Methyl methacrylate and zinc oxide nanoparticles based composite material for skylight. 2023

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Dedication

This work is dedicated to our parents and teachers who are always with us in every hardship of life and waited for us to be here at this final stage.

May Allah give them a long life (Ameen).

Certificate

This thesis, **"Design Material for Skylight Glazing".** Written by **Majid Ali** & **Ubaid-Ur- Rehman** Under the direction of **Dr. Asif Hafeez** and Mr. **Muzammil Mehmood.** This approved all the members of the thesis committee, has been presented to and accepted by the Department of Materials in fulfilment of the requirement of the degree of Bachelor of Science in Polymer Engineering.

Supervisor **Internal**
Examiner

Chairman DOM **Dean SET**

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Primarily, we are grateful to the ALLAH ALMIGHTY for the good health and wellbeing that were necessary to complete this project.

We express our sincere thanks to our research Supervisor **Dr. Asif Hafeez** and Co-Supervisor **Mr. Muzammil Mehmood** who giving us a chance to show abilities and skills. We are thankful to them from the bottom of our heart because without their assistance and committed participation at each step of the process, this project would not have been completed. We appreciate all of your help and advice, so please accept our sincere gratitude.

We are also thankful to the whole faculty members of Department of Materials and for their help and support.

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List of Abbreviations:

SDG	**(**Sustainable Development Goals)
MMA	(Methyl MethAcrylate)
PMMA	(PolyMethyl MethAcrylate)
ZnO	(Zinc Oxide)
GLYMO	(3-Glycidyloxypropyltrimethoxysilane)
BPO	(Benzoyl Peroxide)
PVA	(Polyvinyl Alcohol)
UV	(Ultraviolet)
Wt.%	(Weight Percentage)
FTIR	(Fourier Transform Infrared Spectroscopy)

Abstract:

This study focusses on the development and characterization of a skylight glazing sheet fabricated from Methyl Methacrylate (MMA). We focused on utilizing Benzoyl Peroxide (BPO) as an initiator and Zinc Oxide (ZnO) as a UV resistance additive to enhance the performance, UV stability and sustainability of the glazing sheet. The research begins with a detailed investigation of the synthesis process, involving the polymerization of MMA using BPO as an initiator. Effects of various parameters including initiator concentration, reaction time and temperature are analyzed to optimize the polymerization process and achieve a desired molecular weight and polymer structure. To enhance the glazing sheet's UV resistance, Modified ZnO with coupling agent [Silane] and pure ZnO is incorporated as an additive during the MMA polymerization. The impact of ZnO concentrations on optical and mechanical properties of resulting glazing sheet is evaluated. In addition, accelerated ageing tests and exposure to artificial UV radiation are used to study the compatibility of ZnO with the MMA matrix and its capacity to offer long-term UV protection. Skylight glazing sheets made of PMMA are put through a thorough characterization procedure. Optical properties like light transmittance and mechanical characteristics such as impact resistance and tensile strength are evaluated using Spectrophotometry, Tensile test and Charpy impact test to ensure glazing sheet's transparency, durability, and resistance to external forces. By using modified ZnO the resistance against UV light and mechanical properties of the sheet improves much better than pure ZnO additive. FTIR and Zeta potential of the pure and modified ZnO particles was also evaluated.

SDG Goals:

Figure 1:SDG Goal 7

SDG Goal 7 (Affordable and Clean Energy) attempts to make modern, dependable, and sustainable energy sources accessible. This focus is on promoting renewable energy, enhancing energy efficiency, and increasing access to power in developing countries. There is a direct connection between SDG Goal 7 and UV stable glazing sheets. UV stable glazing sheets provide the dual aim of letting light through while preventing harmful UV rays when used in applications like skylights, greenhouse panels, or protective covers. SDG Goal 7's sustainability and energy efficiency objectives are largely supported by the indirect contribution of UV resistant glazing sheets to the both. Despite the fact that UV stable glazing sheets may not be able to immediately address the issue of affordable and clean energy access, their energy-efficient features and compatibility with renewable energy systems can aid in achieving SDG Goal 7's objectives.

Figure 2:SDG Goal 9

Goal 9 of the Sustainable Development Agenda focuses on fostering innovation and calls for creating sustainable buildings and inclusive, sustainable development. It is concentrated on advancing technology, sustainable industrialization, and infrastructural development. Infrastructure offers the fundamental physical systems and structures required for a community or business to function. Industrialization promotes economic boom, creates employment opportunities, and reduces income inequality. Innovation fosters the growth of fresh talents and boosts their technological capabilities in the industrial sectors. All people's living standards may rise quickly and consistently as a result of inclusive and sustainable economic growth, which also offers the technological resources required for industrialization that is environmentally beneficial. UV stable glazing sheets can aid infrastructure expansion by providing a reliable and effective solution for a variety of uses. These sheets can be utilized in buildings, infrastructure for the transport industry, and commercial constructions to enhance durability. Recycling materials, waste treatment techniques, and energy-saving techniques could be integrated into the production processes.

Environmental Impacts:

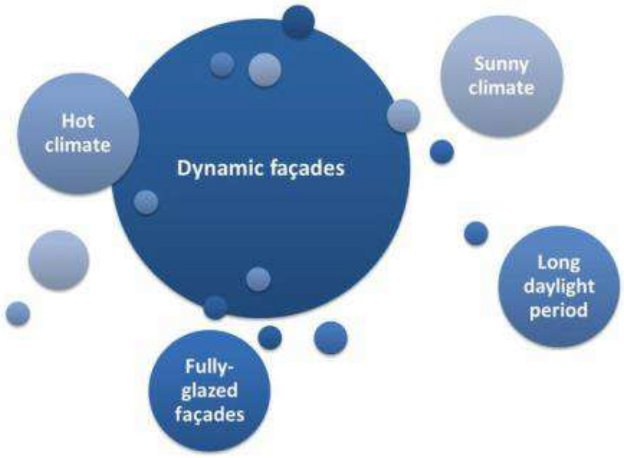


Figure 3:Environmental impacts

Energy is frequently needed to produce products derived from MMA, which could lead to greenhouse gas emissions. The use of BPO as an initiate in the polymerization process has the potential to produce fumes (VOCs) and other hazardous air pollutants if handled improperly. The production of waste during the process of production could come in the form of rejected goods, trims, and scrap materials. To avoid any harmful effects on the environment, solid waste techniques like recycling and proper waste disposal should be implemented. ZnO, a UV stabilizer, is added to protect the skylight glazing sheet against UV radiation-related damage. This can reduce any need for repeated replacements thus extending the product's lifespan and reducing resource use and garbage output. After achieving its purpose, the skylight glazing sheet should be properly disposed of or reused. ZnO is commonly used as a UV absorber, however manufacturing it has concerns, involving hazardous environmental discharge. Inadequate zinc mining and processing practices can have a severe impact on the environment and pose a risk to aquatic life. To lessen the environmental effects of Our product, think about utilizing sustainable production techniques, enhancing energy efficiency, promoting recycling initiatives, and ensuring proper waste management throughout the life cycle process.

Chapter: 01

1. Introduction:

1.1. Skylight Glazing:

Skylights are popular architectural elements that provide natural light, energy savings, and aesthetic appeal.

Figure 4:Skylight Glazing

To solve problems like heat gain, glare, and UV radiation, the glass used for the design of the skylight is quite important. The interior energy efficiency of the structure is significantly influenced by the glazing material choice. Heat gained via unshaded glass is 100 times higher than heat gained through an insulated wall, and poorly built skylights or glazed surfaces can cause an uneasy indoor climate.

1.1.1. Importance of Skylight Glazing:

Skylight glazing is a translucent or transparent material that encloses the skylight structure's opening. Its primary purpose is to let natural light in, which lessens the demand for artificial lighting during daylight hours. By reducing electricity use, this feature helps to improve energy efficiency while cutting costs and having a less negative impact on the environment.

1.1.2. Challenges of Conventional Skylight Glazing:

Despite the significant benefits of skylights, traditional glazing materials used in their construction pose certain limitations. Heat gain is a major issue, as sunlight passing through glazing can increase indoor temperatures, leading to higher cooling loads. Excessive light transmission can also cause glare, which can be uncomfortable for occupants and interfere with visual tasks. Furthermore, the transmission of harmful UV radiation is a potential drawback, as it can cause fading of interior furnishings and pose health risks to occupants.

1.1.3. The Need for Advanced Skylight Glazing Solutions:

Modern skylight glazing solutions are becoming more and more necessary to solve the drawbacks of conventional glazing materials. While minimizing heat gain, glare, and UV radiation, these methods seek to maximize natural lighting. By incorporating advanced materials and technologies, such as spectrally selective coatings, low-emissivity (low-e) coatings, and smart glazing systems, skylight glazing can be improved to achieve superior performance in terms of energy efficiency, occupant comfort, and overall building sustainability.

1.2. Materials for Glazing Sheets:

- Poly Methyl Meth Acrylate or Acrylic (PMMA)
- Polycarbonate
- Glass

1.2.1. Polymethyl methacrylate [PMMA]:

PMMA, commonly referred to as Plexiglas, Acrylate, or Lucite, is a transparent thermoplastic polymer that finds widespread use in a variety of industries. It is derived from acrylic acid and methanol through polymerization.

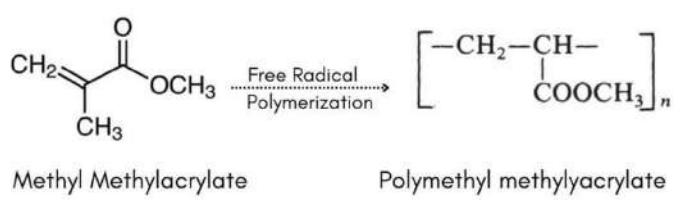


Figure 5:PMMA

PMMA is a popular substitute for glass because of excellent optical characteristics, such as high light transmission and resistive to yellowing. Its impact resistance is superior to that of glass, making it safer in environments prone to breakage. PMMA is also highly resistant to weathering, UV radiation, and chemicals, making it suitable for outdoor use. It may be shaped and manufactured in a variety of ways due to its simplicity of manufacturing, and adhesives can be used to bond it quickly. It excels in light transmission, improves the aesthetics of skylight designs, and offers resilience against UV radiation. Although it provides some thermal insulation, other materials like polycarbonate or insulated glass may perform better. However, PMMA remains a cost-effective alternative to glass for skylight glazing.

1.2.2. Polycarbonate:

Polycarbonate (PC) is transparent, amorphous thermoplastic renowned for its outstanding strength, impact resistance, and optical clarity. It is widely utilized in diverse industries due to its versatility. Bisphenol A (BPA) and phosgene are polymerized to obtain polycarbonate. With the ability to withstand substantial impacts without shattering or fracturing, polycarbonate offers superior protection compared to materials like glass. Consequently, it is extensively employed in safety goggles, face shields, bullet-resistant windows, and automotive components. Polycarbonate also possesses excellent optical properties, boasting high light transmission akin to glass. This enables the transmission of light without significant loss or distortion.

1.2.3. Glass:

Glass is a solid, translucent material that is transparent or translucent and is known for having certain qualities that make it useful in many different sectors. It is created by rapidly cooling a silica, soda ash, and limestone mixture that has been melted at high temperatures to produce a hard, non-crystalline structure. One of the distinguishing characteristics of glass is transparency, which enables clear viewing through windows, lenses, and glassware. Its popularity in architecture is a result of this feature, which allows for the passage of natural light while providing protection from the elements. Glass has a high level of chemical resistance, making it resistant to most chemicals, acids, and alkalis without corroding. As a result, it is appropriate for keeping and carrying a variety of things, such as food, drinks, medications, and chemicals. Moreover, glass is an environmentally friendly material due to its inertness, recyclability, and absence of harmful emissions during production and use. Glass cannot be used in applications where weight is an issue because it is much heavier than certain alternatives.

1.3. Initiator:

- Benzoyl Per Oxide (BPO)

1.3.1. Benzoyl per Oxide (BPO):

Chemical reactions frequently use benzoyl peroxide as an initiator, especially during the polymerization processes. It provides free radicals that start and spread polymer chains. Benzoyl peroxide decomposes and produces these extremely reactive molecules with unpaired electrons when subjected to special conditions or heated.

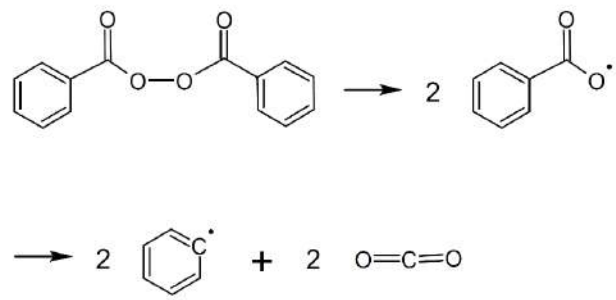


Figure 6:Free Radicals Of BPO

The polymerization of the monomers is then started by these radicals. Benzoyl peroxide is typically mixed with a monomer or group of monomers during polymerization operations. It breaks down and releases free radicals, which interact with the monomer(s), causing polymer chains to begin to form. As monomers join the expanding chains, the process proceeds, resulting in the development of polymers. In the manufacturing of polymers like polystyrene, poly (methyl methacrylate), and polyacrylates, it is widely used. Because of its breakdown characteristics and thermal stability, benzoyl peroxide was chosen as an initiator. It breaks down at relatively low temperatures, usually between 60 and 70 °C (140 and 158 °F), allowing regulated polymerization reactions to begin at moderate temperatures. Temperature, benzoyl peroxide content, and the presence of additional chemicals or co-initiators are the variables that might affect how quickly polymerization is completed.

1.4. Additive:

- Zinc Oxide
- Coupling Agent

1.4.1. Zinc Oxide:

Zinc oxide (ZnO), a universal inorganic compound, is an intrinsic n-type semiconductor material. In molecular form, it is written as ZnO. It is found naturally as zincite mineral which is generally contaminated with Mn and some other impurities. Therefore, this natural form may change color from yellow to red. The pure ZnO extracted from zincite is an odorless, white colored powder that is insoluble in water. Zinc oxide is the member of those metal oxides which acts as amphoteric in nature because it is soluble in most dilute acids and bases. Zinc oxide has an extremely high melting point of 1975^{o}C at which it decomposes. Zinc oxide is a bulky white polycrystalline powder however considered as a non-combustible, non-irritating, nonallergenic and non-comedogenic material.

Zinc oxide has been ranged over a vast array of applications. Similarly, the reactivity of Zinc Oxide declared it exemplary in its uses for a precursor to obtain other compounds of Zn. Zinc oxide has been proved a backbone for material science just because of having a combination of ideal properties like UV absorption, constant optical and thermal properties, and anti-microbial properties.

1.4.2. Coupling Agent:

Silane coupling agents work as a bonding or bridging agent in the interphase region, which is the space between two substrates, to increase the adhesion of the two different components. Other desired modifications result from altering the interphase regions, enhances filler dispersion in liquid polymers and the polymer's ability to wet out the inorganic substrate.

3-Glycidyloxypropyltrimethoxysilane:

The versatile silane coupling agent 3-Glycidyloxypropyltrimethoxysilane, sometimes known as GLYMO, is widely used in a variety of industries. It belongs to the class of substances known as organosilanes, which are made up of silicon atoms linked to organic functional groups. The special reactivity and functionality of GLYMO are derived from its chemical structure, which consists of a silicon atom coupled to three methoxy groups and a glycidyloxypropyl group that contains an epoxy ring. GLYMO's function as a coupling agent and adhesion promoter. Application of GLYMO is also to surface modification and functionalization. By covalently attaching to the surface and adding desirable functions, it is used to change the surface properties of materials like ZnO.

1.5. Mold Releasing agent:

- Polyvinyl Alcohol

1.5.1. Polyvinyl Alcohol:

PVA is a versatile polymer that is frequently used in many sectors, particularly in casting and manufacturing processes, as a mold releasing agent. It creates a thin, continuous layer when applied to the surface of a mold or casting tool, serving as a barrier between the mold and the material being cast. The casted product is directly removed from the mold mainly to this film's ability to avoid adherence. It is simple to combine it with water to make a solution or emulsion, which may then be applied to the mold surface by spraying, brushing, or dipping. High release effectiveness of PVA reduces the possibility of component distortion, surface flaws, or other damage during the demolding procedure.

1.6. Why we use PMMA:

When compared to polycarbonate and glass, PMMA (Polymethyl methacrylate) is more affordable, especially when it comes in thinner sheets. It is a more cost-effective option for a variety of uses. In contrast to polycarbonate, PMMA has good UV resistance and is less likely to yellow or degrade when exposed to sunshine. PMMA is therefore preferred for exterior applications including signage, windows, and skylights.

PMMA also offers exceptional optical clarity and distortion-free light transmission. Due to its great transparency, which is comparable to glass, it can be used in applications that call for exceptional optical qualities. PMMA is much lighter than glass, making it simpler to install and handle. Despite being lighter than polycarbonate, it is not significantly lighter.

1.7. Why we use ZnO:

Depending on the application and required performance characteristics, ZnO and TiO_2 have different advantages. Their efficiency is also influenced by variables like particle size, surface treatment, and formulation. Cost-wise, ZnO is typically more economical and easily accessible, making it the favored option when cost is a major consideration. ZnO trumps

TiO2 in terms of mechanical characteristics and UV protection. While TiO2 primarily absorbs UVB rays, ZnO has the capacity to absorb UVA and UVB rays, offering efficient defense against damaging UV radiation. Additionally, ZnO has increased transparency in the visible light spectrum, making it appropriate for uses where maintaining aesthetic appeal is important. ZnO is more scratch- and wear-resistant because to its superior mechanical qualities, including hardness, abrasion resistance, and durability. It is preferred for uses like coatings and films where mechanical strength is crucial. Additionally, ZnO exhibits greater stability under challenging environmental settings and resists deterioration over time. This qualifies it for outdoor applications that are subject to the elements and sunlight.

Chapter: 02

2. Literature Review:

Karam M. Al-Obaidi researched to examine the varieties of glazing used in the skylight roofing system as well as their performance. The review focuses on solar light and solar heat as two crucial components of glazing performance. The evaluation highlights this overarching relationship throughout the design phase to provide more visibility in the product selection as well as several additional benefits, including low mechanical loads, efficient use of energy, and comfort in boundary zones. The glazing materials chosen have a considerable impact on the building's interior energy efficiency. Uncomfortable skylights, windows, and glazed surfaces can be based on bad construction. Heat input via an unprotected glass can have a 100-fold greater impact than it would be in the same space of an insulated wall.[1]

The use of PC sheets for bay window coating also contributes to reduced energy consumption and gas emissions, with single coating reducing use by 2% to 28%, double coating by 3% to 42%, and triple coating by 4% to 49%. The 25mm 9 wall X-Design PC sheet also proves to be the ideal option for windows and lookout windows across all coating frameworks (single, twofold, and triple). A key factor in determining the PC sheets' warm and environmentally friendly presentation is their thickness and piece.[2]

Danny Santoso Mintorogo explored the considerable developments in energy-saving techniques and the creation of high-tech glass, primarily for building facades and skylights around the world. Skylight utilization in buildings to maximise daylighting while taking energy savings into consideration is still a challenging task, especially in areas with unique climatic circumstances. The sustainable energy-saving dripped-water skylight emerges as the best choice among the numerous types of skylights. This skylight considerably lessens the negative effects of direct and global solar radiation on horizontal or sloped skylights from any direction in addition to optimising the entry of direct sunlight and daylight into a room. Additionally, the installation of the dripped-water skylight results in a significant drop in the temperature of the skylight frames and louvres, directly lowering the cooling load needed for the building. This strategy might be referred to as "water-friendly design" because water is essential for cooling applications, which ultimately saves energy. [3]

Elisa Moretti researched that plastic transparent parts are becoming more and more popular in the glazing industry because of their good performance, significant weight reduction over glass, and affordable cost. Multi-sheet coextruded polycarbonate systems that are UV-protected to delay premature ageing are one popular product category. These parts must be bonded by male-female connections and are restricted in size, which could be a weakness in building facades. The thermal and optical analysis of three polycarbonate building systems with various chamber counts and geometries is the focus of this study. The results imply that the researched polycarbonate systems might be a practical replacement for conventional windows in commercial structures.[4]

C.M. Lampert investigated flat panel displays with a big surface area and dynamic glazing is actively being developed by several companies across the world, while academic institutions and national laboratories are looking into new materials .and technologies to improve these products. movable glazing in buildings & automobiles is a very appealing concept. Dynamic glass with changeable transmittance offers an ideal solution with range of lighting climate and glare, in contrast to standard glazing, which offers fixed transmittance and limited control on the energy passing from it. Furthermore, development of self-sufficient switchable window systems is made possible by the incorporation of photovoltaics as power for smart windows. These screens are used in a variety of contexts, including dynamic pricing and banner ads at retail locations, and electronic books. The switching technologies that are the subject of this study are Encapsulated liquid crystals, suspended particles, and electrochromic. [5]

A. Karthicka examines how semitransparent photovoltaic (STPV) modules might take the place of glazing in home skylights. The study intends to reduce energy consumption associated with the demand on the heating and cooling system and artificial lights of buildings by inserting STPV modules into skylights. The goal of his study is to assess the STPV skylights' electrical, thermal, and daylight performance in actual outdoor environmental settings. Analysis is done on variables including power production, light output, daylight factor, solar heat gain, module surface temperatures, electrical efficiency, and CO_2 reduction. The results show that STPV skylights with a PVCCR of 0.62 can produce an indoor illumination of 850 lux and a maximum daylight factor of 4%.

Additionally, it has been determined that installing PV skylights reduces summer cooling requirements by 248 kWh/year. The PVCCR of 0.72, or 450 kWh per year, is noted to have the ability to save the most energy overall. For this design, the projected Unit cost of producing electricity is 0.0354 $/kWh.[6]

M. DABBOUR and S. ARAFA investigated Applying silicone resin 1-2577 to an open weave leno fabric using a specialised coating tower located in Basaisa village, A1 Sharkiya Governorate, Egypt, produces silicone glazing, a translucent material reinforced with glass fabric. Notably, the coating mechanism of this tower, powered by a photovoltaic module, as well as the heating of its curing chamber, both use solar energy. The study examined the silicone glazing's optical and mechanical characteristics. According to the study, silicone glazing has a solar transmission of 90% and efficiently blocks UV and infrared light with wavelengths below 270 nm. Excellent tensile strength can be seen in the material, particularly in the fill and wrap orientations of the reinforcing fabric. Tensile strength reaches 50 pli (Pounds Per Lineal Inch) in fill direction and 80 pli in wrap direction at a strain rate of 0.8. The results show that silicone glazing is appropriate for a range of solar applications, including skylights in buildings, solar food dryers, greenhouse screens, and space solar heating, with specific advantages for rural locations.[7]

NOOR HARIAH BINTI WAHAB studied the chemical mechanism by which tiny molecules unite to create polymers, which are big chain or network molecules. These small molecules might share characteristics or be made up of two or more distinct compounds of various molecular weights. This study aims to investigate the effect of temperature on the MMA polymerization kinetics in the presence of an initiator. The mass of the initiator, azo-bisisobutyronitrile (AIBN), will be held constant at 2 milli grammes, while the mass of the methyl methacrylate monomer will remain constant at 3 milli grammes. Using a micropipette, these two components will be delicately deposited onto a pan. After being completely sealed, the pan will be placed inside a differential scanning calorimetry (DSC) device. Each sample will endure five hours of exposure to a range of temperature (35°C to 75°C). The DSC method will be used to examine the heat release and subsequent polymerization kinetics. Information on temperature, duration, and heat release will be provided by the collected DSC data. The findings show that the reaction time shortens with increasing temperature.[8]

Danny Santoso Mintorogo investigated whether aquatic skylight modules are suitable for construction in tropical and subtropical climates. It concentrates particularly on the utilization of aquatic-polycarbonate skylight systems as an energy-saving method in tropical areas. In order to solve this problem, maximize the benefits of daylighting, reduce the surface temperature of indoor polycarbonate, and capture solar hot water, this study suggests using aquatic-polycarbonate skylight systems. Three key goals are served by the idea of using water as a shading mechanism. First off, by continuously flushing water over the polycarbonate surface, the water in the polycarbonate perforations helps scatter the direct sunlight coming from skylights that are horizontal or made of tiles, reducing the amount of heat that is produced.[9]

Yanping Yang According to research on the cooling-dominant climates, it can be difficult to maintain enough daylighting and energy efficiency in big atrium structures. Fortunately, because of its special qualities of light transmission and thermal insulation, aerogel glazing systems have become a promising option for energy-saving architectural glass. This study focuses on the experimental analysis of aerogel glazing. Through experiments optical & thermal properties of the aerogel glazing were determined, and the daylighting effectiveness was evaluated. Installing aerogel glazing on the skylight is more efficient than at exterior windows system. [10]

Mehmet Serkan investigated the description of an innovative polymer called polycarbonate that provides remarkable strength, transparency, and durability. It is a sought-after building material due to its distinctive qualities, which include high strength, light transmittance, recyclability, lightweight nature, and vapor permeability. Contrary to many thermoplastics, polycarbonate can flex significantly without breaking or cracking, enabling the creation of a variety of sizes and shapes. Multiple walls of differing densities make up polycarbonate panels. Particularly, the quantity of walls is anticipated to influence qualities like transparency and heat transmittance. This study intends to analyze the distinctive characteristics of polycarbonate panels, including light transmittance, water vapors transmission, impact strength, and bending strength, while taking various numbers of walls or thicknesses into account. It is expected that reducing the thickness and number of walls will result in polycarbonate panels' distinguishing qualities.[11]

Carl M. Lampert developed wide-ranging applications for switchable windows In contrast to conventional glazing, which only gives fixed transmittance and limited control over energy flow, switchable glazing offers changeable transmittance, which is appealing for both buildings and automobiles. Liquid crystals, thermotropism, gaschromism, electrochromism, or suspended particles are all examined in this study. At the moment, deposition methods appropriate for glass substrates are the main focus of switchable device development. The use of plastic substrates, however, is becoming more and more popular as a way to reduce weight. Significant obstacles to these technologies include production costs and flaws in large-area deposition. For glass and plastic businesses, as well as building designers, switchable glazing technologies bring both obstacles and opportunities.[12]

Fangxin Zou prepared Using the freeze-casting technique, polysaccharide-based bioderived cryogels offer notable advantages over biological structures while also replicating the anisotropic pore structure present in plant stems. Using a freeze-casted pectin cryogel as a template, a novel composite material made of pectin and poly (methyl methacrylate) (PMMA) was created in this study. This composite exhibit outstanding optical transparency, with an optical transmittance of up to 84 percent and haze levels between 38 and 73 percent. Like normal glass, it also provides better thermal insulation. It demonstrates exceptional UV blocking characteristics. By adjusting temperature during freeze casting and pectin concentration, and their optical characteristics can be made as good as possible. Pectin/PMMA composite’s also have far fewer thermal conductivities than glass (ranging from 0.110 to 0.126 W/(mK)). Numerous uses, like optically UV-protective screens, transparent materials, and solar cell substrates, are possible for these multifunctional composites.[13]

T. OGAWA investigated Due to the vast range of applications for methyl-methacrylate auto polymerizing resin, certain mechanical qualities—such as strength, stiffness, and hardness—are essential. Methyl-methacrylate resin, the auto-polymerizing resin, was polymerized in a variety of environments, including air and water, under pressure or not, and at temperatures ranging from 10 to 80 degrees Celsius. The resin specimens were put through transverse tests (three-point flexural tests) and micro-Brinell surface hardness tests. Using a scanning electron microscope, the specimens from the transverse tests' cracked surfaces were examined (SEM). No matter whether the environment was moist or dry, the results showed that the transverse strength and transverse modulus rose as the curing temperature increased. When pressure was applied in wet conditions, the transverse strength and modulus were higher than in non-pressured wet and dry environments. At the same temperature, the resin polymerized in dry conditions showed better surface hardness than the resin polymerized in wet conditions. Porosity in the polymer base and cracks between the base and PMMA particles were visible in SEM images of broken surfaces at lower curing temperatures. [14]

S. Eve A investigated how poly (methyl methacrylate) (PMMA) materials' thermo-mechanical characteristics are impacted by UV light exposure. At various UV irradiation doses, we concentrated on measuring important mechanical characteristics, such as fracture strength, stress-strain behavior, and Young's modulus. Our research showed that UV light significantly affects the mechanical characteristics of PMMA. In particular, the material's ductility was lost, and strength and strain at rupture were both significantly reduced (by more than 30%). We also looked at how Young's modulus varied according to how much the materials were cross-linked. The observation of surface damage also added to the degradation of these mechanical properties. In conclusion, our study emphasizes how UV light affects the thermo-mechanical characteristics of PMMA. The findings show modifications in Young's modulus along with reductions of ductility, resistance, and rupture strain. Development of surface deterioration worsens the loss of these mechanical properties. [15]

Ankita Bisht focused on creating a polymer composite material that is transparent and has great strength and UV protection. The goal was to find a solution to the problem of adding reinforcement for strength and UV protection without sacrificing transparency. To do this, we combined poly (methyl methacrylate) (PMMA) with boron-nitride nanoflakes (BN) to produce a transparent sheet appropriate for UV-shielding applications. The homogeneous dispersion of BN nanoflakes inside the PMMA matrix and robust interfacial contact made possible by their amine functionalization. With a 2-wt. percent BN content, this resulted in efficient load transmission from the matrix to the reinforcement, leading to a significant increase in strength (by 155%) and modulus (by 148%). Additionally, for all compositions, the addition of BN nanoflakes increased the UV-B and UV-C shielding qualities in comparison to pure PMMA. For instance, adding 0.5 weight percent of BN to PMMA improved UV wavelength blocking by an astounding 325 percent. The composite was appropriate for uses like window shields and automobiles since it had improved UV protection while retaining transparency.[16]

Mohamed H. El-Newehy1 | worked on a PMMA material that is rigid, translucent, and newly produced with long-lasting photoluminescent and photochromic properties. The substance displayed a propensity for color alterations when exposed to UV light. To create this substance, alkaline earth aluminate (AEA) nanoparticles were simply immobilized within the methyl methacrylate matrix by a simple polymerization process. The colorless PMMA plastic substrates clearly changed to a greenish hue when exposed to UV light, according to CIELAB testing. Transmission electron microscopy was used to look at the morphology of the AEA nanoparticles. The transparent PMMA samples were examined using hardness tests, energy-dispersive X-ray spectra, scanning electron microscopy, and X-ray fluorescence spectroscopy. To comprehend the photoluminescence characteristics, the excitation and emission spectra were studied. Three emission peaks at 433, 494, and 513 nm, as well as an excitation band at 370 nm, were present in the resulting photoluminescent PMMA plastic substrates. Samples of photochromic PMMA with higher AEA contents showed long-lasting luminosity that could be used as a torch instead of electricity, whereas samples with lower AEA contents showed rapid and reversible color changes under UV light. The recently developed photoluminescent colorless PMMA plastic substrates displayed enhanced UV shielding and extremely hydrophobic characteristics.[17]

Gulsen Bayraktar compared the effects of several curing procedures (for heat- and auto-polymerized specimens), with identical polymerization techniques and the length of storage on the remaining methyl methacrylate. More than 100 resin specimens have been examined with the aid of high-performance liquid chromatography to determine residual MMA content. Heat-polymerized resins took a lengthy terminal boil cure and stored in water for one day to lower the remaining MMA content. Auto polymerized resins that also cured in water on 60°C and kept in pure water for one day had lowest residual MMA level. When kept in distilled water for at least a month, resins that had been Microwave polymerized displayed the minimum residual MMA concentration. The heat-polymerized samples with the lowest residual MMA level have been those that received a prolonged terminal boil cure and were kept in distilled water for one day. It was found that the residual MMA content was affected differently by various curing and polymerization techniques[18]

X. Colom[a,] study how poly (methyl methacrylate) is affected by artificial ageing (PMMA). A xenon-arc lamp was used to replicate sun radiation and age the materials. The maximum amount of time for artificial ageing was 1570 hours, or almost 750 days of solar exposure. This study's goal is to look at PMMA's characteristics and see how they evolve as a result of ageing. We used Fourier-transformed infrared spectrophotometry (FTIR) to examine chemical and structural alterations. The acquired spectra proved that hydrogen abstraction, which causes chain breaking and the production of carbon-carbon unsaturated bonds, is the initial driving force behind the ageing process. Tensile tests were used to determine the samples' fracture toughness. The results showed that after 1570 hours of age, hardness had decreased by almost 40%.[19]

Ashna Rawat Examine the creation of a nanocomposite film that contains nanoscale Zinc Oxide (ZnO) and Polymethyl-methacrylate (PMMA), as well as its possible use in museums and art galleries to absorb damaging ultraviolet (UV) rays that could injure delicate goods. The ZnO-PMMA polymer nanocomposite film was made by simply combining the ZnO nanoparticles, which were created using a sol-gel method. Optical and electron microscopy were used to analyze the thin layer and determine the size and homogeneity of the nanoparticles. Thermogravimetric analysis was used to evaluate the ZnO-PMMA nanocomposite's heat stability. Under simulated museum conditions, the thin coated film's capacity to absorb UV radiation was assessed using a UV monitor.[20]

G. A. Farzi1 the emphasis is on improving the surface properties and raising the hydrophobicity of zinc oxide (ZnO) nanoparticles. To produce the change, coupling agents such as trimethoxy vinyl silane (TMVS) and oleic acid were utilized in a range of mole ratios. The surface of the nanoparticles was modified with the aim of improving the dispersion of the surface-modified nanoparticles in different monomers with different degrees hydrophobicity, such as methyl methacrylate, butyl acrylate, and styrene. The modified ZnO nanoparticles were characterized by scanning electron microscopy, Fourier transform infrared, X-ray diffraction, and elemental analysis. According to the research, the surface-modified ZnO nanoparticles demonstrated increased compatibility as seen by their improved dispersibility in the studied organic mediums. Oleic acid-treated ZnO shown greater compatibility with styrene, although TMVS performed better as a coupling agent to obtain compatibility with MMA. A combined coupling agent with a weight ratio of 50% TMVS and 50% oleic acid additionally shown improved compatibility with BuA.[21]

Chapter No. 3.

3. Material and Method

3.1. Overview:

This chapter contains synthesis of the modified Zinc oxide with coupling agent (Silane), formulation and fabrication of sheets of methyl meth acrylate, and Design of experiment and fabrication. It also contains the materials which is required for modification of ZnO and for the PMMA sheet.

3.2. Materials Used:

Figure 7: Materials

3.3. Equipment's Used:

Figure 8: Equipment's used

3.4. Experimentation of Zinc Oxide modification:

3.4.1. Methodology:

1. Zinc Oxide (1g), Dynal silane (1.5ml), and Distilled water (50ml) were added in a beaker and mixed thoroughly. Beaker was set for continuously stirring the mixture at 50^{o}C for 1hrs.

Figure 9:Shows stirring of water, ZnO, Silane at 50 ^{0}C

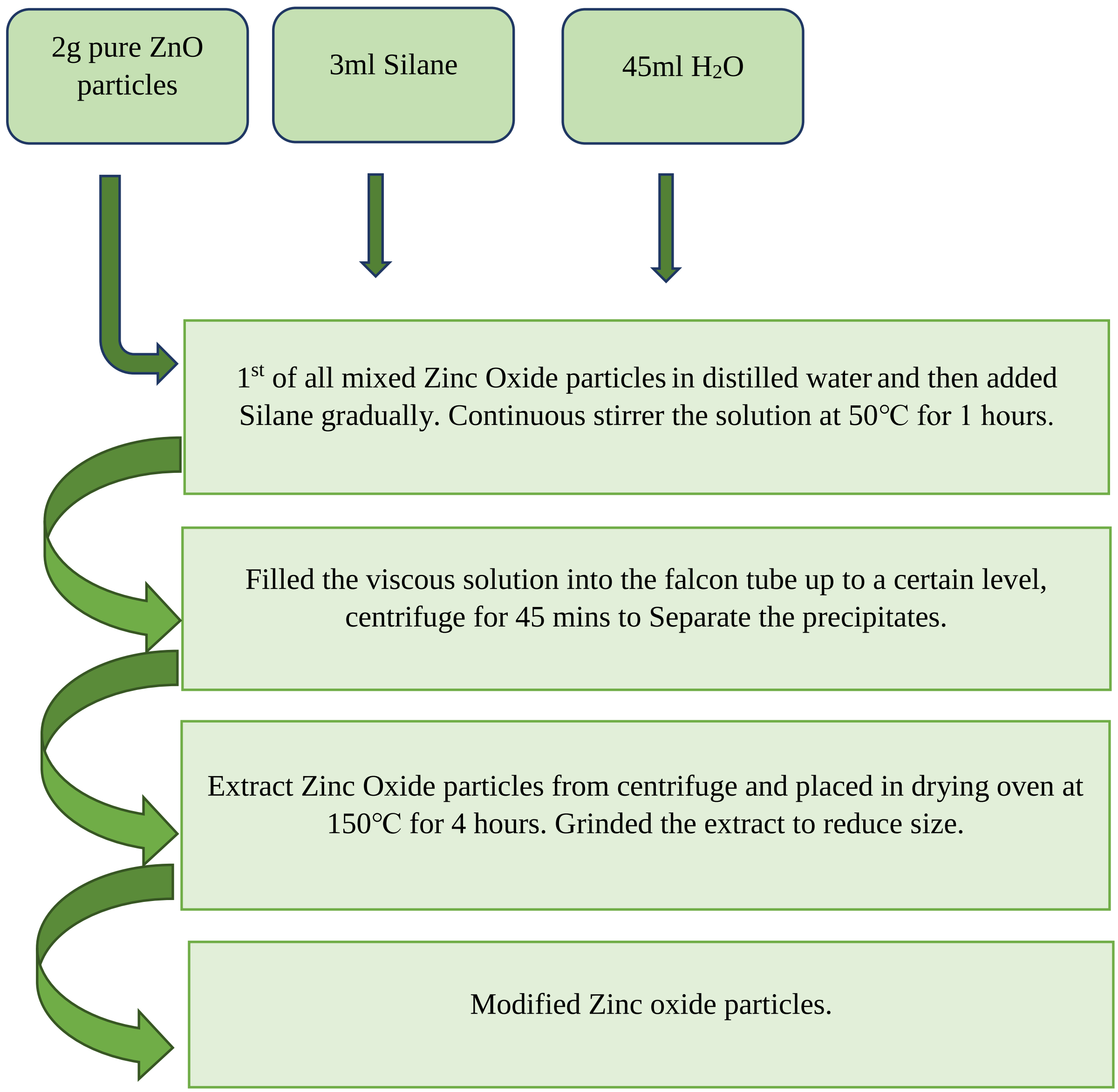
2. Zinc Oxide particles was centrifuged for 30 minutes to separate the Zinc oxide as separate which obtained as settle material in falcon tube.

Figure 10: Sample placed for Centrifuge.

3. The Zinc oxide was obtained by draining solvents. ZnO poured in a crucible. Then the crucible was placed in a furnace at $150^{o}C$ for 6 hrs. And the result was thermally reduced Zinc oxide particles in powder form.

Figure 11: Modified ZnO Particles

3.4.2. Schematic Diagram for modified ZnO particles synthesis:



Schematic diagram modification of ZnO particles

3.4.3. Design of Experiment:

Table 1: DOE of Zinc Oxide Modification (Silane)

Sr#	Modification with silane	Pure zinc oxide %	Water (Solvent)%	Silane (Coupling Agent)	Total Percentage%
1	Glymo Silane	1.5	97	1.5	100
2	Glymo Silane	2.00	95	3.00	100

3.5. Experimentation for Glazing Sheet:

3.5.1. Methodology:

In first step Zinc Oxide particles are mixed in a sonicator bath for 30mins to improve mixing of particles into MMA. Because proper mixing is first parameter for sheet.

Figure 12:Sonication of ZnO in MMA

Then initiator benzoyl per oxide (BPO) is added to the MMA solution to initiate the reaction of polymerization and it is stirred for 30 min on magnetic stirrer at temperature 50^{o}C.

Figure 13:BPO stirring in MMA

Polymerization of MMA solution to polymer is done in a Vacuum oven under vacuum at temperature from 60- 70°C for 20-30 minutes.

Figure 14: Polymerization in Vacuum Oven

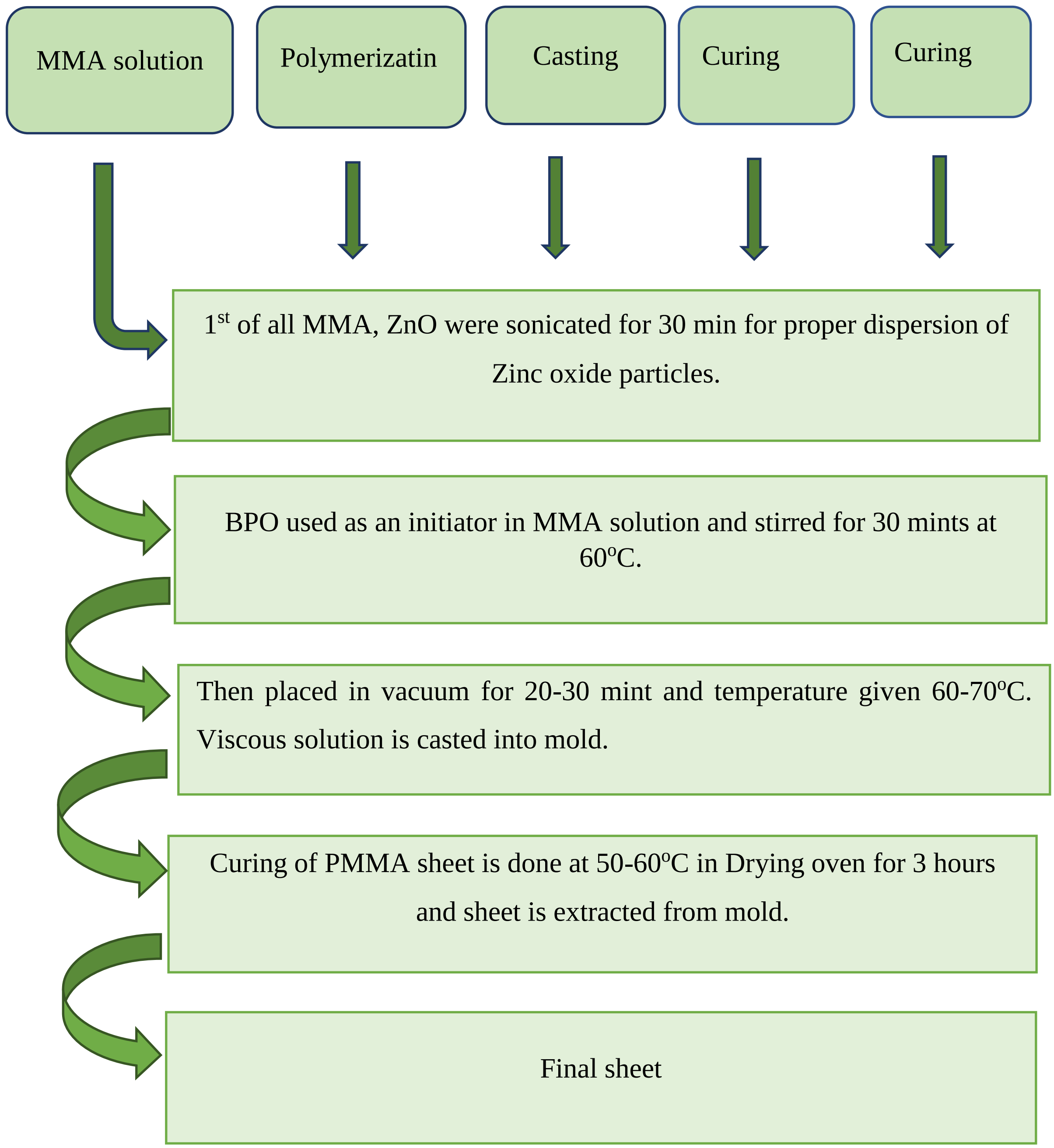
PVA solution is used as mold releasing agent to easily remove product from the mold. Viscous solution is casted into glass mold to develop a sheet according to the dimensions of the sheet.

Figure 15:Casting into mold

Curing of the sheet is done in a Dying Oven at temperature about 50-60^{o}C to properly cure sheet and achieve our desired product.

Figure 16: Final Sheet

3.5.2. Methodology for MMA Sheet:



Schematic diagram Skylight Glazing Sheet

3.5.3. Design of Experiment:

Table 2: DOE of Skylight Glazing Sheet

Sr.#	MMA	ZnO (Modified)	BPO	Total %wt.
1	(98 wt. %)	1wt%	1 wt.%	100
2	98.50 wt.%	0.5 wt.%	1 wt.%	100
3	98.750 wt.%	0.250 wt.%	1 wt.%	100
4	98.875 wt.%	0.125 wt.%	1 wt.%	100

3.6. Techniques used:

3.6.1. Free Radical Polymerization:

To generate a polymer unit, free radicals are used to start the polymerization of the monomers and this process is free radical polymerization. It belongs to the family of chain-growth polymerizations, which also includes cationic, anionic, and coordination polymerizations. Free radical polymerization has three stages: initiation, propagation, and termination.

Initiation of Free Radical:

Initiation is the initial phase of polymerization. An active site is produced to begin off the polymerization procedure. It's not like every monomer is in charge of the beginning step.

- First of all initiators produce one or two free radicals.
- Then these radicals are moved from the starting molecules to the monomer units to start polymerization.

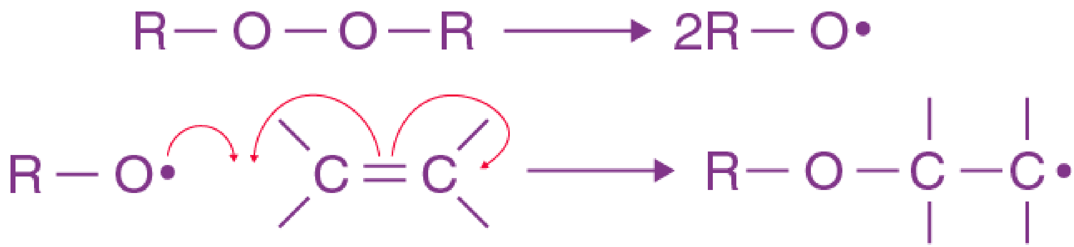


Figure 17: Initiation Step

Propagation of Free Radical:

Propagation or chain lengthening takes up most of a polymer's time. Following its initial attack, a free radical target a different monomer subunit. With the help of one of the pi bond electrons, it forgoes a solid bond with another carbon atom. By returning the other electron to the second carbon atom, the entire molecule is changed into a radical. Following chain initiation, the chain grows until it terminates or until no more monomers are left.

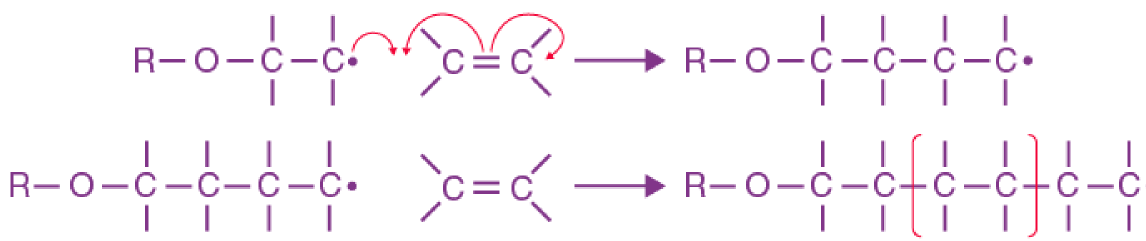


Figure 18: Propagation Step

Termination of Free Radical:

The polymerization process comes to a halt when termination occurs. There are different ending stages. The initiator concentration should be decreased if longer chains are anticipated; otherwise, numerous little chains will develop.

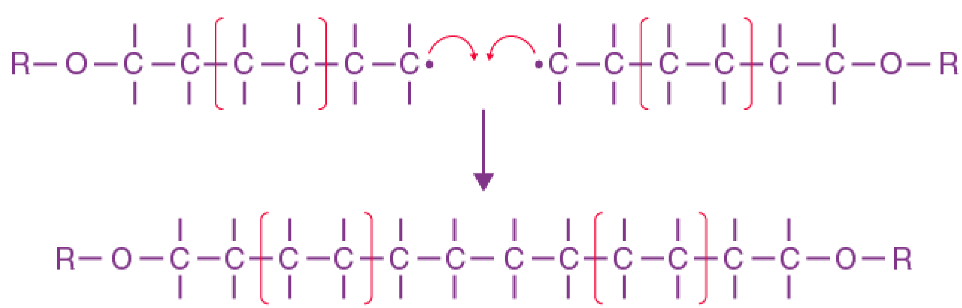


Figure 19: Termination Step

3.6.2. Sol Gel Technique:

Sol-gel is referred to as a conventional method that is widely used to fabricate polymeric network of metal oxides. This method comprises two major reactions i.e., hydrolysis and poly-condensation. Sol' is a colloidal solution whereas 'gel' consists of a unified network having a liquid phase.

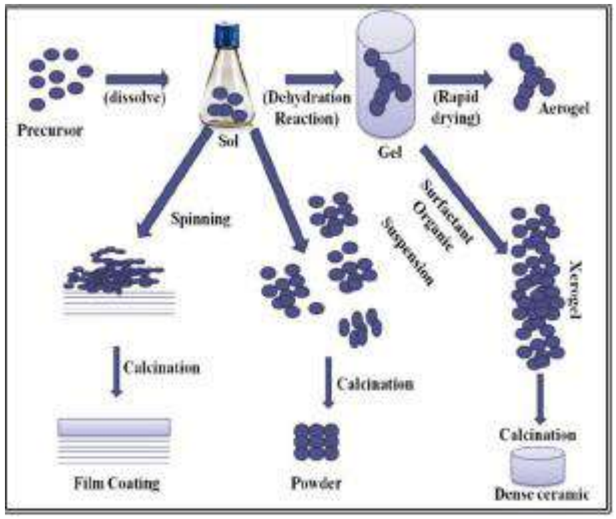


Figure 20: Sol-Gel Technique

3.6.3. Centrifugation:

Depending on factors including size, shape, density, medium viscosity, and rotor speed, centrifugation is a technique used to separate particles in a solution. Place the particles in a separatory funnel, suspend them in a liquid medium, and rotate the tube at a predetermined speed. By creating a centrifugal force with this spin, the particles are pressured to separate based on their properties. Sedimentation, which occurs naturally owing to gravity, is significantly accelerated by centrifugation. The mixture's less dense constituents move in the opposite direction of its denser constituents, toward the axis of rotation. Chemists and biologists can ensure that the particles precipitate quickly and fully to the tube's bottom, leaving a supernatant or separate liquid above, by increasing the effective gravitational force.

Chapter 4. Results and discussion

Overview

This chapter includes results of characterization of materials that was done. The types of characterization that were done with in this project. In this chapter we will interpret the results of FTIR to measure the modification of Zinc Oxide particles, Zeta sizer to interpret size of modified and pure ZnO particles, Tensile testing, Charpy testing (impact testing), and Light transmission test.

4. Characterization:

- FTIR (Fourier Transform Infrared Spectroscopy)
- Zeta Sizer
- Tensile Test
- Charpy Impact Test
- Light transmission test (Spectrophotometer)

4.1. FTIR:

FTIR is a vibrational tool of spectroscopy which is sensitive to composition in a material. Therefore, it is used to study organic and inorganic compounds. The detailed study of spectrum can give qualitative as well as quantitative analysis. Absorption or transmission spectrum of IR can be observed by employing FTIR spectroscopy. There are certain possibilities like stretching, rotations and vibrations in between the bonds during the absorption of light by the molecules. In an electromagnetic spectrum of light, IR region is categorized as the near infrared region (14000-4000 cm^{-1}) having high energy, the mid infrared region (4000-400 cm^{-1}) and the far infrared region (400-10 cm^{-1}).

FTIR Spectrometer at NTU, Faisalabad. Company Bruker Model ALPHA. Figure shows a Michelson interferometer which is the heart of Fourier transform infrared spectroscopy. An interferometer contains a beam splitter, and its function is to distribute the beam of light. There are two mirrors used in an interferometer. The first mirror is a fixed (stationary) mirror which collects half of the light beam reflected from splitter at an angle of 90^o. The second mirror is a rotating (moving) mirror which collects the light directly from the beam splitter. The reflected beams of light from both mirrors after that recombine. The beam of light when passes through the sample some of the light is transmitted while the rest of light is absorbed by the sample. The absorbed light thus passes through the detector and forms an interference pattern on monitor screen called an interferogram.

Figure 21:FTIR

We performed FTIR for Zinc oxide modification to check the silane functional groups are attached to the ZnO particles after the silane modification of ZnO.

Black peak in figure 22 indicates pure ZnO. Peak at 605 cm^{-1} indicating lattice defects or impurities present in ZnO. At 860 cm^{-1} shows a ring vibration in the zinc oxide. At 1400 cm^{-1} indicates the C-H bending vibrations, it can also be due to asymmetric stretching vibrations in Carboxylic ions. Peak 3300 cm^{-1} is indication of O-H vibrations, it is basically due to OH stretching mode which are due to the presence of Hydroxy group on the surface of ZnO.

Red peak in Figure 22 indicates modified ZnO. Peak at 601 cm^{-1} is formation of siloxane bond between Glymo silane and ZnO which is due to the presence of O-H group. At 906 cm^{-1} corresponds to Si-O-C functional groups which showed proper addition of silane bonds on Zinc Particles. At 1096 cm^{-1} also corresponds to Si-O-C symmetric stretching mode which shows proper addition of silane. At 3372 cm^{-1} corresponds to O-H starching vibration from absorbed water molecule at ZnO particles, it indicates presence of water.

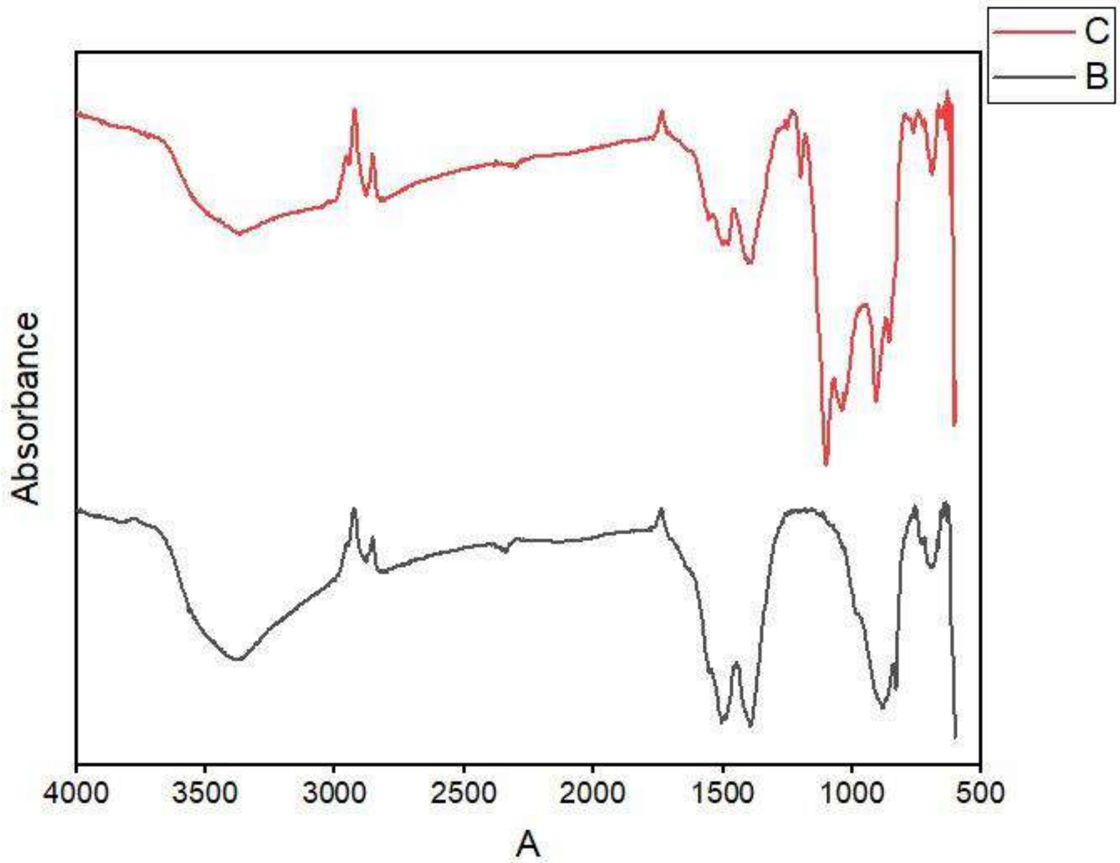


Figure 22:FTIR Pure ZnO and Modified ZnO

FTIR graph shows attachment of silica functional groups on the surface of the Zinc oxide particles. Red peak shows modified ZnO & Black peak shows pure ZnO.

4.2. Zeta Sizer

An advanced tool called the Zeta Sizer is used to measure the size, zeta potential, and molecular weight of particles suspended in liquids. It functions according to the dynamic light scattering (DLS) and electrophoretic light scattering (ELS) principles, allowing for the nanometer-scale characterization of particles and molecules. Here are the results of the zeta sizer for ZnO particles that we used to measure the particle size of particles both before and after the alteration of the Silane.

Results

			Size (d.nm):	% Intensity:	St Dev (d.n...
Z-Average (d.nm):	1269	Peak 1:	1279	100.0	280.6
PdI:	0.123	Peak 2:	0.000	0.0	0.000
Intercept:	0.920	Peak 3:	0.000	0.0	0.000

Result quality : Refer to quality report

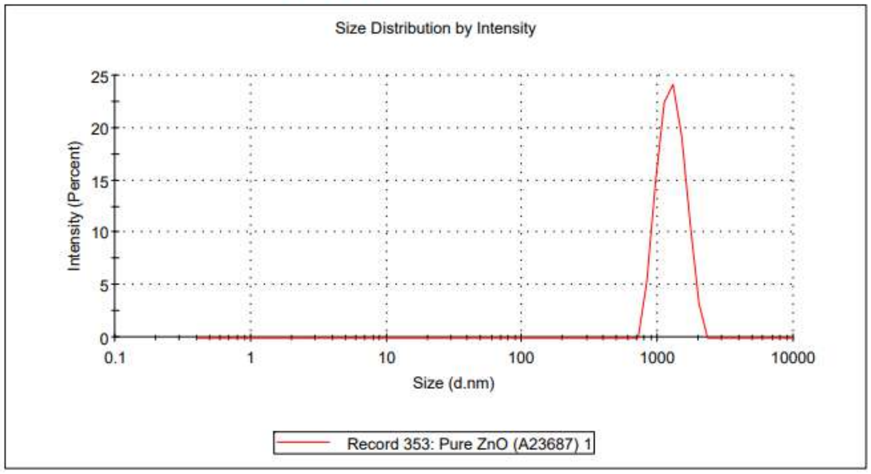


Figure 23:Zeta Sizer of Pure Zinc Oxide

Results

			Size (d.nm):	% Intensity:	St Dev (d.n...
Z-Average (d.nm):	1164	Peak 1:	998.0	96.7	296.4
PdI:	0.383	Peak 2:	5450	3.3	266.9
Intercept:	0.902	Peak 3:	0.000	0.0	0.000

Result quality : Good

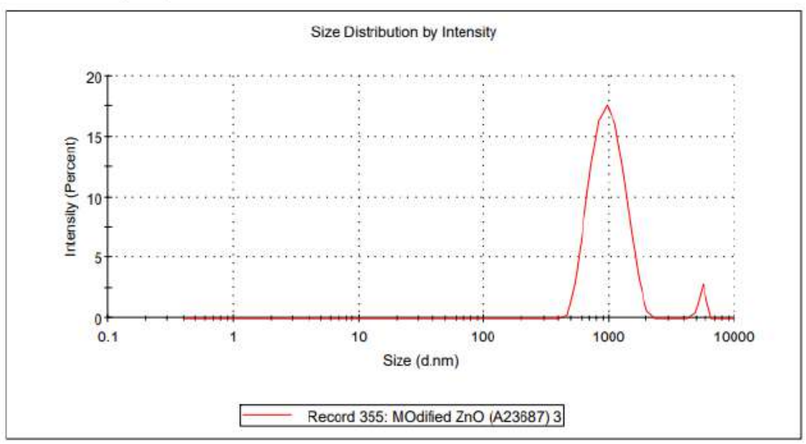


Figure 24:Zeta Sizer of Modified ZnO

4.3. Tensile Testing:

An important mechanical test used to evaluate a material's mechanical properties is the tensile test, often known as the tension test. In this test, a sample is pulled or tensioned under controlled conditions until it deforms or breaks. Tensile tester provides important information on the material tensile strength, elasticity, ductility, and other mechanical properties. Typically, a standardized specimen of a particular shape must be prepared for a tensile test. Using a tensile testing machine or a universal testing machine, the specimen is firmly clamped at both ends. The specimen is then subjected to a progressively rising tensile tension, often at a steady rate. The specimen stretches and deforms as the force is applied to it. The tensile test data is utilized to ascertain the material's varied mechanical properties.

We have conducted two tensile tests:

Standards Used for tensile Test: ISO 527-1

- ❖ Without Zinc Oxide
- ❖ With Zinc Oxide

4.3.1. Without Zinc Oxide:

In without zinc oxide we conducted three tensile test of samples.

- ❖ Without UV Ageing
- ❖ 4-Hour UV Ageing
- ❖ 8-Hour UV Ageing

In without UV Ageing Graph the sample bears a force of 20.911mpa.

In 4-Hour Aging Graph the sample bear a force of 14.006mpa.

In 8-Hour Aging Graph the sample bear a force of 12.750mpa.

From these results it is observed that in sample 1 in figure 25 with no UV Ageing is applied and it bears a high force to break. But in sample 2 & 3 (figure 25) in which UV Ageing is applied 4-Hour and 8-Hour respectively, it decreases its Tensile strength. This is because when UV is applied it affects the properties of the PMMA and a sudden change is absorbed in tensile properties with respect to time.

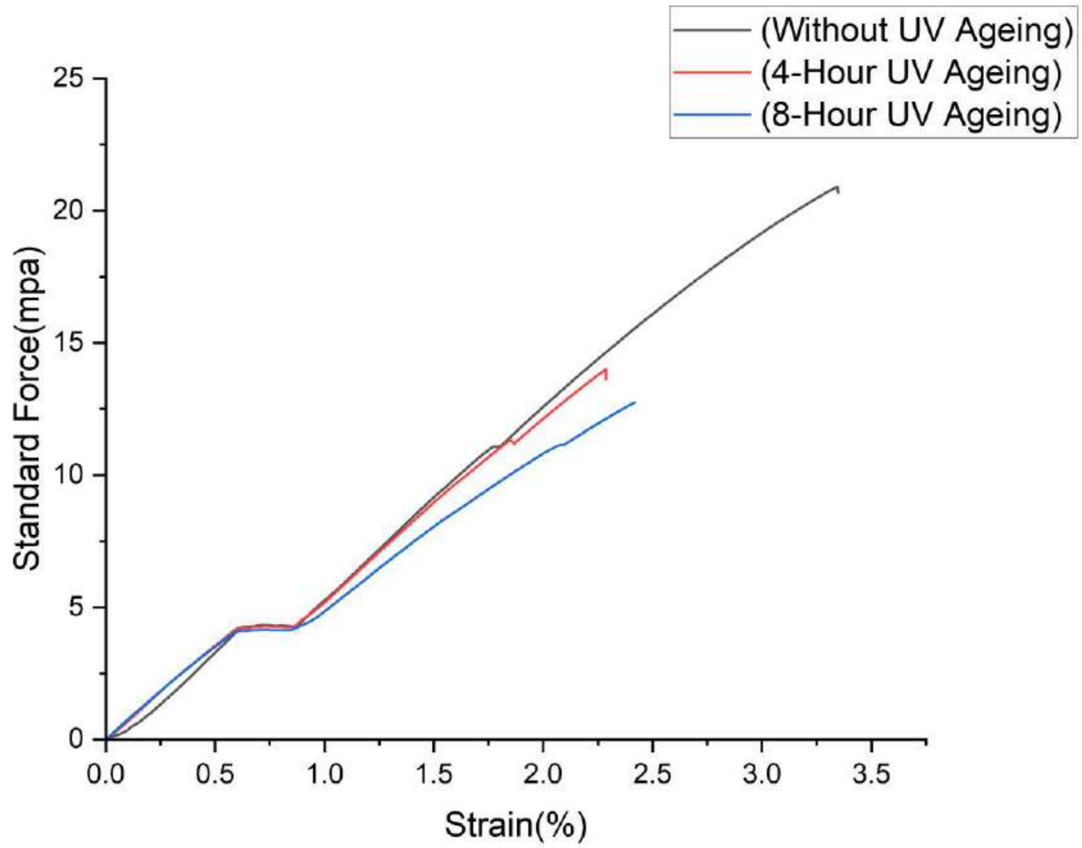


Figure 25:Tensile Test without ZnO

4.3.2.With Zinc Oxide:

With Zinc Oxide we conducted three tensile tests of samples.

- Without UV Ageing
- 4-Hour UV Ageing
- 8-Hour UV Ageing

In without UV Ageing Graph the sample bears a force of 26.25mpa.

In the 4-Hour Aging Graph the sample bear a force of 27.80mpa.

In the 8-Hour Aging Graph the sample bear a force of 31.25mpa.

From this test we can observe clearly in figure 26 that the sample is changing into a brittle material with respect to the ageing time of the sample. But there is no sudden change in the properties of the sample when we used MMA sheet with modified ZnO particles because ZnO absorbs UV radiation when placed in a UV ageing chamber.

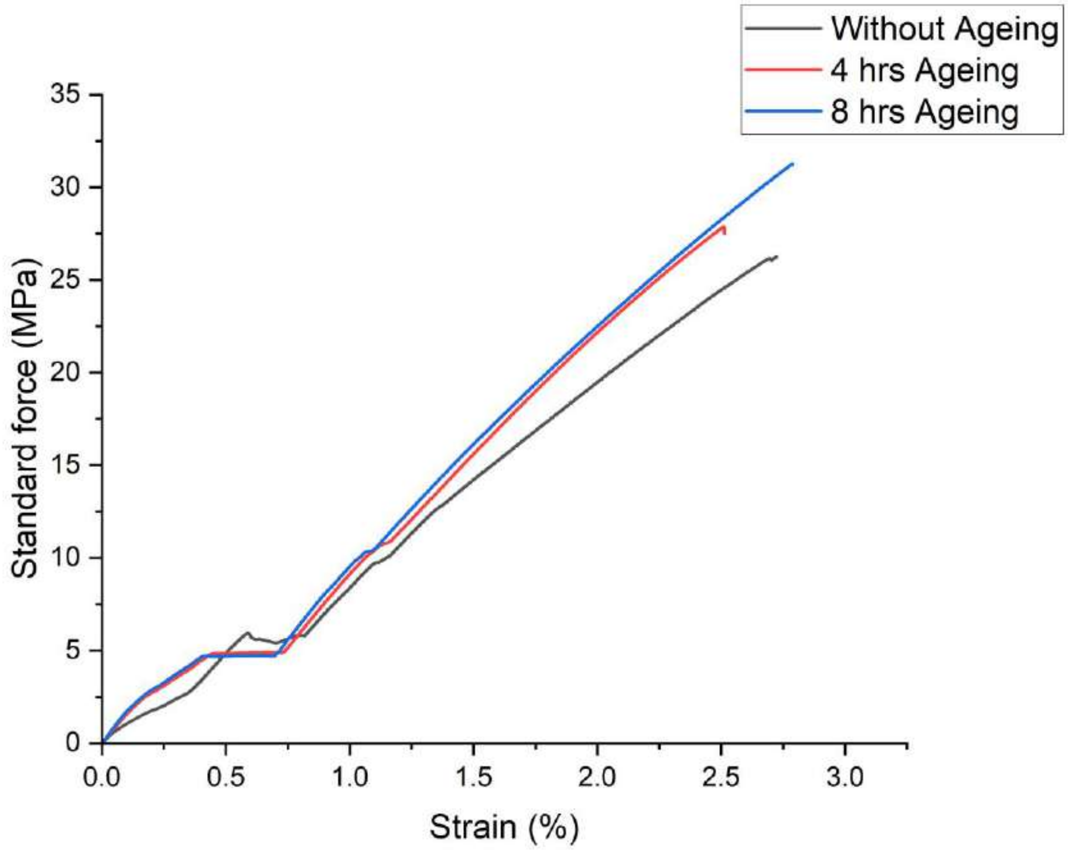


Figure 26:Tensile Testing graph

4.4. Charpy Impact Test:

A popular mechanical test for assessing the durability and impact resistance of a material that largely focuses on metals is the Charpy impact test. By determining how much energy a material can hold under sudden impact or shock loads, it can be determined whether or not it will remain resilient and whether or not brittle fracture is a possibility. For this test, an impact tester is used to safely fix a standardized specimen. The specimen often resembles a V-shaped bar with a notch. After being elevated to a predetermined height and then let go, a pendulum with a striking edge swings the specimen at its notched portion. The specimen breaks or deforms due to this collision. The impact tester calculates the impact toughness or strength of the material by measuring the energy that the specimen absorbs during fracture or deformation.

4.4.1. Without Zinc Oxide:

In without zinc oxide, we conducted three Charpy test of samples.

Standards Used for tensile Test: ISO 179-2

- ❖ Without UV Ageing
- ❖ 4-Hour UV Ageing
- ❖ 8-Hour UV Ageing

In without UV Ageing Graph the sample bears a force of 103.62.

In the 4-Hour Aging Graph the sample bears a force of 77.78.

In the 8-Hour Aging Graph the sample bears a force of 64.00.

In Figure 27. peak force value is up to 103.62, at time parameter near about 5-6. This result is obtained from a sample without ageing. This is higher than the other two values.

In figure 28 & figure 29 Graphs are taken from a sample with a UV ageing of 4-hours, and 8-hours. Its values of force are 77.78 & 64 respectively. Properties are decreased because force is applied side way and material breaks because of degradation of polymeric sheet to some extent under UV ageing.

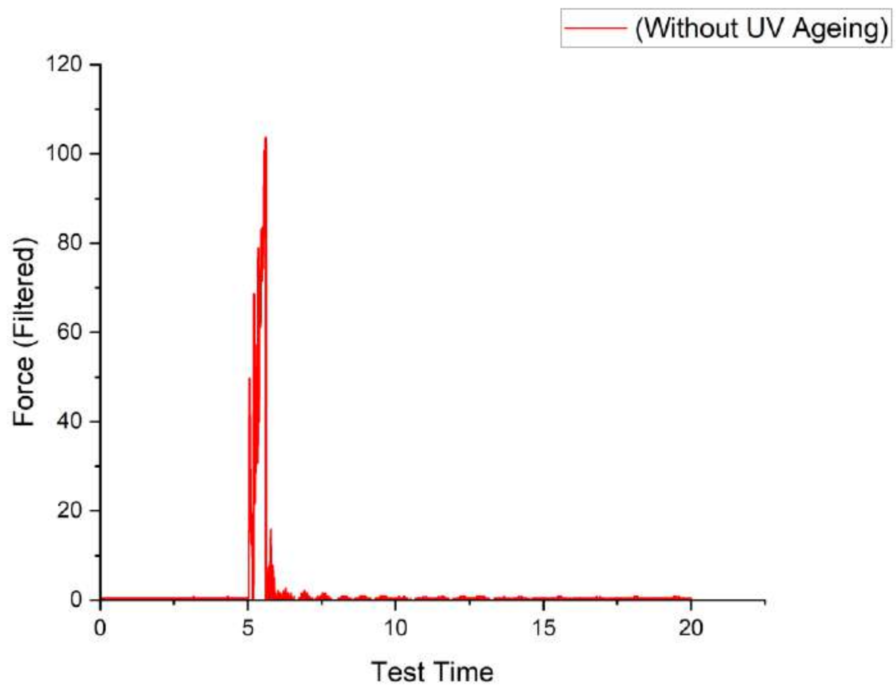


Figure 27: Charpy Test without ZnO (Without UV Ageing)

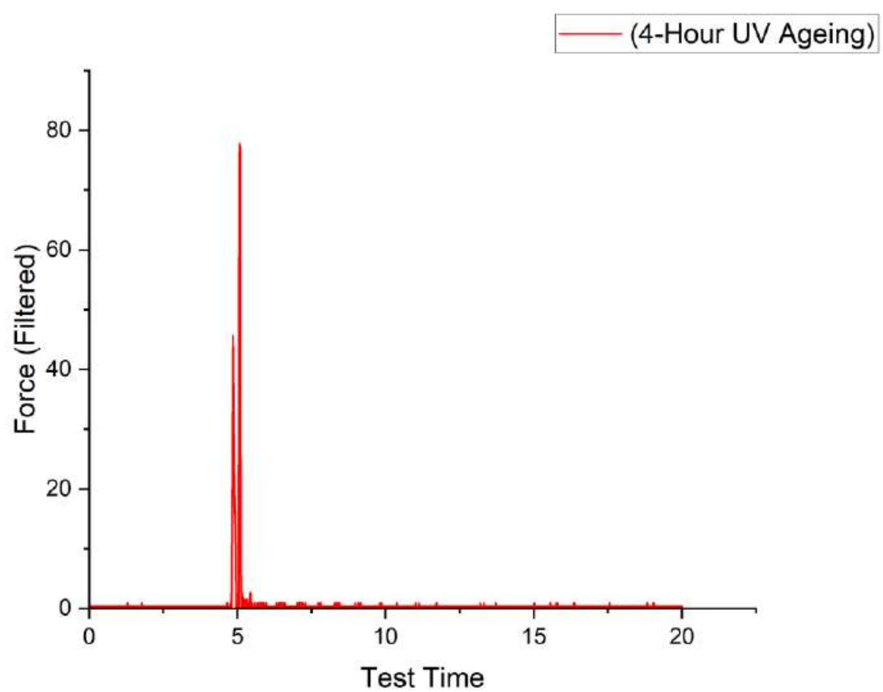


Figure 28: Charpy Test without ZnO (4-Hour UV Ageing)

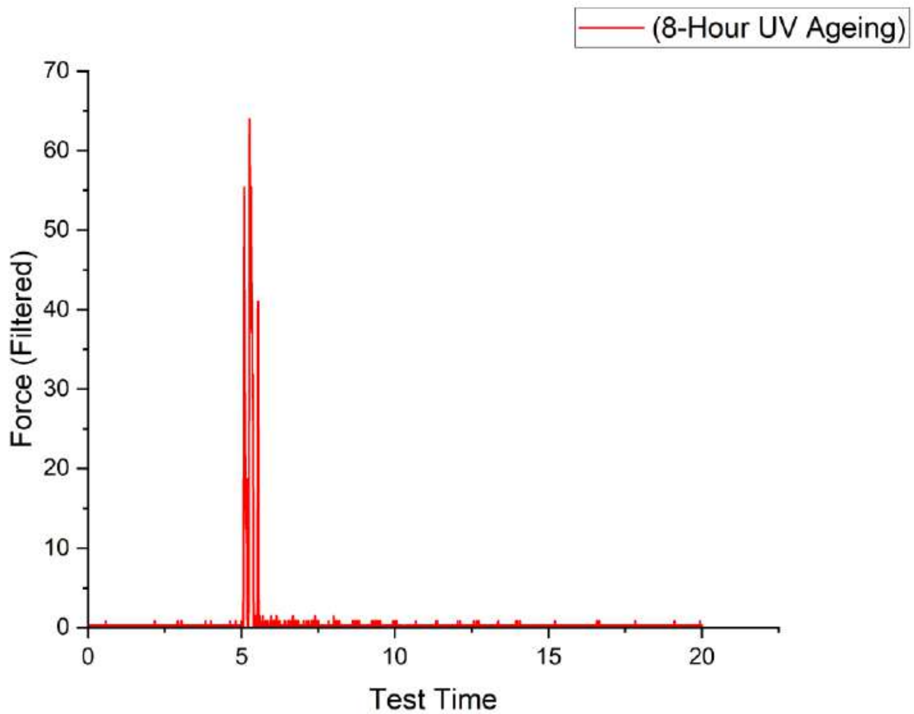


Figure 29: Charpy Test without ZnO (8-Hour UV Ageing)

4.4.2.With Zinc Oxide:

With Zinc Oxide we conducted three Charpy test of samples.

- ❖ Without UV Ageing
- ❖ 4-Hour UV Ageing
- ❖ 8-Hour UV Ageing

In without UV Ageing Graph the sample bear a force of 26.25mpa.

In 4-Hour Aging Graph the sample bear a force of 27.80mpa.

In 8-Hour Aging Graph the sample bear a force of 31.25mpa.

In Figure 29 peak force value is up to 200, at time parameter near about 5. This result is obtained from a sample without ageing and with the addition of the ZnO as an additive.

In Figure 30 Graph-2 is taken from a sample with a UV ageing of 4-hours. Its value of force is 160 at time 5-6 on the graph. The values of force are decreased because of the UV ageing. Properties are decreased because force is applied side way and material breaks because of degradation of polymeric sheet at some extent under UV. But a sudden change is not absorbed from the sample.

In Figure 31 Graph-3 is taken from a sample with an UV ageing of 8-hours. Its value of force is 140 at time 5-6 on the graph. The values of force are decreased because of the UV ageing. Properties are decreased because force is applied side way and material breaks because of degradation of polymeric sheet to some extent under UV.

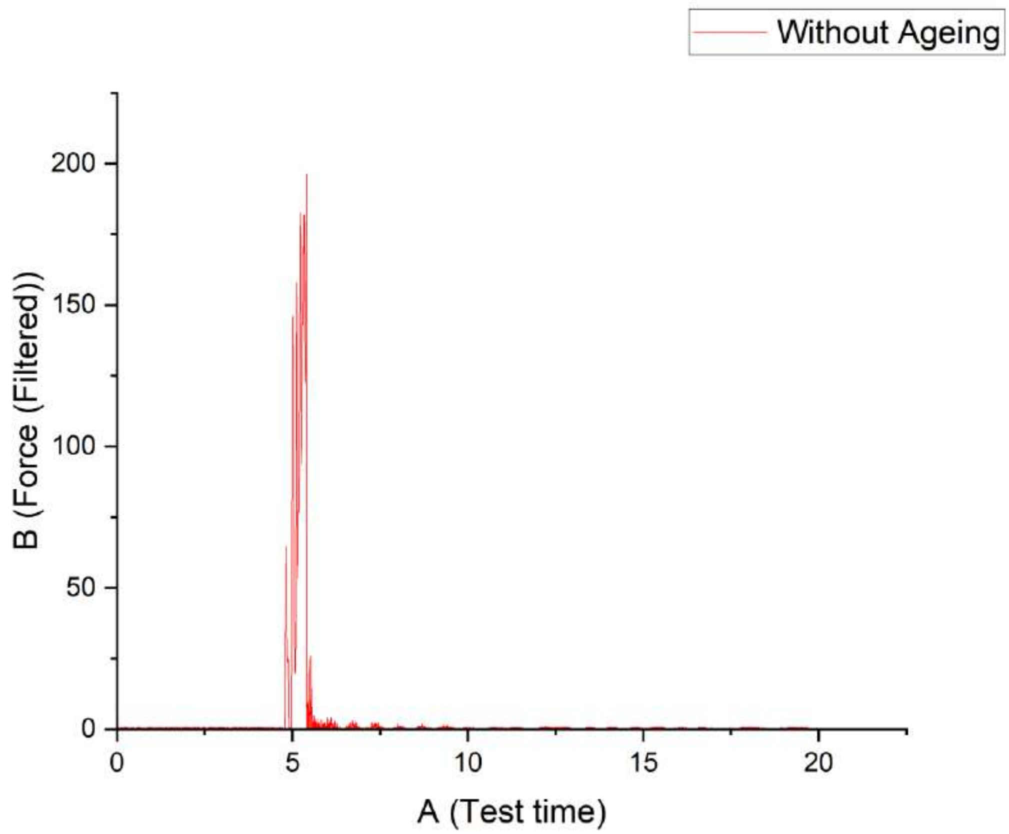


Figure 30: Charpy Test with ZnO (Without UV Ageing)

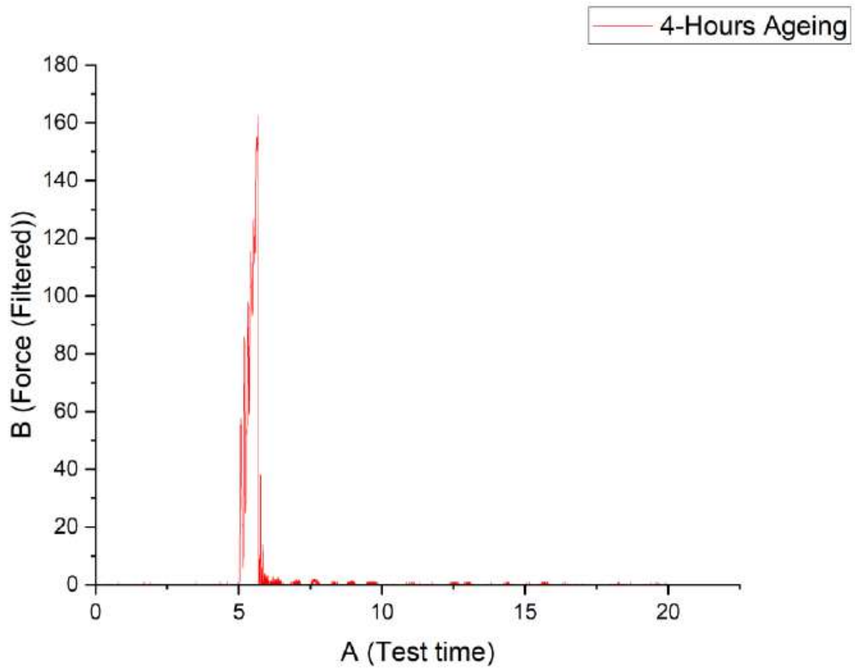


Figure 31: Charpy Test with ZnO (4-Hour UV Ageing)

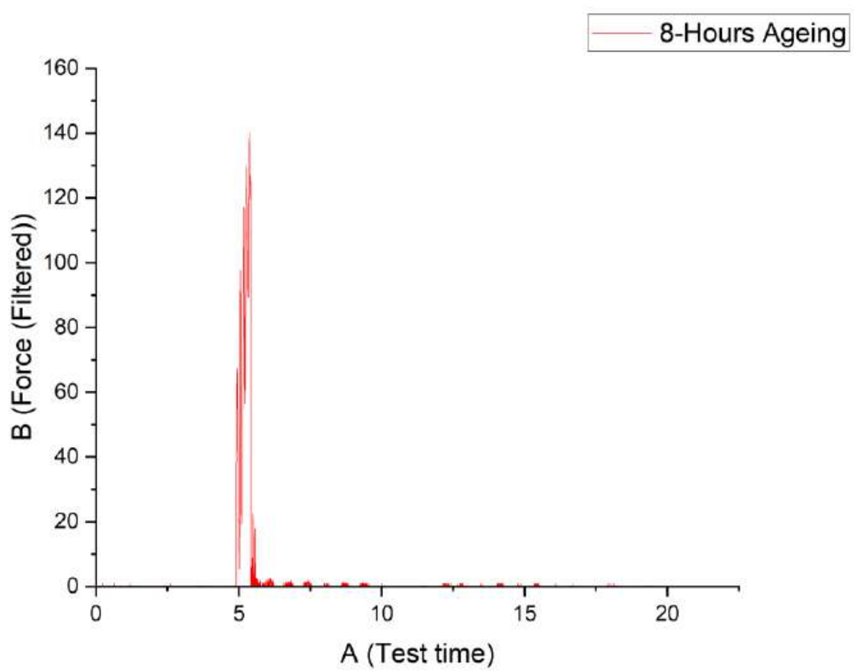


Figure 32: Charpy Test with ZnO (8-Hour UV Ageing)

4.5. Light transmission test (Spectrophotometer):

Photo spectroscopy is used for determining optical properties of a substance. In this method the amount of light absorbed, reflected or transmitted after interaction with the material is measured. In a spectrophotometer, photons carrying energy in the ultraviolet to visible region of EM spectrum are incident on the sample. Absorption occurs when the frequency of light matches with the difference in energy levels (vibrational and rotational if frequency is high). The result is excitation of atoms. Transmission occurs when light is neither absorbed nor scattered. Reflection occurs when light is absorbed and re-emitted in the same medium.

4.5.1. With Zinc Oxide:

In these results we can easily absorb that transparency of the material or sample is continuously increasing as the wavelength of the light is increasing. With the increasing time of the UV Ageing of the sample there is deflection in the transparency of the sample i.e., in graph-1 the values are high, in graph-2 values are less than the graph-1, but from graph we can clearly observe that the values are meeting at the wavelength of 850nm. Similarly, this pattern is also clear in graph-3 and its properties are approximately similar with increasing the UV Ageing timing of the sample.

In Figure 32. We can observe that Our material transmits approximately 41.97% of light.

In Figure 33. We can observe that Our material transmits approximately 37.56% of light.

In Figure 34 We can observe that Our material transmits approximately 37.12% of light.

From these results 41.97% light transmits because our material was not UV Age’d. That’s why it passes more light than other two materials. After UV ageing under UV light the transparency of material affects that why it transmits low light. Which is 37.56% & 37.12%.

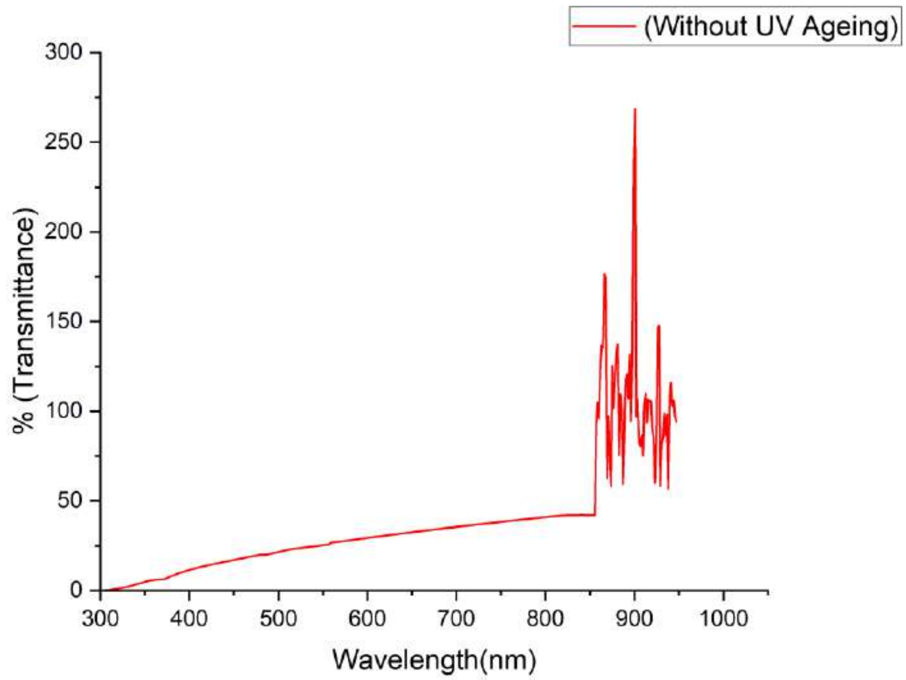


Figure 33: Light Transmission Test with ZnO (Without UV Ageing)

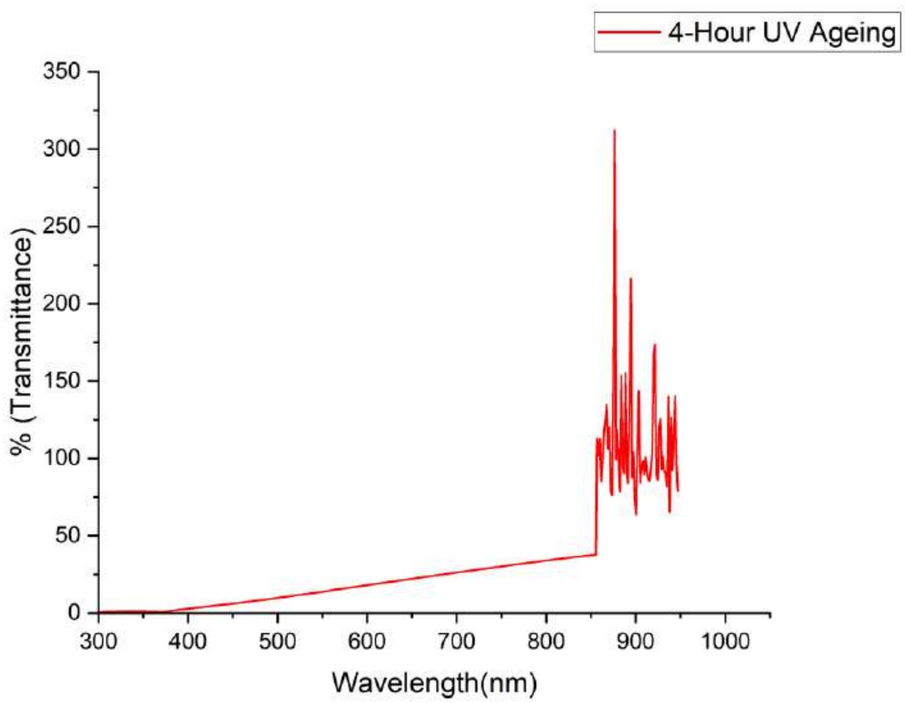


Figure 34: Light Transmission Test with ZnO (4-Hour UV Ageing)

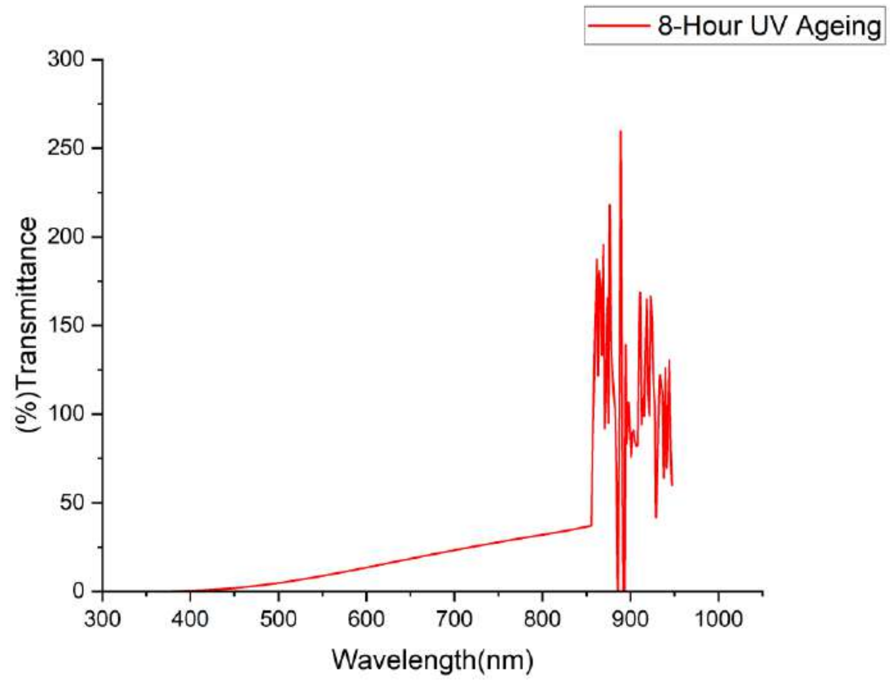


Figure 35: Light Transmission Test with ZnO (8-Hour UV Ageing)

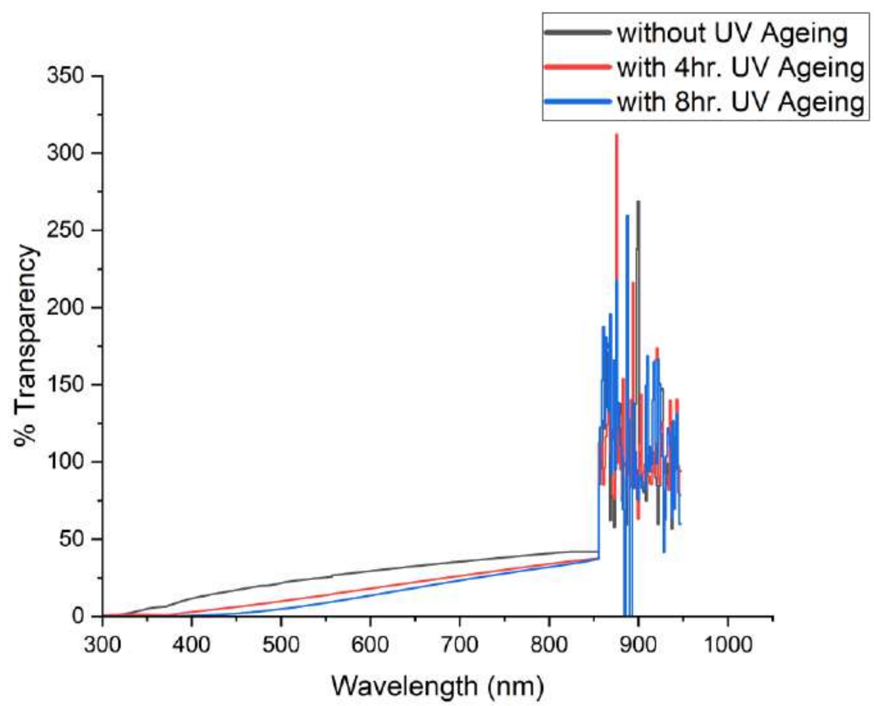


Figure 36: Light Transmission Test with ZnO (Without, 4-Hour & 8-Hour UV Ageing)

5. Conclusion:

The properties of PMMA without ZnO and with zinc oxide as a UV stabilizer additive. Modified ZnO is used to improve dispersion and to avoid agglomeration in samples. FTIR results illustrated the presence of Silica bonding at the surface of the ZnO particles and peaks on the modified Zinc Oxide showed presence of Si-O-Si, Si-O-C, and Si-O-C functional groups. The Size of the modified and simple ZnO particles analyzed by Zeta Potential, it was noted that after modification size of the ZnO particles remained almost same. The optical studies Zinc oxide has been proved a backbone for material science just because of having a combination of ideal properties like UV absorption, constant optical and thermal properties. Mechanical properties of the glazing sheet are analyzed, when ZnO is not used & in presence of ZnO and conducted at without UV ageing, 4-Hour UV ageing, and 8-Hour UV ageing. Tensile properties in absence of ZnO under UV ageing decreased with respect to time. While in the presence of ZnO particles sample brittleness changed to some extent, but no change is observed in tensile properties of the sample. Similarly, Charpy impact test conducted, and results showed that with the addition of ZnO particles improves the properties of the sample. Therefore, these materials are useful for outdoor applications where come in contact with the environment and UV radiation directly.

6. References: