THE EFFECT OF NANOCOPPER OXIDE INCORPORATION ON THE PROPERTIES OF ABS MEMBRANE

This report is submitted in accordance with requirement of the University Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)

by

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Tajuk: THE **EFFECT OF COPPER OXIDE NANOPARTICLES (CUO NPS) INCORPORATION ON THE PROPERTIES OF ABS MEMBRANE**

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APPROVAL

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ABSTRACT

The aim of this research is to investigate the effect of nanocopper oxide on the mechanical, structural, physical and morphological properties of ABS membrane. ABS/CuO composites at weight ratio of 99:1, 97:3 and 95:5 was prepared using electrospinning method. Mechanical, structural, physical and morphological properties of the composites were carried out. Obtained results indicated that the addition of nanocopper oxide with small amount increased the tensile strength, while increasing amount of nanocopper oxide decreased the tensile strength. The highest value for tensile (0.13889 MPa) were obtained from 99/1 ABS/CuO composite. Wettability test obtained that 97/3 ABS/CuO have the highest contact angle (111.72°). Scanning electron microscopy show that smoothness of ABS is broken by presence of nanocopper oxide. Overall, the ABS/CuO composites enhances the properties of the membrane for application such as waterproof packaging for medical devices.

ABSTRAK

Matlamat penyelidikan ini adalah untuk menyiasat kesan nano-tembaga oksida ke atas sifat mekanikal, struktur, fizikal dan morfologi membran ABS. Komposit ABS/CuO pada nisbah berat 99:1, 97:3 dan 95:5 telah disediakan menggunakan kaedah electrospinning. Sifat mekanikal, struktur, fizikal dan morfologi komposit telah dijalankan. Keputusan yang diperolehi menunjukkan bahawa penambahan nano-tembaga oksida dengan jumlah yang kecil meningkatkan kekuatan tegangan, manakala peningkatan jumlah nanocopper oxide mengurangkan kekuatan tegangan. Nilai tegangan tertinggi (0.13889 MPa) diperoleh daripada komposit 99/1 ABS/CuO. Ujian kebolehbasahan memperoleh bahawa 97/3 ABS/CuO mempunyai sudut sentuhan tertinggi (111.72°). Pengimbasan mikroskop elektron menunjukkan bahawa kelicinan ABS dipecahkan oleh kehadiran nano-tembaga oksida. Secara keseluruhannya, komposit ABS/CuO meningkatkan sifat membran untuk aplikasi seperti pembungkusan kalis air untuk peranti perubatan.

DEDICATION

my beloved father, Abdull Rahman bin Ali

my most appreciated mother, Saadiah binti Saat

my adored brothers and sister, Azmi, Zulkifli, Sazwan, Khir and Aini

for giving me a moral support, financial helps, cooperation, encouragement and understandings

Thank You So Much & Love You All Forever

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In the name of ALLAH “SWT”, the Most Gracious and the Most Merciful

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LIST OF ABBREVIATIONS

ABS		Acrylonitrile Butadiene Styrene
CuO		Copper Oxide
NPs		Nanoparticles
ASTM	-	American Society for Testing and Material
FTIR	-	Fourier Transform Infrared Spectroscopy
EDX	-	Energy-Dispersive X-Ray Spectroscopy
SEM	-	Scanning Electron Microscopy
CNTs	-	Carbon Nanotubes
XPS		X-ray photoelectron spectroscopy
SWCNT		single-wall carbon nanotube
MWCNT		multi-wall carbon nanotube

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Membrane technology has shown to be a flexible and efficient method for a range of industrial uses, such as electronics, biomedical engineering, and water treatment. Acrylonitrile butadiene styrene (ABS) is one of the many membrane materials available, and it has attracted a lot of interest because of its advantageous qualities, which include high mechanical strength, chemical resistance, and processing ease. Nonetheless, improving ABS membrane performance to satisfy the more demanding needs of contemporary applications continues to be a significant problem (Abo-Khalil et al., 2023).

(Sarkar & Chakraborty, 2021) stated that nanocomposite membranes have become a viable option for enhancing the functionality and performance of conventional membrane materials in recent years. Membrane mechanical, structural, and surface properties can be improved by utilizing the special qualities that nanoparticles such as copper oxide nanoparticles (CuO NPs) offer. By fusing the special qualities of nanoparticles with the intrinsic benefits of ABS, multifunctionality can be achieved by the insertion of copper oxide (CuO) into ABS membranes (Navya & Daima, 2016).

The incorporation of CuO NPs into ABS membranes is justified by its capacity to mitigate significant constraints associated with conventional membranes (Ojha, 2020). ABS membranes treated with CuO NPs may find use in a variety of industries by improving mechanical strength, thermal stability, antibacterial activity, and surface characteristics. For example, the antibacterial qualities of CuO NPs may assist reduce biofouling and extend the life and effectiveness of membrane systems in water treatment. Similar to this, improved mechanical strength and surface qualities in biomedical engineering may make it possible to create more durable and biocompatible membranes for drug delivery systems and implanted devices (Ciganė et al., 2021).

Based on (Gopinath et al., 2024), ABS membranes modified with CuO NPs show great promise, however there are still unanswered questions about the specific impact of CuO NPs loading on membrane characteristics. By methodically examining the mechanical, structural, and surface characteristics of ABS membranes after the addition of CuO NPs, this effort aims to close these gaps. By employing a range of experimental characterization methods, such as surface chemical analysis, mechanical testing, and electron microscope imaging, the research seeks to clarify the fundamental mechanisms and enhance the functionality of nanocomposite membranes for uses (Solangi et al., 2023).

This study intends to contribute to the development of next-generation membrane materials with customized characteristics and better functionality by deepening our understanding of ABS membranes modified by CuO NPs. The results of this study could have a significant impact on a variety of industries, including electronics, healthcare, and water treatment, by providing creative answers to urgent problems and creating new opportunities for technological development.

1.2 PROBLEM STATEMENT

Copper oxide nanoparticles (CuO NPs) integration into acrylonitrile butadiene styrene (ABS) membranes presents a few potentials and problems, thus an in-depth analysis of its effects and consequences is required. The possible modification of mechanical and structural characteristics with different loading levels of CuO NPs is one of the main causes for worry. It is essential to comprehend how varying CuO NPs deconcentrating effect characteristics like modulus, impact resistance, and tensile strength in order to guarantee the robustness and dependability of ABS membranes in real-world uses (Kannan & Ramamoorthy, 2020) . The goal of this study is to optimize material formulations to attain the appropriate balance between the integration of nanoparticles and mechanical performance.

The effect of CuO NPs inclusion on ABS membrane surface chemistry is another important factor to consider. Adhesion, wettability, and chemical resistance are just a few examples of the many aspects of interactions with the environment that may be greatly impacted by changes in surface functional groups and chemical composition. Therefore, to customize ABS membranes to meet the needs of applications, such strengthening chemical stability in harsh environments or improving adhesion in composite materials, a detailed examination of the surface chemistry changes brought about by CuO NPs insertion is necessary.

Furthermore, a major obstacle is the efficient dispersion of CuO NPs in the ABS membrane matrix. For the material qualities and performance to be consistent across the membrane, uniform dispersion must be achieved. Agglomeration or uneven distribution of nanoparticles, however, can impair structural integrity, mechanical strength, and other important characteristics (I. Khan & Kumar, 2020a) . To determine the best processing parameters and guarantee uniform nanoparticle dispersion, it is essential to examine the morphological characteristics and dispersion of CuO NPs within ABS membranes.

Consideration should be given to the scalability and manufacturability of ABS membranes modified with CuO NPs. While research conducted on a laboratory scale offer insightful information, considerations like cost, efficiency, and repeatability must be considered when applying these findings to large-scale manufacturing operations. It is imperative to tackle these obstacles in order to enable the extensive implementation of ABS membranes modified with CuO NPs in diverse sectors and uses.

The primary focus of the issue statement is the requirement to conduct a thorough investigation into the impact of adding CuO NPs to ABS membranes. This includes examining changes in surface chemistry, dispersion of nanoparticles, scalability, and mechanical and structural features(Akhil et al., 2024). This work intends to overcome these obstacles to further our knowledge of ABS membranes modified with CuO NPs and open the door to their practical use in a variety of industrial settings.

Critical factors to consider are the effects of adding CuO NPs to ABS membranes on the environment and human health. Even though CuO has desired qualities and functions, issues with toxicity, environmental effect, and possible nanoparticle release need to be carefully considered (Mallakpour et al., 2020). To protect workers, consumers, and ecosystems, it is crucial to comprehend the behaviour and destiny of CuO NPs during the stages of production, use, and disposal. As a result, evaluating the health and environmental risks related to ABS membranes modified with CuO NPs is a crucial component of this research, as is investigating ways to reduce potential negative effects and advance sustainable practices in the creation of nanocomposite materials. The work is to minimize potential hazards to these issues while promoting the ethical and responsible development of ABS membranes modified with CuO NPs.

1.3 OBJECTIVES

The primary objective of this work is to investigate how the mechanical, structural, physical, and morphological behavior of ABS membrane is affected by the integration of copper oxide nanoparticles (CuO NPs). The following is the study's goal:

1. To evaluate the effects of nanocopper oxide loading on the mechanical and structural properties of ABS membranes.
2. To assess changes in surface chemistry of the ABS membrane due to nanocopper oxide incorporation.
3. To characterize the morphological property and dispersion of nanocopper oxide within the membrane using SEM-EDX.

1.4 SCOPE

The purpose of this study aims to provide a thorough assessment of the complex effects of copper oxide nanoparticles (CuO NPs) loading on acrylonitrile butadiene styrene (ABS) membranes in terms of mechanical, structural, and physical aspects. To systematically evaluate the changes in the mechanical qualities, like hardness and toughness, and the physical properties, like tensile strength and flexibility, of the resultant composite membranes, the inquiry will use different concentrations of CuO NPs. Furthermore, the investigation will explore the structural modifications brought about by the integration of CuO NPs, specifically concentrating on the crystallinity and molecular arrangement inside the ABS matrix.

In addition to the mechanical and structural elements, the study will evaluate the surface chemistry changes caused by CuO NPs, providing insight into any possible chemical interactions and how these can affect membrane performance. Additionally, the study's scope includes a thorough assessment of the morphological characteristics and dispersion patterns of CuO NPs inside the membrane using SEM-EDX analysis, which offers insightful information about the homogeneity and geographical distribution of nanoparticle integration.

CHAPTER 2

LITERATURE REVIEW

This study's literature evaluation entails a methodical and critical analysis of previous academic publications, research studies, and pertinent literature that discuss how the integration of copper oxide nanoparticles (CuO NPs) affects the characteristics of acrylonitrile butadiene styrene (ABS) composite membranes. The goal of this thorough review is to identify and summarize important theories, concepts, and research results in the field of nanocomposite materials, with an emphasis on studies pertaining to CuO NPs and ABS membranes. The present study is motivated by gaps, disagreements, or limitations in the existing literature, which are highlighted in the literature review, which serves as a basis for comprehending the current state of knowledge.

2.1 ACRYLONITRILE BUTADIENE STYRENE (ABS)

Acrylonitrile butadiene styrene, or ABS, is a popular thermoplastic polymer that possesses a remarkable equilibrium of strength, toughness, and impact resistance as stated by (Singh et al., 2022). It is a widely used material in many different sectors, including as 3D printing, consumer products, automotive, and electronics. Based on (Shanmugam et al., 2021) studies, ABS is appropriate for applications needing robustness and dependability as it is lightweight, strong, and resistant to a wide range of acids, alkalis, and oils. Its adaptability is further enhanced by its strong electrical insulating qualities and capacity to function effectively in a temperature range of -20°C to 80°C (-4°F to 176°F) as stated by (Abeykoon et al., 2020a). Because of these beneficial properties, ABS is frequently used in products including toys, sports equipment, automotive parts, and electrical device casings.

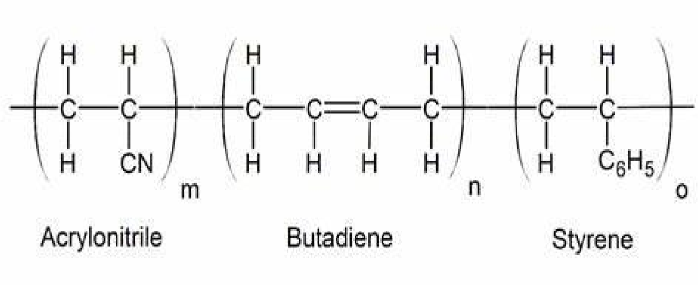

Figure 1: ABS Polymer Structure

Acrylonitrile, butadiene, and styrene are the three monomers that make up the polymer structure of ABS. The three monomers might have different ratios, although the usual range is 15 to 35% acrylonitrile, butadiene 5 to 30% and 40% to 60% styrene (Moritz et al., 2023). Styrene delivers rigidity and processability, butadiene offers toughness and impact resistance, and acrylonitrile adds hardness and chemical resistance. By combining these elements, a polymer with a special set of characteristics is created. Impact resistance is increased by butadiene-styrene copolymers, and acrylonitrile has a propensity to create chemical bonds with other materials (Shanmugam et al., 2021). The polybutadiene rubber phase is distributed throughout the stiff matrix made of acrylonitrile and styrene, improving the material's toughness and impact strength. Because of its structural makeup, ABS is able to keep a good balance between stiffness and flexibility, which makes it a great material for a variety of uses (Randhawa & Patel, 2021).

2.1.1 MECHANICAL PROPERTIES OF ABS

Because of its well-known mechanical qualities, acrylonitrile butadiene styrene (ABS) is a widely sought-after material for a wide range of industrial applications (Roy & Mukhopadhyay, 2020). Its strong resilience to impact is one of its most remarkable qualities. This implies that ABS is perfect for items that must tolerate hard handling or high-stress settings since it can bear substantial force or shock without cracking or breaking (I. Khan & Kumar, 2020b). The main cause of this impact resistance is the butadiene component, which gives the material flexibility and toughness.

Tensile strength is another important mechanical characteristic of ABS especially for applications where materials must be able to bear pulling or stretching pressures without deforming or breaking (Dhinesh et al., 2021). This tensile strength is a result of the stiffness and hardness that the acrylonitrile in ABS provides. (Behera & Thirumurugan, 2022) stated that this characteristic, together with ABS's capacity to maintain structural integrity and form under pressure, makes it ideal for producing strong and long-lasting parts, such those for automobiles, consumer electronics, and a range of home products.

Additionally, ABS shows high creep resistance and dimensional stability. ABS is guaranteed to retain its size and form across a range of mechanical stresses and environmental conditions thanks to dimensional stability (Kannan & Ramamoorthy, 2020b). For components that must maintain their shape and functionality over time, creep resistance in ABS refers to the material's ability to withstand deformation under extended stress. Acrylonitrile, butadiene, and styrene are balanced constituents that together provide a material with these qualities that can function dependably in a variety of applications. ABS's versatility is further increased by its simplicity of machining and processing, which makes it possible to implement intricate and exact designs in production procedures.

2.1.2 STRUCTURAL PROPERTIES OF ABS

Acrylonitrile butadiene styrene (ABS) has a high level of durability and impact resistance, which contribute to its structural integrity (I. Khan & Kumar, 2020b) . Because butadiene produces a rubbery matrix inside the stiff styrene-acrylonitrile structure, ABS is able to absorb impact energy and release it without shattering or cracking based on (I. Khan & Kumar, 2020a) studies. This rubbery phase is distributed throughout the polymer, creating specific pliable zones that improve the material's overall resilience (Chang et al., 2022a). This structure is especially useful in areas where ABS items are often or suddenly subjected to mechanical pressures, such consumer electronics, protective gear, and automobile parts.

Moreover, two notable structural characteristics of ABS are its dimensional stability and creep resistance (Chang et al., 2022) . For precise parts and assemblies, dimensional stability guarantees that ABS keeps its size and form under varied mechanical stresses and environmental conditions (Chang et al., 2022b). The phrase "creep resistance" describes a material's capacity to withstand deformation under continuous stresses, guaranteeing dependability and long-term performance. Because of these combined structural qualities, ABS is a better option for applications including piping systems, enclosures, and structural parts of machinery and equipment that need to function consistently over time. ABS's easy processing and adaptable structural qualities further solidify its place as a key component of contemporary industry and design.

Amorphous in ABS give its distinctive toughness and impact resistance since the polymer chains are randomly organized and lack a crystalline structure (Ng & Susmel, 2020). When the material is under mechanical stress, the amorphous region's existence enables it to absorb and release energy, improving its flexibility and durability (J. Wang et al., 2020a). In addition to providing high dimensional stability and creep resistance, this disordered arrangement makes sure ABS components retain their shape and function under a variety of circumstances throughout time (Jiang et al., 2020) . Moreover, ABS's amorphous structure makes it easier to work with, making it ideal for a variety of manufacturing applications. This allows for simple molding and machining into intricate forms and patterns.

2.1.3 PHYSICAL PROPERTIES OF ABS POLYMER

With its diverse range of physical characteristics, acrylonitrile butadiene styrene (ABS) is an extremely adaptable material with a multiplicity of uses. Being able to endure enormous mechanical loads and shocks without breaking or cracking is one of its main physical characteristics (Abeykoon et al., 2020a) . In applications like automobile components, protective gear, and consumer electronics, where durability is crucial, this feature is very significant (J. Wang et al., 2020a) . Because it is flexible and has the capacity to efficiently absorb and release impact energy, the butadiene component of ABS adds to its toughness.

One noteworthy physical characteristic of ABS is its low weight. Because ABS has a relatively low density compared to its strength and durability, it is the perfect material to use in situations where weight reduction is crucial (Abeykoon et al., 2020b). For instance, employing lightweight materials like ABS can assist reduce overall vehicle weight and enhance fuel economy in the automotive and aerospace sectors (Gupta & Singhal, 2022).

Furthermore, its capacity to be lightweight improves its usefulness in consumer goods by making them simpler to handle and move without sacrificing durability and dependability.

ABS also has outstanding thermal and dimensional stability. Its ability to hold its dimensions and form in a range of environmental circumstances is essential for applications needing accurate and reliable parts. ABS works well in a moderate temperature range, usually between -20°C and 80°C (-4°F and 176°F) (Abeykoon et al., 2020a) , which makes it appropriate for a variety of indoor and outdoor uses. ABS also lends itself to easy machining, moulding, and finishing, enabling very precise and smooth surface finishes in produced goods (Wahab Hashmi et al., 2021a) . Because of its strong electrical insulating qualities, it is appropriate for electronic housings and components, shielding them from electrical risks. All things considered, impact resistance, lightweight, dimensional stability, and simplicity of processing make ABS a material of choice for a wide range of commercial and industrial uses.

2.1.4 SURFACE PROPERTIES OF ABS

The surface characteristics of acrylonitrile butadiene styrene (ABS) greatly add to its adaptability and attractiveness in a range of applications. ABS has great finish ability, which is one of its primary surface qualities (Wahab Hashmi et al., 2021b) . ABS surfaces are highly customizable and aesthetically pleasing because to their ease of painting, printing, or coating. Because of this, ABS is a common material for consumer items including toys, home goods, and gadget casings that need to have an eye-catching finish. ABS's smooth surface offers versatility in terms of design and finish possibilities because it may be textured for a matte look or polished for a high-gloss finish.

Good adhesion capabilities are one of ABS's other key surface properties. It is simple to connect extra components or combine ABS pieces together since the material easily forms bonds with a variety of adhesives and coatings (Lepoivre et al., 2020) . This feature ensures robust and long-lasting joints, which is very helpful in industrial operations where many parts must be combined. Additionally, ABS surfaces are readily bonded or welded using conventional methods, which is useful for both do-it-yourself and industrial applications (Roy & Mukhopadhyay, 2020) . ABS may be integrated with other components to improve its functioning in intricate assemblies because of its excellent adhesion to other materials.

Additionally, ABS exhibits high resistance to surface abrasion and wear. Because of its resilience, it may be used in materials that will be handled or put under mechanical stress often, such protective gear, baggage, and car interiors (Kannan & Ramamoorthy, 2020). ABS's surface also resists a wide range of solvents, oils, and greases, which increases its usefulness for harsh situations. ABS is susceptible to UV deterioration; however, this can be lessened by using surface treatments or UV-stabilizing chemicals (S. Gao et al., 2022). All things considered, ABS's surface qualities such as its finish ability, adhesion, and wear resistance that contribute to its broad use and versatility across a variety of sectors.

2.1.5 SURFACE MODIFICATION OF ABS

It is standard practice to modify the surface of acrylonitrile butadiene styrene (ABS) to improve its qualities and increase its application range. Chemical treatments, such as chemical etching or plasma treatment, are among the main techniques for surface modification (Ahangaran & Navarchian, 2020) . These procedures improve ABS's adhesive qualities by changing the surface chemistry of the material. For example, plasma treatment can raise surface energy, increasing ABS's susceptibility to paints, varnishes, and adhesives. This is especially helpful in sectors of the economy where it's necessary to have a strong link between ABS and other materials, such electrical or automotive components.

The use of coatings is a significant additional method of surface modification. ABS can be coated to increase its resistance to chemicals, abrasion, and UV light (S. Gao et al., 2022). For instance, adding a UV-resistant coating can improve the life of ABS in outdoor applications by shielding it from deterioration brought on by continuous exposure to sunshine. In a similar vein, anti-scratch coatings can increase ABS surfaces' resilience in high-wear situations, making them better suited for usage in consumer electronics, car interiors, and other settings where long-term beauty and durability are crucial. Additional features like improved flame retardancy or anti-static qualities can also be offered via coatings.

Another popular modification technique for enhancing the feel and visual characteristics of ABS is surface texturing(Ahmed et al., 2020). Different surface textures may be produced using methods like sandblasting, laser engraving, or embossing. These textures can range from glossy and smooth to matte and gritty finishes. ABS items with these textures not only look better, but they can also have useful properties like better grip and less surface reflection(Ahangaran & Navarchian, 2020). In consumer goods, vehicle interiors, and tool handles where both aesthetics and usefulness are vital textured surfaces are especially advantageous. All things considered, surface modification methods increase the usefulness of ABS by improving its qualities and fitting it for a wider variety of uses.

2.2 NANOFILLERS

The amazing effect that nanofillers which are composed of nanoparticles with dimensions typically ranging from 1 to 100 nanometres have on the characteristics of composite materials has attracted a lot of attention in the field of materials research (Randhawa & Patel, 2021) . These tiny particles can provide previously unheard-of improvements in mechanical, thermal, electrical, and even optical properties when they are carefully added to polymer matrices, metals, or ceramics. Nanofillers are essential for adjusting a material's performance at the nanoscale and provide a creative way to create sophisticated materials with better functions (Ahmed et al., 2020) . The pursuit of nanocomposites lies at the heart of the study of nanofillers. By combining nanofillers with matrix materials in a synergistic way, new materials with customized features are created that frequently outperform those found in conventional material design.

A crucial part of studying nanocomposite materials is choosing the right nanofiller, which is determined by the intended use and result (Kim & Van Der Bruggen, 2010). Graphene, carbon nanotubes, and copper oxide nanoparticles (CuO NPs) are examples of common nanofillers. The mechanical strength, thermal stability, and other important properties of the composite are influenced by the distinct qualities that each variety of nanofiller contributes to it. The investigation and comprehension of the impact of nanofillers on material properties pave the way for progress in a range of sectors, from biomedical applications to aerospace and automotive engineering, where accurate modification of material properties is critical (El-Makaty et al., 2021).

2.2.1 GRAPHENE

Graphene, a hexagonally latticed single sheet of carbon atoms, is being investigated more and more as a potential nanofiller for ABS composite membranes (Tewari et al., 2023) . Because of its remarkable mechanical strength, high heat conductivity, and impermeability, graphene is a viable option for enhancing the membrane's overall functionality. Graphene can be added to ABS membranes to improve their mechanical characteristics, giving them more strength and durability. Furthermore, graphene's two-dimensional structure enables effective reinforcement without appreciably changing the membrane's weight or flexibility, which qualifies it for a few uses in the field of advanced materials (El-Makaty et al., 2021).

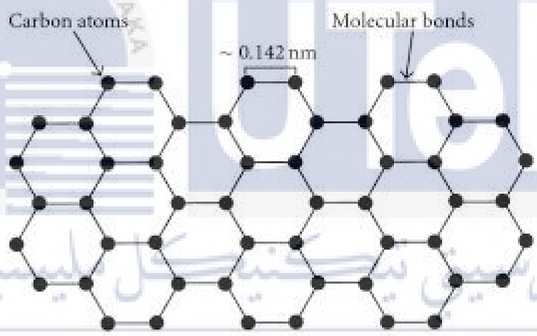

Figure 2: Structure of Graphene Sheet

2.2.2 CARBON NANOTUBES

Another well-liked option for strengthening acrylonitrile butadiene styrene (ABS) composite membranes is carbon nanotubes (CNT), which have exceptional mechanical, thermal, and electrical qualities. CNTs' tubular structure offers superior mechanical reinforcement, improving the composite's modulus and tensile strength (Soni et al., 2023). Furthermore, enhanced thermal stability is facilitated by the high thermal conductivity of carbon nanotubes. Expanding the possible applications of ABS composite membranes in sensors or electronic devices, the special electrical properties of CNTs can also be utilized for applications requiring conductive or semi-conductive membranes.

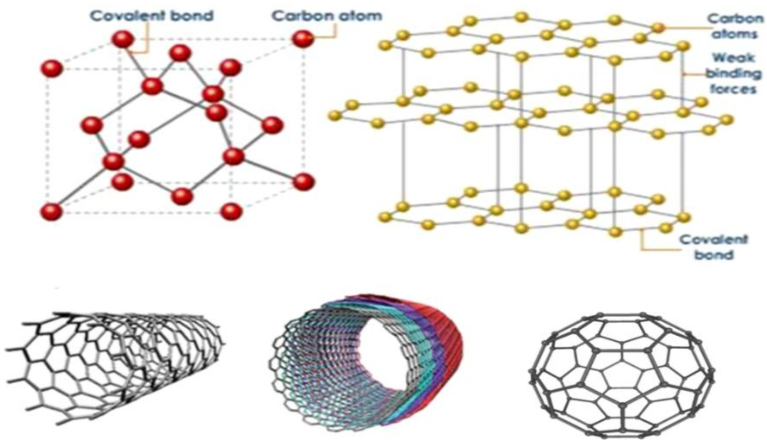

Figure 3: Schematic Diagrams of Diamond, Graphite, Fullerene Single-Wall Carbon Nanotube (SWCNT) and Multi-Wall Carbon Nanotube (MWCNT).

2.2.3 COPPER OXIDE NANOPARTICLE

Materials at the nanoscale, copper oxide nanoparticles (CuO NPs) typically have a diameter of less than 100 nanometres and a high surface area to volume ratio. These characteristics provide CuO NPs unique properties such as improved reactivity, enhanced electrical conductivity, and exceptional antibacterial efficacy (Karuppaiyan et al., 2023). Due to their small size and high surface area, these particles are particularly useful in applications such as catalysis that need fast and efficient reactions. For applications related to hygiene and healthcare, their potent antibacterial properties allow them to inhibit or eradicate a wide range of microorganisms.

Because of their special qualities, CuO NPs have a wide range of uses in many sectors. To lower the danger of infection, these nanoparticles are used as coatings for medical equipment, bandages, and other healthcare supplies (Ross & Knightes, 2022). They can be used in conductive inks, coatings, and electronic components because to their excellent electrical conductivity and strong temperature stability (Abul Kareem Alghurabi et al., 2021a). They also use their catalytic properties in chemical reactions, especially oxidation-reduction processes. All things considered, the multifunctionality of CuO NPs indicates their potential for wide-ranging use across several domains, helping to develop industrial processes, electronics, and healthcare.

2.2.3.1 MECHANICAL PROPERTIES OF COPPER OXIDE NANOPARTICLES

The unique mechanical characteristics of copper oxide (CuO NPs) make them extremely desirable in a range of applications. CuO NPs remarkable strength and hardness are two of their main mechanical benefits. When added at the right quantities, these nanoparticles have been demonstrated to dramatically improve the mechanical characteristics of composite materials (Karuppaiyan et al., 2023). CuO NPs can be added to polymer matrices, including Acrylonitrile Butadiene Styrene (ABS), to boost their tensile strength. This can improve the composite materials' durability and longevity by increasing their resistance to mechanical deformation.

CuO NPs also help composite materials become more resilient and resistant to fracture. Because of their high aspect ratio and robust interfacial interaction with the host matrix, they can dissipate stress more efficiently, which inhibits the growth of cracks and increases the material's overall toughness (Wakamoto et al., 2024) . This is especially helpful for materials that have to endure a lot of stress and impact, such protective coatings, building materials, and automobile parts. For safety and dependability, the materials must be able to retain their structural integrity in harsh circumstances, which is made possible by their increased toughness and fracture resistance.

CuO NPs affect composite materials' thermal stability and wear resistance in addition to their strength and toughness-enhancing effects (W. Chen et al., 2022). Because of the reinforcement provided by these nanoparticles, the matrix is more resilient to abrasion and other mechanical stresses that cause wear and tear. The ability to withstand wear and tear is essential for prolonging the lifespan of materials utilized in high-wear settings, such as industrial machinery and cutting instruments. Furthermore, materials can maintain their mechanical qualities at high temperatures thanks to the thermal stability that CuO NPs impart, which is crucial for applications in high-temperature settings (Hamedi, n.d.) . Overall, the mechanical characteristics of composite materials are significantly improved when CuO NPs are added, which qualifies them for a variety of cutting-edge engineering and industrial applications.

2.2.3.2 STRUCTURAL PROPERTIES OF COPPER OXIDE NANOPARTICLES

Nanoscale dimensions and a high surface area-to-volume ratio are the primary characteristics that set copper oxide nanoparticles (CuO NPs) apart from their bulk counterparts. The stability and toughness of these particles at the nanoscale are largely attributed to their monoclinic crystal structure (Abul Kareem Alghurabi et al., 2021b). CuO NPs enormous surface area and tiny size typically fewer than 100 nanometres significantly improve their interaction with surrounding materials and surroundings (Ahangaran & Navarchian, 2020). In applications where surface interactions are crucial, including catalysis and sensor technologies, this large surface area is essential.

Another significant structural characteristic of CuO NPs that affects their functioning is their surface shape. CuO NPs may be produced with a variety of morphologies, such as spherical, rod-like, or flower-like structures, and each has a unique surface reactivity profile (Abul Kareem Alghurabi et al., 2021b) . During the synthesis process, the particular morphology can be modified to influence the behaviour of the particles in various applications. For example, due to variations in surface area and active sites, rod-like CuO NPs may display distinct catalytic characteristics from spherical ones. CuO NPs may be tailored to satisfy specific needs in domains including environmental cleanup, energy storage, and biological applications because to their versatile shape.

Furthermore, the total performance of CuO NPs is significantly influenced by their crystalline quality and fault configurations (Prabha et al., 2021a). Superior crystalline CuO NPs with less imperfections often have superior electrical and mechanical characteristics. The electrical conductivity and catalytic effectiveness of the nanoparticles can be affected by defects such as vacancies and dislocations. By comprehending and managing these flaw structures throughout the synthesis process, it is possible to produce CuO NPs with improved characteristics that are suited for certain uses (Abul Kareem Alghurabi et al., 2021b) . For instance, CuO NPs performance in solar cells and batteries, where exact control over electrical characteristics is essential, can be increased by improving the crystalline structure. Overall, CuO NPs structural characteristics such as their shape, defect density, and crystal structure are essential to their many uses and efficiency across a range of technological domains.

2.2.3.3 PHYSICAL PROPERTIES OF COPPER OXIDE NANOPARTICLES

Copper oxide nanoparticles (CuO NPs) have several unique physical characteristics that make them extremely valuable in a wide range of research and industrial applications (Naz et al., 2020) . CuO NPs large specific surface area is one of their main physical characteristics; this is a direct result of their nanoscale size. They are perfect for use in catalysis, sensors, and antimicrobial applications because of their enormous surface area, which also improves their reactivity and interaction with other compounds (Ahangaran & Navarchian, 2020). When utilized as fillers or additives, the nanoparticles overall efficacy is enhanced by their larger surface area, which also makes them easier to disperse in composite materials (Solangi et al., 2024).

The optical behaviour of CuO NPs is another noteworthy physical characteristic. CuO NPs exhibit distinct optical characteristics, such as notable photoluminescence and robust absorption in the visible portion of the electromagnetic spectrum (Abul Kareem Alghurabi et al., 2021b). These characteristics result from the high density of surface states and quantum size effects, which can change the electronic transitions in the material (Prabha et al., 2021a) . CuO NPs are appropriate for use in photovoltaics, photocatalysis, and optoelectronic devices due to their optical properties (M. A. Khan et al., 2020a) . For example, their excellent absorption of visible light may be used to increase the light-harvesting efficiency of solar cells.

CuO NPs thermal characteristics are likewise noteworthy. Their strong thermal conductivity and exceptional thermal stability make them useful in a variety of high-temperature applications (Sone et al., 2020) . Because of their high thermal conductivity, which makes them valuable in thermal management applications, the nanoparticles thermal stability guarantees that they will retain their structural integrity and performance under harsh temperatures. For instance, adding CuO NPs to polymer matrices can improve the composite materials thermal conductivity, which qualifies them for usage in electronics heat-dissipating components and other high-performance materials. CuO NPs large surface area, distinct optical characteristics, and superior thermal behaviour highlight their adaptability and potential for a variety of uses.

2.2.3.4 SURFACE MODIFICATION OF COPPER OXIDE NANOPARTICLES

Copper oxide nanoparticles (CuO NPs) may be made more functional and have a wider range of applications by surface-modifying them. Researchers can enhance CuO NPs dispersion stability in a range of solvents and matrices by modifying their surface chemistry, which is crucial for use in coatings and composites. Surfactants, polymers, and tiny molecules that adhere to the surface of nanoparticles to avoid agglomeration and improve compatibility with various media are examples of common surface modification approaches (M. A. Khan et al., 2020a). CuO NPs, for example, can be better dispersed in nonpolar solvents by coating them with oleic acid, and their integration into polymer matrices can be improved by using silane coupling agents.

Moreover, surface modification is essential for adjusting CuO NPs catalytic characteristics(M. A. Khan et al., 2020a). The addition of functional groups to the surface of the nanoparticles during surface modification can change their catalytic activity by serving as active sites or by affecting their electrical environment. For instance, adding amine groups to the surface of CuO NPs can improve their capacity to catalyse specific chemical reactions, increasing their efficiency in procedures like oxidation and hydrogenation. CuO NPs may be optimized for certain catalytic applications, such as chemical synthesis and environmental remediation, thanks to this surface property customisation.

CuO NPs can also acquire new functional qualities by surface modification, such as enhanced biocompatibility and tailored usefulness for biomedical purposes (Solangi et al., 2024). Biocompatible molecules, including polyethylene glycol (PEG) or certain peptides, can be affixed to the surface of CuO NPs to enhance their suitability for therapeutic, imaging, and drug administration applications (M. A. Khan et al., 2020a). These changes can lessen toxicity, increase the stability of the nanoparticles in biological settings, and improve their capacity to interact with certain biological targets. CuO NPs usefulness is expanded beyond conventional uses thanks to this customized surface modification method, making them suitable for use in cutting-edge biomedical technologies and targeted therapeutics(Ahmed et al., 2020).

2.3 COMPOSITE MATERIAL

Engineered materials called composites are made up of two or more separate parts with various chemical or physical characteristics. When these ingredients are combined, a material is produced with improved properties that could not be possible with any of the parts working alone. Fibers like carbon or glass are frequently used to reinforce a polymer matrix in composite materials. These composites have fibres that add strength and stiffness and a polymer matrix that offers flexibility and lightness (Nurazzi et al., 2021) . The composite material produced by this synergistic combination has a good property balance and can be used for a variety of applications, including sports equipment and aircraft components.

Composite materials constituent selection and arrangement enable the material's qualities to be tailored to specific engineering requirements. The mechanical, thermal, and electrical properties of the composite are affected by the matrix type, orientation, and volume percent of the reinforcing elements (Egbo, 2021) . Composite materials are incredibly versatile and can be used for a wide range of applications, such as biomedical devices, construction materials, and automobile parts. In an effort to push the limits of composite materials' performance, utility, and durability, researchers are constantly experimenting with new material combinations and fabrication methods.

Adding nanoparticles to polymer matrices like copper oxide nanoparticles (CuO NPs), for example is one prominent class of composite materials. In addition to improving mechanical strength and thermal stability and occasionally adding new capabilities, nanoparticles give the composite special structural and functional characteristics (J. Gao et al., 2022). An intriguing area of materials science is the research and creation of nanocomposites, which open the door to the creation of sophisticated materials with never-before-seen combinations of features for innovative applications.

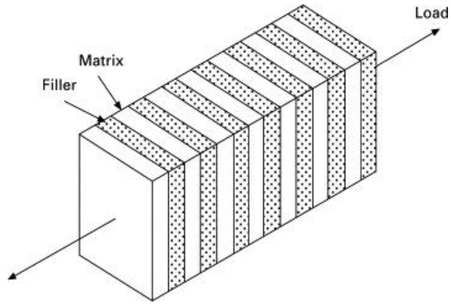

Figure 4: Composite material

2.4 EFFECT OF COPPER OXIDE NANOPARTICLES ON ABS

Acrylonitrile butadiene styrene (ABS) can benefit greatly from the addition of copper oxide nanoparticles (CuO NPs) in terms of a few material qualities. (J. Wang et al., 2020b) proved that tensile strength and impact resistance, for example, are significantly improved by the dispersion of CuO NPs inside the ABS matrix. The reason for this improvement is that the nanoparticles efficiently reinforce the polymer matrix through their reinforcing impact. Moreover, a rise in the composite material's heat deflection temperature indicates CuO NPs can improve ABS's thermal stability (J. Wang et al., 2020b) . Furthermore, the addition of CuO NPs can enhance ABS's flame-retardant qualities, making it better suited for uses where resistance to fire dangers is a need. All things considered, adding CuO NPs to ABS is a viable way to improve its functionality and adaptability in a variety of industrial and commercial applications.

2.4.1 MECHANICAL PROPERTIES

The mechanical characteristics of acrylonitrile butadiene styrene (ABS) can be significantly altered by adding copper oxide nanoparticles (CuO NPs) to it. The tensile strength, stiffness, and impact resistance of ABS may all be significantly increased by the dispersion of CuO NPs inside the matrix (Amali Hamzah et al., 2019). This improvement results from the nanoparticles' reinforcing action, which strengthens the polymer matrix by functioning as fillers. Strong interfacial contacts between the CuO NPs and the ABS matrix are made possible by their high surface area-to-volume ratio, which improves mechanical performance and load transmission mechanisms (El-Makaty et al., 2021).

Additionally, ABS/CuO composites show an enhanced elastic modulus, a sign of increased stiffness and decreased susceptibility to deformation under load (Behera & Thirumurugan, 2022) . Applications needing dimensional stability and structural stiffness would especially benefit from this characteristic. CuO NPs are added to the composite to increase its wear resistance, which makes it more resilient and appropriate for situations where there is frequent mechanical contact or abrasion. The improved thermal stability that CuO NPs offer helps to sustain the mechanical performance of the composite at high temperatures, even if it is not just a mechanical feature. All things considered, these advancements make ABS/CuO composites perfect for demanding applications where high mechanical qualities are essential, including in the automotive, aerospace, electronics, and medical device sectors.

2.4.2 STRUCTURAL PROPERTIES

Acrylonitrile butadiene styrene (ABS) can have a substantial impact on its structural characteristics by the addition of copper oxide nanoparticles (CuO NPs), mainly through modifications to its morphology and crystalline structure. CuO NPs scattered throughout the ABS matrix can act as nucleating agents, encouraging the development of a more homogeneous and refined crystalline structure (Vaes & Van Puyvelde, 2021) . By creating more effective load transfer channels and lowering internal flaws, this crystal structure refinement improves the material's mechanical qualities, such as stiffness and strength. Furthermore, enhanced dimensional stability and decreased processing shrinkage can result from the presence of CuO NPs, improving overall structural integrity.

Moreover, the heat and electrical conductivity of the material may be affected by the dispersion of CuO NPs inside the ABS matrix. Excellent thermal conductivity characteristics of CuO NPs can improve ABS nanocomposites capacity for heat dissipation (Amali Hamzah et al., 2019) . This increased thermal conductivity can result in more effective thermal management in situations where heat generation is an issue, strengthening the structural integrity of the material at different temperatures. Furthermore, CuO NPs can help ABS have higher electrical conductivity, which can be advantageous for applications where electrical conductivity is needed, including shielding against electromagnetic interference or protecting against electrostatic discharge. Thus, modifying the structural characteristics of ABS to satisfy certain performance standards in a range of functional and technical applications is made possible by the addition of CuO NPs.

2.4.3 PHYSICAL PROPERTIES

Acrylontirite Butadiene Styrene (ABS)'s physical properties, including density, thermal expansion, and optical qualities, may be significantly changed by adding copper oxide nanoparticles (CuO NPs) to the material. Because CuO has a higher density than the polymer matrix, adding CuO NPs usually results in an increase in the density of the ABS nanocomposite (Shah et al., 2018) . The total weight and mass distribution of ABS components may be impacted by this density increase, which may influence applications where weight is a concern. Additionally, the addition of CuO NPs can affect how ABS expands thermally. This is because the nanoparticles act as crystallization nucleation sites, which can lower ABS expansion coefficients and increase dimensional stability at different temperatures.

Furthermore, depending on variables like nanoparticle size, dispersion, and concentration, CuO NPs can provide ABS nanocomposites special optical characteristics. Depending on the particular interactions between the nanoparticles and the polymer matrix, the presence of CuO NPs may change the material's transparency, or opacity (Rastogi et al., 2021) . This change in optical characteristics can be used for practical or aesthetic applications that need a certain level of optical opacity or clarity. Furthermore, the addition of CuO NPs may have an impact on other physical attributes including adhesion, surface roughness, and moisture absorption. This might lead to chances for customized material performance in a variety of applications, including automotive components and packaging. Consequently, the incorporation of CuO NPs offers a flexible method for altering ABS's physical characteristics to satisfy particular needs in a range of industrial applications

2.5 MORPHOLOGICAL PROPERTIES OF COPPER OXIDE NANOPARTICLES WITHIN MEMBRANE USING SCANNING ELECTRON MICROSCOPY (SEM)

The morphological features of copper oxide nanoparticles (CuO NPs) within membranes are mostly unlocked by scanning electron microscopy (SEM), which offers in-depth understanding of the structural features at the micro- and nanoscale levels. High-resolution imaging of the membrane's surface is made possible by SEM, which also reveals the location, dispersion, and configuration of the CuO NPs inside the matrix (Krifa & Yuan, 2016). The homogeneity or agglomeration of CuO NPs can be seen clearly by SEM analysis, providing important insights into the material's regularity and possible effects on overall structural integrity. Understanding how CuO NPs interacts with the membrane material and maximizing the dispersion for applications depend on these surface-level measurements.

Furthermore, the microstructural relationship between CuO nanoparticles and the polymer matrix may also be seen using SEM investigation (Georget et al., 2021). It can draw attention to any nanoparticle aggregation or clustering that may be affecting the membrane's overall functionality. The optimal SEM pictures should exhibit little to no aggregation, signifying that the nanoparticles are evenly distributed and enhance the membrane's mechanical strength, thermal stability, and other functional aspects. SEM aids in understanding how the addition of CuO nanoparticles improves the membrane's characteristics by offering in-depth insights into the surface topography and internal structure (Krifa & Yuan, 2016b). This understanding directs additional optimization for applications like filtration, catalysis, or antimicrobial treatments.

2.6 PRODUCTION METHOD

A complicated technique is used in the manufacturing of polymer composites to blend polymers with reinforcing components to produce a material with improved mechanical, thermal, and/or chemical properties (Khalid et al., 2022). The first steps in this process usually involve choosing and preparing polymer matrices, which are often thermosetting or thermoplastic resins, as well as reinforcing elements like fibers such as glass, carbon, or aramid. The purpose of the reinforcing step is to increase the composite's overall strength and functionality. Depending on the needs of the composite and the intended use, the production process may involve procedures like hand lay-up, compression molding, injection molding, or more sophisticated processes like filament winding or resin transfer molding.

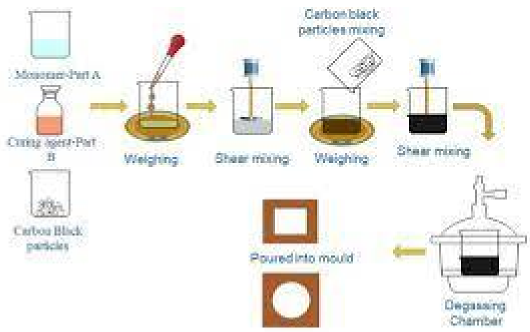

Figure 5: Example of fabrication step of polymer composite

Achieving the appropriate material properties during the fabrication of polymer composites requires careful consideration of parameters such as resin dispersion, fibre orientation, and curing conditions. To guarantee uniformity and dependability in the finished product, quality control procedures are incorporated at every stage of the process (Hsissou et al., 2021). The need for lightweight and high-strength materials in sectors including aerospace, automotive, and construction is fuelled by developments in polymer composite production techniques. Furthermore, efforts to create sustainable production processes are having an impact on the creation of environmentally friendly composite manufacturing techniques.

2.6.1 ELECTROSPINNING TECHNIQUE

The versatile and inventive process of electrospinning has been utilized to generate nanofibrous materials, including acrylonitrile butadiene styrene copper oxide nanoparticles (ABS-CuO NPs) composites with improved characteristics. This technique involves applying a high voltage to a melt or polymer solution, creating a charged jet that moves toward a grounded collector while stretching and thinned (Wang & Su, 2024a) . The incorporation of copper oxide nanoparticles (CuO NPs) into the acrylonitrile butadiene styrene (ABS) solution during the electrospinning process adds a reinforcing element and gives the resultant composite distinct properties.

An ABS polymer solution must first be made to ABS/CuO composite solution. Typically, an ABS polymer is dissolved in an appropriate solvent such as acetone to create this solution (Wang & Su, 2024b). Then, the surface-modified CuO NPs particles which are more compatible with the polymer matrix are distributed throughout the polymer solution. The final combination is put through the electrospinning procedure, which creates nanofibers by applying an electric field. During the electrospinning procedure, the CuO NPs are incorporated into the nanofibrous framework.

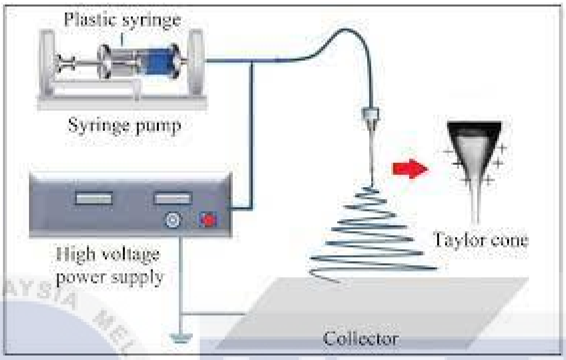

Figure 6: Electrospinning process


Figure 7: Nanofiber Electrospinning Unit

2.6.1.1 ELECTROSPINNING ADVANTAGES

There are several benefits to using the electrospinning technique to make acrylonitrile butadiene styrene copper oxide (ABS/CuO) composites. First, it makes it possible to precisely regulate the morphology and diameter of the nanofiber. Second, the method offers a high surface area to volume ratio, which improves the interaction between the CuO NPs and the ABS matrix (Arifeen et al., 2023). In addition, this process makes it easier to create a nanoscale composite structure, which, when compared to conventional macro-scale composites, may have better mechanical, thermal, and barrier qualities (Soukarie et al., 2024) . All things considered, electrospinning is a scalable and efficient method for creating ABS/CuO composites with customized qualities appropriate for a range of uses, such as improved coating, tissue engineering and filtration.

2.7 APPLICATIONS OF ABS COPPER OXIDE NANOPARTICLES COMPOSITE

By adding copper oxide nanoparticles (CuO NPs) to Acrylonitrile Butadiene Styrene (ABS), the material's characteristics are improved, and its application range is expanded. ABS is widely used in consumer electronics, 3D printing, and automotive parts because of its strength, durability, and adaptability (Vaes & Van Puyvelde, 2021) . Additional advantages including higher antibacterial capabilities, greater mechanical strength, and improved thermal stability are imparted when CuO NPs is introduced. Because of these improvements, ABS/CuO composites are especially useful in industries where sanitary and long-lasting materials are needed, such high-performance engineering components, food packaging, and medical equipment. Thus, the combination of ABS with CuO NPs offers up new avenues for the development of sophisticated, multipurpose materials across a range of sectors.

2.7.1 WATERPROOF PACKAGING FOR MEDICAL DEVICES

Because of several beneficial qualities that specifically meet medical application demands, the ABS/CuO composite is used for waterproof packaging in medical equipment. Above all, ABS (Acrylonitrile Butadiene Styrene) is chosen to ensure durability and protection for fragile medical equipment or devices during handling, shipping, and storage because of its exceptional mechanical strength and impact resistance (Kannan & Ramamoorthy, 2020). These characteristics are essential because they aid in preventing harm that can affect the medical device's sterility or operation.

Furthermore, the antibacterial characteristics of the composite material are strengthened by the addition of CuO. It is commonly known that copper oxide may stop bacteria, viruses, and fungus from growing on surfaces (Siddiqi & Husen, 2020). Incorporating CuO into the packaging material adds an extra layer of protection in medical settings where preserving sterility is crucial to preventing infections and guaranteeing patient safety. This antimicrobial action contributes to overall infection control strategies in healthcare contexts by lowering the danger of contamination during storage and transportation.

Additionally, the ABS/CuO composite gives a great deal of design and production adaptability. It may be moulded into a variety of sizes and forms to precisely suit medical instruments, making the best use of available space and packing resources. The flexibility to customize medical device packaging is essential for accommodating a range of shapes and sizes while preserving a tight, watertight seal (Bitkina et al., 2020) . The medical equipment that are enclosed are shielded from moisture by the composite's resistance to water infiltration, which prevents delicate components from corroding or degrading.

Finally, sustainability has a role in the selection of the ABS/CuO composite. Because ABS is durable and recyclable, it has a lower environmental effect when resources are reused. This is in line with international initiatives for sustainable healthcare practices, which place an increasing emphasis on reducing waste and resource consumption. In conclusion, ABS/CuO composite is a great option to protect medical instruments and devices throughout their lifetime in healthcare settings because it combines mechanical strength, antimicrobial protection, design flexibility, and sustainability. This composite is used for waterproof packing in medical devices.

2.7.2 APPLICATIONS IN OTHER INDUSTRIES

Beyond oil-water separation, acrylonitrile butadiene styrene (ABS) may be used in a wider range of industries because of the addition of copper oxide nanoparticles (CuO NPs). acrylonitrile butadiene styrene copper oxide (ABS/CuO) composites have improved mechanical qualities that make them a good fit for interior parts including door panels, dashboards, and trim in the car industry. The material's strength and thermal stability are increased by the inclusion of CuO NPs, assuring durability and performance in harsh automotive conditions (Huang et al., 2023). Additionally, these composites are useful in consumer products and electronic enclosures, where their antibacterial qualities enhance the lifetime and cleanliness of the product. For manufacturers looking for long-lasting, high-performing materials for a variety of applications in the automotive and consumer electronics industries, the ABS materials infused with CuO NPs present an appealing option.

Beyond consumer electronics and automobiles, ABS/CuO composites have potential applications in the medical field (Kavitha Sri et al., 2020). These materials work well for medical device applications such equipment housings, surgical instruments, and prosthetic devices because of their antibacterial qualities. By adding CuO NPs, ABS becomes more biocompatible and lowers the risk of infection that comes with using medical equipment. Furthermore, ABS/CuO composites enhanced mechanical qualities add to the robustness and dependability of medical equipment, hence enhancing patient safety and care. This demonstrates how adaptable ABS/CuO materials are in meeting important requirements in a variety of industries, highlighting their potential for broad application in domains outside of oil-water separation.

CHAPTER 3

METHODOLOGY

3.1 OVERVIEW

This chapter will present and detail the methodology and materials used to achieve the research objectives. This chapter's four subsections are as follows:

- Process flowchart
- Materials
- Sample preparation
- Characterization and testing

3.2 FLOWCHART

The methodology for this research has been summarized in the flowchart available is shown in Figure 8. The first stages are raw material selection which is acrylonitrile butadiene styrene (ABS) is used as a polymer matrix (100, 99, 97, and 95 wt. %), and copper oxide nanoparticles (CuO NPs) (1, 3, and 5 wt.%). Next the ABS will be dissolved in using acetone. Later, CuO NPs will be gradually added into the mixture of ABS. Membrane is later created by using electrospinning method. Then, the sample has gone through characterization analysis, among of the testing that were conducted are tensile testing, Fourier Transform Infrared Spectroscopy (FTIR), wettability testing, Scanning Electron Microscopy with Energy-Dispersive X-ray (SEM-EDX) testing.

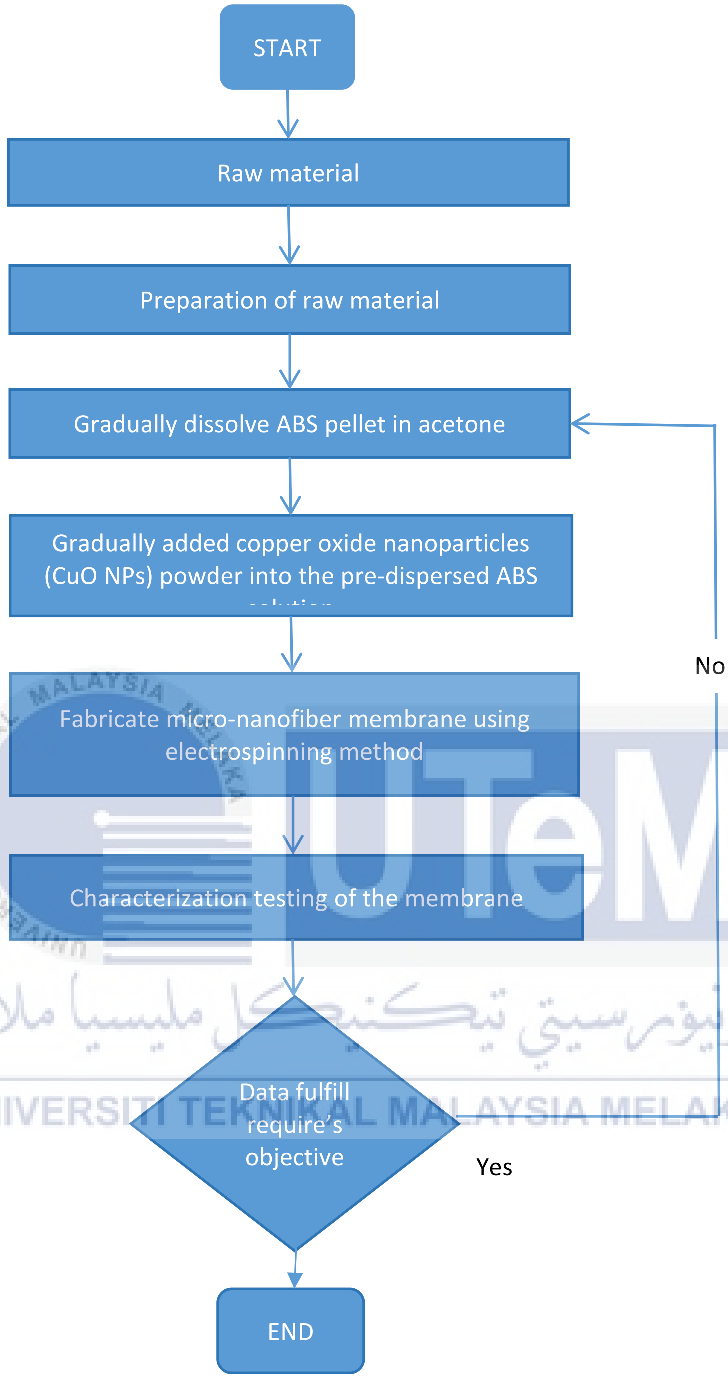

Figure 8: Process Methodology Flowchart

3.3 MATERIALS

The materials used in this study are acrylonitrile butadiene styrene (ABS) pellet, copper oxide nanoparticles (CuO NPs) powder, and solvent which are acetone.

3.3.1 ABS PELLETS

Pellets of acrylonitrile butadiene styrene (ABS) were used for this experiment because of their well-established characteristics and extensive application in a variety of manufacturing processes. Because ABS is a thermoplastic polymer, it has great mechanical strength, toughness, and dimensional stability, which makes it perfect for creating parts that are both practical and long-lasting (Sola, 2022). Precise control over the production process is made possible by the pellets' uniform size and shape, which provide a constant melt flow during processing. Furthermore, ABS is quite versatile and may be readily modified with additives or colorants to satisfy certain experimental needs.

ABS pellets can also be used in laboratory-scale research with results that can be extended to bigger industrial applications because they are easily accessible and reasonably priced. ABS pellets are a sensible and trustworthy option for this investigation because of their accessibility and cost as well as their strong mechanical qualities and simplicity of processing. All things considered, ABS offers the right combination of qualities required to produce significant and useful research results.

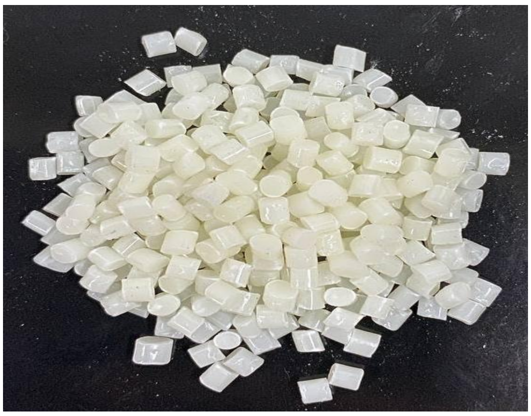

Figure 9: ABS Pellets

3.3.2 COPPER OXIDE NANOPOWDER

For this experiment, copper oxide nanoparticles (CuO NPs) were chosen because of their special qualities that fit in nicely with the goals of the study. CuO NPs' intrinsic catalytic activity and high surface area-to-volume ratio make them perfect for regulated catalysis in a variety of chemical processes (M. A. Khan et al., 2020b). Their wide range of uses, including environmental cleanup, sensing, and photocatalysis, attests to their adaptability. CuO NPs are also appropriate for a variety of biological and medical applications due to their antimicrobial qualities (Prabha et al., 2021b).

Furthermore, it is possible to precisely manipulate the experimental variables by tailoring the synthesis of CuO NPs to get nanoparticles of certain sizes and shapes. CuO NPs are a great candidate for the experiment because of their versatility, efficiency, and simplicity of synthesis. All things considered, CuO NPs offer an exceptional blend of catalytic efficacy, adaptability, and controlled synthesis techniques, which precisely corresponds with the objectives of the investigation.

Figure 10: CuO Nanopowder

3.3.3 ACETONE

Acetone is the solvent of choice for integrating copper oxide nanoparticles (CuO NPs) into ABS membranes due to its exceptional solubility and compatibility with ABS. This compatibility allows for the efficient dissolving and even dispersion of CuO NPs, ensuring a uniform distribution within the ABS matrix. Acetone's low boiling point and high volatility enable it to evaporate quickly during the membrane casting process, preventing nanoparticle aggregation and promoting the formation of a consistent membrane structure (Akhil et al., 2024). Additionally, acetone is chemically neutral toward both ABS and CuO NPs, ensuring that no unintended chemical reactions occur during processing.

Besides, acetone is a good choice for industrial and scientific applications due to its readily available nature and ease of handling. Its application offers enhanced control over the membrane production process, including the critical membrane performance parameters of thickness and porosity. This degree of control guarantees that the finished product satisfies certain specifications for a range of uses, including sensing, catalysis, and filtering. Overall, acetone's characteristics, which include efficiency, compatibility, and control throughout the production process, make it the perfect solvent for creating ABS/CuO membranes.

Figure 11: Acetone

3.4 SAMPLE PREPARATION

The methodical and meticulous process of preparing materials for examination or investigation is known as sample preparation. To make sure the samples correctly reflect the qualities under study, it involves procedures including gathering, processing, and occasionally treating samples. To attain a homogeneous composition or size, the sample may need to be chopped, ground, or mixed during preparation, depending on the sample's nature and the planned analysis. Furthermore, the process of preparing a sample frequently involves eliminating undesired components or contaminants that can cause problems for the analysis. As it immediately affects the quality and dependability of the results from further testing or analysis, sample preparation is essential.

3.4.1 ABS/CUO POLYMER SOLUTION PREPARATION

The first step is to calculate how much acetone, acrylonitrile butadiene styrene (ABS) pellets, and copper oxide nanoparticles (CuO NPs) powder are needed for each sample. Table 1 provides the sample formulation meanwhile Table 2 provide the computation for the sample solution. The second step is to place the glass container placed magnetic stir bar and filled with Acetone which has been weighed according to Table 2 over the lab magnetic stirrer. Within 30 minutes, gradually add the ABS pellets into the container. The purpose of introducing the ABS pellets gradually is to avoid it from clumping. To obtain the ABS/CuO composite solution, the solution is gradually supplemented with CuO NPs once the addition of ABS is complete. The polymer solution will initially be run for 2 hours with temperature and 22 hours without temperature on the lab magnetic stirrer. The sample can be utilized to make membranes after 24 hours.

Table 1: Sample Formulation

Sample	ABS (wt%)	Copper oxide nanoparticles (CuO NPs) (wt%)
ABS	100	0
ABS/CuO	99	1
ABS/CuO	97	3
ABS/CuO	95	5

Table 2: Material Weigh Calculation

Sample	**ABS**	**Acetone**	**CuO-NPs wt%**	**Magnetic Stirrer Parameter (24hours)**
Pure ABS	10 grams	40 grams	-	Heat = 60 C (run for 2 hours only) Speed = 200rpm

ABS/CuO 1%	10 grams	40 grams	Total amount of acetone + ABS x 1% = 0.5 grams	Heat = 60 C (run for 2 hours only) Speed = 200rpm
ABS/CuO 3%	10 grams	40 grams	Total amount of acetone + ABS x 3% = 1.5 grams	Heat = 60 C (run for 2 hours only) Speed = 200rpm
ABS/CuO 5%	10 grams	40 grams	Total amount of acetone + ABS x 5% = 2.5 grams	Heat = 60 C (run for 2 hours only) Speed = 200rpm

3.4.2 ABS/CUO MEMBRANE PREPARATION

First step is to place a layer of aluminium foil on the collector of the Nanofiber Electrospinning Unit machine. Setting up the machine parameters with a target speed of 0.5 m/min, syringe pump speed of 0.289 mm/min, high voltage of 15 kV, and leakage current of 0.01µA is the next important step. Next, fill two syringes with the acrylonitrile butadiene styrene copper oxide (ABS/CuO) composite solution, 10 millilitres each syringe, place needle and place the syringes in the machine's assigned location. It is possible to operate the machine. After that, check the syringe for any clumps or agglomerates that may form at the needle tips during the first 15 minutes of operation. If such clumps do form, remove them. After then, keep an eye on the machine every half-hour. To get the right thickness, the machine will be run for two hours. Repeat the steps above if the sample is not thick enough.

3.5 CHARACTERIZATION AND TESTING

Characterization and testing are important steps in evaluating the properties and performance of a material. Determining a material's mechanical, structural and physical characteristics as well as doing a morphological examination is referred to as characterization. This includes methods such as the use of a tensile testing machine to ascertain mechanical properties like tensile strength, the analysis of the chemical composition of materials using Fourier Transform Infrared Spectroscopy (FTIR), the assessment of surface energy using a wettability test, and the morphological analysis of the material using Scanning Electron Microscopy with Energy-Dispersive X-ray Spectroscopy (SEM-EDX). Table 3 shows analysis parameters for each test.

Table 3: Analysis Parameter

Tensile (ASTM D368)	FTIR	Contact angle	Microscopic analysis
3x	Yes	Yes	Yes
5x	Yes	Yes	Yes
5x	Yes	Yes	Yes
5x	Yes	Yes	Yes
5x	Yes	Yes	Yes

In general, characterization and testing are critical to comprehending a material's characteristics and performance as well as assessing if it is appropriate for a certain use. The tests and characterization that will be used in this investigation are listed below.

3.5.1 TENSILE TESTING

The tensile testing was carried out using EZ-LX 1kN according to ASTM D638 since the EZ-LX 1kN testing apparatus is accurate and well-suited to detecting the mechanical characteristics of thin materials. Testing the tensile strength, Young's modulus and elongation break of the composite is made possible by this machine's ability to precisely apply and quantify tiny forces up to 1 kilonewton (Inokoshi et al., 2023). For the purpose of identifying minute modifications in the mechanical characteristics that the CuO NPs imparts, its sophisticated load cell technology guarantees excellent sensitivity and precision. Furthermore, software integration and adjustable test settings are provided by the EZ-LX 1kN device, enabling thorough analysis and reliable, repeatable outcomes. For research and quality control applications where accurate mechanical characterisation of sophisticated materials is required, this makes it a great option (Inokoshi et al., 2023).

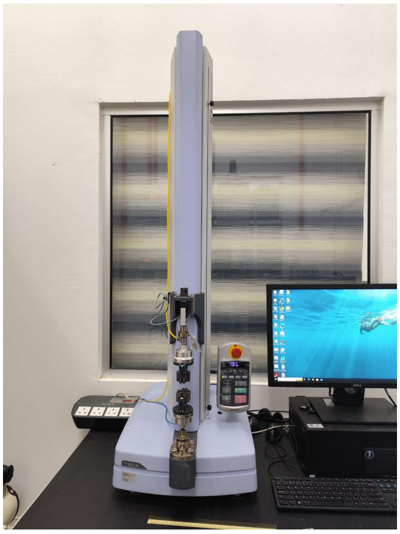

Figure 12: EZ-LX 1kN Tensile Machine

3.5.2 FOURIER TRANSFROM INFRARED SPECTROSCOPY (FTIR)

In this study, the chemical makeup of the acrylonitrile butadiene styrene (ABS) membranes reinforced with copper oxide nanoparticles (CuO NPs) is examined using Fourier Transform Infrared Spectroscopy, or FTIR. A small sample of the composite material is put inside the FTIR device and exposed to infrared radiation as part of the operation (Tiernan et al., 2020) . Understanding the effect of CuO NPs inclusion on the chemical composition of the ABS membranes is made easier by the resultant spectrum, which offers comprehensive information about the material's molecular structure and chemical bonding.

Figure 13: Fourier Transform Infrared Spectroscopy (FTIR)

3.5.3 WETTABILITY TESTER

The purpose of the wettability test is to determine how well liquids interact with the acrylonitrile butadiene styrene (ABS) membranes reinforced with copper oxide nanoparticles (CuO NPs). The material's surface is gently touched with a droplet of liquid, and the contact angle that forms between the droplet and the surface is measured. Important details on the composite material's wettability are revealed by the ensuing contact angle, which also sheds light on its surface energy, adhesion, and spreading behavior. The acrylonitrile butadiene styrene copper oxide (ABS/CuO) membranes' hydrophobic or hydrophilic behaviour may also be determined with the use of this test.

Figure 14: Wettability Tester

3.5.3.1 HYDROPHOBIC

Water droplets on hydrophobic materials bead up and maintain a high contact angle on their surfaces, indicating a low affinity for water in a wettability test. An important measure is the contact angle, which is usually larger than 90 degrees for hydrophobic surfaces (Niknejad et al., 2021) . These tests are essential for assessing the efficacy of treatments and coatings intended to repel water, guaranteeing performance and longevity in a range of applications, from corrosion-resicstant surfaces to waterproof fabrics. Tests for wettability aid in the comprehension of surface energy and adhesion characteristics, revealing the appropriateness of materials for certain settings and applications.

3.5.3.2 HYDROPHILIC

Hydrophilic materials are attracted to water and interact with it easily; they frequently dissolve or mix nicely. Their polar molecular structure or the existence of charged groups that can establish hydrogen bonds with water molecules are the causes of this. An important measure is the contact angle, which is usually smaller than 90 degrees for hydrophilic surfaces (Ahmad et al., 2023) . Hydrophilic coatings can enhance bioavailability in medication delivery, which is another area in which these characteristics are relevant. Applications for hydrophilic materials range from contact lenses to absorbent goods like paper towels and sponges.

3.5.4 SCANNING ELECTRON MICROSCOPY WITH ENERGY-DISPERSIVE X-RAY SPECTROSCOPY (SEM-EDX)

Acrylonitrile butadiene styrene (ABS) membranes reinforced with copper oxide nanoparticles (CuO NPs) are subjected to elemental composition and surface morphology analysis using Scanning Electron Microscopy with Energy-Dispersive X-ray Spectroscopy (SEM-EDX). After preparing a small portion of the material, high-resolution images are obtained by scanning the sample surface with the SEM apparatus (Georget et al., 2021) . The EDX detector that is attached simultaneously analyzes the X-rays that are released, enabling elemental mapping and identification within the material.

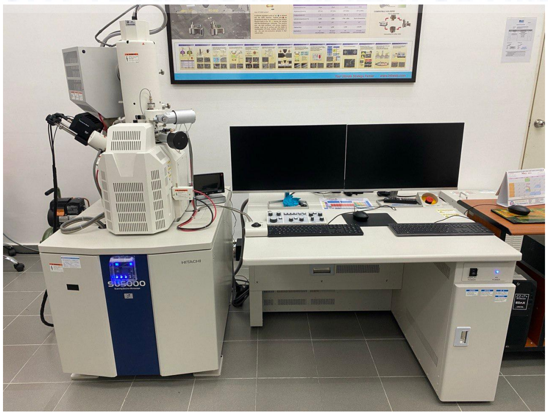

Figure 15: Scanning Electron Microscopy with Energy-Dispersive X-ray Spectroscopy (SEM-EDX)

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

The results and discussion component of scientific research presents an overview and analysis of an experiment's or study's findings. The results from experiments, observations, or analyses are usually presented in this part in an easy-to-understand and succinct way. It presents the study's conclusions, including any noteworthy discoveries made throughout the investigation process as well as any trends or patterns. Furthermore, this section's offers an analysis and interpretation of the findings, frequently contrasting them with previously published work or theoretical predictions. Scholars engage in discourse on the consequences of their discoveries, proffer elucidations for documented occurrences, and, drawing from their conclusions, may propose avenues for further investigation. Overall, the study's major conclusions and their importance to the scientific community are communicated in the results and discussion section.

4.2 TENSILE TESTING

One method that is frequently used to evaluate the mechanical properties of different materials, including fibre membranes, is tensile testing. ABS membranes have been the subject of this study, which includes four samples: pure ABS, 99/1 ABS/CuO, 97/1 ABS/CuO, and 95/5 ABS/CuO. Tensile testing was conducted on these membranes to investigate their mechanical characteristics. The ASTM D638 standard, which specifies a uniform approach for assessing the properties of polymers, including fibres, films, and sheets, was followed in this process.

Understanding a material's mechanical behaviour requires knowing how it reacts to stretching forces, which is assessed by tensile testing. Tensile strength is an indicator of a material's ability to resist breaking under strain. It is the highest stress a material can bear before cracking. For structural applications, the material's stiffness, or Young's modulus, is important since it shows how much the material deforms under stress. The capacity of a material to stretch before failing is measured by its percentage elongation, which is crucial for applications needing deformation without rupture. Together, these characteristics offer information about how a material behaves under tensile stress, which is helpful for designing, choosing, and maintaining materials in a variety of sectors.

4.2.1 TENSILE STRENGTH RESULT

Tensile strength, a basic attribute of materials, is the highest tensile stress that a material can bear before breaking or failing. Determining the appropriateness of a material for different structural and mechanical purposes is essential. In a tensile test, a specimen is exposed to a controlled tension until it breaks to determine the tensile strength value. To guarantee performance and safety in engineering designs, this attribute aids in determining how materials will respond to axial loads. High tensile strength materials are commonly utilized in sectors including manufacturing, and construction where resistance to pulling or stretching pressures is necessary. Tensile strength is essential for material selection and quality control since it guarantees that components

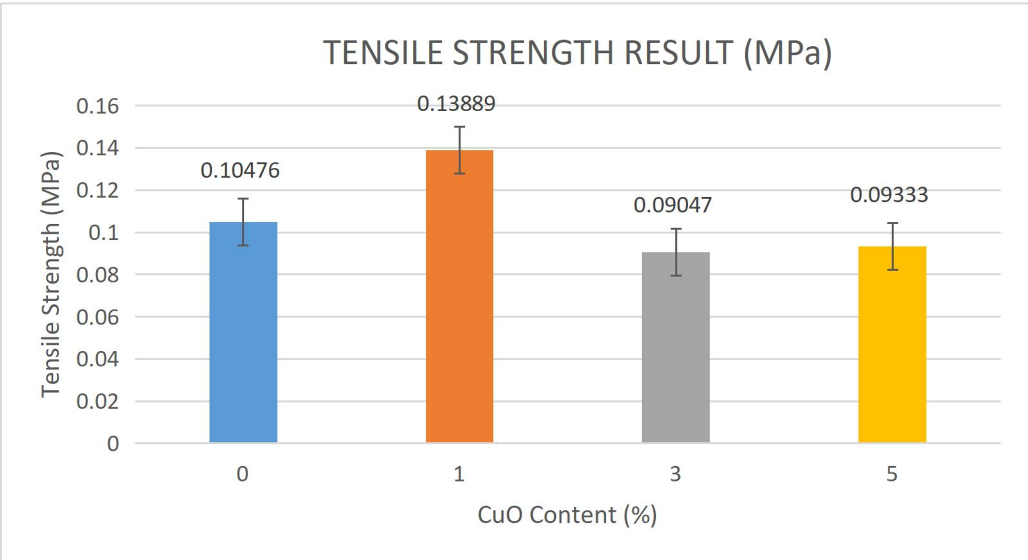

Figure 16: Tensile Strength Result

Results on the tensile strength of ABS composites with different nano CuO concentrations show complex influences on mechanical performance. As a baseline, pure ABS has a tensile strength of 0.10476 MPa. The tensile strength increases to 0.13889 MPa with the addition of 1% CuO. This enhancement implies that the polymer matrix is successfully reinforced by the micro CuO nanoparticles, improving its resistance to tensile pressures. It is probable that the nanoparticles serve as stress concentrators, enhancing load distribution throughout the material and reducing plastic deformation under stress. This finding is consistent with the hypothesis that nanofillers can improve mechanical qualities by changing the structure of the polymer matrix and increasing its deformation resistance.

Higher CuO concentrations, however, cause the trend to change. Tensile strength drops to 0.09047 MPa at 3% CuO loading, which is less than pure ABS. This sudden drop might be explained by the inappropriate dispersion or agglomeration of nanoparticles at greater concentrations, which would result in lower mechanical integrity and stress concentrations. This result emphasizes the fine tuning needed for nanoparticle integration, since higher than ideal concentrations may reduce the intended mechanical improvements because of ineffective stress transfer pathways.

Tensile strength for the 5% CuO composite is somewhat higher at 0.09333 MPa, although it is still less than that of the 1% CuO composite. This implies that the dispersion of nanoparticles, interfacial bonding, and overall composite structure interact intricately.

These results highlight how crucial it is to optimize nanoparticle concentration and dispersion techniques to consistently and reliably improve the mechanical characteristics of ABS/CuO composites. These variations also show the intricate relationship between ABS and CuO, where a material's ability to balance strength and other mechanical qualities depends on the ideal concentration of CuO. This result also indicates that addition of CuO weaken the tensile strength of ABS. (Akhil et al., 2024) studies show that this may be happen because of CuO particles may be creating defects and stress concentrations that reduce the overall strength of the composite.

4.2.2 YOUNG'S MODULUS

The stiffness or rigidity of a material is determined by its Young's modulus, also called the modulus of elasticity. It measures the amount of deformation a material will experience when subjected to a specific tensile or compressive stress. While materials with low Young's modulus values are more flexible and deform more easily, those with high values are stiffer and less deformable. Young's modulus is a basic characteristic that is widely utilized in materials science and engineering to forecast the behaviour of materials under different loading scenarios. When designing buildings and components, it is essential to consider the pressures that they will experience in practical applications.

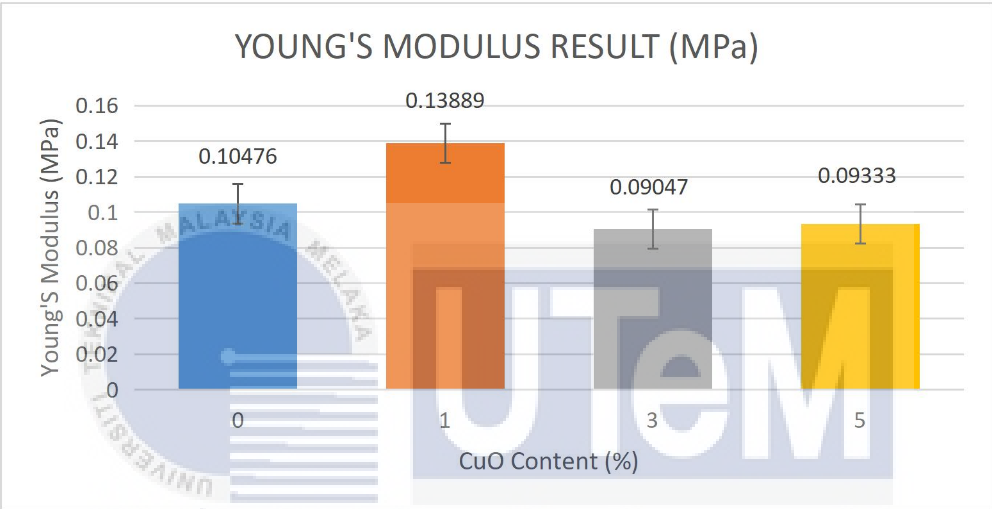

Figure 17: Young's Modulus Result

All the data obtained above are based on formula shown below:

Young's Modulus = stress / strain

Figure 17 show that in the case of pure ABS, the resultant Young's modulus of 0.10476 MPa suggests a degree of flexibility in the material due to its relatively low stiffness. Still, the Young's modulus rises significantly to 0.13889 MPa with 1% CuO added to the composite, indicating increased stiffness. Such large increase in modulus suggests that a small amount of CuO can greatly increase the stiffness of the material (Huang et al., 2020).

However, a non-linear connection between CuO concentration and stiffness is suggested by the ABS/CuO 3% composition, which provides a slightly lower Young's modulus of 0.09047 MPa compared to the ABS/CuO 1% composite. The ABS/CuO 5% composite also shows a comparable Young's modulus of 0.09333 MPa, which suggests that even with a larger CuO content, the stiffness is constant.

The outcome highlights the intricate interaction between ABS and CuO, which shows how little compositional changes may have a big impact on mechanical capacity. This might occur because the CuO nanoparticles are not dispersed uniformly, which could lead to weak areas and a decrease in the composite's overall stiffness (Akhil et al., 2024). This information is helpful for engineering applications that need certain material qualities.

4.2.3 PERCENTAGE ELONGATION BREAK (EB)

A crucial mechanical parameter that gauges a material's capacity to flex before breaking under tensile stress is percentage elongation at break (EB). It shows the percentage increase in a specimen's length from its initial length to the moment of fracture. Low EB values imply brittleness and limited elongation capability, but high EB values suggest better ductility, since the material may sustain substantial deformation before collapsing. EB data is used by the building, industrial, and automotive industries to choose materials that are appropriate for applications that call for resilience to elongation. Selecting materials that can sustain stress and deformation requires an understanding of elastic band. This helps ensure product performance and dependability. EB measures are used by engineers and designers to improve designs and increase the robustness of different parts and structures.

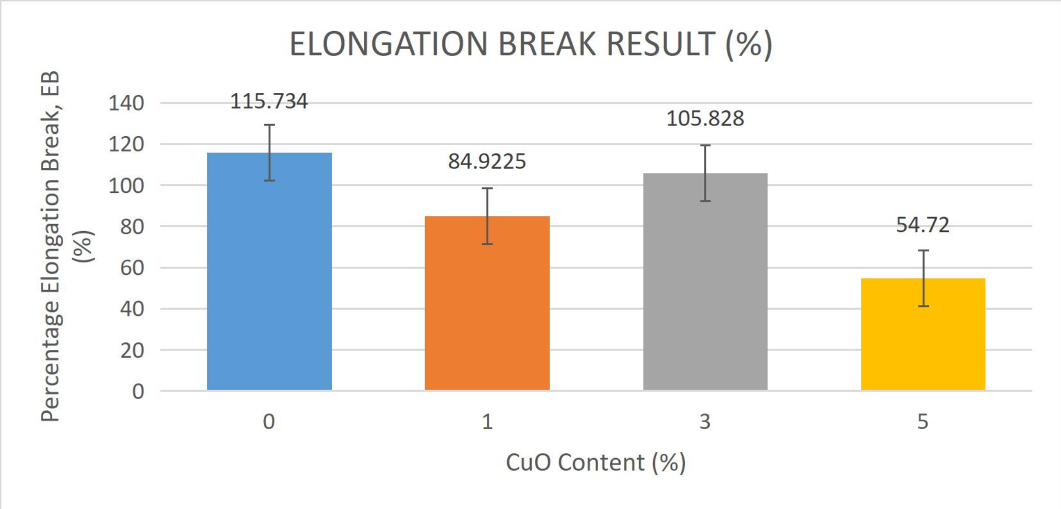

Figure 18: Percentage Elongation Break (EB) Result

Figure 18 obtained the maximum EB of 115.734% is seen in pure ABS, demonstrating its remarkable capacity to experience substantial deformation before to fracture. Nonetheless, there are noticeable modifications with the addition of CuO nanoparticles. When even a little quantity of CuO is added, the ABS/CuO 1% composite shows a fall in EB to 84.9225%, indicating a reduction in ductility.

Higher CuO concentrations are continuing this trend, as seen by the ABS/CuO 3% composite, which has an EB of 105.828%, which is still less than that of pure ABS. Remarkably, the ABS/CuO 5% composite shows a further drop in EB to 54.72%, suggesting that a greater CuO component causes a considerable loss in ductility. Agglomeration of nanoparticles or elevated stress concentrations inside the matrix are most likely the reason for causing the matrix to collapse prematurely under tensile stress.

This focuses on the trade-off between the ductility of the material and the reinforcement that CuO provides, which are important factors to consider for applications that need both strength and flexibility. It also emphasizes how crucial it is to precisely balance composite compositions to obtain the required mechanical characteristics for certain engineering applications.

4.3 FOURIER TRANSFORM INFRARED ELECTROSCOPY (FTIR)

A material's molecular makeup and structure may be thoroughly examined using an FTIR test. Through the examination of infrared light absorption at various wavelengths, FTIR identifies certain functional groups and chemical bonds present in the sample. This method yields a molecular fingerprint that may be used to identify unknown materials, verify sample composition, and find contaminants or impurities. Furthermore, FTIR can track alterations in chemical composition throughout processes, evaluate the extent of polymerization, and investigate the interplay among various constituents in composite materials. The generated spectra help with material development, quality control, and guaranteeing adherence to industry standards by allowing researchers to comprehend the chemical characteristics of the material.

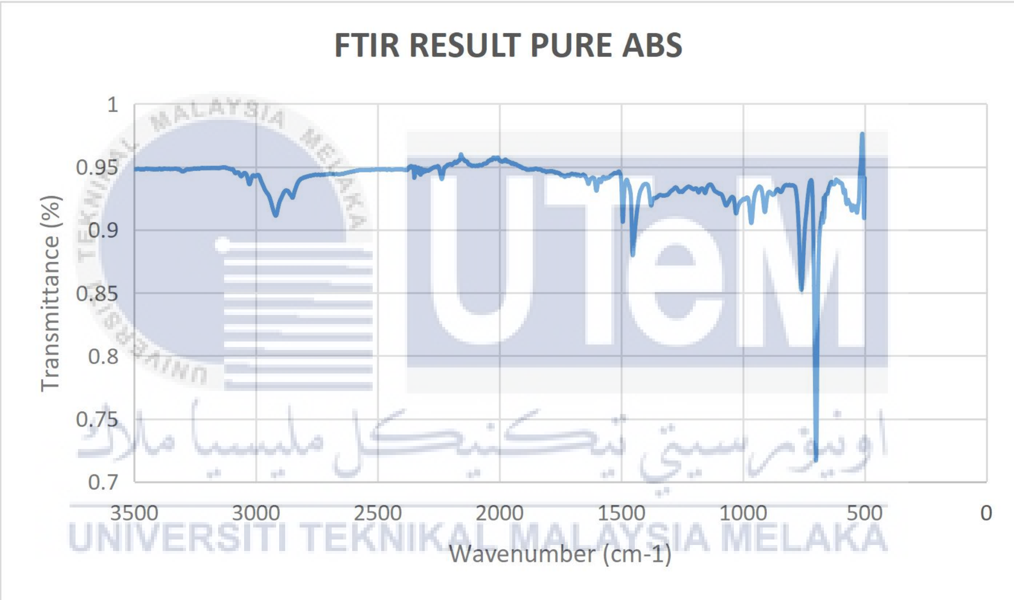

Figure 19: FTIR Result Pure ABS

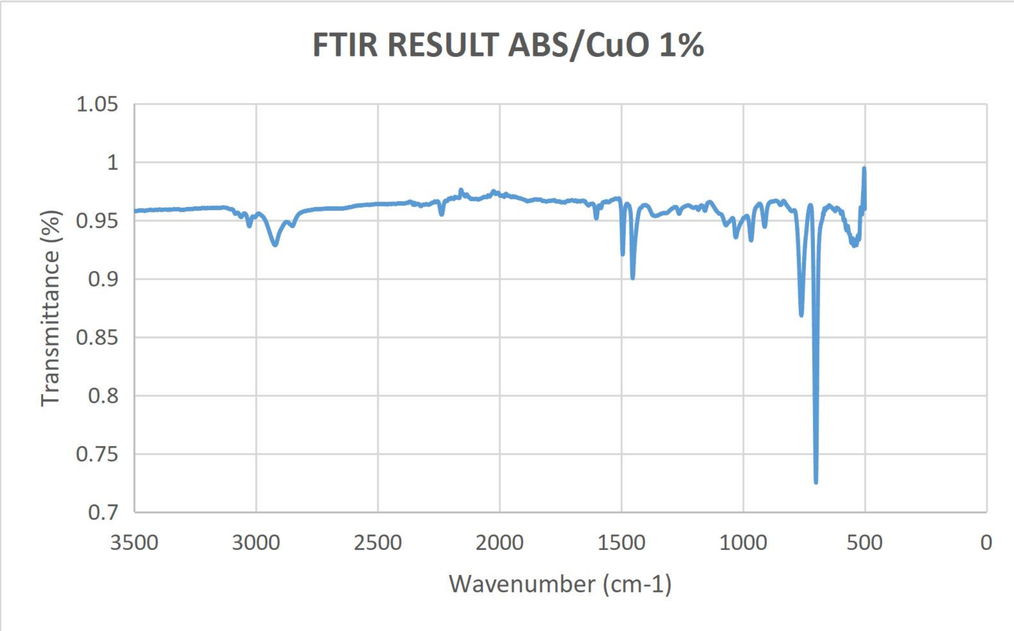

Figure 20: FTIR Result ABS/CuO 1%

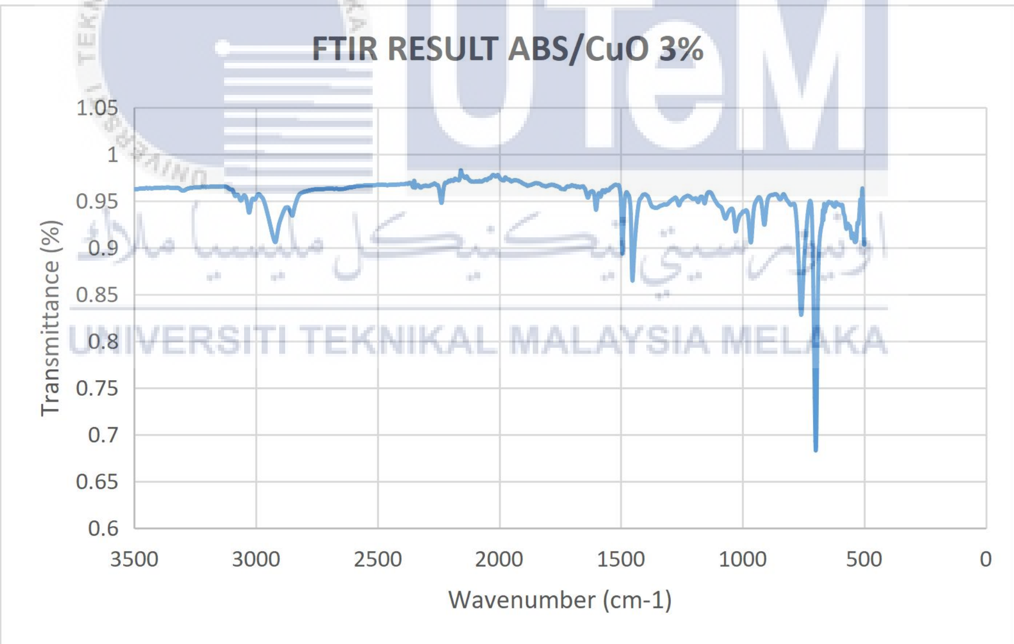

Figure 21: FTIR Result ABS/CuO 3%

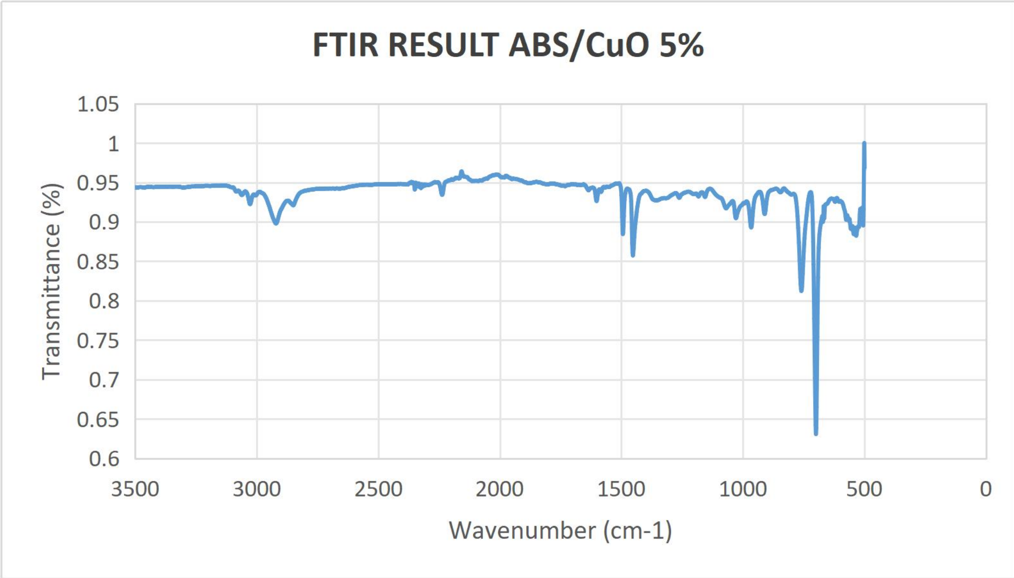

Figure 22: FTIR Result ABS/CuO 5%

Figure 19 to Figure 22 represent FTIR analysis result for each sample.

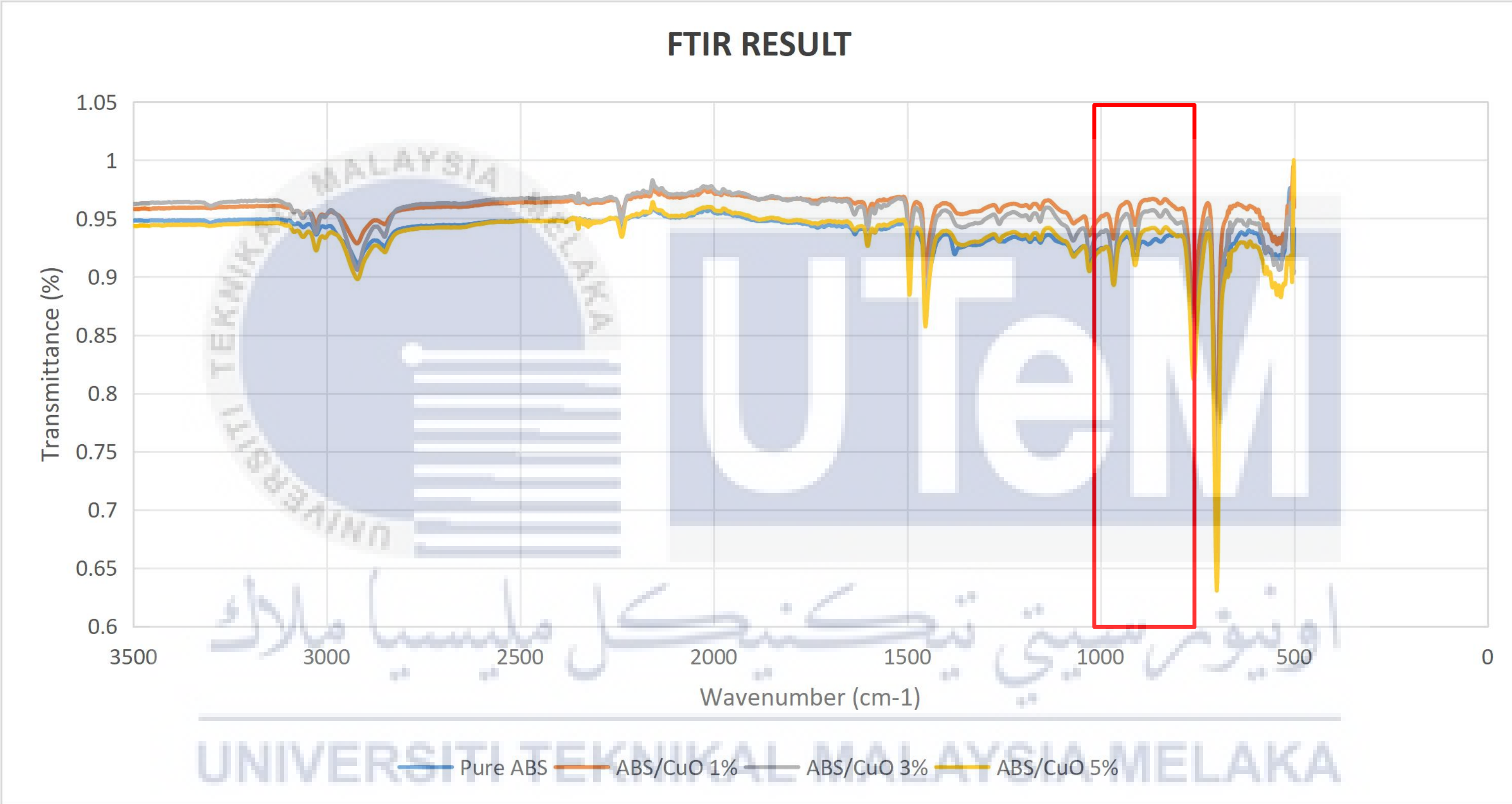

Figure 23: FTIR Spectrum of Copper Oxide Nanoparticles (CuO NPs)

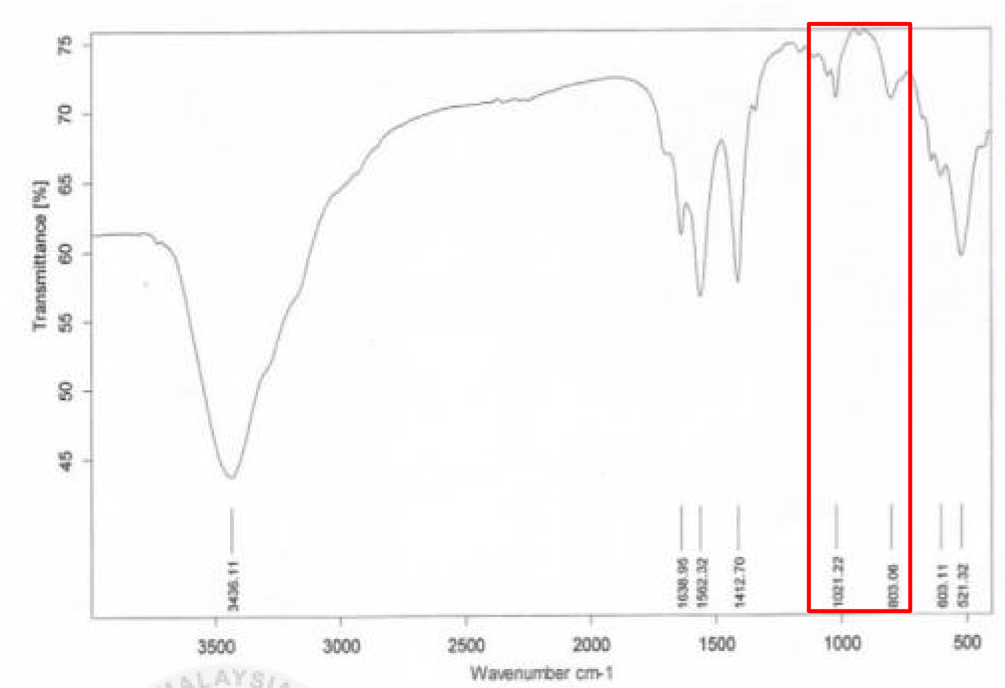

Figure 24: FTIR Spectrum CuO Nano Powder

The FTIR results for all samples are displayed in Figure 23, and the FTIR spectrum for CuO nano powder is displayed in Figure 24.

Figure 23 shows that each sample appears to have the same FTIR spectrum pattern. Conversely, the FTIR spectra of the ABS/CuO composites show a bigger peak in the same region in between 700 to 1000 cm^{-1}, indicating a possible interaction between the CuO nanoparticles and the ABS matrix. As the highlighted area exhibits a distinct shift, it is probable that the low absorption of CuO in this spectral range means that the region is not greatly impacted by the mineral. The molecular structure of the ABS polymer is more noticeable in this area, which usually correlates to the fingerprint region of the FTIR spectrum (Nandiyanto et al., 2019).

Based on (N. F. Chen et al., 2021) studies, these interactions may change the CuO crystal structure, leading to a larger peak. Furthermore, the larger peak in the FTIR spectra of the ABS/CuO composites may also be explained by the formation of hydrogen bonds between the CuO nanoparticles and the ABS matrix. A broader peak might be produced by hydrogen bonding-related shifts in the FTIR peak positions (Parekh et al., 2021). Because of the few alterations seen here, it appears that the ABS polymer's molecular structure mostly stays the same when CuO is present.

4.4 WETTABILITY TESTING

Wettability tester is generally use to identify the contact angle of each samples. ABS membranes have been the subject of this study, which includes four samples: pure ABS, ABS/CuO 1%, ABS/CuO 3%, and ABS/CuO 5%. Important details on the interaction between a liquid and a material's surface may be obtained from a wettability test, mainly by measuring the contact angle. The hydrophilicity or hydrophobicity of the surface may be ascertained with the use of this data, which is crucial for a variety of applications. Furthermore, the creation of materials that are water-repellent, the improvement of ink adhesion in printing technologies, and the optimization of surface treatments in the electronics manufacturing industry all depend on wettability testing. Understanding wettability characteristics allows industry to produce higher-quality, performance and ability goods.

Figure 25: Pure ABS Contact Angle Result

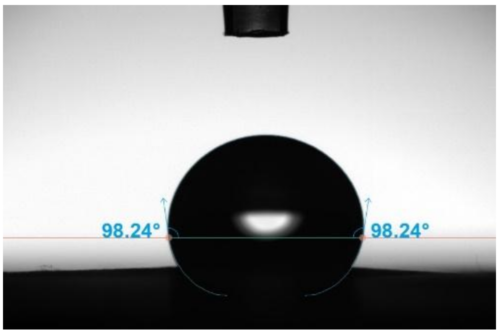

Figure 26: ABS/CuO 1% Contact Angle Result

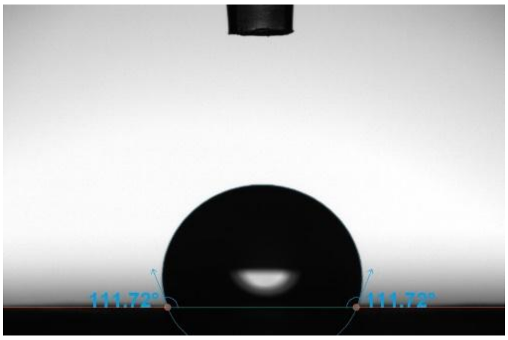

Figure 27: ABS/CuO 3% Contact Angle Result

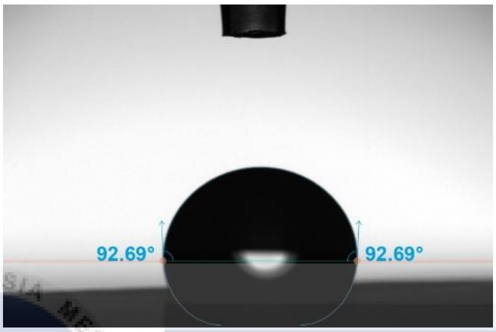

Figure 28: ABS/CuO 5% Contact Angle Result

Figure 25 to Figure 28 shows the samples contact angle result.

Table 4: Contact Angle Result

SAMPLE NAME	**CONTACT ANGLE (°) (A+B) / 2**
PURE ABS	(79.07+79.07)/2 = 79.07
ABS/CuO 1%	(98.24+98.24)/2 = 98.24
ABS/ CuO 3%	(111.72+111.72)/2 =111.72
ABS/ CuO 5%	(92.69+92.69)/2 = 92.69

Table 4 shows that the pure ABS sample had a contact angle of 79.07°. This serves as the benchmark for comparing the composite samples. Because of its moderate surface energy, the thermoplastic polymer ABS stands out in terms of how it interacts with liquids. ABS reached 98.24° when 1% CuO nanoparticles were added. When compared to pure ABS, the contact angle rises to 98.24°, indicating an obvious decrease in wettability. This implies that the surface becomes more hydrophobic even with a little addition of 1% CuO nanoparticles.

The contact angle increases to 111.72° when the concentration of CuO reaches 3%. This implies that when the surface gets more hydrophobic, there will be even less wettability. The significant increase in contact angle suggests that the addition of CuO nanoparticles has a significant impact on the surface properties of ABS. Interestingly, at 5% CuO concentration, the contact angle decreases to 92.69°. Nevertheless, still larger than that of pure ABS, this is less than the contact angles for 1% and 3% CuO composites.

CuO nanoparticles cause the polymer matrix to break down, which makes the surface less attractive to liquids. The contact angle reduces at 5% CuO concentration, possibly because of microstructural alterations or agglomeration (Mallakpour & Mansourzadeh, 2017) . This points to a complicated relationship between the ABS matrix and CuO nanoparticles, with larger concentrations producing surface roughness and marginally increasing wettability.

4.5 SCANNING ELECTRON MICROSCOPY WITH ENERGY-DISPERSIVE X-RAY SPECTROSCOPY (SEM-EDX)

At high magnification and resolution, scanning electron microscopy (SEM) examination yields precise information about the surface shape and composition of materials. High-quality, three-dimensional pictures that show a sample's topography, texture, and structural characteristics can be obtained using SEM examination. This makes it possible to examine surface characteristics at the nanoscale level, which makes it possible to identify phase distributions, flaws, and grain patterns. Energy Dispersive X-ray Spectroscopy (EDX) capabilities can also be added to SEMs, enabling elemental analysis and surface mapping of the material. This combination offers thorough insights on the elemental distribution, composition, and possible impurities of the substance. SEM analysis is essential for quality control, failure analysis, and the creation of novel materials and products in the fields of materials science, engineering, biology, and nanotechnology.

4.5.1 PURE ABS

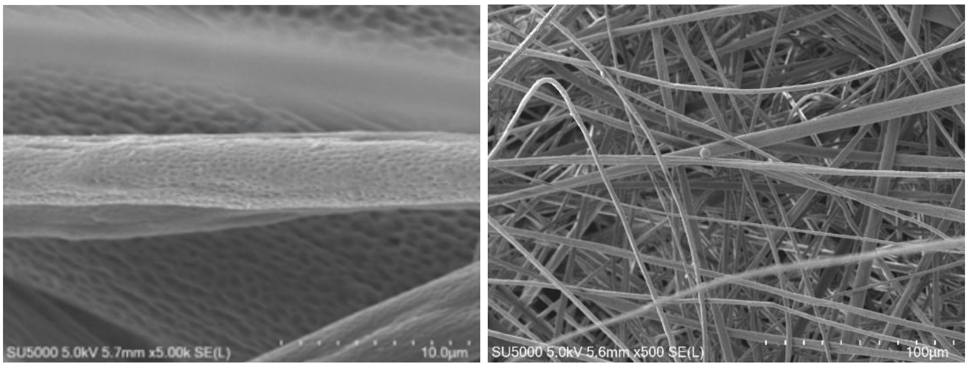

Figure 29: SEM Images for Pure ABS

Figure 29 show that pure ABS has a relatively uniform and smooth surface texture, as shown in the SEM images. The low porosity suggests a solid polymer matrix devoid of large spaces and imperfections on the surface. Pure ABS has a smooth texture that adds to its mechanical qualities, which include impact resistance and ductility.

4.5.2 ABS/CuO 1%

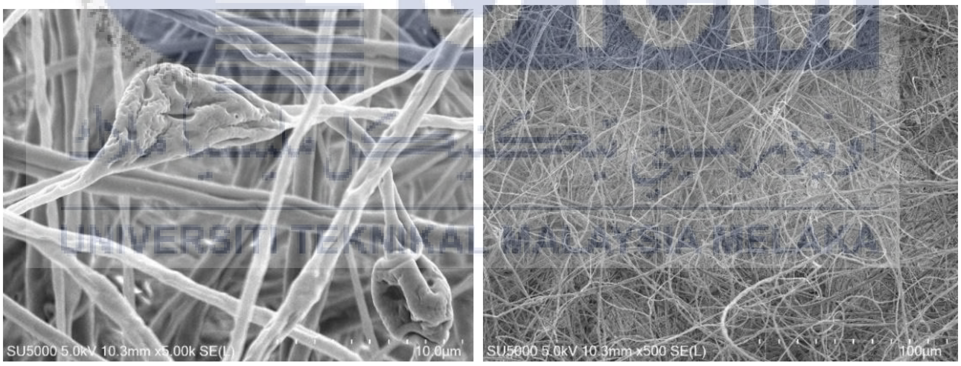

Figure 30: SEM Images for ABS/CuO 1%

Figure 30 shows ABS/CuO 1% composite's SEM pictures clearly demonstrate a different texture. The uniform smoothness is broken by the presence of CuO nanoparticles, giving the surface a less smooth appearance. When compared to pure ABS, the porosity slightly rises. Surface roughness is somewhat increased when CuO nanoparticles are present because they create voids and interfacial gaps between the particles and the polymer matrix.

4.5.3 ABS/CuO 3%

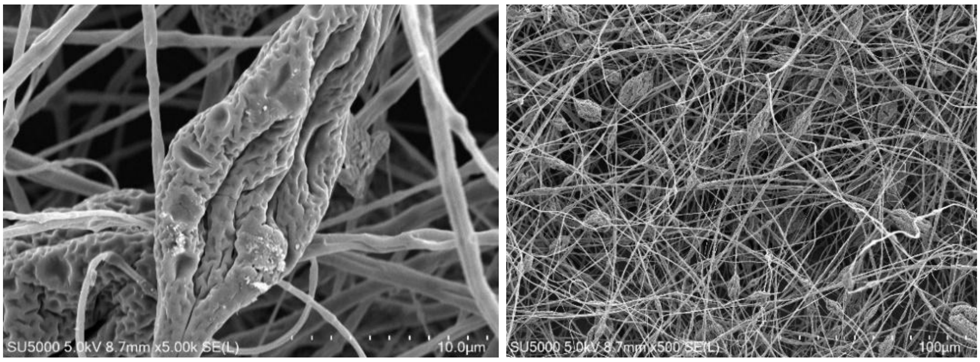

Figure 31: SEM Images for ABS/CuO 3%

The ABS/CuO 3% composite's SEM pictures reveal notable variations in texture and porosity as shown in Figure 31. There is a noticeable increase in the density of CuO nanoparticles and the surface is noticeably rougher. CuO nanoparticle aggregation causes a considerable increase in porosity. Large voids and interfacial gaps are produced by the clusters, making the structure less homogeneous and more porous.

4.5.4 ABS/CuO 5%

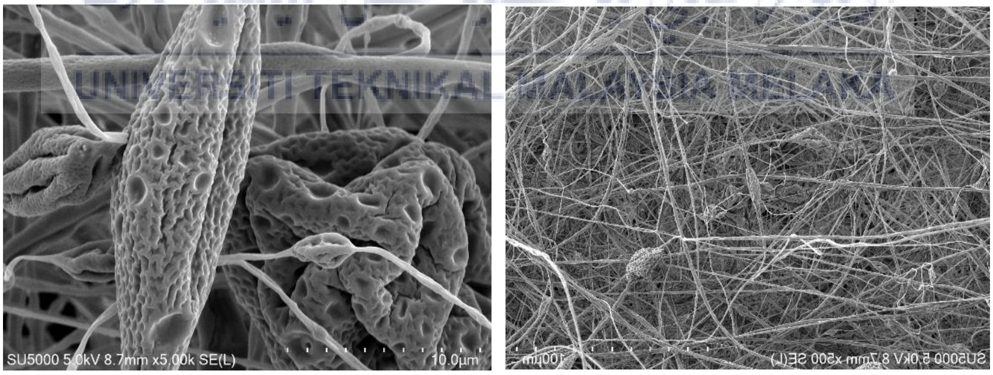

Figure 32: SEM Images for ABS/CuO 5%

The ABS/CuO 5% composite's SEM pictures reveal notable variations in texture and porosity can be clearly seen in Figure 32. There is a noticeable increase in the density of CuO nanoparticles and the surface is noticeably rougher. The nanoparticles tend to aggregate at this concentration, creating bigger clusters. The polymer matrix exhibits apparent holes and gaps due to the increased porosity caused by these agglomerations.

4.6 EDX ANALYSIS

EDX is employed in conjunction with SEM to ascertain the sample's elemental makeup. The elements included in the material may release distinctive X-rays when the electron beam contacts the sample. EDX can recognize and measure the components by identifying and evaluating these X-rays. This combination is essential for understanding the structure and composition of samples at the microscale in a variety of domains, including materials science, geology, biology, and engineering. It permits both exact elemental characterisation and in-depth morphological study.

4.6.1 ABS/CuO 1%

Table 5: EDX Analysis Result for ABS/CuO1%

ELEMENT	WEIGHT %
C	88.0
N	8.2
O	2.8
Cu	1.1

Table 5 shows that the bulk composition of ABS, a polymer largely made of carbon-based structures, is compatible with the predominate presence of carbon (C) at 88.0%. The acrylonitrile component of the ABS, which has nitrogen atoms in its chemical structure, is represented by nitrogen (N) at 8.2%. The 2.8% oxygen (O) level indicates the possibility of oxygen-containing functional groups or small oxidation products, which may result from the material's processing or exposure to the environment. Lastly, the 1.1% copper (Cu) element verifies that CuO nanoparticles have been incorporated into the composite.

This rather modest proportion of copper corresponds to the targeted composition, which aims to improve certain mechanical qualities without causing a substantial change to the polymer matrix. The elemental distribution predicted by the EDX findings is confirmed for an ABS/CuO composite, ensuring that the integration of CuO nanoparticles has been successfully achieved.

4.6.2 ABS/CuO 3%

Table 6: EDX Analysis for ABS/CuO 3%

ELEMENT	WEIGHT %
C	85.7
N	8.8
O	4.5
Cu	1.0

The EDX results show that 85.7% of the composite is made up mostly of carbon (C), which is indicative of the ABS matrix's significant presence and composition of carbon-based polymers as shown in Table 6. The acrylonitrile component of ABS is probably the reason for the 8.8% presence of nitrogen (N), which adds to the stability and hardness of the material. 4.5% of the composition is oxygen (O), suggesting that the ABS contains oxygen-containing compounds or that there may have been some little oxidation during processing. Copper (Cu) at 1.0% indicates that CuO nanoparticles have been incorporated into the composite.

4.6.3 ABS/CuO 5%

Table 7: EDX Analysis for ABS/CuO 5%

ELEMENT	WEIGHT %
C	90.9
N	6.8
O	1.9
Cu	0.4

As shown in Table 7, 90.9% of the element carbon is found in ABS/CuO 5% composite. The acrylonitrile component of ABS is consistent with a nitrogen level of 6.8%. Although the oxygen element's relatively low percentage reveals that CuO is present in modest numbers, as would be expected for a 5% composite by weight, its measurement of 1.9% suggests the integration of CuO nanoparticles. It's interesting to note that the recorded copper content of 0.4% is less than expected. This might mean that some CuO was not identified because it was dispersed at a size that was below the resolution of the EDX, or that the distribution of CuO nanoparticles inside the ABS matrix was not uniform.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

An important development in material science is the incorporation of copper oxide (CuO) nanoparticles into acrylonitrile butadiene styrene (ABS) membranes, which provide a combination of improved characteristics appropriate for a variety of applications. The mechanical properties of the ABS/CuO composite are one important area of research. While the addition of rigid particles that may serve as stress concentration points can potentially compromise some mechanical properties like tensile strength and elongation at break, it simultaneously reinforces other properties like hardness and impact resistance.

Another important factor that is impacted by the inclusion of CuO nanoparticles is the wettability of the ABS/CuO composite. Water repellence has significantly improved, as shown by wettability tests, which have changed the surface properties of ABS from hydrophilic to hydrophobic. This improvement is explained by the hydrophobic properties of CuO nanoparticles, which decrease the composite's surface energy and decrease its attraction for water. These hydrophobic qualities are very helpful in situations where moisture resistance is required, including in outdoor settings or when packing delicate electronic equipment, when keeping the environment dry is essential for durability and performance.

Analysis using scanning electron microscopy (SEM) sheds light on the structural modifications made to the ABS matrix by CuO nanoparticles. In comparison to pure ABS, SEM pictures show a rougher and more porous surface features that potentially aid adhesion and bonding with other materials or coatings. Furthermore, the material's flexibility and impact resistance may be enhanced by the increased surface roughness and porosity, strengthening its overall durability in a variety of applications and increasing its resilience to physical stressors.

To sum up, the ABS/CuO composite presents a flexible option with increased mechanical strength, better water resistance, and possible flexibility gains. These characteristics make it a good fit for applications that call for reliable performance in demanding settings, such waterproof medical device packaging. The potential uses and capabilities of the composite in a variety of technological and industrial domains appear to be further enhanced by ongoing research and development aimed at refining the incorporation of CuO nanoparticles into ABS matrices.

5.2 RECOMMENDATION

A few suggestions for improving the incorporation of CuO nanoparticles or comparable nanofillers into ABS membranes for improved performance in certain applications may be made considering the study's conclusions and considerations.

First, it's essential to use advanced mixing techniques in controlled environments, including melt blending or ultrasonication. By ensuring that the nanoparticles are evenly distributed throughout the ABS matrix, these techniques avoid agglomeration, which might potentially compromise the material's mechanical and surface qualities. Controlled settings are also helpful in preserving quality and consistency throughout the production process, which is necessary to provide outcomes that are dependable and repeatable.

Second, functionalization methods or coupling agents introduced beforehand to the ABS surface seem like an appropriate approach to improve the interfacial contacts between the nanoparticles and the polymer matrix. By enhancing these interactions, the ABS's nanoparticle dispersion and bonding are improved, which may enhance the material's overall performance and mechanical reinforcement. This method optimizes the material's compliance with various application needs, such greater water repellence or higher flexibility, while also enhancing the material's structural integrity.

Finally, it is advised to investigate the usage of different nanofillers besides CuO and methodically compare their results for certain applications. The performance of ABS composites in various settings can be greatly impacted by the distinct qualities that each type of nanofiller possesses. Researchers can determine which nanofiller is best for a certain application by comparing options, such as carbon-based nanomaterials or other metal oxides, and considering attributes like durability in the environment, chemical resistance, and mechanical strength. By using a comparative approach, material design and optimization may be customized to fit the specific needs of different industrial and technical sectors, making ABS composites an efficient solution.

5.3 SUSTAINABILITY

When incorporating nano CuO into ABS membranes, sustainability requires evaluating the effects on the environment as well as the economy. While nano CuO improves mechanical strength and water repellence in ABS membranes, it is important to consider possible sustainability issues including the energy-intensive procedures involved in producing nanoparticles and the disposal of composite materials at the end of their useful lives. Sustainable practices should concentrate on investigating recyclability or biodegradability alternatives for ABS/CuO composites, as well as improving nanoparticle manufacturing procedures to decrease energy consumption and waste formation. Assuring that the advantages of improved membrane characteristics by nano CuO inclusion are consistent with sustainable principles in material development and usage requires evaluating the life cycle implications and advocating for environmentally acceptable disposal techniques.

5.4 COMPLEXITY

The study procedure had been impeded 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 complicated when renewable elements like copper oxide nanoparticles (CuO NPs) are used, necessitating careful formulation and optimization. This study becomes even more challenging because of the need for a detailed understanding to evaluate and correlate data from various testing methods.

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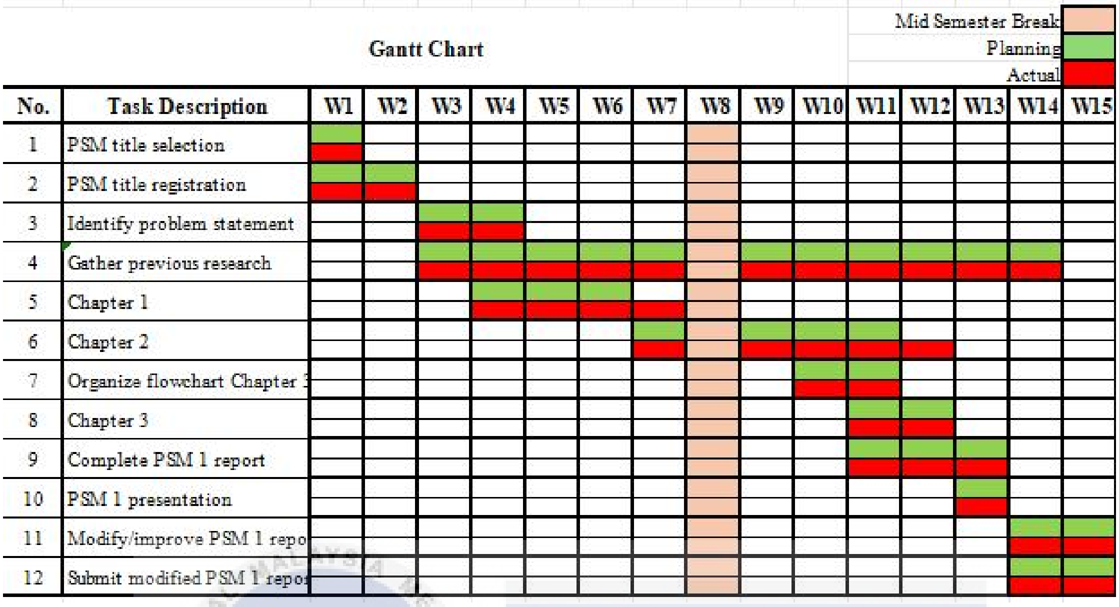
APPENDICES


Gantt Chart
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1 PSM title selection
2 PSM title registration
3 Identify problem statement
4 Gather previous research
5 Chapter 1
6 Chapter 2
7 Organize flowchart Chapter
8 Chapter 3
9 Complete PSM 1 report
10 PSM 1 presentation
11 Modify/improve PSM 1 repo
12 Submit modified PSM 1 repo