THE IMPACTS OF GAMMA RADIATION ON THE PROPERTIES OF ABS COMPOSITE MEMBRANE

Submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Hons.)

By

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DECLARATION

I hereby declared this report entitile "The Impact of Gamma Radiation on The Properties of ABS Composite Membrane" is the result of my own research except as cited in the reference.

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APPROVAL

This report is submitted to the Faculty of Industrial and Manufacturing Technology and Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons.). The member of the supervisory committee is as follow.

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ABSTRAK

Tujuan kajian ini adalah untuk mengkaji bagaimana radiasi gamma mempengaruhi tingkah laku mekanikal, fizikal, dan morfologi membran komposit ABS (Acrylonitrile Butadiene Styrene). Kekuatan tegangan dan ketegaran membran ABS tulen meningkat pada dos radiasi yang lebih tinggi (100 kGy) disebabkan oleh pengikatan silang, mengatasi kelekangan yang teruk pada dos yang lebih rendah. Sebaliknya, kekuatan tegangan membran komposit ABS-CuO berkurangan dengan radiasi yang lebih tinggi. Analisis FTIR menunjukkan bahawa radiasi gamma mengubah struktur molekul membran, mempengaruhi penyerapan dan penghantaran inframerah. Imej SEM menunjukkan kekasaran dan ketidaksempurnaan yang ketara pada membran yang disinari. Secara keseluruhannya, radiasi gamma melemahkan membran, tetapi dengan dos yang tepat, ia berpotensi memberikan manfaat, terutamanya dalam aplikasi perubatan. Penemuan ini menekankan kepentingan mengawal pendedahan radiasi dengan teliti untuk mengoptimumkan prestasi membran komposit ABS.

ABSTRACT

The aim of this study is to examine how gamma radiation affects the mechanical, physical, and morphological behaviours of ABS composite membranes Acrylonitrile Butadiene Styrene (ABS). The tensile strength and stiffness of pure ABS membranes increased at higher radiation doses (100 kGy) due to cross-linking, counteracting the severe ductility observed at lower doses. In contrast, the tensile strength of ABS-CuO composite membranes decreased with higher radiation. FTIR analysis revealed that gamma radiation altered the molecular structure of the membranes, affecting their infrared absorption and transmission. SEM imaging showed notable roughness and imperfections on the irradiated membranes. Overall, gamma radiation weakened the membranes, but with the right dosage could potentially provide benefits, especially in medical applications. The findings highlight the importance of carefully controlling radiation exposure to optimize the performance of ABS composite membranes.

DEDICATION

Only
My beloved father, Mohd Faizal Wai Kai Kee Bin Abdullah
my mother, Siti Nurleni,
my adored sisters and brother, Fadzlin Hasina, Fatin Fayadah, and Mohd Fadatul FarokAik
for giving me moral support, cooperation, encouragement, resources and also understandings.
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LIST OF ABBREVIATIONS

ABS	-	Acrylonitrile Butadiene Styrene
rpm	-	Rotation Per Minute
rGO	-	Reduce Graphene Oxide
CF	-	Carbon Fiber
CuO	-	Copper (II) Oxide / Cu
CTE	-	Coefficient pf Thermal Expansion
EDX	-	Energy Dispersive X-Ray Spectroscopy
ESD	-	Electrostatic Discharge
EMI	-	Electromagnetic Interference
FTIR	-	FOURIER Transform Infrared Spectroscopy
GTR	-	Guided Tissue Regeneration
LLDPE	-	Low-Density Polyethylene
MCC	-	Microcrystalline Cellulose
MPa	-	Mega Pascal
PB	-	Polybutadiene
PSD	-	Pore Size Distribution
PVA	-	Polyvinyl Alcohol
PVC	-	Polyvinyl Chloride
ROS	-	Reactive Oxygen Species
SAN	-	Styrene Acrylonitrile Resin
SBR	-	Styrene Butadiene Rubber
SEM	-	Scanning Electron Microscopy
UV	-	Ultraviolet
3D	-	Three Dimensional

LIST OF SYMBOLS

%	-	Percentage
wt%	-	Weight Percentage
kGy	-	Kilogray
°C	-	Degree Celsius
mL	-	Millilitre
cm	-	Centimetre
mm	-	Millimetre

CHAPTER 1

INTRODUCTION

1.1 Research Background

Many studies have been conducted on the effects of gamma radiation on the characteristics of Acrylonitrile Butadiene Styrene (ABS) composite membranes. It is well recognized that gamma radiation can alter the chemical, mechanical, and physical characteristics of polymeric materials, such as ABS.

Numerous research works have examined the impact of gamma irradiation on ABS composite materials. For instance, one study looked at how gamma-ray irradiation affected PVA-collagen-chitosan membranes, which are possible materials for guided tissue regeneration (GTR) applications (Komara et al., 2023).

The membranes' tensile strength, elongation, and water absorption were all analysed. The tensile strength of the membrane increases when the radiation dose was raised, while elongation and water absorption declined, according to the researchers. FTIR analysis however showed that the membranes' functional groups stayed the same (Komara et al., 2023).

A different study looked at the compatibility of polyvinyl chloride (PVC) and low-density polyethylene (LLDPE) compounds in relation to gamma irradiation and the amount of Styrene Butadiene Rubber (SBR) (Sharshir et al., 2022). The compatibility of the immiscible PVC and LLDPE blend was found to be enhanced by gamma irradiation and the inclusion of SBD as a compatibilizer (Sharshir et al., 2022).

Furthermore, studies on the application of plastic aggregates exposed to gamma radiation in cementitious composite materials have been carried out. Comparing the resulting cementitious composite with non-irradiated plastic aggregates. These investigations have demonstrated that the addition of gamma-irradiated plastic aggregates can boost the compressive strength of the latter (Lee, Cheon, Kang, Roh, & Kim, 2021).

1.2 Problem Statement

Gamma radiation is a common practice especially in the healthcare sector in sterilizing medical equipment and gadgets. However, the performance and properties of composite membranes, such those composed of Acrylonitrile Butadiene Styrene (ABS) composite membranes' great mechanical strength, chemical resistance and biocompatibility are reasons why they are being used more and more in medical applications, such as filtration and dialysis. Nevertheless, little is known about how gamma radiation affects these membranes' permeability, biological compatibility, and structural integrity.

The mechanical characteristics of ABS composite membranes, such as their tensile strength, elongation of break, and impact resistance, may alter as a result of exposure to gamma radiation. Furthermore, the membrane's permeability can be changes by gamma radiation, which is important for its planned usage in medical applications. Gamma radiation, which is important for its planned usage in medical applications. Gamma radiation may also jeopardize the membrane's biological compatibility, which is crucial for its safe application in the human body.

However, ABS composite membranes have demonstrated significant potential in various industrial applications, owning to their remarkable physical and mechanical properties. Yet, the impact of gamma radiation on these membranes is not yet fully understood, necessitating a comprehensive investigation to address this critical knowledge gap. The objective of this study is to evaluate the multifaceted effect of gamma radiation on the properties of ABS composite membranes. Specifically, this research aims to assess the changes in physical and mechanical properties, and morphological structure induced by varying levels of gamma radiation.

1.3 Objectives

The primary goal of this research is to examine how gamma radiation affects the mechanical, physical, and morphological behaviours of ABS composite membranes. The following are the research's goals.

1. To evaluate changes in physical and mechanical properties such as pore size distribution, and tensile strength in ABS composite membranes subjected to various levels of gamma radiation.
2. To evaluate the effects of gamma radiation on the chemical composition and functional groups present on the membrane's surface by using FTIR and EDX.
3. To analyse the morphological changes in the ABS composite membranes as a result of gamma radiation.

1.4 Scopes of the Research

The goals of the study are to thoroughly investigate how gamma radiation affects the characteristics of ABS composite membranes. The study will examine the structural alteration brought about by exposure to gamma radiation, analysing changes at the molecular level with methods including X-ray diffraction and microscopy. Tensile strength, flexibility, and elasticity tests will be part of the mechanical property assessments, which will give a detailed picture of how gamma radiation affects the mechanical behaviour of the membranes.

A comprehensive analysis of the ABS composite membranes' surface morphology, and porosity will be carried out to assess changes in their physical properties. The ultimate objective is to present a thorough report that clarifies the various effect of gamma radiation on ABS composite membranes. With implications for a wide range of application such as gas separation, water purification, and medical devices.

1.5 Organization of Thesis

The thesis is structured into five (5) chapters, each of which explains a different aspect pf the research focus about the impacts of gamma radiation on the properties of ABS composite membrane.

- Chapter 1: The start of this research includes the background study, problem statement, objectives, scopes, and its organization. The material used, the methodology employed, and the analysis that will be used in this research will all be disclosed to the reader.
- Chapter 2: The project's review of the literature is covered in chapter 2. It goes into the fundamentals of the gamma radiation and ABS composite membranes. Additionally, it will describe the procedure chosen to be carried out.
- Chapter 3: The approach used, the methodological flow involved, and the characterization process for ABS composite membranes will al be covered in chapter 3. This chapter also includes the overall research flowchart.
- Chapter 4: The research's findings and discussions will be presented in chapter 4. Additionally, this chapter contains all the data and associated figures from the testing and characterization of the ABS composite membrane.
- Chapter 5: The research's result and recommendations are provided in chapter 5. This last chapter will serve as an exclusive summary and conclusion of the entire conversation surrounding this research. The section on recommendations is meant to make suggestions for how to make research better for the upcoming research cycle.

CHAPTER 2

LITERATURE REVIEW

The effects of gamma radiation on composite material, especially ABS membranes have attracted attention in recent year. It is imperative to assess and appreciate the complex changes generated by such irradiation on the properties of these membranes as radiation technology advances further. The goal of this literature review is to present a thorough analysis of the body of knowledge about the effects of gamma radiation on ABS composite membranes. This review aims to pinpoint important discoveries, patterns, and knowledge gaps by synthesising and critically evaluating the existing information.

2.1 Gamma Radiation

According to (McTaggart et al., 2020), high energy electromagnetic radiation released from radioactive atom nuclei is referred to as "gamma radiation'. In this investigation, different dosages of gamma radiation were applied to 3D-printed sample of carbon fiber reinforced ABS (CF-ABS). A cobalt 60 gamma irradiator, which emits gamma rays with particular energies, was the source of gamma radiation that was referenced in the study. It is well known that gamma radiation may profoundly penetrate materials and interact with their atomic structure, breaking chemical bonds, creating cross-links, and producing free radicals in the process. Gamma irradiation was employed in the study to mimic radiation exposure conditions pertinent to medical imaging, radiation therapy, space applications, and sterilization procedures.

Gamma radiation sometimes referred to as gamma rays, which are high-energy electromagnetic radiation. Gamma radiation is a processing method used in the context of polymeric materials to cause different changes in the molecular structure of polymers.

Processes like grafting and cross-linking may result from this radiation, improving the materials' mechanical, thermal, and chemical characteristics (Naikwadi et al., 2022).

The gamma ray energy interacts with the polymer chains to produce free radical production, chain scission, and crosslinking. The material's characteristics, such as its strength, thermal stability, and chemical resistance, may alter as a result of these processes (Naikwadi et al., 2022).

In (Naikwadi et al., 2022) study, gamma radiation's effects on a variety of polymers, such as blends of nitrile rubber, EPDM rubber, and polyethylene, have been investigated by researchers. Customizing the characteristics of the materials for particular high-performance applications can be achieved by controlling the radiation dose and processing conditions.

According to Stalter & Howarth, high frequency and high energy electromagnetic radiation is referred to as "gamma radiation." It is frequently referred to as "photons" that travel at the speed of light and is comparable to x-rays in that it may readily pass through living materials. Because of their high energy, gamma rays can ionize materials, which could harm living cells. The quantity of ionizing pathways generated in the absorbing material directly correlates with the degree of damage caused by gamma radiation.

In the journal written by (Künzel & Okuno, 2012), the effects of concentration and particle size on CuO compound X-ray absorption were investigated. According to this study, X-ray absorption can be improved by using larger concentrations of CuO and smaller particle sizes.

Based on (Shahabi et al., 2014) the study discovered that the molecular weight, thermal behaviour, wettability, alkaline phosphatase activity, and cell viability of the composite and its constituents can all be considerably impacted by gamma irradiation. While smaller doses of gamma irradiation showed no discernible impact on thermal behaviour, higher doses increased activation energy.

Polymer composites based on polyimide track membranes packed with lead nano dispersed were examined to determine how they were affected by gamma radiation.

According to (Cherkashina et al., 2021) studies, adding lead nanoparticles to these composites may improve their radiation resistance.

Cherkashina et al., (2021) also stated that ABS has a limited radiation stability of up to 25 kGy, making it well-known for its radiation resistance.

2.1.1 Benefit of gamma radiation

Many advantages have been found from applying gamma radiation to ABS composite membranes, according to a thorough analysis. According to (Nasef et al., 2019) the induction of crosslinking, which improves the mechanical characteristics and thermal stability of the composites, is one of the main benefits. (Lee, Cheon, Kang, Roh, Kim, et al., 2021; Naikwadi et al., 2022) mention that gamma radiation can also change the thermal, structural, and optical characteristics of ABS composites, which makes them appropriate for a range of uses.

ABS composites can also be sterilized using gamma radiation, which makes them appropriate for biomedical applications where sterility is essential. By adding nanofillers to ABS composites, such as metal/oxide oxide and carbon-based nanoparticles, the materials' capacity to filter out impurities from water can also be enhanced (Naikwadi et al., 2022; Nasef et al., 2019).

According to (Naikwadi et al., 2022) by adding components like tungsten, molybdenum disulfide, and boron carbide, ABS composites can be created with radiation shielding qualities.

2.2 Acrylonitrile Butadiene Styrene (ABS) Material

Acrylonitrile Butadiene Styrene, or ABS, is a typical thermoplastic polymer valued for its resilience to abrasion and its adaptability. Three monomers combine to form the copolymer ABS: styrene, butadiene, and acrylonitrile. It is extensively utilized in many different industries for products including toys, consumer goods, electronic housings, and automobile parts. ABS is a common material for producing a variety of goods using techniques including injection moulding, extrusion, and 3D printing because of its strength, ease of processing, heat resistance, and affordability (Vakharia et al., 2022).

Acrylonitrile Butadiene Styrene, or ABS, is a popular thermoplastic polymer that is renowned for its heat resistance, toughness, and resistance to impacts. Three monomers make up this copolymer: styrene, butadiene, and acrylonitrile. Because of its adaptable qualities, ABS is widely employed in many different applications, such as the manufacturing of toys, consumer items, electrical housings, and automotive parts. According to the journal written by (Lu & Chen, 2023) the main polymer of interest that is being recovered and recycled from toy waste is ABS. The study emphasizes the value of material recycling and waste reduction in the plastics sector by concentrating on creating a sustainable recycling procedure to recover ABS from abandoned toys.

2.2.1 Benefit of Acrylonitrile Butadiene Styrene (ABS)

Acrylonitrile-Butadiene-Styrene (ABS) is a thermoplastic polymer that is widely used in various industries, including consumer goods, automotive, electronics, and construction. Its combination of strength, durability, resistance to temperature, resistance to chemicals, ease of processing, surface finish capabilities, and electrical insulation properties make it a versatile polymer. ABS is the material of choice for applications that demand a balance between performance, cost, and diversity because of its exceptional mechanical qualities, resistance to heat, resistance to chemicals, and ease of processing (Vakharia et al., 2022).

Acrylonitrile Butadiene Styrene, or ABS, is a thermoplastic polymer with a broad range of applications due to its remarkable toughness, heat resistance, and impact resistance. ABS highlights its recyclability through dissolution-precipitation procedures using safer solvents in the context of the research on material recycling from toy trash, demonstrating its environmentally beneficial and sustainable nature. For industries like toy production, where durability, resistance to heat, and capacity for recycling are crucial factors in developing products and minimize waste efforts, ABS is a valuable material choice because of its capacity to sustain its mechanical behaviour in addition to its versatility and recyclability (Lu & Chen, 2023).

2.2.2 Physical properties of Acrylonitrile Butadiene Styrene (ABS)

According to (Barskov et al., 2019) on the study of ABS plastics and polyamide products for turbine construction, the physical properties of ABS plastics disclose important features necessary for their use in industrial settings. Because ABS plastic has a low viscosity within a particular temperature range, it can be utilized to create non-porous objects without internal tensions. ABS products show a density that nearly matches the desired range. ABS goods retain their strength characteristics even after being manufactured without pressure during 3D printing; compositional changes impact attributes like impact strength and hardness. Interestingly, increasing the butadiene concentration of the copolymer used in 3D printing might decrease hardness while increasing impact strength. Additionally, ABS plastic samples created via 3D printing exhibit mechanical characteristics that fall within the range of values mentioned in scholarly publications. These characteristics include toughness, Brinell hardness, relative elongation at break, destructive stress under compression, bending stress, and destructive stresses under tension. Together, these physical characteristics make ABS plastics suitable for use in turbine construction, guaranteeing the best possible performance, robustness, and dependability from parts made using ABS materials utilizing 3D printing technology.

2.2.2.1 Pore size distribution on Acrylonitrile Butadiene Styrene (ABS)

Pore size distribution, or PSD, has a major effect on the characteristics and functionality of materials made of Acrylonitrile Butadiene Styrene, or ABS. The following are some salient details regarding PSD's impact on ABS:

- The injection moulding parameters and post-processing processes used during the manufacturing process might affect the pore size distribution of ABS (Eskandari-Ghadi & Zhang, 2022; Yokoyama et al., 2014). Processing errors can result in a PSD that is larger and has unwanted pores.

- The mechanical properties of ABS are impacted by the size and distribution of its pores. Bigger pores can lessen elongation at break, impact resistance, and tensile strength because they behave as stress concentrators (Eskandari-Ghadi & Zhang, 2022). For superior mechanical performance, an ideal PSD with smaller, uniformly dispersed pores is desirable.
- PSD affects ABS's permeability and surface area. Higher surface area from a narrower PSD with smaller pores can improve filtration and adsorption applications (Al Marzouqi, 1999). Very tiny pores, however, have the potential to impede fluid movement and raise pressure drop.
- ABS's abilities as an electrical and thermal insulator are influenced by its pore structure and PSD. Better insulation is produced by a homogeneous PSD with smaller pores because it lowers heat and electrical conductivity through the material (Eskandari-Ghadi & Zhang, 2022).
- PSD has an impact on ABS's chemical resistance. Greater pore size can enable chemicals to enter the body more deeply, which can cause swelling, plasticization, and breakdown of the polymer matrix (Eskandari-Ghadi & Zhang, 2022). Chemical resistance is improved with a reduced pore size and tighter PSD.

To summarize, managing the distribution of pore sizes is essential for enhancing the mechanical, thermal, electrical, and chemical characteristics of ABS materials for diverse uses. To get the appropriate PSD in ABS parts, the right manufacturing settings and post-processing methods must be chosen.

2.2.3 Mechanical properties of Acrylonitrile Butadiene Styrene (ABS)

Understanding the behaviour of ABS under varied loads and environments requires an understanding of its mechanical properties. The following are ABS's principal mechanical attributes:

- Tensile Strength: When compared to other engineering polymers, ABS has a comparatively low tensile strength, ranging from 30 to 40 MPa (Sabah et al., 2019).
- Elongation at Break: ABS typically exhibits an elongation at break of 2% to 5%, showing a comparatively low degree of elasticity (Sabah et al., 2019).
- Folding Endurance: A measure of an ABS's resistance to fatigue and repetitive loading, its folding endurance ranges from 200 to 300 times (Sabah et al., 2019).
- ABS demonstrates a strong resistance to impact, making it a valuable material for applications where abrupt or intense stresses may be applied to it (Sabah et al., 2019).
- Hardness: ABS has a low hardness, usually between 70 and 90 Shore D, indicating that it is a rather soft and flexible material (Sabah et al., 2019).

These mechanical properties make ABS suitable for a wide range of applications, including consumer products, automotive parts, and industrial components.

2.2.3.1 Tensile strength on Acrylonitrile Butadiene Styrene (ABS)

Acrylonitrile Butadiene Styrene's (ABS) tensile strength varies according to part geometry and manufacturing process. The following are important details regarding ABS's tensile strength:

- Compared to injection molded parts, printed ABS parts attain around 3/4 of the elastic modulus (2300 MPa) and at most, 2/3 of the tensile strength (44 MPa) (Sabah et al., 2019).
- The purpose of this study is to determine the tensile strength of automobile spoiler items manufactured of ABS plastic that is purchased on the open market (Irawan et al., 2020).
- The effect of specimen mesostructure on the monotonic tensile behavior of ABS components is defined by the experiment using the fused deposition modeling (FDM) technique (Maddaloni et al., 2021).

- As an example, compared to injection molded parts, printed ABS parts achieve around 3/4 of the elastic modulus (2300 MPa) and just two-thirds of the tensile strength (44 MPa) (Sabah et al., 2019).

In conclusion, the manufacturing process can have a substantial impact on the tensile strength of ABS, with injection-molded parts showing a higher tensile strength than printed parts. For a variety of applications, ABS parts' tensile strength is crucial, and experimental characterisation is required to comprehend the behaviour of the material under tensile loads.

2.2.4 Application of Acrylonitrile Butadiene Styrene (ABS)

Here are some additional sources that provide information on ABS applications:

i) ABS in Medical Devices**:** In the medical industry, ABS materials are used to make disposable syringes, equipment casings, medical device components, and housings for medical instruments. ABS is perfect for medical applications because of its strength, resistance to chemicals, and simplicity of sterilizing.

ii) ABS in Automotive Industry: In the automotive sector, ABS is frequently used for items such instrument panels, door liners, handles, seat backs, dashboard components, and seat belt components. It helps automobiles become lighter by acting as a lightweight metal replacement.

iii) ABS in 3D Printing**:** Acrylonitrile Butadiene Styrene, or ABS, is a common thermoplastic used in 3D printing because of its great durability, high impact resistance, and convenience of usage. It is frequently utilized for manufacturing parts, modelling, and prototyping.

iv) ABS in Consumer Goods**:** ABS is a material that is frequently used to make toys, luggage, household appliances, and casings for electronic devices. It can be used in a range of consumer products due to its durability, resilience to impact, and stability in dimensions.

v) ABS in Gardening Tools**:** Gardening equipment are frequently made of ABS because of its affordability and durability. Garden tools that are lightweight and reasonably priced, such as shovels, rakes, hoes, and claws, are frequently constructed from ABS.

2.3 Composite Material

According to (Żółkiewski, 2011.), a composite material is a remarkable combination of two or more distinct materials, each with its own distinctive qualities, either chemically or physically, that work in concert. The final composite material is intended to display properties that are very different from those of each of its component elements. This idea is similar to taking the superpowers of different parts and combining them to make something really amazing.

The blending of several elements is deliberate and intentional in the field of composite materials. Every component is chosen based on a unique combination of characteristics, such as conductivity, strength, flexibility, or other qualities. Scientists and engineers may precisely customise the composite to match the needs of a particular application by carefully combining various elements.

The combined effect of composite materials frequently results in improved functionality and performance beyond what would be possible with each component working alone. It's similar to fusing two materials' strengths—one with flexibility, the other with durability, or one with lightweight properties. This cooperative method enables the development of materials with exceptional properties that tackle a broad range of issues in different sectors.

Combining superpowers metaphorically draws attention to how transformational composite materials may be. It's about forming a new material entity that surpasses the confines of its constituent parts, not just coexisting. This combination of characteristics makes it possible to create materials specifically designed for a variety of uses, such as structural elements, medical devices, automotive and aerospace engineering.

Fundamentally, the magic of composite materials resides in the skilful fusion of various components to create something more than the sum of their parts. By pushing the limits of what materials can accomplish and creating opportunities for improvements in technology, design, and overall material performance, this strategy exemplifies innovation.

2.3.1 Type of Acrylonitrile Butadiene Styrene (ABS) composite material

The thermoplastic polymer recognized for its toughness, impact resilience, and ease of production is ABS. By adding different fillers and reinforcements, ABS can be altered to improve particular qualities, resulting in composite materials with customized features. The following are a few typical ABS composite material types:

I. Glass Fiber Reinforced ABS (GF-ABS)

Short glass fibers are combined with acrylonitrile butadiene styrene (ABS) polymer to create Glass Fiber Reinforced ABS (GF-ABS), a composite material. Glass fibers are added to ABS to improve its mechanical qualities, including:

- Elevated elastic modulus: when compared to pure ABS, GF-ABS containing 15 weight percent short glass fibers exhibited a 14% increase in elastic modulus, while GF-ABS containing 30 wt% short glass fibers shown a 26% increase (Mohan et al., 2022).
- Increased tensile strength: The composite material's tensile strength is increased when short glass fibers are incorporated into ABS (Mohan et al., 2022).
- Enhanced fracture resistance: The ABS matrix's use of glass fibers helps to prevent cracks from spreading and enhances the composite's overall fracture behaviour (Mohan et al., 2022).
- Application:
    - Automotive Parts: Components like instrument panels and under-the-hood parts.
    - Electrical Enclosures: Durable housings for electronic devices.
    - Structural Components: Load-bearing parts in various applications.

Due to its enhanced mechanical qualities, GF-ABS is a better material than pure ABS for a variety of uses, especially in the 3D printing of functional parts that need more strength and stiffness (Mohan et al., 2022).

II. Carbon Fiber Reinforced ABS (CF-ABS)

Carbon Fiber Reinforced ABS (CF-ABS) is a composite material made of carbon fibers and acrylonitrile butadiene styrene (ABS) resin. As a result, a material is created that maximizes the advantages of carbon fibers and ABS such as:

- Improved Mechanical Properties: When short carbon fibers were used to reinforce ABS instead of clean ABS, the study discovered that the mechanical rigidity of ABS rose dramatically by 272% (Mohan et al., 2022) . This improvement in mechanical characteristics is essential for uses requiring high rigidity and strength.
- Increased Thermal Stability: Of the materials evaluated, the study also showed that ABS reinforced with carbon fibers had the highest level of thermal stability. This indicates that compared to pure ABS or ABS reinforced with glass fibers, the composite material can maintain its shape at higher temperatures (Mohan et al., 2022).
- Enhanced Thermal Conductivity: ABS's heat conductivity was improved by the inclusion of carbon fibers. By lessening the coefficient of thermal expansion (CTE), this increase in thermal conductivity can aid in lessening the tendency for part distortion (Mohan et al., 2022).
- Impeded Polymer Chain Mobility: Impeded Polymer Chain Mobility: The dynamic mechanical study revealed that the impeded polymer chain mobility raised the glass transition temperature in ABS reinforced with carbon fibers. This suggests that the mobility of polymer chains is impacted by the presence of carbon fibers, and that this can influence the composite's overall mechanical and thermal properties (Mohan et al., 2022).

- Application:
  - Aircraft Components: Strong, lightweight parts for spaceships and airplanes.
  - High-performance sporting goods include things like golf clubs and bicycles.
  - Automobile Parts: Exquisite auto parts, such as dashboards and door panels.

III. Mineral Filled ABS

Mineral fillers are added to ABS resin to create a composite material known as mineral filled ABS. These mineral fillers are added to increase certain qualities including rigidity, dimensional stability, and the effectiveness of costs. They can comprise materials like talc, mica, glass beads, or calcium carbonate.

a) Mineral Microspheres as Filler
   - Mineral microspheres, namely enlarged perlite microspheres with sizes that vary ranges (below 150 µm and 400 µm), are present in the ABS matrix (Sanchez-Herencia et al., 2022).
   - Perlite serves as a multipurpose filler in composites and is a lightweight, inorganic, foamy material with a spherical shape. It is also chemically inert (Sanchez-Herencia et al., 2022).

b) Manufacturing Methods
   - Mineral-filled ABS composites are typically made by extrusion or compression moulding, which involves hot pressing the filler into the plastic matrix (Sanchez-Herencia et al., 2022).
   - Even though there are some air gaps in ABS, higher density composites are produced by raising the infill ratio (volume fraction) of the mineral microspheres (Sanchez-Herencia et al., 2022).

c) Effects on Properties

- The filler type and infill ratio affect mechanical parameters like yield strength and compressive stiffness. In comparison to neat ABS, a greater infill ratio (40 vol%) of lighter mineral microspheres can lead to a 9.5% better yield strength but a 13% poorer compressive stiffness (Sanchez-Herencia et al., 2022).
- Because mineral microspheres are inexpensive, lightweight, inflammable, and can change the characteristics of composite materials, their application as fillers in ABS is encouraging (Alghadi et al., 2020; Sanchez-Herencia et al., 2022).

d) Application:

- Household Appliances: Durable, heat-resistant components.
- Electrical Housings: Stable and sturdy casings for electronic devices.
- Automotive Interior Parts: Panels and trim components that require a good balance of strength and cost.

IV. Conductive ABS

Acrylonitrile Butadiene Styrene, or "conductive ABS," is an ABS material that has undergone modifications to increase its electrical conductivity. Conductive additives or fillers are added to the ABS matrix to accomplish this. These fillers can be substances like metal particles, carbon fibers, carbon nanotubes, or carbon black, which give the polymer the required electrical pathways.

Acrylonitrile Butadiene Styrene, or "conductive ABS," is an ABS material that has been altered to facilitate electrical conductivity. The popular thermoplastic polymer ABS is well-known for its robustness, adaptability, and simplicity of usage in 3D printing. Electrical conductivity qualities are added to ABS by mixing conductive additives or fillers into the polymer. When electrical conductivity is needed, conductive ABS is utilized in a variety of applications. These include the construction of antennas, electronic parts, sensors, and other electrically conducting equipment. Conductive ABS makes it possible to design antennas with integrated conductive parts in the context of 3D printing antennas, facilitating the transmission and reception of electromagnetic signals (Mirzaee et al., 2015).

Application:

- Electronic Housings: Cases for devices that require Electrostatic Discharge (ESD) protection.
- ESD-Safe Components: Parts for handling and manufacturing electronic devices.
- Electromagnetic interference (EMI) Shielding: Protects electronic equipment from electromagnetic interference.

V. Flame Retardant ABS

Acrylonitrile Butadiene Styrene, sometimes known as Flame Retardant ABS, is an ABS plastic that has been altered to impede the propagation of flames and prevent ignition. Flame-retardant chemicals are added to the ABS polymer during the production process to achieve this. In situations where the material may come into contact with heat or flames, these additions improve its safety.

a) Composition

- ABS resin serves as the foundation polymer in flame retardant ABS, which also includes stearic acid, polyvinyl chloride (PVC) resin, and a specially blended flame-retardant mixture (Lin et al., 2017).

b) Manufacturing Process

- In a mixing machine, the flame-retardant mixture, stearic acid, PVC resin, and ABS resin are combined to create flame retardant ABS (Lin et al., 2017).
- After that, the combined ingredients are pelletized and extruded to create the final flame-resistant ABS material (Lin et al., 2017).

c) Improved Properties

- The ABS material's fire resistance and flame retardancy are enhanced by the inclusion of the flame-retardant blend.
- When compared to regular ABS, flame retardant ABS also shows less flue gas emission during combustion. The substance doesn't produce secondary pollution and is free of halogens (Lin et al., 2017).

d) Applications

- Applications where fire safety and flame resistance are crucial, such those in the electronics, automotive, and construction industries, are suited for flame retardant ABS (Lin et al., 2017).
- Electrical and Electronic Equipment: Components that need to meet fire safety regulations.
- Automotive Interiors: Parts that require flame resistance.
- Public Transportation Components: Seats and panels in buses, trains, and aircraft.

To put it briefly, flame retardant ABS is an improved form of regular ABS that has specific flame-retardant additives added to it to increase its safety and fire resistance.

VI. Impact Modified ABS

Impact Modified ABS is a kind of ABS plastic that has had extra ingredients added to increase its resistance to impact. These changes improve the ABS material's suitability for uses requiring high levels of toughness and durability, especially in settings where the material may be subjected to impacts, mechanical stress, or harsh handling.

a) Composition

- Impact-modified ABS includes additional impact modifier components in addition to ABS resin, which serves as the basic polymer.

- Usually composed of rubber-based components, such as butadiene rubber, the impact modifiers are integrated into the ABS matrix.

b) Manufacturing Process

- By combining the ABS resin with the impact modifier components using methods such as injection moulding or extrusion, impact modified ABS can be created.
- To obtain the required level of impact resistance, the impact modifiers can be added in-line during processing or during the compounding stage.

c) Improved Properties

- The impact strength and toughness of ABS are greatly increased by the inclusion of impact modifiers, particularly at low temperatures.
- When compared to regular ABS, impact-modified ABS shows better elongation and less delamination. Impact modifiers aid in absorbing and dispersing impact energy, halting the spread of cracks and material failure.

d) Application

- Impact-modified ABS is used in a variety of industries where high impact resistance is needed, including toys, consumer electronics, automobiles, and appliances.
- Applications involving impact, shock, or sudden loading, such the manufacture of housings, enclosures, and protective components, benefit greatly from its utilization.
- Protective Gear: Helmets, pads, and other safety equipment.
- Automotive Bumpers: Absorb impact energy to protect vehicle occupants.
- Sporting Goods: Items like hockey sticks and ski boots that require high impact resistance.

In conclusion, impact-modified ABS is an improved variant of regular ABS that combines impact modifiers based on rubber to greatly increase its toughness, resistance to impact, and performance at low temperatures. This makes it appropriate for applications requiring high impact strength and durability.

VII. Heat Resistant ABS

Heat resistant ABS is Acrylonitrile Butadiene Styrene (ABS) plastic which has undergone some sort of formulation or modification to enable it to endure greater temperatures without losing its mechanical qualities or deforming. This alteration usually entails adding fillers or additives to improve the thermal stability of the material.

The study "Highly conductive and light-weight acrylonitrile-butadiene-styrene copolymer/reduced graphene nanocomposites" addresses the application of reduced graphene oxide (rGO) to improve ABS's thermal conductivity with the goal of enhancing its heat dissipation capabilities in the context of the search results that were provided (Gao et al., 2019). This suggests a way to improve ABS's capacity to dissipate heat efficiently, thereby increasing the material's heat resistance.

Application:

- Under-the-Hood Automotive Parts: Components exposed to engine heat.
- Electrical Components: Parts that need to perform reliably in hot environments.
- Kitchen Appliances: Items that encounter high temperatures, such as blender bases and toasters.

VIII. UV Stabilized ABS

UV Stabilized ABS (Acrylonitrile Butadiene Styrene) is a type of ABS plastic that has been treated with additives to enhance its resistance to ultraviolet (UV) radiation. This treatment makes the material appropriate for outdoor applications or locations with considerable UV exposure by preventing it from degrading when exposed to sunlight or other sources of UV light.

A modified kind of ABS plastic known as UV Stabilized ABS has UV stabilizers added to it to increase its resistance to UV light. Because of this, it is the perfect material for outdoor uses and any setting where exposure to UV light is substantial. It prolongs the lifespan and preserves the beauty of items created from it by offering further protection against UV-induced degradation while retaining the advantageous qualities of regular ABS, including as hardness, impact resistance, and chemical resistance.

Application:

- Outdoor Applications: Products like lawn furniture and garden tools.
- Automotive Exterior Parts: Components exposed to sunlight, such as mirror housings and trim.
- Outdoor Furniture: Durable and weather-resistant furniture.

IX. Biodegradable ABS Composites

Acrylonitrile Butadiene Styrene (ABS) combined with biodegradable additives or components is referred to as biodegradable ABS composite. This type of composite material allows the material to decompose organically in the environment. Although ABS is not biodegradable in and of itself, the composite becomes more sustainable and environmentally friendly when biodegradable components are added.

The idea of biodegradable ABS composites is not specifically discussed (Shrivastava & Dondapati, 2021) Nonetheless, the study highlights the characteristics and uses of biodegradable composites made of natural bast fibers and biopolymers.

Author (Shaharin & Ab Wahab, 2019) focuses on the characteristics of PLA/ABS composites filled with microcrystalline cellulose (MCC). The study demonstrates how improving the surface treatment and MCC content enhances the composites' tensile qualities. By using a soil burial test on a laboratory scale to assess the composites' biodegradability, it was shown that both systems lost weight as they broke down.

Application:

- Disposable Products: Single-use items that benefit from biodegradability.
- Packaging Materials: Eco-friendly packaging solutions.
- Consumer Goods: Products aimed at reducing environmental impact.

X. Recycled ABS Composites

Recycled ABS composite refers to a composite material that is produced by incorporating recycled Acrylonitrile Butadiene Styrene (ABS) into the manufacturing process. In order to reduce waste and promote sustainability, this entails repurposing ABS plastic waste or scrap components to make new composite items. The study focuses on recycling recycled ABS from product waste to generate a new filament in the context of the source that is provided. Composite materials are then created using the recycled filament. By repurposing abandoned ABS materials, this approach supports the circular economy in addition to aiding in the recycling of ABS waste (Mat et al., 2020).

Application:

- Various Applications: Depending on the purity and properties, including consumer products and industrial components.
- Sustainable Manufacturing: Products focused on sustainability and reducing environmental footprint.

CHAPTER 3

METHODOLOGY

This chapter explained the overall process flow involved in conducting and performing this final year project research. The methodology of this research includes the method of raw materials characterization, sample preparation, fabrication procedure as well as their related experimental testing.

3.1 Flowchart

The methodology for this research has been summarized in the flowchart available is shown in Figure 1. The first stages are raw material selection which is ABS is used as a polymer matrix (100, and 95 wt. %), and Nano-CuO (5 wt.%). Next the ABS will be dissolved in using Acetone. Later on, Nano-CuO will be gradually added at into the mixture of ABS. Membrane is later created by using electrospinning method. Later on, the sample is sent to gamma radiation laboratory to be radiate. The doses of radiate is (50 kGy and 100 kGy). For characterization analysis, among of the testing that were conducted are tensile testing, SEM & EDX testing, and FTIR testing. Lastly, the samples will be measured and collected.

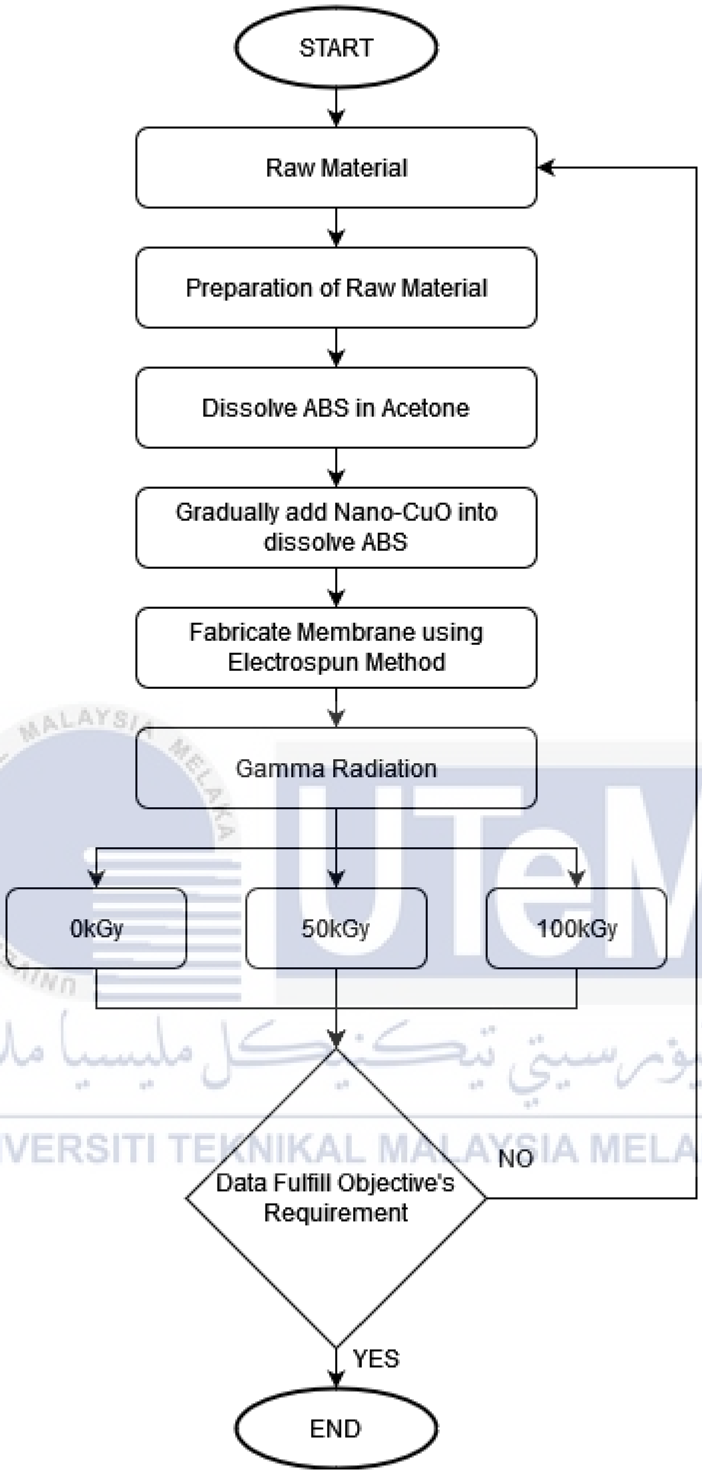


Figure 1: Process Flowchart

3.2 Material

The materials that were chosen for this study are quite varied, and each one is essential to the experimental inquiry. The main component is Acrylonitrile Butadiene Styrene (ABS), a synthetic material with strong mechanical qualities that is adaptable and durable. The study's inclusion of ABS provides the framework for analyzing its interactions with other components and comprehending how it behaves in particular experimental scenarios.

Nano-Copper Oxide (Nano-CuO) particles add a nanoscale component to the composite by balancing the ABS. The addition of Nano-CuO to the material confers distinct attributes, including but not limited to improved barrier qualities, surface feature modification potential, and reinforcing. The purpose of adding Nano-CuO is probably to explore the synergies between the polymer and nanoscale particles as well as to fine-tune the properties of the composite material.

The experimental setting becomes much more intricate due to the selection of solvents, specifically acetone. The polar solvent acetone is used to dissolve and work with the Nano-CuO particles. Acetone is a good option for several applications because of its low toxicity, high solubility and compatibility with a variety of compounds. Given its ability to dissolve and solubilize ABS, acetone may play a crucial role in generating a uniform solution that can be processed further. For this research, a complete set of materials is essentially formed by the selection of ABS, nano-CuO particles, and the solvents acetone.

3.2.1 Acrylonitrile Butadiene Styrene (ABS) pellets

Acrylonitrile butadiene styrene, or ABS, is a common thermoplastic polymer with a wide range of uses. It's a hard, stiff material that works well for creating computer casings, appliance parts, and other parts for cars. Three monomers make up ABS: styrene, butadiene, and acrylonitrile. Styrene offers the polymer a glossy appearance, butadiene adds toughness and impact resistance, and acrylonitrile provides chemical and thermal stability.

Among ABS's essential characteristics are:

- High resilience to impact and toughness

- Strength and rigidity
- Simple to paint, sand, and mold
- Able to withstand chemical corrosion
- 1.0 to 1.05 g/cm³ is the density.

Figure 2: ABS Pellets

3.2.2 Nano-Copper Oxide (Nano-CuO)

Copper oxide nanoparticles, also known as nano-copper oxide (nano-CuO) are a particular kind of semiconductor metal nanoparticle with distinctive optical, electrical, and magnetic characteristics. They have a brownish-black powdery appearance and, at high temperatures, can be converted to metallic copper when exposed to hydrogen or carbon monoxide.

Among nano-CuOs' essential characteristics are:

- High catalytic activity and electrical conductivity
- Outstanding antibacterial and antimicrobial qualities
- Possibility of producing too many reactive oxygen species (ROS), which might put cells under oxidative stress
- Because of their small size and ability to penetrate cells and tissues, they have the potential to be harmful to animals and cells at large doses.

Figure 3: Nano-Copper Oxide

3.2.3 Acetone

Because of its advantageous characteristics in this particular application, acetone was chosen as the solvent to dissolve the ABS. Good compatibility between acetone and ABS makes it a useful medium for stabilizing and spreading the particles. Because of its polarity, a variety of materials, including ABS, can dissolve in it and form a homogenous mixture. Acetone is also a good option in situations where environmental concerns are critical or in circumstances in which the solvent being used could come in contact with biological systems due to its low toxicity.

Figure 4: Acetone

3.3 Sample Preparation

The first step is measured the amount of ABS, acetone, and nano-CuO required for each sample. Refer table 1 for the calculation. Second step, place the container containing acetone on the magnetic stirrer with the parameter mention in the table 1. Gradually add the ABS inside the container within 30 minutes. The reason of adding the ABS gradually is to prevent it from clumping. As for ABS+nano-CuO sample, nano-CuO is added gradually into the solution after finish adding ABS. The sample solution will run for 24 hours. For first 2 hours, the sample will stir with additional of heat, after 2 hours the sample will be stirred without heat for the remaining 24hours. After 24 hours, the sample can be used to produce membrane.

Table 1: Material Calculation

Sample	ABS	Acetone	Nano-CuO wt%	Magnetic Stirrer Parameter (24hours)
Pure ABS	10 grams	40 grams	-	Heat = 60℃ (run for 2 hours only) Speed = 200rpm
ABS + Nano-CuO 5%	10 grams	40 grams	Total amount of acetone + ABS x 5% = 2.5 grams	Heat = 60℃ (run for 2 hours only) Speed = 200rpm

Third step, place a layer of aluminium foil on the electro spun machine roller. Fourth step, set the machine parameter as target Speed 0.5m/min, syringe punp speed 0.289mm/min, voltage 15kV, and leakage current 0.01µA. Fifth step, insert the stirred sample inside 2 syringes, each syringes contain 10ml and place the syringes in the designated place in the machine. Close and run the machines. Sixth step, observe the syringe for any clump or agglomerate occurs at the tip of the needles, remove the clump if happen. Repeat step 5 if the sample is not thick enough.

Last step, measure and cut the sample into smaller sizes before sending to do gamma radiation. Repeat all step for another sample.

Table 2: Formulation for Experiment

Sample	ABS (wt%)	Nano-CuO (wt%)	Gamma Radiation (kGy)
PURE ABS	100	0	50
PURE ABS	100	0	100
ABS+Nano-CuO	95	5	50
ABS+Nano-CuO	95	5	100

3.4 Characterization and Testing

Testing and characterization are crucial processes in assessing a material's characteristics and capabilities. Characterization includes morphological analysis and the determination of a material's mechanical, structural, and physical properties. This includes techniques like measuring mechanical properties like tensile strength with a tensile testing machine, analyzing a material's chemical composition with Fourier Transform Infrared Spectroscopy (FTIR), and analyzing a material's morphology with Scanning Electron Microscopy (SEM) and Energy-Dispersive X-ray (EDX). To understand a material's properties and performance and determine if it is suitable for a certain use, characterization and testing are often essential. The following is a list of the tests and characterizations that will be used in this inquiry.

3.4.1 Tensile Strength Test

EZ-LX tensile machine was used to determine the tensile properties of the membrane. A tensile test involves clamping a sample of the material inside an equipment and applying a tensile load on it until it breaks. The device calculates the material's tensile strength, its elongation at break, and Young's modulus while keeping an eye on the load and displacement during the test. To pass the test, samples must be at least 5mm wide, and 25mm length. The test can be used to determine the quality of the material and compare it to other options for raw materials or production methods.

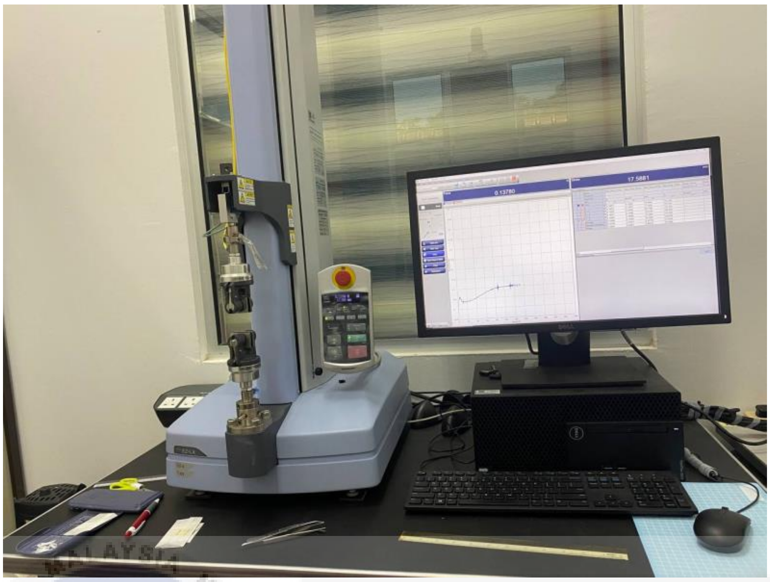


Figure 5: 1kN Tensile Test Machine.

3.4.2 Scanning Electron Microscope (SEM) and Energy Dispersive X-Ray (EDX)

Utilizing Scanning Electron Microscopy (SEM) and Energy-Dispersive X-ray Spectroscopy (EDX), the elemental composition and surface morphology of ABS membranes reinforced with nano-CuO are examined. The SEM device is used to scan the sample surface in order to produce high-resolution images once a tiny section of the material has been prepared. The X-rays that are released are simultaneously analyzed by the associated EDX detector, which allows for elemental mapping and identification within the material.

Figure 6: Scanning Electron Microscopy (SEM) and Energy-Dispersive X-ray Spectroscopy (EDX)

3.4.3 Fourier Transform Infrared Spectroscopy (FTIR)

By measuring how much infrared light a sample absorbs, a technique known as Fourier-transform infrared spectroscopy (FTIR) can be used to determine the chemical makeup of the sample. The methodology relies on the idea that various chemical substances absorb infrared light at particular wavenumbers, or frequencies. The chemical groups contained in the sample can be identified, as well as their relative quantities, by measuring the absorption of infrared radiation at various wavenumbers.

Figure 7: Fourier-transform infrared spectroscopy (FTIR) Machine

3.5 Morphological

When gamma radiation causes morphological changes in ABS composite membranes, the membrane's physical structure is usually affected. This may involve changes in surface morphology, porosity, and crystallinity, all of which can affect the membrane's overall characteristics and performance. Understanding the effects of gamma radiation on the structure and functionality of the material requires an analysis of these changes.

ABS composite membranes undergo a number of microscopic and macroscopic morphological changes upon exposure to gamma radiation. One significant adjustment is the shift in crystallinity, which occurs when the polymer chains in the membrane are rearranged. This may affect the mechanical characteristics and structural integrity of the membrane.

Gamma radiation may also have an impact on the membrane's porosity. The permeability and filtration capacities of the membrane may be impacted by variations in the size and distribution of its holes. The membrane's surface morphology may also be impacted, which could result in changes to the roughness of the surface or the creation of new structures

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

The study's findings are presented in the following part, which also offers an in-depth discussion the impact of gamma radiation on the properties of ABS composite membrane. Characterisation of the material is done by Fourier Transform Infrared Spectroscopy (FTIR) test, and Scanning Electron Microscopy and Energy-Dispersive X-ray Spectroscopy (SEM-EDX) Test. The physical and mechanical properties will be discussed based on the results obtained from tensile test.

4.2 Tensile Test

The tensile test is a widely used method to evaluate the mechanical properties of materials, including fiber membranes. In this context, we will explore the tensile characteristics of two types of fiber membranes: Pure ABS and ABS + Nano-CuO 5%. Additionally, these fiber membranes have three types: non-radiated, 50kGy gamma radiated, and 100kGy gamma radiated.

To assess the mechanical behaviour of these fiber membranes, the tensile test will be conducted by following the outlined guidelines. This guideline provides a standardized procedure for determining the tensile properties of plastics, including fibers, films, and sheets.

The objective of this study is to investigate how gamma radiation impacts the mechanical properties of the membrane. Specifically, this study aims to analyse the tensile strength, young’s modulus, and elongation at break of both samples with and without radiation. By understanding the mechanical response of membranes, this study can help gain insights into their structural integrity, durability, and suitability for various application.

4.2.1 Comparison for Pure ABS

Tensile characteristics of the radiated Pure ABS composite membrane were compared with those of the non-radiated Pure ABS composite membrane in order to comprehend the effect of radiation on the material's mechanical performance. This experiment in making this comparison was to ascertain how radiation impacts the mechanical behaviour of the composite material and to shed light on any modifications brought about by the radiation treatment with regard to strength, flexibility, and overall performance.

4.2.1.1 Tensile Strength, MPa

In this research study, we investigated the tensile strength properties of electro spun fiber samples prepared using the electrospinning method. The aim of this study is to assess the influence of the gamma radiation on the membrane. There are three type of sample, one non-radiated sample, and two radiated sample. Each of the radiated sample consist of difference doses of radiation, 50kGy and 100kGy. The ability of a material to withstand breaking or deformation under stretching pressures is measured by its tensile strength, which is an essential mechanical attribute. Given their potential uses in filtration, tissue engineering, and composite materials, it's critical to comprehend the behaviour of electro spun fibers' tensile strength.

$$Tensile\ strength, s = \frac{Force\ required\ to\ break, P}{Cross - sectional\ area, a}$$

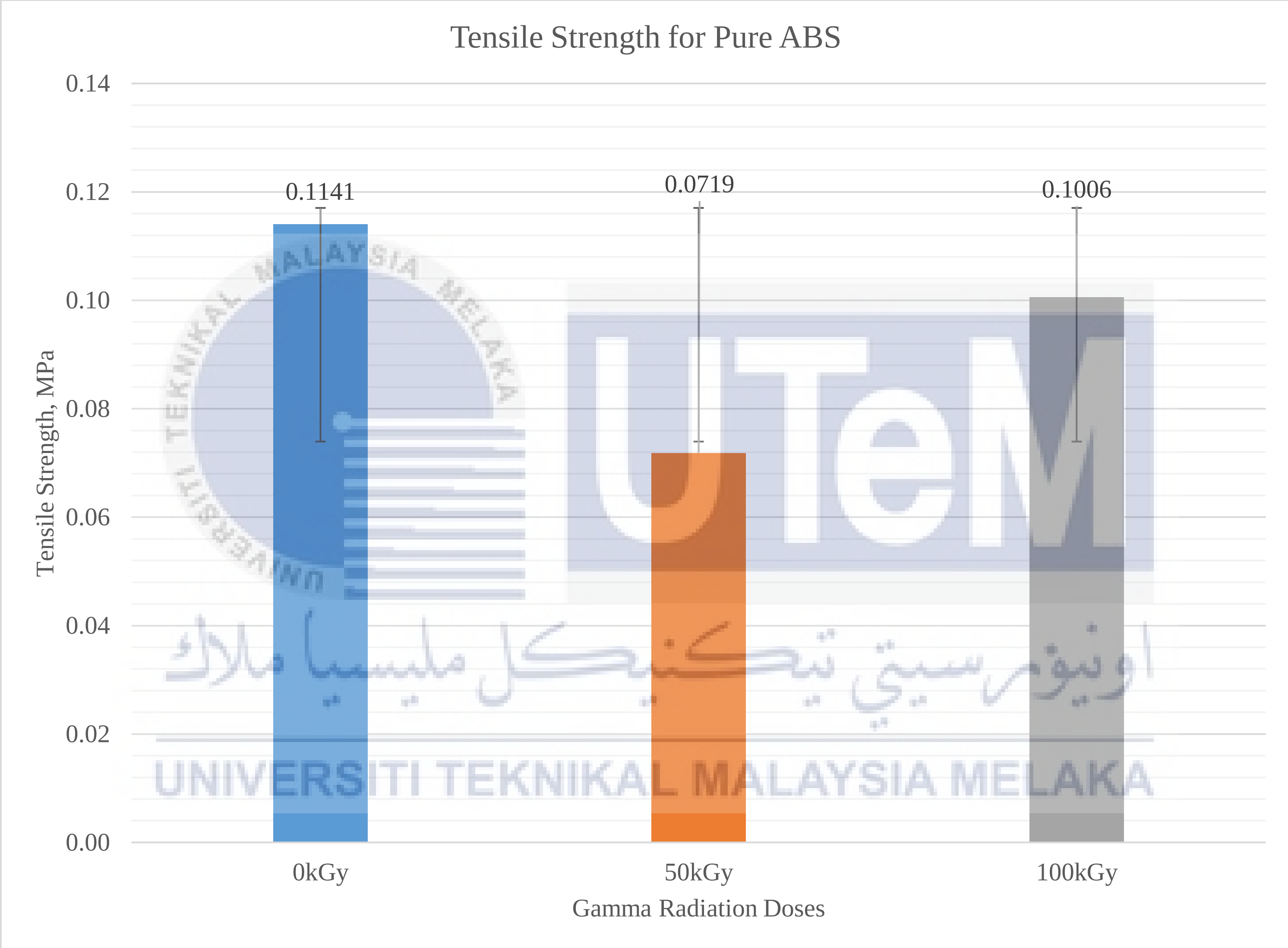


Figure 8: Tensile Strength Result for Pure ABS.

Based on Figure 8, from testing found out that the pure ABS sample that isn't exposed to radiation has a tensile strength of 0.1141 MPa. This number indicates the material's underlying tensile strength independent of radiation. It provides a starting point for comparing the effects of radiation exposure on the material's ability to tolerate tensile stress.

After 50 kGy of radiation exposure, ABS's tensile strength drops dramatically to 0.0719 MPa. This significant decrease implies that the polymer structure has been degraded by radiation. Chain scission, in which the polymer chains split apart and produce a weaker material that can only withstand a certain amount of stress before failing, is one theory for this degradation. The ABS is more prone to breaking under stress because of the drop in tensile strength, which suggests a loss of molecular integrity.

Tensile strength rises to 0.1006 MPa when ABS is exposed to a higher radiation dose of 100 kGy. This number is much higher than that of the 50 kGy radiated sample, even though it is lower than the tensile strength of non-radiated ABS. This rise implies that the polymer's internal cross-linking intensifies at 100 kGy.

According to (Wady et al., 2020), these results highlight how crucial it is to comprehend radiation exposure and manage it in order to modify ABS's mechanical characteristics for certain uses.

4.2.1.2 Young's Modulus, MPa

Young' modulus is a way to measure the material's stiffness, which also expresses the amount of strain or deformation a material will experience in response to a specific stress level (Williams, 2022).

$$Young's\ Modulus, E = \frac{Stress, \sigma}{Strain, \varepsilon}$$

Before the material begins to deform plastically, the stress and strain values must be obtained in the linear, elastic portion of the stress-strain curve. The material's young's modulus is determined by the gradient or slope.

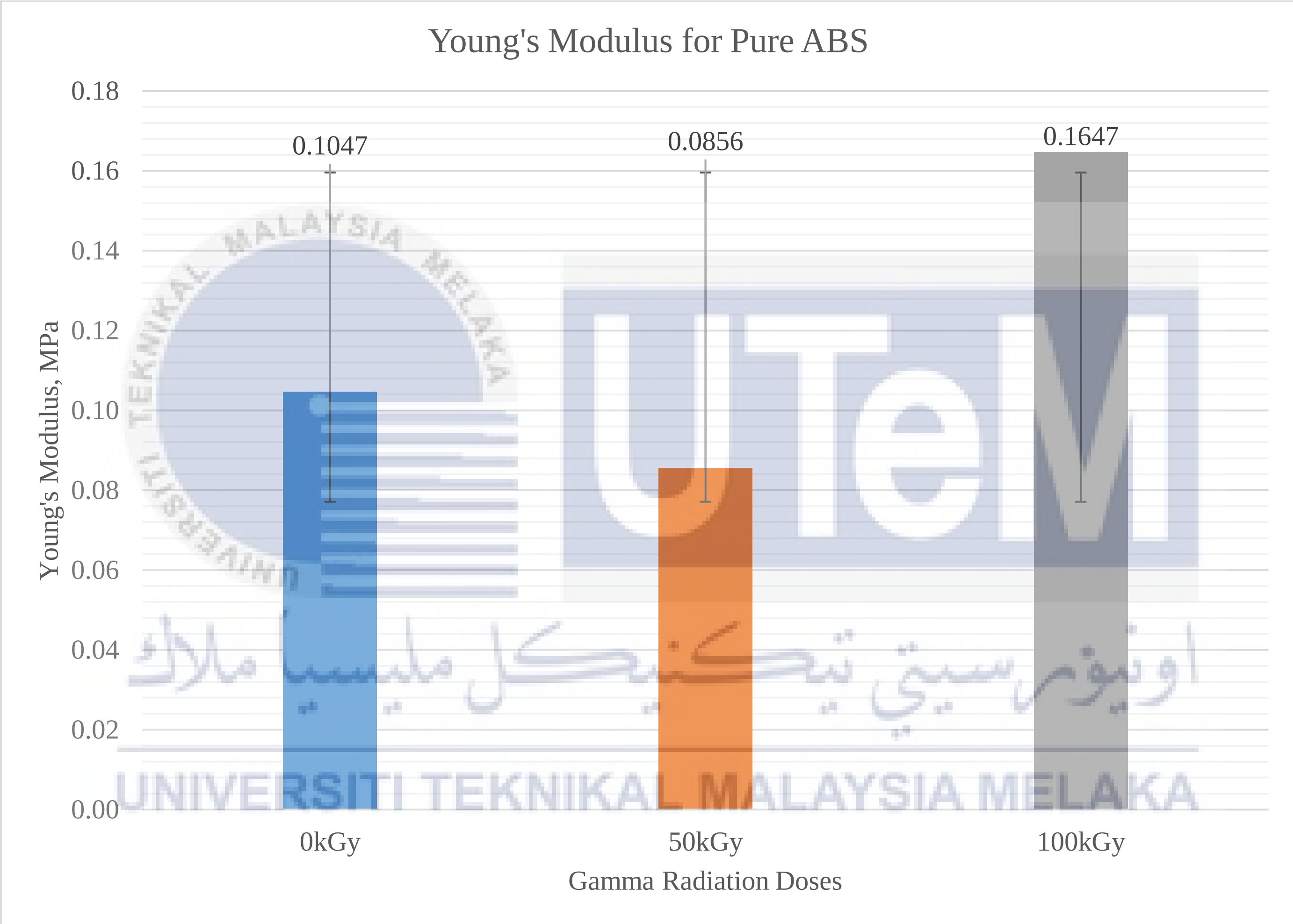


Figure 9: Young' Modulus Result for Pure ABS.

Based on Figure 9, from testing found out that the pure ABS sample that isn't exposed to radiation has a Young's modulus of 0.1047 MPa. This number indicates the material's baseline mechanical stiffness independent of radiation. It provides a baseline against which to compare the impact of varying radiation exposure levels on the stiffness of the material.

The ABS experiences a reduction in Young's modulus to 0.0856 MPa upon exposure to a radiation dose of 50 kGy. The young's modulus decreased, indicating that the material has been more plasticized or degraded as a result of radiation exposure. In contrast to the 50 kGy exposure, the ABS undergoes a substantial rise in Young's modulus to 0.1647 MPa during exposure to a greater radiation dose of 100 kGy. The material's internal structure may have changed as a result of the breaking of polymer chains or cross-linking, which decreased the material's stiffness and increased its susceptibility to deformation under stress.

According to (Wady et al., 2020), a non-linear response may be seen in the tensile test data for ABS's Young's modulus at various radiation exposure levels. Higher radiation (100 kGy) greatly increases the material's stiffness, while moderate radiation (50 kGy) decreases it. These findings highlight how crucial it is to manage radiation exposure in order to modify ABS's mechanical characteristics for a range of applications. To gain a deeper understanding of the mechanisms underlying these discoveries, additional research could investigate the microstructural alterations in the polymer

4.2.1.3 Elongation of break, %

Elongation of break measures the percentage increase in length that a material experiences before breaking. To compute it, devide the length change by the initial length, then multiply the result by 100.

$$Elongation\ of\ break, \varepsilon = \frac{Final\ length, \Delta L}{Initial\ length, L}$$

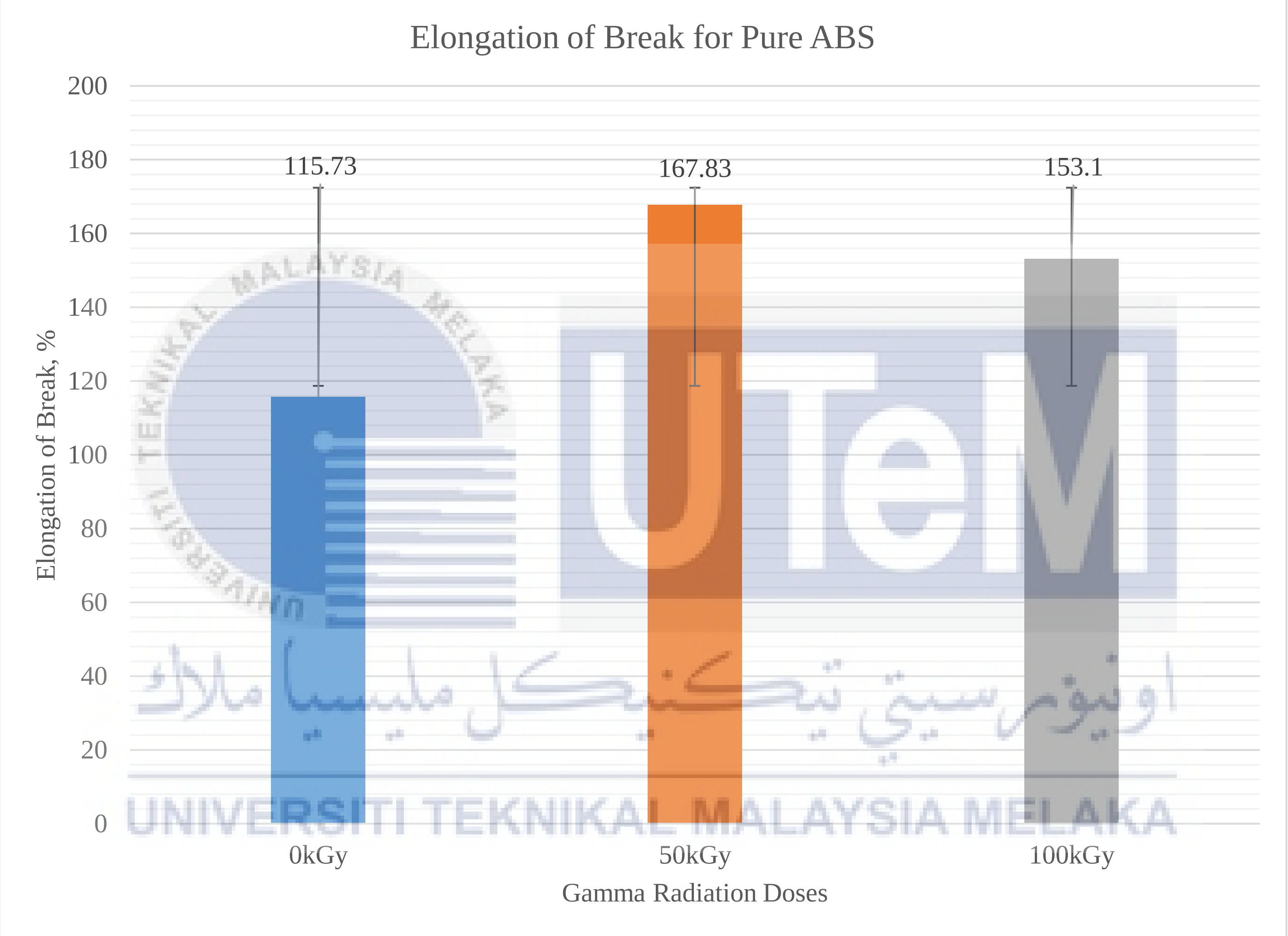


Figure 10: Elongation of Break Result for Pure ABS.

Based on Figure 10, the non-radiated pure ABS sample elongation at break is 115.73%. This shows that it can stretch to 115.73% of its initial length before breaking.

ABS experiences a considerable increase in elongation at break to 167.83% when exposed to a radiation dosage of 50 kGy. This significant rise implies that this dose of radiation improves the ductility of the material.

However, the elongation at break drops to 153.1% with a higher radiation dose of 100 kGy, although it still remains more compare to non-radiated ABS. This implies that, although the material's ductility remains higher than the non-irradiated sample, the effects of radiation begin to balance between potential cross-linking. In contrast to non-radiated ABS, cross-linking can add some stiffness, counteracting the severe ductility seen at 50 kGy while yet preserving a higher overall elongation.

According to (Zulfi et al., 2019), the mechanical characteristics of the electro spun nanofiber membranes can be influenced by a variety of elements, such as the fiber composition, diameter, shape, and size uniformity. a notable improvement in PAN nanofibers' mechanical characteristics as a result of a smaller fiber diameter. Better molecular orientation and crystallinity in lower fiber diameters translated into higher mechanical strengths

4.2.1.4 Conclusion

To sum up, the outcomes of the tensile test demonstrate the intricate relationship between radiation exposure and ABS's mechanical characteristics. Although the material's tensile strength and stiffness are greatly reduced by gamma radiation (50 kGy), its ductility is improved, as shown by the higher elongation at break. This indicates that at this dose, chain scission and degradation predominate, which increases the polymer's susceptibility to deformation under stress.

Even though not same as non-radiated ABS, further radiation exposure (100 kGy) does restore tensile strength and stiffness by cross-linking. Even though it is less than 50 kGy, the elongation at break is still greater. These results suggest that at 100 kGy, cross-linking becomes more common, counteracting the severe ductility observed at lower dosages and retaining part of the enhanced elongation capabilities.

According to (McTaggart et al., 2020), when printed with pre-irradiated filament, various characteristics of ABS showed nearly a 20% drop following exposure to 1 kGy of radiation; these phenomena did not occur in ABS when samples were printed prior to irradiation.

4.2.2 Comparison for ABS + Nano-CuO 5%

Tensile characteristics of the radiated ABS + Nano-CuO 5% composite membrane were compared with those of the non-radiated ABS + Nano-CuO 5% composite membrane in order to comprehend the effect of radiation on the material's mechanical performance with regard to strength, flexibility, and overall performance.

4.2.2.1 Tensile Strength, MPa

In this research study, we investigated the tensile strength properties of electro spun fiber samples prepared using the electrospinning method. The aim of this study is to assess the influence of the gamma radiation on the membrane. There are three type of sample, one non-radiated sample, and two radiated sample. Each of the radiated sample consist of difference doses of radiation, 50kGy and 100kGy. The ability of a material to withstand breaking or deformation under stretching pressures is measured by its tensile strength, which is an essential mechanical attribute. Given their potential uses in filtration, tissue engineering, and composite materials, it's critical to comprehend the behaviour of electro spun fibers' tensile strength.

$$Tensile\ strength, s = \frac{Force\ required\ to\ break, P}{Cross - sectional\ area, a}$$

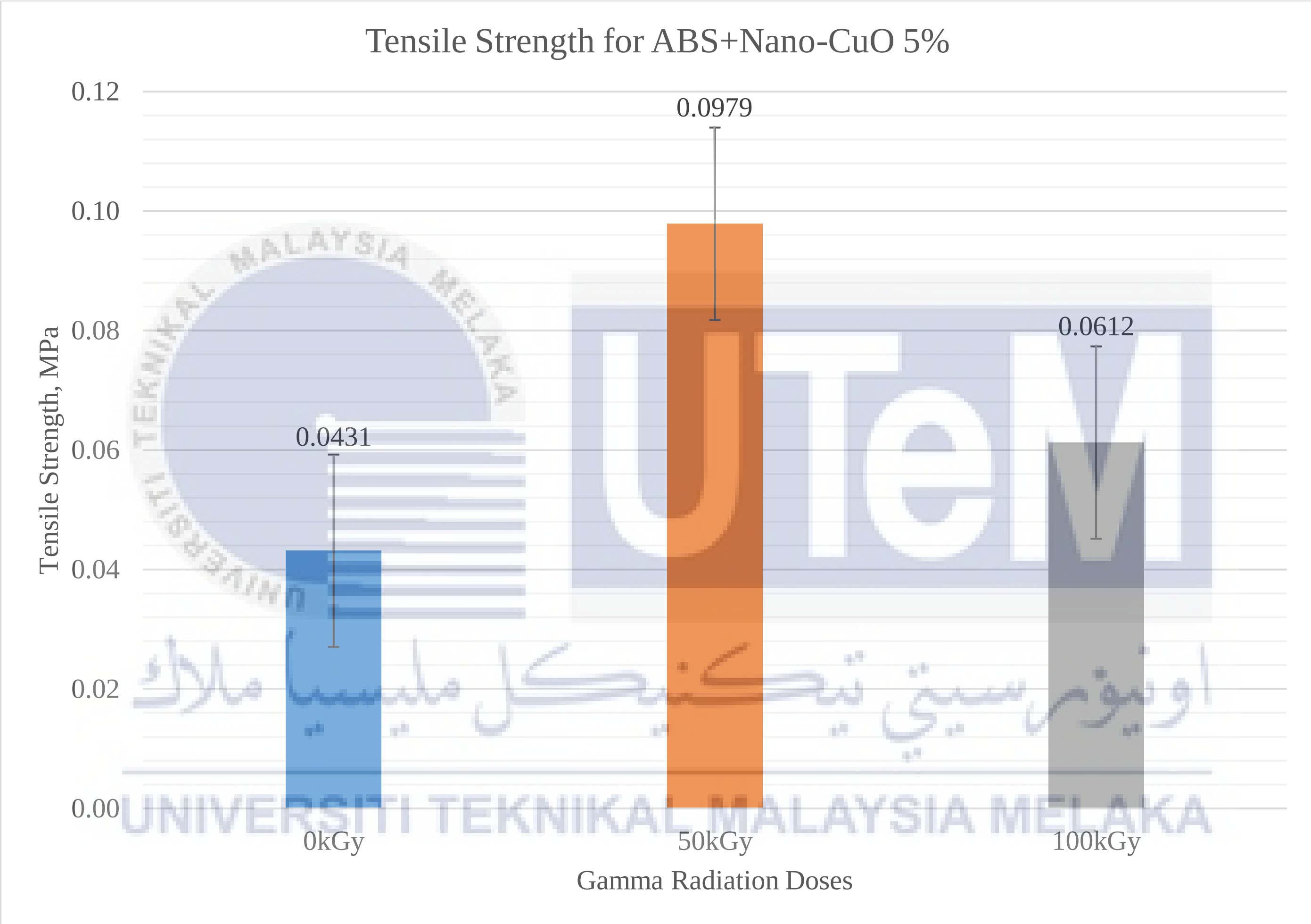


Figure 11: Tensile Strength Result for ABS+Nano-CuO 5%.

The non-radiated ABS + Nano-CuO 5% sample has a tensile strength of 0.0431 MPa. This baseline value serves as a point of reference for comprehending how the addition of Nano-CuO affects ABS's tensile strength. When compared to pure ABS, it doesn't seem like the addition of Nano-CuO really increases the tensile strength. This could be because of inadequate dispersion or interfacial bonding between the non-radiated Nano-CuO particles and the ABS matrix.

Based on Figure 11, ABS + Nano-CuO 5% exhibits a notable improvement in tensile strength to 0.0979 MPa after being exposed to a radiation dose of 50 kGy. This more than twofold increase in tensile strength suggests that this level of radiation benefits the composite's mechanical characteristics.

The tensile strength drops to 0.0612 MPa at a greater radiation dose of 100 kGy, yet it still surpasses that of the non-radiated sample. This decrease in comparison to the sample exposed to 50 kGy of radiation raises the possibility that excessive radiation may start to introduce material-weakening breakdown mechanisms such chain scission. In spite of this, the tensile strength is still higher than in the non-radiated state, suggesting that radiation has a beneficial effect overall up to a certain point.

The ABS + Nano-CuO 5% tensile test data under various radiation exposures shows a distinct trend of increased strength with intermediate radiation doses. In the non-radiated state, the addition of Nano-CuO nanoparticles does not considerably increase the tensile strength; nevertheless, radiation exposure, especially at 50 kGy, greatly increases the material's strength (Tarawneh et al., 2021).

4.2.2.2 Young's Modulus, MPa

Young' modulus is a way to measure the material's stiffness, which also expresses the amount of strain or deformation a material will experience in response to a specific stress level (Williams, 2022).

$$Young's\ Modulus, E = \frac{Stress, \sigma}{Strain, \varepsilon}$$

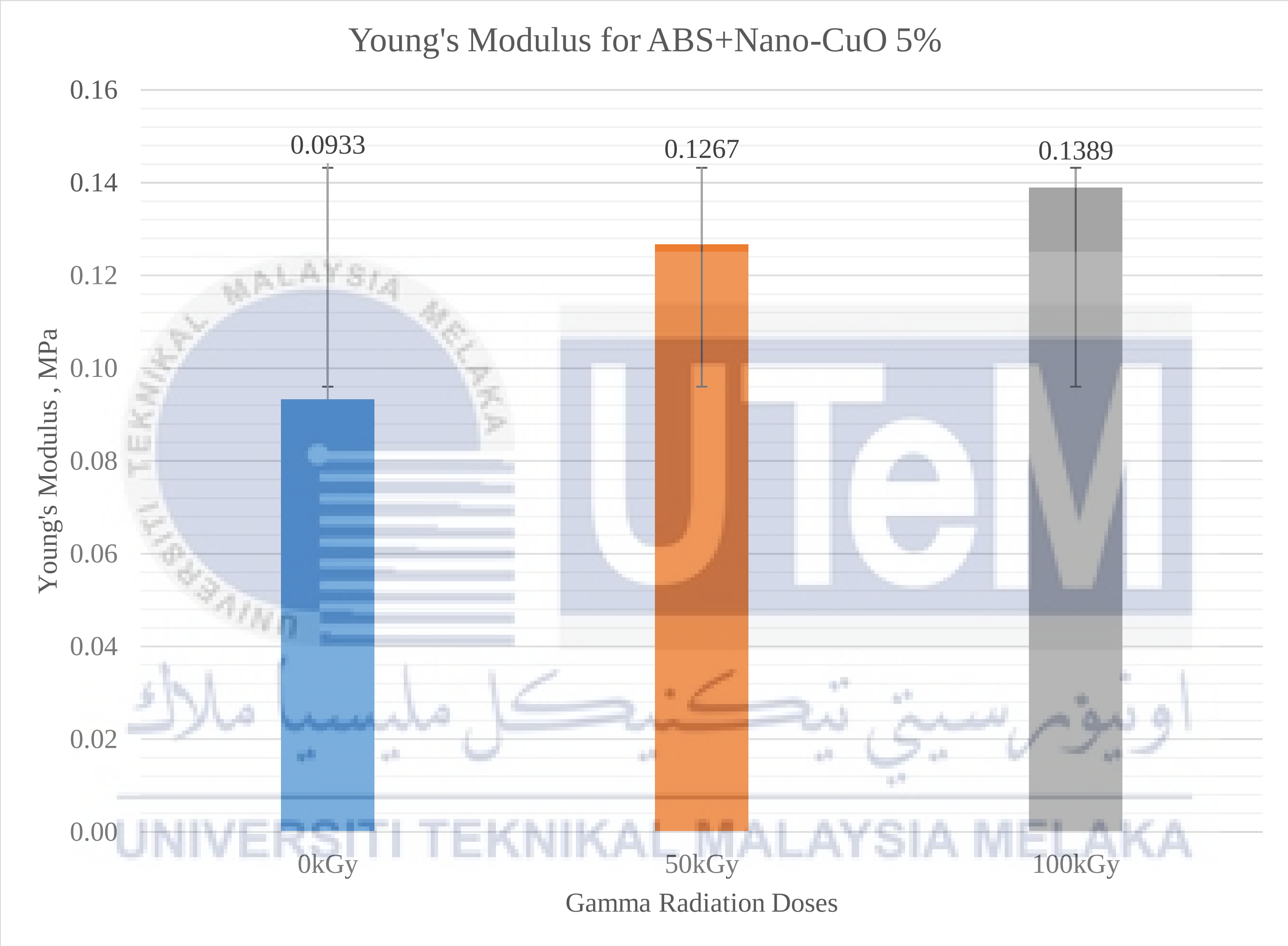


Figure 12: Young's Modulus Result for ABS+Nano-CuO 5%.

Based on Figure 12, the non-radiated ABS + Nano-CuO 5% sample has a Young's modulus of 0.0933 MPa. This value acts as a reference point to determine how the stiffness of the material changes in relation to pure ABS when Nano-CuO particles are added. Remarkably, as compared to pure ABS, the inclusion of Nano-CuO lowers the Young's modulus, suggesting that there may be a plasticizing impact or less efficient stress transmission between the nanoparticles and matrix in the non-radiated condition.

ABS + Nano-CuO 5% exhibits a notable rise in Young's modulus to 0.1267 MPa following exposure to a radiation dosage of 50 kGy. This significant increase implies that radiation at this intensity improves the composite material's rigidity. As for the Young's modulus increases further to 0.1389 MPa at a radiation exposure of 100 kGy. This sustained enhancement suggests that the impacts observed at 50 kGy are enhanced with higher doses.

The data from the tensile test for the Young's modulus of ABS + Nano-CuO 5% under different radiation exposures show a complex reaction that is affected by both the radiation dose and the nanoparticle addition. While higher radiation (100 kGy) introduces a balance between additional augmentation and degradation effects, moderate radiation (50 kGy) greatly increases stiffness. These results highlight how crucial it is to maximize radiation exposure and nanoparticle reinforcement in order to customize the mechanical characteristics of ABS composites for particular industrial uses (Tarawneh et al., 2021; Trukhanov et al., 2023).

4.2.2.4 Elongation of Break, %

Elongation of break measures the percentage increase in length that a material experiences before breaking. To compute it, devide the length change by the initial length, then multiply the result by 100.

$$Elongation\ of\ break, \varepsilon = \frac{Final\ length, \Delta L}{Initial\ length, L}$$

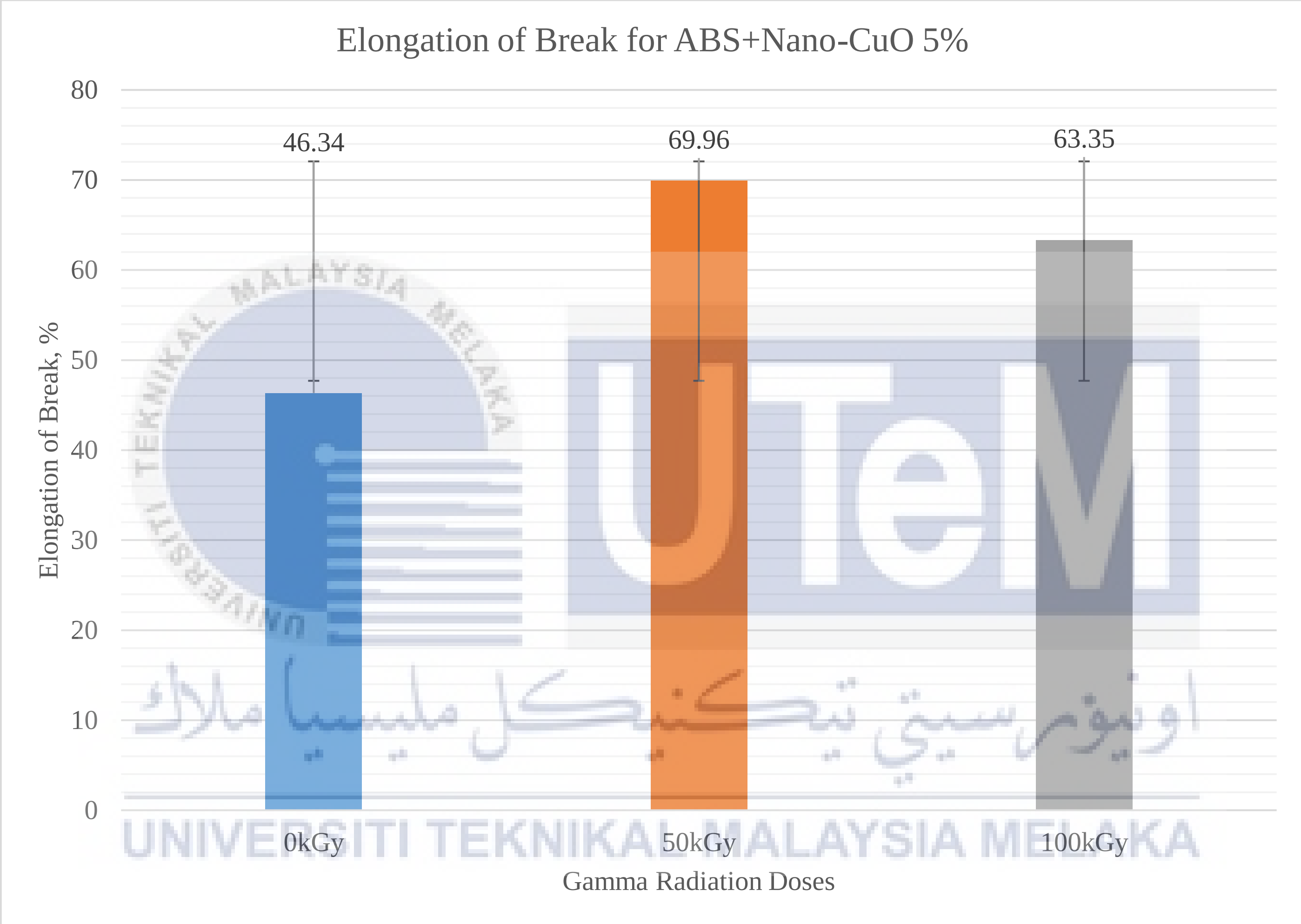


Figure 13: Elongation of Break Result for ABS+Nano-CuO 5%.

Based on the result in Figure 13, for the non-radiated ABS + Nano-CuO 5% sample, the elongation at break is 46.34%. The baseline ductility of the material is represented by this value, which shows how far it can stretch before breaking. The ductility of the ABS does not appear to be greatly increased by the addition of Nano-CuO in the non-radiated condition. This could be because of things like insufficient nanoparticle dispersion or poor interaction between the Nano-CuO particles and the ABS.

After 50 kGy of radiation exposure, the elongation at break of ABS+Nano-CuO 5% increases to 69.96%. This rise implies that the ductility of the material is improved by radiation at this level. The elongation at break drops to 63.35% at a higher radiation dose of 100 kGy, although it still remains much higher than the non-radiated sample. This decrease in comparison to the sample exposed to 50 kGy of radiation raises the possibility that excessive radiation may begin to introduce conflicting effects, including cross-linking, which can decrease ductility and increase stiffness.

A distinct pattern of enhanced ductility with moderate radiation doses can be seen in the tensile test data for elongation at break of ABS+Nano-CuO 5% under different radiation exposures. In the non-radiated condition, the addition of Nano-CuO nanoparticles does not considerably improve ductility; nevertheless, radiation exposure, especially at 50 kGy, significantly increases the material's stretchability before breaking. The aforementioned results underscore the significance of nanoparticle reinforcement and regulated radiation exposure in customizing the mechanical characteristics of ABS composites for distinct industrial uses (Al-Saleh et al., 123 C.E.; Ndukwe et al., 2021; Tarawneh et al., 2021).

4.2.1.4 Conclusion

To sum it up, when subjected to gamma radiation, the ABS + Nano-CuO 5% composite shows notable improvements in its mechanical properties. In particular, at a radiation dose of 50 kGy, the tensile strength improves by more than two times to 0.0979 MPa, demonstrating a significant improvement in the mechanical properties of the composite. At a greater radiation dose of 100 kGy, the tensile strength decreases to 0.0612 MPa, but it still exceeds that of the non-radiated sample, indicating that radiation is helpful up to a certain limit. The emergence of material-weakening breakdown mechanisms like chain scission may be the cause of this decline.

Additionally, at a radiation dose of 50 kGy, the Young's modulus shows a considerable increase, rising to 0.1267 MPa, suggesting that radiation enhances the stiffness of the composite material. At larger radiation dosages, this augmentation is maintained as well; at 100 kGy, the Young's modulus increases even more to 0.1389 MPa.

Furthermore, after a radiation dose of 50 kGy, the elongation at break rises to 69.96%, suggesting that radiation at this level improves the material's ductility. At a greater radiation dose of 100 kGy, the elongation at break decreases to 63.35%, but it still exceeds that of the non-radiated sample. Conflicting effects, including cross-linking, which can enhance stiffness and decrease ductility, could be the cause of this drop.

Nevertheless, gamma radiation exposure can have a beneficial effect on the mechanical properties of ABS + Nano-CuO 5% composites, particularly at moderate radiation doses. On the other hand, high radiation levels could cause material-weakening breakdown mechanisms that would be detrimental to the composite's characteristics.

4.3 Fourier-transform infrared spectroscopy (FTIR) Test

Fourier-transform infrared spectroscopy (FTIR) is an advanced analytical method utilized to look into the molecular makeup and structure of many materials, including ABS composite membranes. FTIR can offer important insights into the chemical composition, bonding qualities, and structural attributes of ABS composite membranes.

A spectrum of infrared wavelengths is exposed to the membrane sample during an FTIR test on ABS composite membranes. Certain chemical bonds in the ABS polymer and any other components (such fillers, additives, or reinforcing agents) absorb the infrared light at distinct frequencies as it interacts with the sample. An FTIR spectrum is produced as a result of these chemical bonds' absorption of infrared light. It shows the strength of absorbed light as a function of wavelength.

The kinds of chemical groups that are present in an ABS composite membrane can be determined by examining the FTIR spectra of the membrane. Furthermore, the presence of additives or fillers, the degree of polymerization, and any chemical interactions or changes taking place inside the composite structure can all be determined using FTIR.

In conclusion, Fourier-transform infrared spectroscopy (FTIR) testing offers comprehensive molecular details regarding ABS composite membranes, providing insightful knowledge about their structural attributes, bonding qualities, and chemical composition. Understanding and maximizing the performance of ABS composite membranes in a range of commercial and scientific applications requires knowledge of this information.

4.3.1 Pure ABS Fourier-transform infrared spectroscopy (FTIR) Test

Fourier-transform infrared spectroscopy is a commonly employed analytical method that offers essential details on the molecular makeup of both organic and inorganic substances. It is especially helpful for the chemical non-destructive characterisation (Chen et al., 2015).

The FTIR test conducted on pure ABS is a very advanced analytical technique that is well-known for its capacity to reveal minute details about the molecular structure and chemical makeup of the material.

This method, which is highly sensitive, fast to analyse, and non-destructive, proves to be an important tool in many different contexts. FTIR is an essential tool that can be used in material identification processes, strict quality control methods, innovative research and development projects, or thorough forensic studies.

Its ability to offer thorough insights into the structure and makeup of pure ABS enables analysts, engineers, and researchers to make well-informed decisions, guaranteeing the material's suitability for a range of applications and improving our comprehension of how it behaves under various circumstances.

4.3.1.1 Pure ABS without Radiation Result

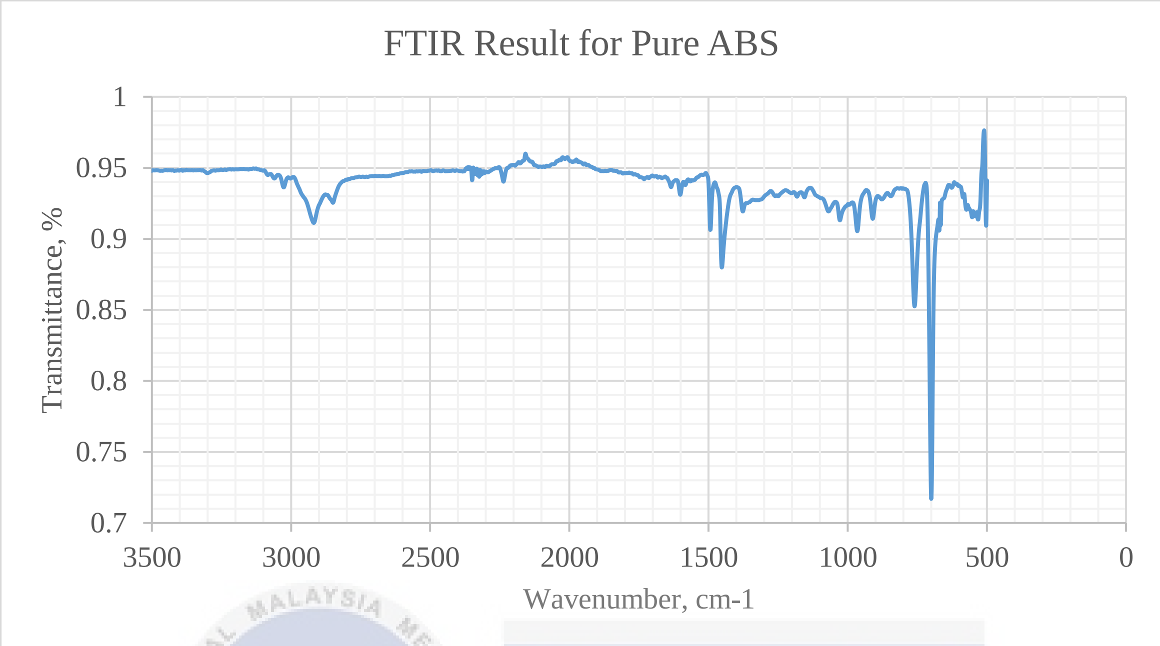


Figure 14: FTIR Result for Non-Radiated Pure ABS.

4.3.1.2 Pure ABS with 50kGy Gamma Radiation Result

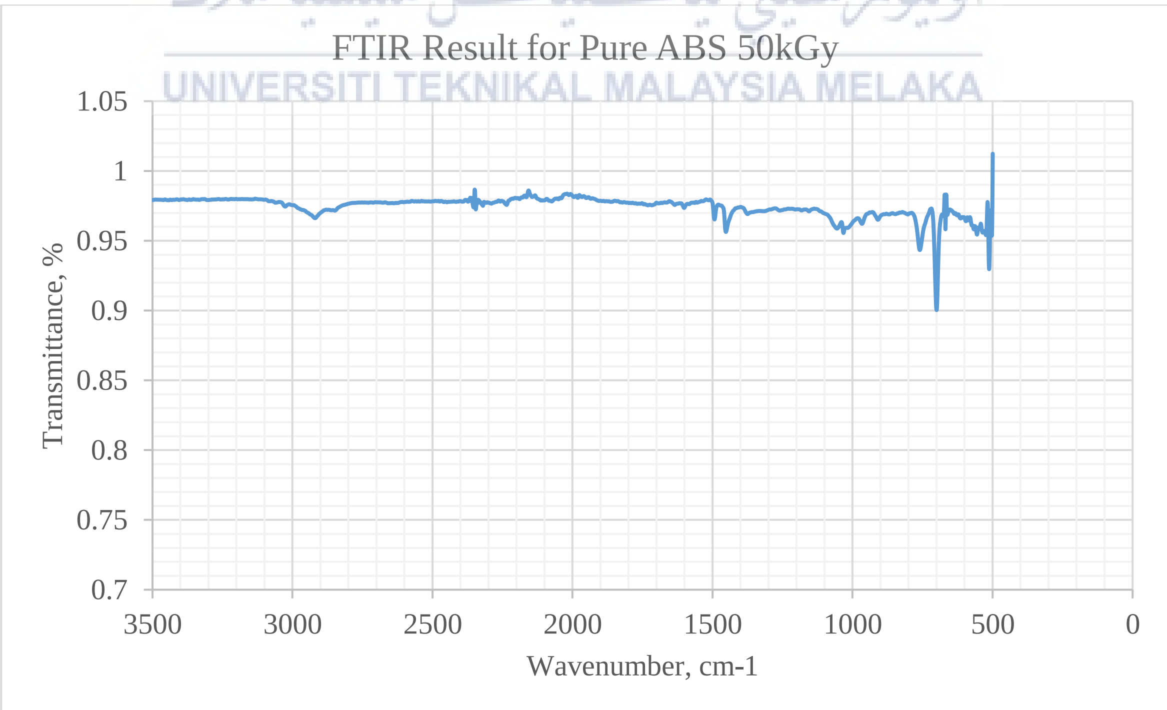


Figure 15: FTIR Result for 50kGy Radiated Pure ABS.

4.3.1.3 Pure ABS with 100kGy Gamma Radiation Result

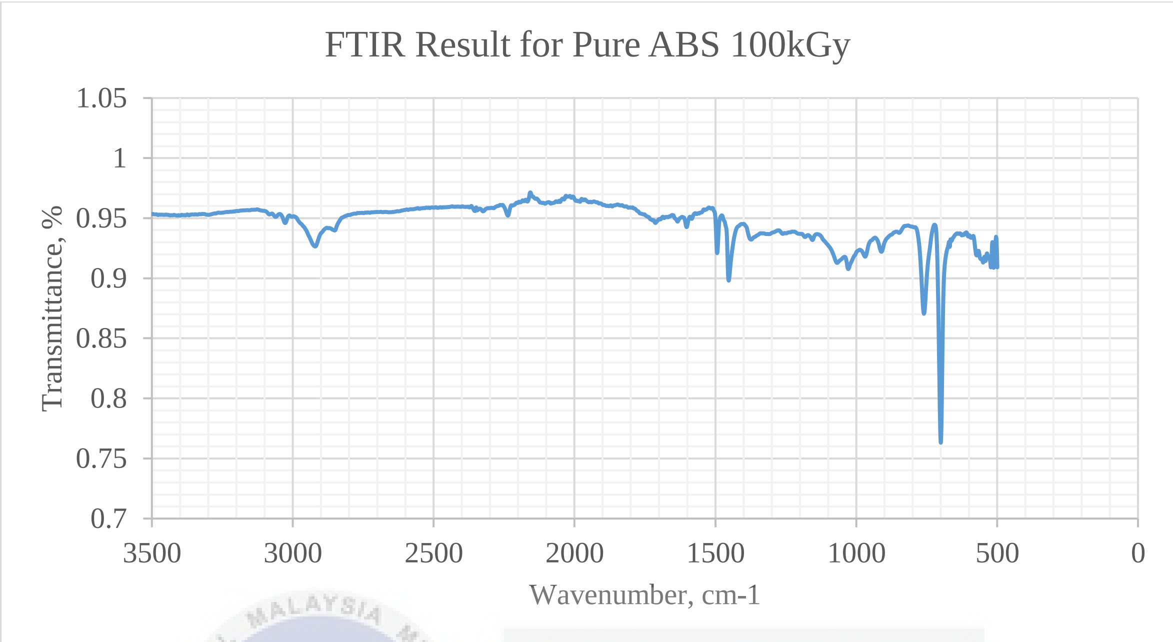


Figure 16: FTIR Result for 100kGy Radiated Pure ABS.

4.3.1.4 Comparison for Pure ABS

The molecular structures of a sample that was not exposed to radiation and samples that were exposed to radiation at doses of 50kGY and 100kGY were analysed and compared using FTIR spectroscopy.

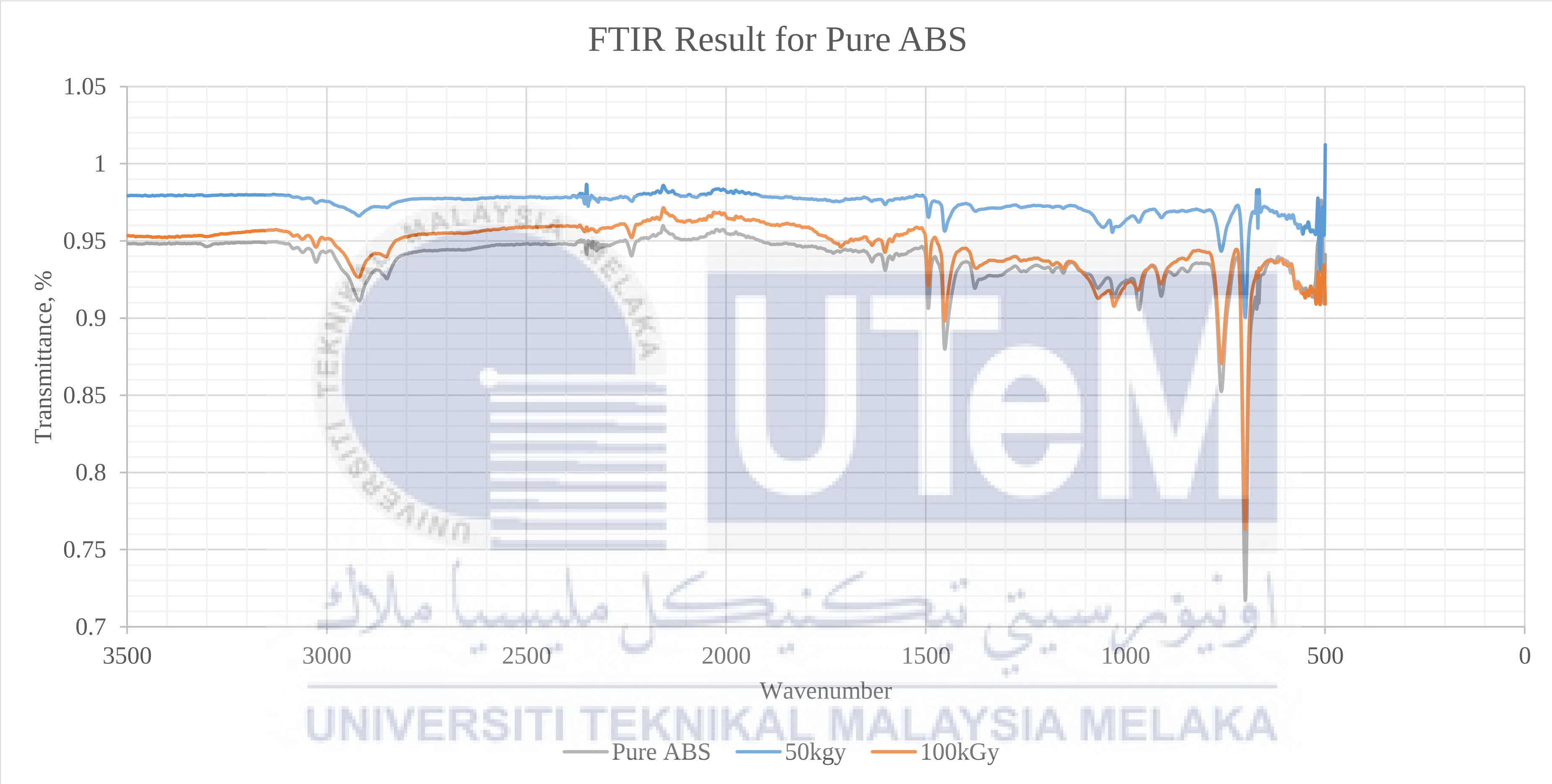


Figure 17: FTIR Result Comparison for Pure ABS.

Based on Figure 17, the FTIR result for pure ABS sample shows a significant variation in the fraction of incident infrared radiation that passes through the sample without being absorbed. The non-radiated, 50kGy, and 100kGy samples have transmittance values of 71%, 90%, and 76% respectively. The effects of radiation on the sample can be attributed on the fluctuation in transmittance levels. The sample's molecular structure is altered by the radiation, which has an impact on the infrared radiation's absorption and transmission.

Following are some hypothesized causes of the observed variation:

i) Non-radiated sample: With transmittance value of 71%, the non-radiated sample shows that it absorbs 29% of the infrared input energy. Might be due to the inherent properties of the ABS material.

ii) Radiated 50kGy sample: The transmittance of 50kGy sample has increased significantly to 90%. This rise probably the result of the sample's molecular structure changing as a result of radiation exposure. It might be because of certain chemical connections were disrupted by the radiation, which decreased absorption and increased transmission.

iii) Radiated 100kGY sample: The transmittance of 100kGy sample drops to 76%. The sample's overall exposure to radiation may be the cause of this drop. Increase absorption and decrease transmission may result from more noticeable radiation induced alterations in the molecular structure at higher radiation doses. This might be the result of the material developing new chemical bonds.

4.3.2 ABS + Nano-CuO 5% Fourier Transform Infrared Spectroscopy (FTIR) Test.

The Fourier-transform infrared spectroscopy (FTIR) test conducted on ABS+Nano-CuO 5% is a very advanced analytical technique that is well-known for its capacity to reveal minute details about the molecular structure and chemical makeup of the material. This method, which is highly sensitive, fast to analyse, and non-destructive, proves to be an important tool in many different contexts. FTIR is an essential tool that can be used in material identification processes, strict quality control methods, innovative research and development projects, or thorough forensic studies. Its ability to offer thorough insights into the structure and makeup of ABS+Nano-Cu) 5% enables analysts, engineers, and researchers to make well-informed decisions, guaranteeing the material's suitability for a range of applications and improving our comprehension of how it behaves under various circumstances.

4.3.2.1 ABS + Nano-CuO 5% without Radiation Result

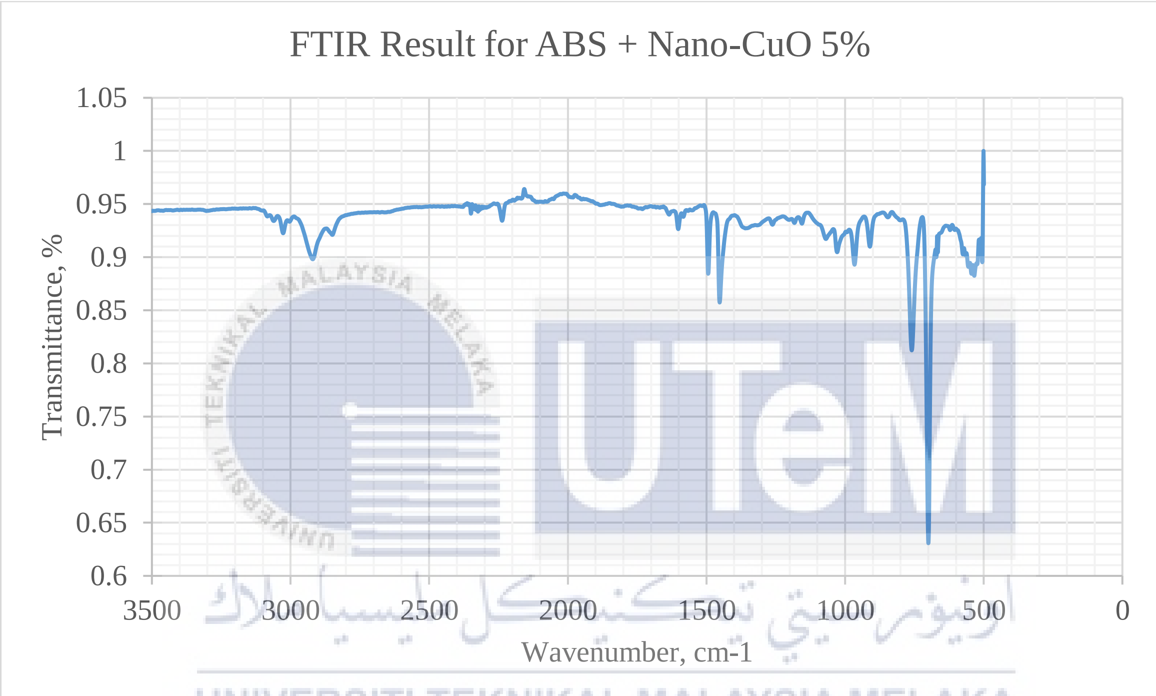


Figure 18: FTIR Result for Non-Radiated ABS+Nano-CuO 5%.

4.3.2.2 ABS + Nano-CuO 5% with 50kGy Gamma Radiation Result

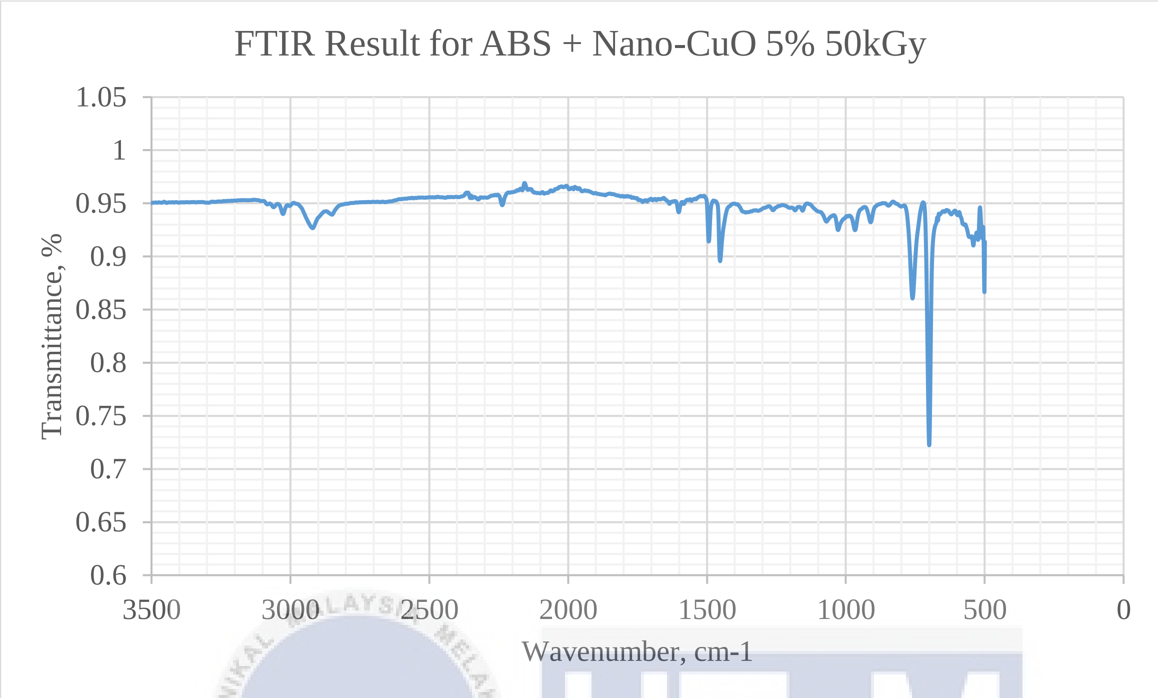


Figure 19: FTIR Result for 50kGy Radiated ABS+Nano-CuO 5%

4.3.2.3 ABS + Nano-CuO 5% with 100kGy Gamma Radiation

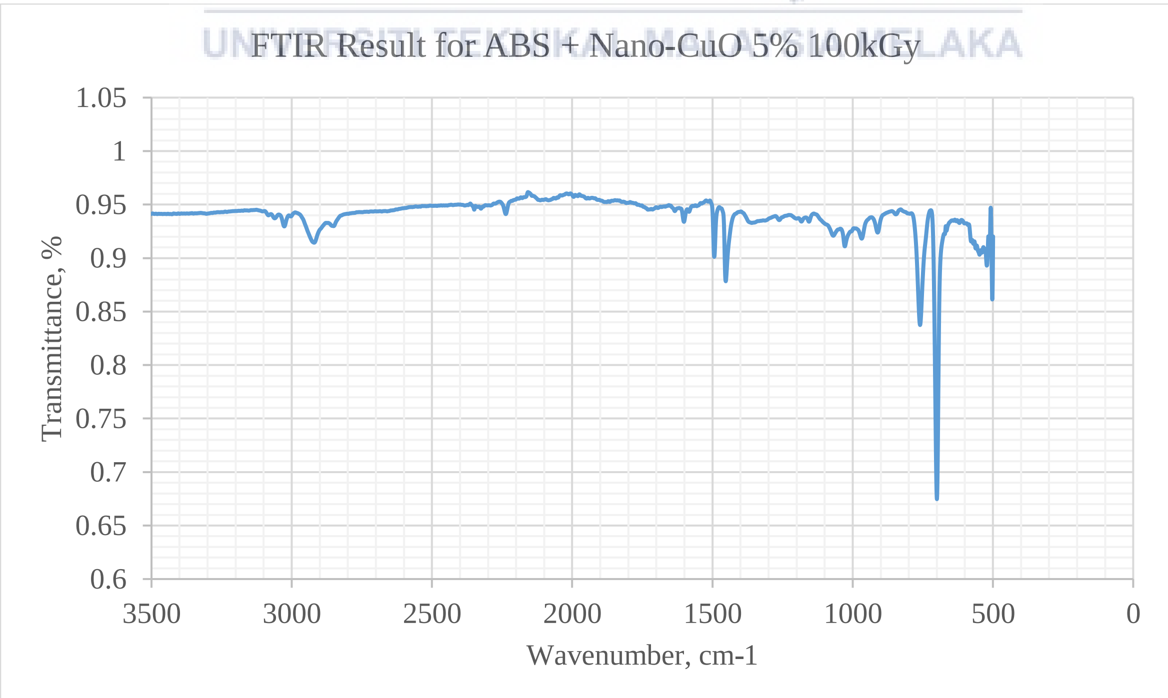


Figure 20: FTIR Result for 100kGy Radiated ABS+Nano-CuO 5%

4.3.2.4 Comparison of ABS + Nano-CuO 5%

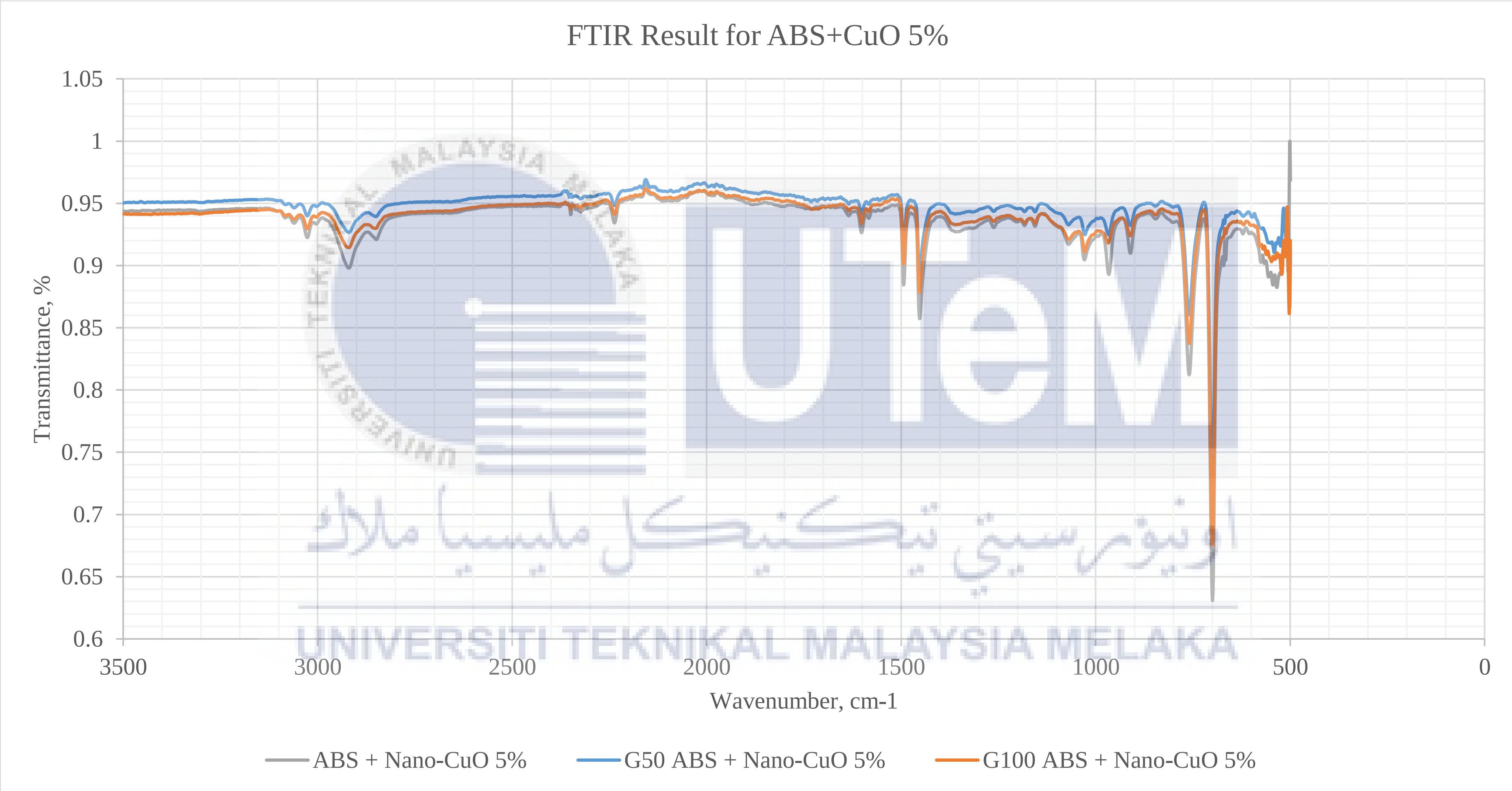


Figure 21: FTIR Result Comparison for ABS+Nano-CuO 5%.

The transmittance value, which measures the percentage of absorbed infrared radiation that passes through the sample unabsorbed, varies significantly according to the FTIR result for the sample ABS+Nano-CuO 5%. The non-radiated, 50kGy radiated, and 100kGy radiated samples have transmittance values of 63%, 72%, and 67% respectively. The effects of radiation on the sample can be blamed for the fluctuation in transmittance levels. The sample's molecular structure is altered by the radiation, which has an impact on the infrared radiation's absorption and transmission.

Following are some hypothesized causes of the observed variation.

i) Non- radiated sample: Non-radiated sample with a transmittance value of 63% shows that it absorbs 37% of the input infrared energy. The AbS materials. The ABS material's inherent properties and the presence of CuO nanoparticles are to blame for this early absorption.

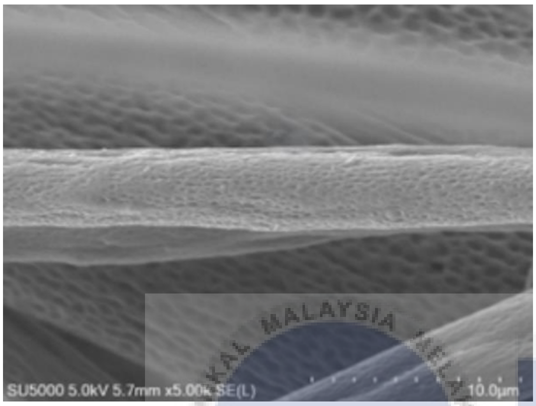
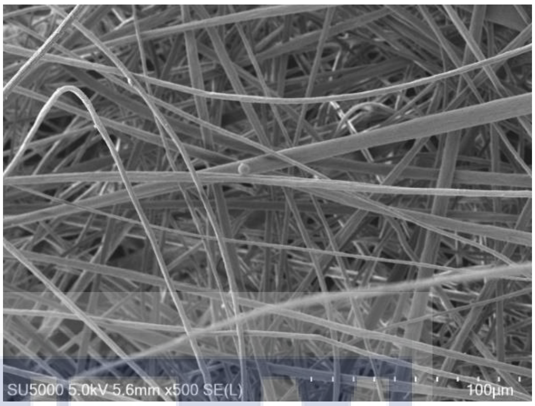
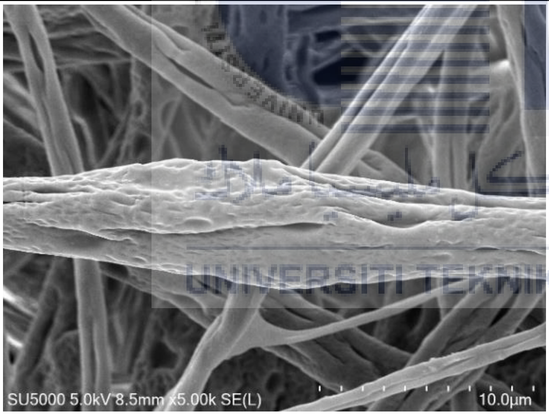
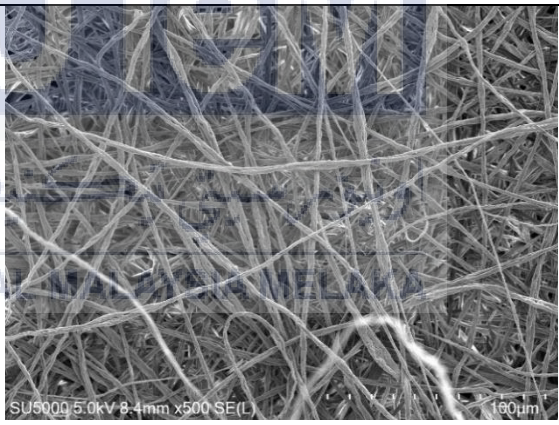
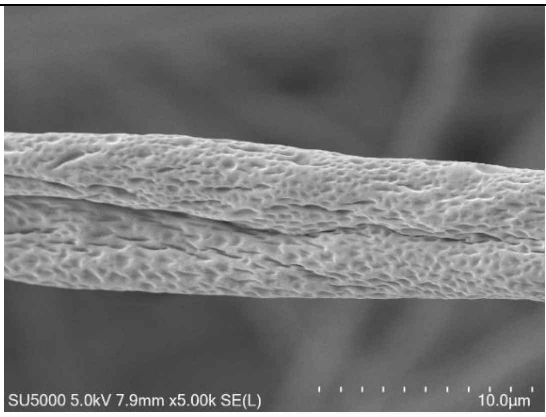
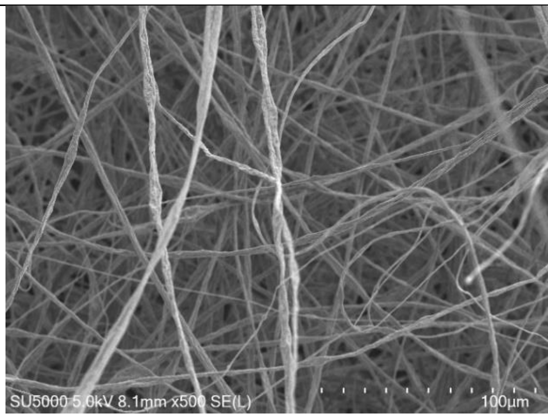
ii) Radiated 50kGy sample: The transmittance increases to 72% in 50kGy sample. This rise is probably the result of the sample's molecular structure changing as a result of radiation exposure. it's possible that certain chemical connections were disrupted by the radiation, which decreased absorption and increase transmission.

iii) Radiated 100kGy sample: The transmittance decreased to 67% in 100kGy sample. The sample's overall exposure to radiation may be the cause of this decline. Increase absorption and decrease transmission may result from more noticeable radiation-induced alterations in the molecular structure at higher radiation doses. This might be the result of the material developing new chemical bonds or flaws that increase the substance's ability to absorb infrared light.

4.4 Scanning Electron Microscopy (SEM) Test

4.4.1 Comparison for Pure ABS

Table 3: Radiated and non-radiated Pure ABS Comparison.

5000x Magnification	500x Magnification
 Pure ABS	 Pure ABS
 Gamma radiated 50kGy Pure ABS	 Gamma radiated 50kGy Pure ABS
 Gamma radiated 100kGy Pure ABS	 Gamma radiated 100kGy Pure ABS

The Scanning Electron Microscopy (SEM) result revealed detailed morphological features of the sample, providing valuable insights into its structure and composition. The SEM testing produced micrographs that clearly distinguished the several sample sections, each with unique surface characteristics and textures. Small details that were invisible with traditional light microscopy, such as the existence of pores, texture, cracks, and other flaws, could be observed thanks to the high-resolution pictures.

The Table 3 above show the Scanning Electron Microscopy (SEM) result for non-radiated pure ABS sample, 50kGy radiated pure ABS sample, and 100kGy radiated pure ABS sample. The samples are magnified into two type of magnification which is 500x and 5000x. Based on the result obtain, when analysing the impact of radiation on the texture and the porosity of pure ABS membranes there are significant variations between samples that were not subjected to radiation and those that were exposed to the radiation of 50kGy and 100kGy.

A homogenous, smooth, and even surface with low porosity and restricted permeability describe the non-radiated pure ABS membrane.

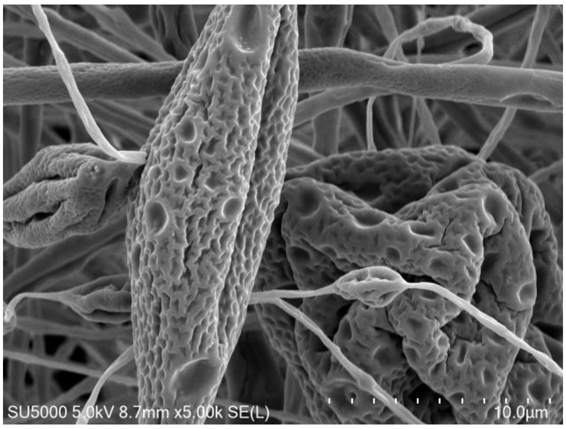
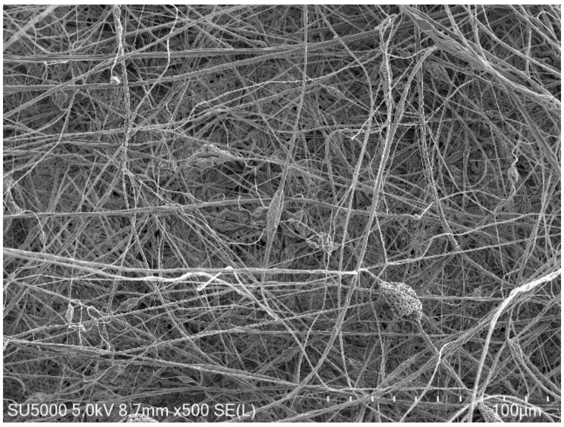
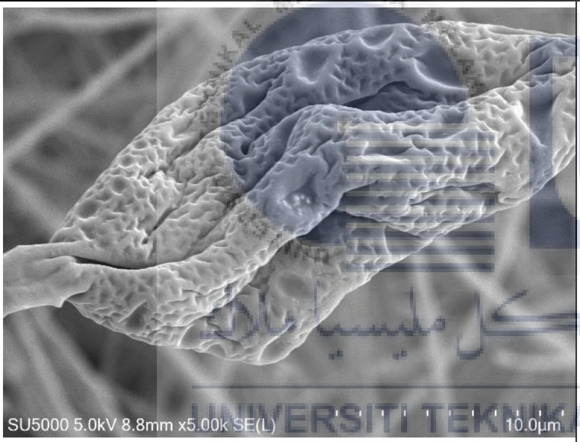
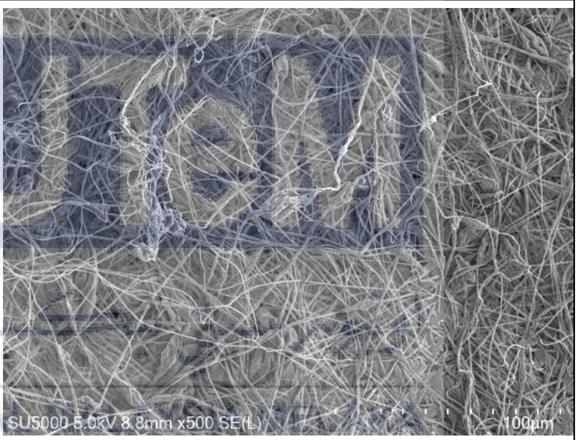
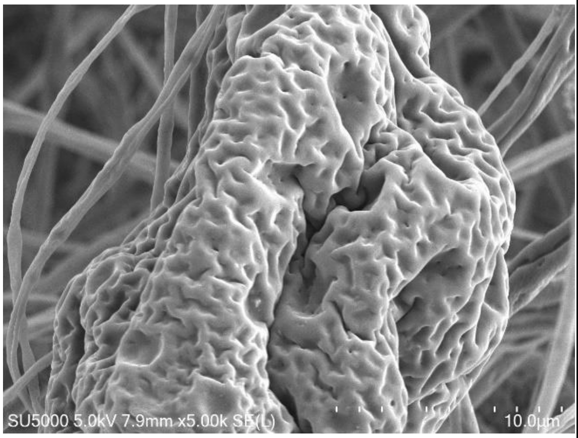
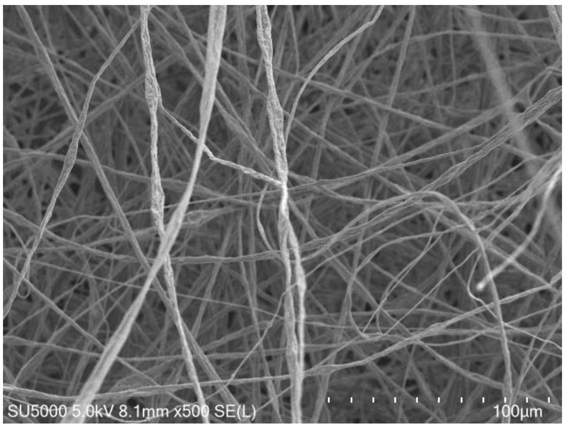
On the other hand, the membrane exposed to 50kGy radiation start to exhibit small abnormalities and a slightly rougher texture. At this radiation intensity, there is a slight increase in porosity, which cause the permeability to slightly increase. Still the alteration is quite minor.

The texture showed notable roughness and obvious surface imperfection and fault at 100kGy radiated sample. There is a noticeable graininess to the touch, and there are a lot larger and more numerous pores, indicating a much higher porosity.

Because of the significantly higher permeability that results from this increase porosity, the membrane's integrity and performance in situations where smooth surfaces and minimal fluid or gas passage are required may be affected.

4.4.2 Comparison for ABS + Nano-CuO 5%

Table 4: Radiated and non-radiated ABS+ Nano-CuO 5% Comparison.

5000x Magnification	**500x Magnification**
 ABS + Nano-CuO 5%	 ABS + Nano-CuO 5%
 Gamma radiated 50kGy ABS + Nano-CuO 5%	 Gamma radiated 50kGy ABS + Nano-CuO 5%
 Gamma radiated 100kGy ABS + Nano-CuO 5%	 Gamma radiated 100kGy ABS + Nano-CuO 5%

Upon testing the radiation response of ABS+Nano-CuO 5% membranes, significant variations in porosity and texture are observed at varying radiation doses. Because nano-CuO particles are present, the non-radiated ABS+Nano-CuO membrane has a somewhat gritty sensation on its otherwise smooth and uniform surface.

Its permeability is restricted because to its low porosity, which is composed of small, evenly dispersed pores. However, as the radiation interacts with the nano-CuO particles, the membrane starts to show some minor abnormalities and roughness after being exposed to 50kGy radiation. This causes the texture to become particularly grainy. Porosity increases as a result, producing pores that are a little bit bigger and more frequent as well as somewhat higher permeability.

The effects are enhanced greatly at 100kGy. Significantly larger pores appear on the surface, which also becomes significantly coarser with noticeable imperfections and a gritty texture. The porosity also is significantly increases. In situations where low permeability is essential, this increased porosity can compromise the membrane's structural integrity and performance due to its significantly higher permeability. The significance of taking radiation effects into account while using ABS+nano-CuO membranes in high radiation exposure situations is shown by these observations.

4.5 Energy-Dispersive X-ray Spectroscopy (EDX) Test

Table 5: EDX Analysis

ELEMENT / SAMPLE	CARBON (C)	NITROGEN (N)	OXYGEN (O)	COPPER (Cu)
Non-Radiated Pure ABS	89.5%	7.7%	2.8%	NIL
50kGy Radiated Pure ABS	97.3%	-	2.7%	NIL
100kGy Radiated Pure ABS	96.7%	-	3.3%	NIL
Non-Radiated ABS + Nano-CuO 5%	90.9%	6.8%	1.9%	0.4%
50kGy Radiated ABS + Nano-CuO 5%	87.3%	8.4%	3.2%	1.1%
100kGy Radiated ABS + Nano-CuO 5%	88.2%	6.2%	3.6&	1.9%

The Energy Dispersive X-ray (EDX) data in Table 5 provides valuable insights into the element composition of the samples.

The 50kGy and 100kGy pure ABS samples that were exposed to radiation caused considerable changes in the material's chemical structure, which prevented the element nitrogen from appearing. The presence of nitrogen in the material was impacted by these modifications to the molecular interactions and chemical bonds. Because of the original composition of the material. Nitrogen was present in the pure ABS sample that was not exposed radiation. ABS is a thermoplastic polymer composed of copolymerized styrene and acrylonitrile (SAN) and rubber phase polybutadiene (PB) polymer distributed in a thermoplastic matrix.

Nitrogen is present in the non-radiated sample because it is present in the acrylonitrile component of the SAN matrix. But radiation-induced chemical reactions and cross-linking processes changes the material's chemical structure when the ABS sample was subjected to radiation. The presence of nitrogen in the material was impacted by these modifications in molecular interactions and the creation of new bonds. The compounds containing nitrogen were exposed to radiation, which broke them down or caused them to react with other molecules, leaving the radiated samples devoid of nitrogen.

There are a few possible reasons such as:

i) Uneven Distribution of nano-CuO: The nano-CuO is not evenly/uniformly distributed throughout the ABS which resulted to certain areas having higher or lower copper concentrations. Because of uneven distribution, the analysis may find less copper in the sample than what was actually added.
ii) Agglomeration of nano-CuO: Nano-Cuo have tendency forming larger clusters due to agglomeration. This aggregation may cause the content of copper to be lower that the EDX method can detect.
iii) Potential loss of nano-CuO during sample preparation: During the sample membrane making using electro-spun, it may lead to the loss of some nano-CuO particles due to the solution to agglomerate at the tip of the syringe. Resulting in lower copper content detected.

The EDX data in this study reveals significant insight on the elemental composition of different ABS samples, taking into account the impacts of nano-CuO addition and radiation exposure. The findings show that radiation exposure dramatically modifies the samples' composition, resulting in variations in the concentrations of carbon, nitrogen, and oxygen. The composition is also altered by adding nano-CuO, mainly through and increase in copper content.

In summary, the presence of nitrogen in the non-radiated pure ABS sample was due to the initial composition of the material, while its absence in the radiated samples was a result of the radiation-induced chemical reactions and changes in the chemical structure of the material.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The study methodically examined the structural and elemental composition changes in ABS composite membranes brought about by gamma radiation dosages that were regulated. Fourier Transform Infrared Spectroscopy (FTIR) and Energy Dispersive X-ray spectroscopy (EDX)) were the primary analytical methods employed.

Significant alterations in the ABS membranes' element composition as a result of radiation exposure were discovered by EDX analysis. Nitrogen was completely absent from the pure ABS samples exposed to 50kGy and 100kGy of gamma radiation, whereas it was present in the pure ABS control sample that was not exposed to radiation. This suggests that the radiation significantly changes the material's molecular connections and chemical bond, which affected the amount of nitrogen present.

The molecular structure, functional groups, and chemical interactions inside the ABS composite membranes were examined using FTIR spectroscopy. The transmittance spectra of the radiated and non-radiated samples different noticeably, according to the FTIR data. The transmittance of the 50kGy and 100kGy radiated samples was 76& and 90%, respectively, whereas the transmittance of the pure ABS, which was not exposed to radiation, was 71%. These variations imply that the radiation exposure changed the ABS's molecular structure, changing its properties related to infrared absorption and transmission.

The thorough insights into the morphological alterations in ABS membranes generated by gamma radiation were obtained by the use of scanning electron microscopy (SEM). The pure ABS that were not exposed to radiation had a low porosity, smooth, and uniform surface. The 100kGy radiated sample, on the other hand, had a noticeably rougher texture with larger and more numerous pores than the 50kGy radiated sample, which only had minor surface imperfections and modestly increased porosity. These variations in porosity and surface shape can have a big effect on how well the membrane works in applications including medical devices, water purification, and gas separation.

The research yielded a thorough grasp of the effects of gamma radiation on the composition and properties of ABS composite membranes thanks to these sophisticated analytical approaches. The results provide important new understandings of how gamma radiation affects the characteristics of ABS composite materials, which is important for maximizing their performance in a variety of technological and industrial applications.

5.2 Recommendation

The study of this study showed that the elemental content and molecular structure of ABS composite membranes can be greatly affected by gamma radiation. Radiation exposure altered the elemental composition of the membranes, as shown by EDX analysis. After radiation exposure, changes were seen in the ABS composites' molecular interactions, functional groups, and chemical bonds according to FTIR spectroscopy.

In order to maximize the performance of BAS composite membranes in a variety of application, it is advised to:

i) Provide standardized testing procedures to evaluate how gamma radiation affects the mechanical strength, permeability, and chemical resistance of ABS composite membranes
ii) Explore by implementing radiation resistant fillers or additions to lessen the damage effects of gamma radiation on the ABS matrix and preserve the structural integrity of the membrane.
iii) Conduct further research to determine the structure property connections and optimize ABS composite composition for particular radiation intensive applications.

iv) Investigate the enduring stability and robustness of irradiated ABS composites in order to ensure their dependability and security in uses such as gas separation, water purification, and medical equipment.

v) During applying gamma radiation doses to ABS composites during the manufacturing or sterilizing process, take great care to regulate and observe the levels. The good qualities of the material can be deteriorated by excessive radiation.

Through the application of these suggested practices, investigators and procedures can fully utilize ABS composite membranes while guaranteeing their dependable functioning in demanding situations including exposure to gamma radiation.

5.3 Sustainable

i) Perform life cycle assessments: Consider the environmental effects of ABS composite membranes at every stage of life cycle, from extraction of raw materials to recycling or disposal at the end of the product's useful life.

ii) Explore alternative processing: Look into environmentally friendly manufacturing process like solvent free extrusion or additive manufacturing to lower the energy usage and waste creation during membrane production.

iii) Improve recyclability: Keep recycling and disassembly in mind during designing ABS composite membranes.

Through the application of these tactics, researchers can create ABS composite membranes that are more environmentally friendly while preserving desired performance attributes.

5.4 Complexity

The research procedure was hindered by the unavailability of specific machines at UTeM, which required the research to be conducted at an external agency. This made it more difficult to finish the study more quickly and reduce the length of the research period. This complicates matters further because it calls for scheduling a time and date that works for the supervisor's and the student's schedules. Moreover, the ABS matrix becomes much more complex when elements like nano-CuO and gamma radiation are used, causing precise formulation and optimization. This study becomes even more challenging because of the need for a detailed understanding in order to interpret and correlate results from various testing methods.

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