halimah et al., 2020; Pandarinath et al., 2016).

In order to enhance the rigidity, chemical resistance, and thermodynamic properties development of glass systems, zinc oxide has been used as glass modifier. The inclusion of zinc oxide within the glass matrix reduces the crystallization rate. Zinc oxide may act as a network former or network modifier that may infiltrate the glass structure. As a network modifier, ZnO causes the formation of non-bonding oxygens (NBOs) by breaking the Te-O-Te bond (Effendy et al., 2021).

Incorporating rare earth elements into different glass oxides plays a pivotal role in advancing of optical devices, including infrared lasers, visible conversion devices, and fibre and waveguide boosters, which are essential for applications in telecommunications networks. In addition, there is considerable interest in employing trivalent rare earth ions as functional components in glass host substances due to the presence of numerous fluorescent states with the 4f electron configuration, the majority of which are visible. These ions play a crucial role in facilitating rapid pumping applications and allowing dye lasers to be tuned (Hasim, 2014).

According to (Jha et al., 2012), the use of rare-earth doped tellurium oxide (TeO_2) in glass lasers provides for more wavelength flexibility as well as superior Q-switching and mode-locking for power density at fewer pump energies as compared to crystal-based products. Neodymium oxide is among the superior rare-earth oxides utilised variety of devices that deal with optics including lasing materials, broadband amplifiers, and laser glass (Azlina et al., 2020). Because of the unique optical properties of the 4f shell, neodymium nanoparticles embedded in tellurite glass may offer a potential laser material to replace the present neodymium-doped phosphate laser glass (Halimah et al., 2020; Shaari et al., 2021).

Moreover, neodymium oxide in tellurite glass provides a minimal laser level of 8 mW and lowers losses within during the development of laser glass, (Azlan et al., 2019; Bell et al., 2014). Also, neodymium-doped tellurite is appropriate for optical amplification or solid-state lasers, and it emits NIR light efficiently at 1062 nm (Venkateswarlu et al., 2015). Therefore, we will be doing this research using rare-earth neodymium nanoparticles as our active element material choice for the tellurite glass systems.

The use of graphene based materials has attracted the interest of researchers, notably in laser applications (Kant et al., 2022; Tseng et al., 2021; Wang et al., 2023) . Novoselov et al. stated in 2004 that graphene has several excellent properties, such as strong electrical conductivity, flexibility, and toughness (Novoselov et al., 2004). Moreover, graphene materials possess exceptional optical properties. However, graphene embedding into long stretches of fibre has limitations because of the difficulty of controlling graphene in particle form, which leads to transmission interruptions (Ruan et al., 2016; Shaari et al., 2022).

So, another graphene-based material derivative known as graphene oxide (GO) and reduced graphene oxide (rGO) has been used as a replacement of graphene flakes in the production of fibres for use in ultrafast laser and sensor applications, among other things. The remarkable characteristics of GO and derivatives have attracted the interest of many uses (Gerosa et al., 2020; Kavitha & Jaiswal, 2016), as shown in Figure 1.2, including optoelectronics, supercapacitors, or an energy storage device like lithium-ion rechargeable batteries based on graphene oxide, sensor (biosensor) solar cells, catalysts, photocatalysts, and more applications. (Azlina et al., 2021; Dideikin &Vul’, 2019).

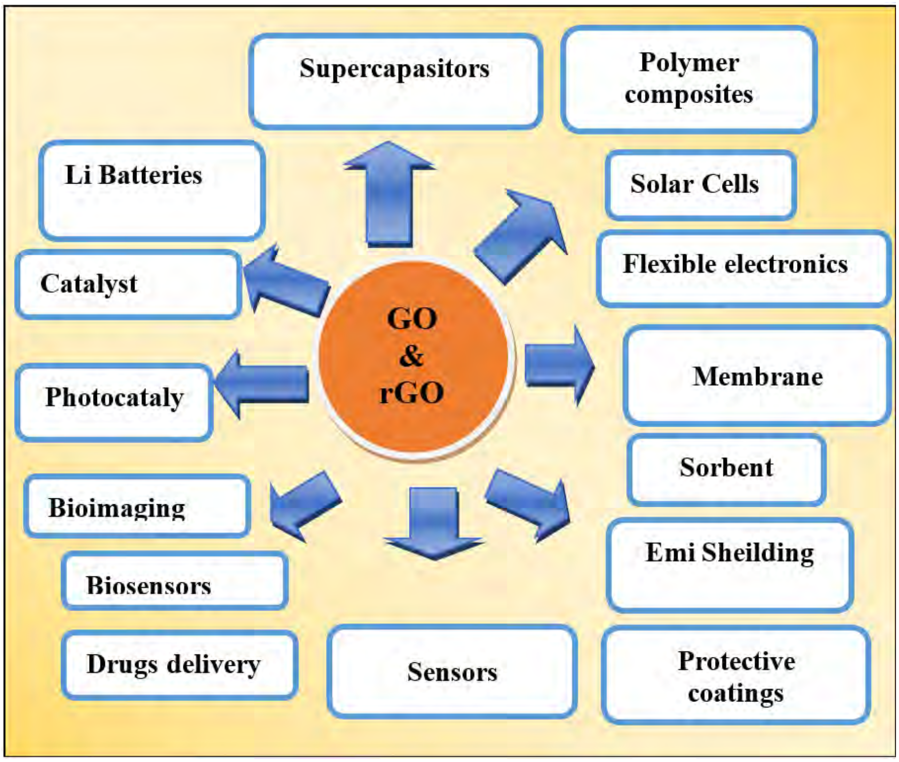

Figure 1.2. Application of GO and derivatives. Adapted from Dideikin & Vul', 2019

Graphene oxide comprises stacked layers with numerous oxygen functional groups, including epoxy, hydroxyl, carboxyl, and carbonyl groups. Azlina et al.,(2020) observed that oxygen-containing functional groups in GO layers improved optical characteristics, indicating that GO significantly impacted tellurite glass for optical fibre (Azlina et al., 2020). Combining this graphene-based material with tellurite glass is yet another technique for increasing the optical properties of the glass network system. Graphene based materials is the most outstanding choice for making superb glass coatings and is highly advantageous to fibre optic applications. According to reports, the graphene-based material coating on the tellurite surface leads to the glass having a high refractive index of more than 2.000, ranging from 2.301 to 2.332 (GO) (Azlina et al., 2021) and 2.402 to 2.775 (rGO) (Azlina et al., 2023). Therefore, this technique can improve superior fibre core materials, especially optical fibre, and will enhance optical fibre laser technology.

As an outcome result, a more comprehensive study into the utilization of graphene-based materials and optical glass materials is essential in order to enhance the optical properties of glass systems. Additionally, this innovative research can yield extremely intriguing outcomes, particularly for the fibre optic and fibre laser technology industries.

1.3 Research Problems

Neodymium-doped phosphate oxide glasses are commonly use as the host material for laser gain media in the fibre laser and laser glass industry due to their high solubility, large emission cross-section, and long lifetimes (He et al., 2017; MetaLaser, 2022a). However, phosphate oxide glass is limited in manufacturing the highest laser power at ambient conditions due to poor optical sensitivity (Deepa et al., 2019), low chemical stability (Elbakey et al., 2020), and high hygroscopic properties (Jan et al., 2019; Zaid et al., 2012). As a result, it has low strength, high fragility, and is prone to fracture (Hamzah et al., 2017), which can increase production costs and sensitivity to back-reflected light, leading to laser glass failure. Furthermore, it has been observed that phosphate glass exhibits a diminished stark splitting effect, leading to certain thermal drawbacks (Azlan et al., 2018). Zhang et al. reported that unsatisfactory lasing performance of Yb^{3+} phosphate glass resulting in narrow stark splitting where effect thermal block during laser operation (Zhang et al., 2015). To overcome this issue, new glass materials with improved optical qualities must be invented to replace the current laser gain media materials. Therefore, tellurite glass is selected to replace the current host material due to of the low hygroscopic, high solubility of rare earth ions and the ease of drawing fibres at low temperatures compared with phosphate glass.

Tellurite glass is a very promising host glass for optical glass in these studies. Due to its exceptional qualities, including its excellent match with rare-earth (RE) ions. It has been chosen over other glass oxides due to its broad transmittance window, outstanding laser medium (Barbosa et al., 2017; Syam Prasad & Venkateswara Rao 2018), excellent laser host (Jha et al., 2012; Oermann, 2011), and good chemical resistance (Elkhoshkhany et al., 2021; Halimah et al., 2021).

Recently, most researchers have been focusing their attention on a few techniques, such as co-doping the host glass with two different REIs and embedding optically effective NP-metallic (Au/Ag) or transition oxide. This approach is an improvement technique that can boost the optical performance of glass systems (Abdullahi et al., 2020; Halimah et al., 2021; Manzani et al., 2017; Peng et al., 2015; Saad, 2019; Yu et al., 2018; Dechun Zhou et al., 2017).

A carbon-based material coating is an additional method. Several studies suggested that deposition of GO, rGO and CNT films onto the surface of tellurite glass could improve the optical characteristics of laser glass (Azlina, 2023; Azlina et al., 2021; Azlina et al., 2020; Shaari et al., 2021). However, the application of carbon-based materials to optical fibre glass remains unestablished, lack of data in publication and requires additional research. Therefore, additional research must be conducted to contribute new information to optical fibre and laser applications. Futhermore, the research on glass coating can be more extented to overcome these limitations.The deposition of carbon-based materials especially graphene oxide (GO) and reduced graphene oxide (rGO) coated on glass surface via a simple spray coating technique can be step to achieve high functionality of optical fibre especially in the application of fiber optics technology. In summary, the research proposed in the present study are summerized in Table 1.3.

Table 1.3

Summary of the research problems and research solutions that relate to the study

Research Problem	Research Solution
Poor optical sensitivity, low chemical instability, and high hygroscopic properties (Hamzah et al., 2017), contribute to the high production cost of phosphate oxide glass.	Replace the new glass host materials, which are tellurite glass, with exceptional characteristics, particularly to improve the optical attributes of the existing glass host.
Enhancement of the properties of optical glass by using co-doping with two different REIs and embedding optically effective NP-metallic (Au/Ag) or transition oxide, which can lead to expensive	Utilising a glass coating approach with graphene-based materials on the glass improved the optical properties of the low-priced glass system.

(continue)

Table 1.3 *(continued)*

Research Problem	Research Solution
production costs in glass fabrication (Abdullahi et al., 2020; Halimah et al., 2021; Manzani et al., 2017; Peng et al., 2015; Saad, 2019; Yu et al., 2018; Dechun Zhou et al., 2017).	
The previous researcher reported the lack of data on publications regarding the usage of carbon-based materials as coating materials for optical glass (Shaari et al., 2021).	Expansion research on carbon-based material coating such as GO and rGO in optical glass may provide novel knowledge for fibre optics technology.

1.4 Research Objectives

The purpose of this study is to examine the impact of deposited carbon-based materials, such as graphene oxide (GO) or reduced graphene oxide (rGO), on tellurite glass systems, with a particular focus on structural and optical property enhancements. Based on the purpose, the following are the objectives of this study are:

1. To study the surface morphology,particle size, and bonding parameter of ZBTNd (NPs) glasses, GO and rGO solution by using FESEM, FTIR, TEM, XRD and Raman Spectroscopy.

2. To analyze the absorption spectra, refractive index, optical band gap energy, Urbach energy, Fermi energy and the nephelauxetic ratio of ZBTNd (NPs)-GO and ZBTNd (NPS)-rGO glasses by using UV-Vis spectroscopy
3. To determine the electronic polarizability, oxide ion polarizability, optical basicity, and metallization criterion of ZBTNd (NPs)-GO and ZBTNd (NPs)-rGO the glasses via the Lorentz-Lorentz equation.
4. To investigate the stimulated emission cross-section and gain efficiency of ZBTNd (NPs)-GO and ZBTNd (NPs)-rGO glasses

1.5 Significance of the Study

The nanomaterial coating technique, which is also very important in nano-intermediate science, will result in significant scientific and technical advances (Cao et al., 2013). Graphene oxide (GO) and reduced graphene oxide (rGO) have been used on glass fibre to enhance their mechanical and electronic properties. According to Ruan et al., (2016) graphene oxide can be combined with glass fibre, which can excite light and capture signals from a distance, making it a perfect medium for a range of practical applications to utilise applications of its unique optical and electronic properties. It could also be used in many fields, especially as flexible conducting wires, multifunctional fibres, and sensitive sensors (Fang et al., 2019). Besides, the ability of GO and rGO also has been explored in past several years to improve the enhanced mechanical and electrical properties, especially on composites reinforced by short fibres (Bhanuprakash, Parasuram, & Varghese, 2019).

Moreover, the graphene oxide can improve the optical properties of tellurite glass samples, making them acceptable for use in applications involving fibre optics. Azlina et al., (2020) found that the graphene-based effect increased the values of optical band gap energy, refractive index, and electronic polarizability after deposit compared to uncoated glass. Thus, it is advantageous to reduce photon energy losses during the transmission process in fibre optics applications.

Thus, the purpose of this study is to investigate the structural and optical properties of carbon-based coated neodymium nanoparticle-doped tellurite glass, which has the potential to contribute to technological advancements in optical applications. In addition, the obtained data may be used to improve the capabilities of glass and raise its laser emission potential. In addition, theoretical and experimental findings may be investigated in these glass materials as potential near-infrared laser active media, as well as the effect of GO/rGO as a glass coating on the optical parameter of tellurite glass systems.

1.6 Scope and Limitation of the Study

Firstly, neodymium-doped zinc borotellurite glass system of {(0.47(1- y)) TeO_2 + (0.2(1-y)) B_2O_3 + (0.29(1- y)) ZnO + (y) Nd_2O_3 (nanoparticles)} GO/rGO (coated), (y=0.01, 0.02, 0.03, 0.04 and 0.05) molar fraction denoted as ZBTNd (NPs)-GO and ZBTNd (NPs)-rGO were fabricated by using conventional melt quenching method.

After the sample preparation, graphene oxide (GO) and reduced graphene oxide (rGO) will be synthesised using electrochemical exfoliation from the graphite electrode and the reduction process of GO. All the glass samples will be coated with GO/ rGO using the spraying method. Several analysis techniques were utilised for characterisation, such as UV-Visible spectroscopy, X-ray Diffraction (XRD), Field emission scanning electron microscopy (FESEM), Fourier Transform Infrared (FTIR) spectroscopy, Transmission Electron Microscopy (TEM), Energy Dispersive X-ray (EDX) and Raman spectroscopy. For optical characteristics, optical absorption, band gap, refractive index, Urbach energy, optical polarizability, oxide ion polarizability, optical basicity, and emission cross-section will be obtained according to the equations.

1.7 Thesis Outline

The present thesis is structured into five distinct chapters. The initial chapter serves as an introductory section covering various components such as the study's background, a comprehensive overview of glass, the research's motivating factors, a problem description, the objectives, the scope, and the limitations. The second chapter provides a literature review that provides a critical analysis of the research, providing an overview of the glass and previous studies regarding the structure and optical properties of rare-earth-doped tellurite glass systems.

The third chapter focuses on the melt-quenched method of fabricating neodymium NPs-doped tellurite glass. In the meanwhile, graphene oxide was synthesised via electrochemical exfoliation. Graphene oxide was then reduced using the reduction technique to produce reduced graphene oxide. In this section, the spray-coating technique is discussed. These materials were examined in order to determine their structural and phase compositions. After glass formation, X-ray diffraction (XRD) analysis and Fourier transform infrared spectroscopy (FTIR) were conducted to verify the amorphous character of the glass and the bonding of the glass structure. Using FESEM and micro-Raman spectroscopy, the morphology and microstructural properties of graphene oxide and reduced graphene oxide on the glass surface were determined. TEM analysis confirmed that the glass samples contained neodymium NPS. Using EDX testing, the atomic composition of GO and RGO was determined. Utilising UV–visible–NIR spectroscopy, the optical properties were determined.

The results and discussion of the structural characterization and optical characteristics of the two glass series are presented in Chapter Four. These glass series are graphene oxide-coated neodymium nanoparticle-doped tellurite glass and reduced graphene oxide-coated neodymium nanoparticle-doped tellurite glass. The fifth chapter concludes this study and makes suggestions for future research.