

Republic of Iraq
Ministry of Higher Education
And Scientific Research
University Of Babylon
College of materials engineering
Department of polymer and petrochemical industries



***Mechanical and Thermal properties of PP and PE blend
reinforced with nano particle for industrial applications***

**A graduated project submitted to Department of polymer and petrochemical
industries**

College of Materials engineering , University of Babylon

By

- 1. Saif Haider jassim**
- 2. Ather Abdullah Mubark**
- 3. Amna Ibraheem Falih**

Supervised By

Assist. Lecture Ban Jawad Kadhim

2021 - 2022

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

﴿وَقُلْ رَبِّ زِدْنِي عِلْمًا﴾

(طه: ١١٤)

صدق الله العلي العظيم

الشكر والأهداء

أولاً

نهدي هذا العمل الى من كان لهم الفضل في بلوغنا التعليم العالي (الوالدين)

ثانياً

الى كل من يبخل بأذيته على الناس،

و يوجد بنفسه الطيبة.

الى كل من يسكن الحب فؤاده،

و يرى السلام مبدأ وغاية له.

هذا العمل الى النفوس النقية والمُحبة.

شكر وتقدير لكل من لم يتوانى في مد لنا يد المساعدة ولو باليسير

شكر خاص الى

مشرفة البحث ذات الروح المميزة

م.م. بان جواد كاظم

والشكر أيضاً الى

م.م. نبيل المطيري

Supervisor

I certify that the dissertation entitled “Mechanical and Thermal properties of PP and PE blend reinforced with nano particle for industrial applications”

was prepared under my supervision at the Department of Polymer and Petrochemical Industries / College of materials engineering /University of Babylon.

Signature:

Name: **Ban Jawad Kadhim**

Date: / / 2022

Table of Content

Abstract

Chapter One: Introduction and Literature Reviewe 1 - 7

1.1 Literatures Review	1
1.2 Aims of this work	2
1.3 Introduction to Polymer Blend	3
1.4 Compatibility in Polymer Blends	4
1.4.1 Types of polymer blends	4
1.4.2 Polymer Blend Vs Polymer Alloy	5
1.5 The Beginnings	6
1.6 The advantages of blending fall into two categories	6
<i>Chapter Two Theory Part</i>	<i>8 - 28</i>
2.1 Introduction To polymer	8
2.2 Polymer Applications	10
2.3 Polymer properties	10
2.4 Polymer Blends	11
2.4.1 Blends Containing a Compatibilizer	11
2.5 Polymer Nanocomposites	13
2.6 Properties of Nanocomposites	14
2.6.1 Mechanical properties	14
2.6.2 Barrier properties	15
2.6.3 Dielectric properties	16
2.7 Polypropylene Plastic	16
2.7.1 Uses for polypropylene	16
2.7.2 Material properties and types of polypropylene	17
2.7.3 Polypropylene As An Injection Molding plastic	18
2.7.4 Polypropylene As A CNC Machinable Plastic	19
2.7.5 Advantages to Polypropylene	19

2.7.6 Polypropylene disadvantages	20
2.7.7 Is polypropylene safe	20
2.8 High-Density polyethylene (HDPE)	21
2.8.1 HDPE Properties	21
2.8.2 Advantages of HDPE	23
2.8.3 Disadvantages of HDPE Material	24
2.8.4 Applications of HDPE	24
2.9 Effect Addition Nanoparticles On The Properties Of (PP/Nano Zno)	26
2.9.1 Crystal structure of Zno	26
2.9.2 Nanoparticles of Zno	27
2.9.3 Interaction and risk	27
2.9.4 Applications	28
<i>Chapter three Practical Part</i>	<i>29 - 35</i>
3.1 Introduction	29
3.2 Materials and methods	29
3.2.1 Materials	
3.2.1.1 Polypropylene	
3.2.1.2 HDPE	30
3.2.1.3 ZNO	30
3.3 Preparation before adding nanoparticles (Zno)	31
3.4 Tests	32
3.4.1 Tensile test	
3.4.2 Hardness test	33
3.4.3 Differential Scanning Calorimetry (DSC) test	34
<i>Chapter four Results</i>	<i>36 – 44</i>
4.1 Introduction	36
4.1.1 mechanical properties	36
4.1.2 Thermal properties	42
<i>Chapter Five Conclusion</i>	<i>45</i>
5.1 Conclusion	45
References	

Table of Figure

Figure (1) Appearance of a true linear polymer as imaged using atomic force microscopy on a surface in the presence of a liquid medium.	8
Figure (2) Application of polypropylene plastic	16
Figure (3) The hexagonal wurtzite structure model of ZnO. The tetrahedral coordination of Zn-O is shown	27
Figure (4) The final shape of the samples before adding nano-zno.	31
Figure (5) Tensile test	32
Figure (6) Diagram showing the Hardness test	33
Figure (7) (DSc) Test.	34
Figure (8) The final shape of the samples After adding nano-zno.	35
Figure (9) mechanical properties by tensile test for polymer blend (PP, HDPE)	37 – 38
Figure (10) mechanical properties by tensile test for polymer blend (PP, HDPE) After adding nano zno.	39 – 40
Figure (11) Diagram showing the hardness curve of the polymer blend (PP/HDPE) before adding ZnO nanoparticles.	40
Figure (12) Diagram showing the hardness curve of the polymer blend (PP/HDPE) after adding ZnO nanoparticles.	41
Figure (13) :- Diagram showing the thermal properties by (DSC) test for polymer blend (PP, HDPE) After adding nano zno.	43 - 44

Tables List

Table (1) : Properties of the used PP. Property Data	29
Table (2) : Properties of the used HDPE Property Data	30
Table (3) : Properties of the used ZNO	30
Table (4) : All samples preparation process.	31
Table (5) : Table of polymer blend (PP, HDPE) showing the values of tensile strength, modulus of elasticity and elongation.	36
Table (6) : Table of polymer blend (PP, HDPE) with addition of Zno nanoparticles	38
Table (7) : Table of polymer blend (PP, HDPE) showing the values Average Hardness before adding Zno nanoparticles.	40
Table (8) : Table of polymer blend (PP, HDPE) showing the values average hardness after adding Zno nanoparticles.	41
Table (9): Table about thermal properties Shows the melting temperature of all samples without nano-zno.	42
Table (10): Table about thermal properties Shows the melting temperature of all samples After adding nanoparticles Zno	4

Abstract

Polymer blend :- A polymer blend is mixture of two or more polymers That have been mixed together to create a new materiel.

Many applications need any specific properties for the purpose of meeting the need for them. Among these properties are mechanical and thermal properties, as polymers usually have low mechanical and thermal properties compared to the rest of the materials, so we usually resort to using other materials that are added to polymers, including nanomaterials.

In this study, five samples of PP and HDPE were prepared in different proportions. Through the tests that we conducted, it was found that the best ratio is (80/20) wherever (Tensile, Hardness, DSC) tests were conducted.

By the **hardness test** that we made, we notice that the increase in the percentage of HDPE in the polymeric mixture consisting of PP and HDPE led to a decrease in the hardness of PP when the percentage of HDPE was increased from (10% to 50%) and this is due to the fact that HDPE is a material that has ductility and flexibility.

When adding ZnO nanoparticles to a mixture (80/20), we notice that the substance increased from the value of (80/20) (55.6) and increased by (3.8, 6.6, 0.1) when the percentage of ZnO was increased from (1% to 3%) due This increase indicates that ZnO has higher hardness than PP.

From the **tensile teste**, we notice that when HDPE is added to the PP, we notice a decrease in the tensile strength when added. A ratio of (10 to 60) by (23Mp), and the best ratio is (80/20). Since the amount of Tensile is (19Mp) and the modulus of elasticity ($E=0.13\text{GPa}$) and the amount of elongation was (16%) when adding ZnO at (1%, 2%, 3%) for the ratio (80/20), we note that the mechanical properties It improved and increased at a rate of (2%, 3%) and the modulus of elasticity € also increased, in contrast, the elongation decreased. The reason is that this increase is due to the fact that the fine particles of the material increased when nanoparticles were added, and this is an indication of a decrease in elongation.

From the **(DSC) teste** , we note that mixing HDPE with PP has a very little effect on the melting temperature of the mixture, as we note that the increase in the percentage of HDPE led to a decrease in the temperature of PP in the mixture, as well as a slight increase in the melting

temperature of HDPE. The increase in the percentage of HDPE led to an increase in the crystallization temperature, which means that the HDPE led to the formation of larger crystals. Also, when adding ZnO to the mixture at a rate of (1%, 2%), we notice that the temperature of the mixture did not change significantly, that is, there is no effect of ZnO on the melting temperature.

As for the percentage of crystallization temperature, we note that at the ratio (90/10) it increased when nano (ZnO) was added, while at the ratio (80/20), we notice that the crystallization temperature decreased when adding nano (ZnO).

The increase in the crystallization temperature means that the (ZnO) particles led to an increase in the ability of the mixture to crystallize forming large crystals, while the decrease in the crystallization temperature means that the (ZnO) particles led to a decrease in the ability of the mixture to crystallize and this means that the crystals are smaller in the case of (90) /10).

Chapter One
Introduction
and
Literature Review

1.1 Literatures Review

In 2017, SitiNikmatin, et al, studied Physical, thermal, and mechanical properties of polypropylene composites filled with rattan nanoparticles. Results showed their composites behaviors are directly compromised. Existing evidence has exhibited that nanoparticle fillers can be employed as an alternative size to overcome this problem. We thus examined in this study the effects of rattan filler of nanoparticle size on the physical, thermal, and mechanical properties of the composite. Neat polypropylene (PP), PP with 5% rattan nanoparticle (PP/R5), and PP with 5% glass fiber (PP/FG5) were considered. For performance assessment, particle size analysis, morphology, X-ray diffraction, thermal inspection, and mechanical tests were carried out. The highest degree of crystallinity was discovered in PP/R5. Tensile properties of both PP/FG5 and PP/R5 were comparable although the former demonstrated higher moduli of elasticity and rupture. Well-distributed constituents were displayed in PP/R5 by means of morphological study, which offered insight into its highest average hardness, maximum strain, and therefore its advantageous ductile behavior compared to the other considered materials [49].

In 2018 , Harekrushna Sutar, et al, studied Mechanical, Thermal and Crystallization Properties of Polypropylene (PP) Reinforced Composites with High Density Polyethylene(HDPE) as Matrix Results showed in Our work aims to evaluate a complete outlook of virgin high density polyethylene (HDPE) and polypropylene (PP) polyblends. Virgin PP of 20, 30 and 50 weight% is compounded with virgin HDPE. The properties like tensile strength, flexural strength, Izod impact strength are examined. Scanning electron microscopy (SEM) and polarised light microscopy (PLM) are used to observe the surface and crystal morphology. X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR) tests verify the non compatibility of both polymers. Differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA) techniques are used to study the thermal behavior of composites. The results manifest co-occurring spherulites for polyblends; indicating the composite to be a physical blend of continuous and dispersed phases, but on the other hand PP improves the tensile and flexural properties of HDPE [50].



In 2020, Isabella L. M. Costa¹, et al, studied Thermal and Mechanical Properties of HDPE Reinforced with Al₂O₃

Nanoparticles Processed by Thermokinetic Mixer. The results showed Polymer nanocomposites are a promising area of research due to quite superior to the conventional composites. However, obtaining a homogeneous distribution of the nanoparticles in the matrix has been a great challenge. Standard processing techniques of nanocomposites are non-practical, requiring longer periods and can affect both mechanical and thermal properties of the final product. The thermokinetic mixer is an interesting alternative due to its high-speed rotation leading to a better dispersion of the nanoparticle without compromising the polymer properties. This paper reports for the first time a nanocomposite of high-density polyethylene (HDPE)/Al₂O₃ processed by the thermokinetic mixer. The addition of Al₂O₃ nanoparticle (0 to 4% wt) to the HDPE led to an increase in both the melting and crystallization temperature. It was also observed an improvement of the mechanical properties due to the increase in the crystallinity degree, which is a consequence of the multiple nucleation sites of Al₂O₃ nanoparticles. An optimal composition was obtained at 4% wt of Al₂O₃. Thus, the nanocomposites processed by the thermokinetic mixer demonstrated a significant enhancement of the mechanical and thermal properties [51].

1.2 Aims of this work

Current work aims to the following steps :

- 1-to identify the mechanical and thermal properties of the polymer blend.
- 2- Study the effect of adding nanoparticles to the polymer blend and its effect on the mechanical and thermal properties .



1.3 Introduction to Polymer Blend

Polymer blend (PB): Mixture of at least two macromolecular Substances, polymers or copolymers, in which the ingredient content is Above 2 wt%. A polymer blend is a mixture of two or more polymers that have been blended Together to create a new material with different physical properties. Generally, There are five main types of polymer blend: thermoplastic–thermoplastic blends; Thermoplastic–rubber blends; thermoplastic–thermosetting blends; rubber–Thermosetting blends; and polymer–filler blends, all of which have been exten-Sively studied. Polymer blending has attracted much attention as an easy and Cost-effective method of developing polymeric materials that have versatility for Commercial applications. In other words, the properties of the blends can be Manipulated according to their end use by correct selection of the component Polymers [1]. Today, the market pressure is so high that producers of plastics need To provide better and more economic materials with superior combinations Of properties as a replacement for the traditional metals and polymers. Although, Plastic raw materials are more costly than metals in terms of weight, they are more Economical in terms of the product cost. Moreover, polymers are corrosion-resist-Ant, possess a light weight with good toughness (which is important for good fuel Economy in automobiles and aerospace applications), and are used for creating a Wide range of goods that include household plastic products, automotive interior And exterior components, biomedical devices, and aerospace applications [2]. The development and commercialization of new polymer usually requires many Years and is also extremely costly. However, by employing a polymer blending pro-Cess – which is also very cheap to operate – it is often possible to reduce the time To commercialization to perhaps two to three years [2]. As part of the replacement Of traditional polymers, the production of polymer blends represents half of all Plastics produced in 2010. Today, the polymer industry is becoming increasingly Sophisticated, with ultra-high-performance injection molding machines and Extruders available that allow phase-separations and viscosity changes to be effec-Tively detected or manipulated during the processing stages [3]. Whilst this mod-Ern blending technology can also greatly extend the performance capabilities of polymer blends, increasing market pressure now determines that, for specific Applications, polymer blends must perform under some specific conditions (e.g., Mechanical, chemical, thermal, electrical). This presents a major challenge as the Materials must often function at the limit of the properties that can be achieved; Consequently, in-depth studies of the properties and performance of polymer Blends are essential.



1.4 Compatibility in Polymer Blends

In general, the compatibility between the polymer phases decides the properties of a heterogeneous polymer blend [4,5]. The interface between the polymer phases in a polymer system is characterized by the interfacial tension which, when approaching zero, causes the blend to become miscible. In other words, if there are strong interactions between the phases then the polymer blend will be miscible in nature. Large interfacial tensions lead to phase separation, with the phase-separated particles perhaps undergoing coalescence; this will result in an increased particle size and, in turn, decreased mechanical properties. The interfacial tension can be reduced by the addition of interfacial agents known as compatibilizers [6]; these are generally molecules with hydrophobic and hydrophilic regions that can be aligned along the interfaces between the two polymer phases, causing the interfacial tension to be reduced and the compatibility of the polymer blends to be increased. Compatibility results in a reduction of the dispersed particle size, an enhanced phase stability, and increased mechanical properties [6]. The physical properties of miscible, compatibilized and uncompatibilized blends can be characterized using techniques such as thermogravimetric analysis, dynamic mechanical thermal analysis, and universal testing machines.

1.4.1 Types of polymer blends:

1-Miscible polymer blend: Polymer blend, homogeneous down to the molecular level, associated with the negative value of the free energy of mixing: $\Delta G_m \leq \Delta H_m \leq 0$, and a positive value of the second derivative: $\partial^2 \Delta G_m / \partial \phi^2 > 0$. It is a single-phase structure, has properties of average values between the values of properties of its components and has one T_g .

2-Immiscible polymer blend: A blend exhibits more than two phases. It is a blend whose free energy of mixing; $\Delta G_m \leq \Delta H_m > 0$. Usually, has two T_g 's, since the two components are phase separated.

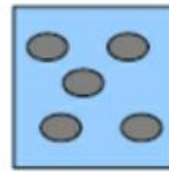
Scientists often measure the T_g of a blend to find out if it is miscible or immiscible. If two T_g s are found, then the blend is immiscible. If only one T_g is observed, then the blend is likely to be miscible.



3-Homologous polymer blend: Mixture of two or more fractions of the Same



Miscible PB



Immiscible PB

polymer each of which has different molecular weight distribution.

4-Isomorphic polymer blend: Polymer blend of two or more different Semi-crystalline polymers are miscible in the crystalline state as well as in The molten state.

5-Compatible polymer blend: An immiscible blend is called compatible If it is useful blend wherein the inhomogeneity (caused by different Phases) is on a small enough scale not to be apparent in use.

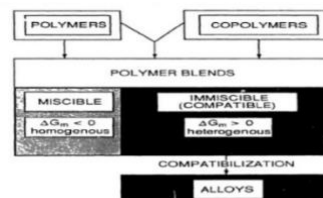
OR:

Blends that miscible in a certain useful range of composition and Temperature, but immiscible in others. Most compatible blends are immiscible and can be made compatible Only by a variety of compatibilization techniques.

6- Polymer alloy: Immiscible, compatibilized polymer blend with Modified interface and morphology.

1.4.2 Polymer Blend Vs. Polymer Alloy

The properties of many plastics can be greatly modified by blending or Alloying two or more polymers. These terms are often used Interchangeably, but technically , blends are mixtures that are not fully Compatible and alloys are mixtures that are fully compatible . Polymer alloy constitutes a specific sub-class of polymer blend; Virtually all high performance engineering blends are alloys



1.5 The Beginnings

The polymer industry traces its beginning to the early modifications of Shellac, natural rubber (NR -an amorphous cis-1,4-polyisoprene), gutta-Percha (GP- a semi-crystalline trans-1,4-polyisoprene), and cellulose.

In 1846, Parkes patented the first polymer blend: NR with GP

Partially co-dissolved in CS₂. Blending these two isomers resulted in Partially crosslinked (co-vulcanized) materials whose rigidity was Controllable by composition. The blends had many applications ranging From picture frames, table-ware, ear-trumpets, to sheathing the first Submarine cables.

For example:

1- Twin-screw extruders with 80 tons/hr throughput and injection (100,000 kN) molding presses with shot size of 100 liters of Polymer are available.

2-Composites where the matrix is a polymer blend that comprises six Different polymers have been introduced.

3-6-Gas and multiple injection processes, melt-core technology, solid- State forming, microcellular foams all lead to new products with Advanced performance.

1.6 The advantages of blending fall into two categories:

A. Blending may improve resin or product performance by:

1. Producing materials having a full set of the desired properties at Lowest cost.
2. Extending the engineering resins' performance by incorporation of Less expensive polymers.
3. Improvement of specific properties.

◆ Brittleness : Toughening brittle polymers, thus eliminating the Need to use low molecular weight additives

◆ Modulus & Dimensional Stability: Blending with more rigid And more heat resistant resin .



◆ Improve Solvent and Chemical Resistance: Incorporation of Semicrystalline polymer into an amorphous resin.

◆ Biodegradability: Incorporation of a biodegradable resin

◆ Blending makes it possible to produce integrated multi-layer Structures.

4-The blending technology makes it possible to rebuild high molecular Weights of partially degraded polymers, thus to produce high performance Articles from the plastics waste.

B. Blending may lead to improved processability:

1-Process the high Tg resin at temperatures well below the thermal Degradation limit: Incorporation of a miscible resin with a lower glass Transition temperature (Tg) (e.g., PS/PPE blends).

2-Blends having a controllable degree of strain hardening (SH):

Blending with resin that either by itself shows high (SH) (e.g., LDPE in Blends with another PO), or when reactively blended forms long chain Branches (e.g., PS in blends with PO). These materials show better Processability in technologies where the extensional flow field is Important, viz., film blowing, blow molding, wire coating, foaming, etc.



Chapter Two

Theory Part

2.1 Introduction To polymer

A polymer is a high molecular weight compound composed of repeating subunits. These substances may be organic, inorganic, or organometallic, and may be natural or synthetic in origin.[9]

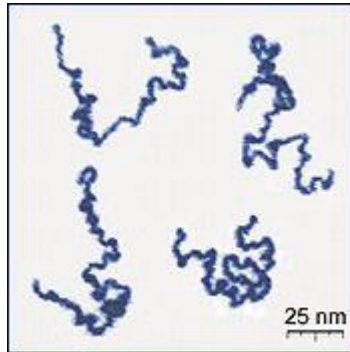


Figure (1) : Appearance of a true linear polymer as imaged using atomic force microscopy on a surface in the presence of a liquid medium. The polymer chain is about 204 nm long and 0.4 nm thick [8].

Polymers have become an integral and total role in daily life [10] due to their unique properties.[11] They are essential materials in everyday industrial sectors, such as adhesives, building materials, paper, clothing, fibres, plastics, ceramics, concrete, liquid crystals and photoresists, and coatings. Polymers are also found in most soil components, plants, and living organisms. They are important in nutrition, mechanical engineering, organismal structure, medicine, computers, space exploration, health, and the environment.[9] The word plastics or elastomers is misused to refer to polymers, while polymers include large classes of synthetic and natural materials with varying properties. Inorganic natural polymers include diamond, graphite, sand, asbestos, garnet, flint, feldspar (aluminum silicate), mica, quartz, and talc. Natural organic polymers include polysaccharides such as starch, cellulose, amino acids, and proteins. Synthetic inorganic polymers include boron nitride, concrete, many high temperature superconductors, and many glassware. Siloxanes or polysiloxanes are organometallic synthetic polymers.[9] Synthetic polymers save energy when compared to metals. Its light weight reduces fuel consumption in vehicles and aircraft. It is superior to most metals in relation to its strength-to-weight ratio. Polymers have been developed and possessed good properties and become economical to manufacture. It can also be used for engineering purposes, so we use gears, bearings, and structures made of polymers.[10]



Plastics started from nature, such as gum arabic and natural rubber. In the 19th century, scientists began trying to imitate nature. In the twentieth century, when the need for rubber increased in World War II, German scientists were able to produce synthetic rubber; It gives the same specifications as natural rubber and almost the same chemical composition. Polymers are chemical compounds characterized by the length of the chain, but the length of the chain that causes the large molecular weight of the compound is caused by the repeating of similar units in the same order along the chain. Hence the compound is called a polymer. The basic unit of a polymer may be composed of one or more substances. A repeating unit of a polymer is called a monomer, i.e. a single unit. For example, material A can react with itself under certain conditions and give the polymer $A + A = A-A$. One of these examples is polyethylene used in the manufacture of plastic bags and so on, and the product of the reaction of ethylene with itself under conditions of high pressure and high temperature in the presence of a catalyst for the reaction, which is often from Metals and the reaction is as follows: $n \text{CH}_2=\text{CH}_2 \rightarrow (\text{CH}_2-\text{CH}_2)_n$ and the molecular weight of ethylene is 28, but by the interaction of thousands of molecules together, a compound with a molecular weight of millions is produced. Polymers have become one of the materials of great importance to modern life due to the variety of purposes for which they are used and their suitability for these purposes, and because of the possibilities of making them in construction to match the output with a specific function. But these materials are alien to the natural environment, and therefore they are not subjected to biological decay, and if they are transferred to the environment, they remain in it, a form of pollution whose effects are exacerbating day by day.[\[12\]](#) Polymers contribute to the distortion of nature as a result of the accumulation of waste, and can be a breeding ground for insects and rodents. Its waste has spread in the seas and oceans, and the movement of water has carried it to remote areas, and it has become a threat to fish. The problem of getting rid of these materials remains, as burning them leads to air pollution, not to mention that this process is incomplete and its effectiveness is incomplete. Rubber tires, for example, burn, releasing thick smoke and unpleasant odors. As for polyvinyl chloride, harmful hydrogen chloride gas is released.



2.2 Polymer Applications

1. All types of plumbing pipes and hoses are polymers.
2. All plastic products are a polymer.
3. All types of car tires are polymers.
4. All rubbers are organic polymers.
5. Carpets, upholstery and floor insulators.
6. Dacron textiles and clothing.
7. Ashtrays and electrical insulators.
8. Artificial heart valves.
9. Synthesis of proteins.

Polymers are used in medicines, dyes, paints, etc [13].

2.3 Polymer properties

Most polymers, especially industrial ones, have the property of plasticity, especially with heat, and this means that when they are heated, they can be recycled and formed many times in addition to enjoying other properties, including: [14]

1. Chemical resistance

This characteristic is observed in plastic containers containing detergents, as they are highly resistant to chemicals that may cause significant damage when in contact with human skin.

2. Electrical and thermal insulation

Polymers are used in the manufacture of handles for cooking utensils because they are an excellent thermal insulator, in addition to their use in covering electrical wires and making refrigerator doors and many external structures of electrical tools because of the lack of electricity through them.

3. Light weight

Polymers are lightweight materials compared to their strength, and this is evident when compared to other materials such as copper, stones and many.



2.4 Polymer Blends

Mixing of two or more different polymers together makes it possible to achieve various property combinations of the final material—usually in a more cost-effective way than in the case of synthesis of new polymers.

Therefore, great attention has been paid to the investigation of these systems, as well as to the development of specific materials. Recently, the problem of polymer blends has also become important for recycling industrial and/or municipal plastics scrap. A considerable amount of information has been collected during more than three decades, summarized in dozens of monographs (see General References).

Basic problems associated with the equilibrium and interfacial behavior of polymers, compatibilization of immiscible components, phase structure development, and the methods of its investigation are described herein. Special attention is paid to mechanical properties of heterogeneous blends and their prediction.

Commercially important types of polymer blends as well as the recycling of commingled plastic waste are briefly discussed.

2.4.1 Blends Containing a Compatibilizer:

The Effect of Compatibilizer on a Blend Microrheology

The presence of a compatibilizer at the interface substantially affects the development of the phase structure of molten blends in the flow and quiescent state. The position and width of the concentration region related to co-continuous morphology are affected by two competing mechanisms. A decrease in interfacial tension caused by a compatibilizer favors the formation and stability of co-continuous structures. On the other hand, the compatibilizer suppresses the coalescence, which is assumed to be a reason for the co-continuity formation [15]. Experimentally, narrowing of the concentration region with co-continuous structure was observed for some systems [15,116,17], but no change was found in other systems [15,18,19]. Fixation of co-continuous structure in a blend containing 20% of minor component by the addition of a compatibilizer was also observed [20]. The effect of a compatibilizer on fineness of the phase structure can be understood through its effects on droplet breakup and coalescence. The decrease in interfacial tension mentioned above leads to a decrease in the critical droplet radius, R_c , at a constant C_{ac} . Generally, C_{ac} of a compatibilized blend differs from that of the related binary blend without compatibilizer [21,22]. The bulk flow convects the compatibilizer towards the ends of the droplets causing a gradient in interfacial tension along the droplet surface.



The lower interfacial tension on the tips promotes tip streaming, tending to reduce Cac . On the other hand, Marangoni stresses oppose deformation. An increase in the droplet surface due to deformation leads to compatibilizer dilution and, therefore, to an increase in interfacial tension. The last two effects tend to increase Cac [21,22]. At breakup by the transient mechanism, a compatibilizer causes an increase in the breakup time due to a decrease in interfacial tension and existence of interfacial tension gradients [21,23]. A decrease in interfacial tension due to the presence of a compatibilizer decreases the droplet radius, R , at which the probability of coalescence, P_c , falls to a negligible value. Two other mechanisms contributing to coalescence suppression were proposed [21,24]. The first involves immobilization of the interface (suppression of liquid circulation in droplet) due to the Marangoni stress. The Marangoni stress is induced by convection of a compatibilizer out of the gap between approaching droplets, which leads to a gradient of interfacial tension. The immobilization of the interface decreases P_c for small R . The other mechanism, repulsion of the droplets arises mainly from the compression of the compatibilizer block extending into the matrix phase. This mechanism is applied only if the dilution of a compatibilizer in the gap between droplets is not large. The effect of a compatibilizer on the breakup frequency and P_c (decrease in interfacial tension and the Marangoni effect) are considered. In the calculation of steady R , changes in interfacial tension induced by changing interfacial area in droplet breakup and coalescence should be considered [25]. The above effect can be quantified if the distribution of a copolymer between the interface and bulk phases, relationship between copolymer concentration at the interface and interfacial tension, and the rate of copolymer migration along the interface and between the interface and bulk phases are known.

2.5 Polymer Nanocomposites

Nanocomposites have been studied for Nearly 50 years. They were first referenced As early as 1950 [26]. Polyamide nanocomposites were reported in 1976 [27]. It was the Efforts of Toyota research group that laid The foundation stone for the interest in this Area [28,29]. Nanocomposites are a combination of two or more phases containing different compositions or structures where at Least one of the phases is in the range of 10 To100 nm. Fillers with a particle size in the Nanometer range have a small number of Atoms per particle and for this reason may Have different properties than the bulk material and strong interactions with the matrix. The separation of fi ller particles is of The order of molecular dimensions, which May modify the properties of polymers. In Polymer nanocomposites research, the primary goal is to enhance the strength and Toughness of polymeric components using Molecular or nanoscale fi llers. Composites That exhibit a change in composition and Structure over a nanometer scale have shown Remarkable property enhancements relative To conventional composites:

- Increased modulus
- Increased gas barrier
- Increased heat distortion temperature
- Resistance to small molecule permeation
- Improved ablative resistance
- Increase in atomic oxygen resistance
- Retention of impact strength.

Interestingly, these performance improvement are achieved without increasing the Density of the base polymer, without degrading its optical qualities and without making It any less recyclable. It is a remarkable fact that in addition to The profound changes in physical properties, which materials display when they are Nanometer in scale, the chemical behavior is profoundly altered as well. When an Inorganic solid is composed of only a few Thousands of atoms, it has a great deal of Surface area. By binding an appropriate organic molecule to this inorganic surface, It is possible to make nanocrystals behave Chemically just like an organic macromolecule. In nature, polymer inorganic nanocomposites materials are frequently encountered (for Example, bone, tendon, dentin and bamboo) And represent some of the fi nest examples of The optimized interfacial interaction. However, it is still inherently difficult to reproducibly generate polymer inorganic composite Architectures with the level of nanometer Scale sophistication responsible for the remarkable properties of biological composites.



Consequently, one of the frontiers in nanotechnology is the advancement of viable methods for the efficient design and synthesis of Polymer inorganic nanocomposites with architectural control and improved properties as a result of this sophistication. A wide variety of methods has been employed to synthesise Polymer inorganic nanocomposites. Depending on whether the inorganic component is grown in the presence of the polymer (monomer) matrix or pre-fabricated, these methods can be basically divided into two categories "in-situ" and "ex-situ". Among all these synthetic strategies, the assembly of inorganic nanoparticles into a polymer matrix appears to be one of the most promising approaches. Nanoparticles are readily obtained and have potentially useful optical, optoelectronic and material properties deriving from their small nanoscopic size. These properties might lead to wide applications including chemical sensors, spectroscopic enhancers, quantum dot and nanostructure fabrication and micro imaging methods. Again, the interfacial interaction between inorganic nanoparticles and polymer matrix exerts important influence on the properties of the resulting nanocomposite. As a result, tailoring and manipulating interfacial interaction becomes a particular preparative challenge.

2.6 Properties of Nanocomposites

2.6.1 Mechanical properties

Schueneman et al. [30] reported that there exists an increase in hardness and scratch resistance with the addition of nanoparticles to polymer matrix. Kojima et al. [31] reported that by intercalating as little as 2 vol % silicates into nylon-6 on a nanoscale, the tensile strength and modulus of the hybrid were improved to more than twice that of the virgin polymer. Again Kojima et al. [32] showed that only 10 phr of organic clay was necessary to achieve tensile strength comparable to a compound loaded with 40 phr of carbon black. It was shown that tensile strength and elongation at break were improved depending on filler loading and compatibilisation. Exfoliated polymer-silicate systems have been found to exhibit superior mechanical properties to the conventionally filled systems. Strawhecker et al. [33] studied the mechanical properties of PVA-Na⁺ montmorillonite nanocomposites. The mechanical tensile properties of these nanocomposites were studied at low silicate loadings, and Young's modulus was found to increase by 300 % for 5-wt % silicate, with only a 20 % decrease in toughness, and no sacrifice of the stress at break compared to the case of neat PVA. In addition, for these low loadings, thermal stability from TGA measurements was shown to be slightly enhanced, and high optical purity was retained.



Granter et al [34] studied the mechanical Properties of rubber nanocomposites using BR and SBR vulcanisates reinforced by Organophilic layered silicates. It was shown That in the absence of coupling agent, the Compounds containing layered silicates show Increased tensile strength and strain at break With respect to unfilled vulcanisates. When Compared with silica compounds, both SBR And BR vulcanisates showed good enhancement in mechanical properties. But when The matrix is chemically bonded to silica By TSEPT, tensile strength remains constant, But strain at break decreases. A similar effect is observed for anisotropic layered silicates also. This is owing to the fact that the Reactive coupling of the elastomer matrix is Also effective on the surface of silicate layers Containing quaternary ammonium salts on The surface. From the hysteresis studies, improved reinforcement by 20–50 % relative to Silica vulcanisates is observed for BR and SBR Organ clay compounds. Chemical bonding of The rubber matrix led to further increase in Reinforcing effect by 50 %–90 % relative to The corresponding silica systems. All the mechanical properties, including Young's modulus, stress at break, strain At break of all nanocomposites and virgin Polymers, were studied by Zheng and Wilkie For polystyrene nanocomposites [35]. At low Amounts of clay, the mechanical properties Are improved. As the amount of clay increases, there is a decrease in all of the mechanical properties. It is possible that above some Level, there is some plasticisation, which results in a reduction of the melting point or Softening point.

2.6.2 Barrier properties

With the dispersion of the ultra thin inorganic layers throughout the polymer matrix, The barrier properties of the nanocomposites are expected to be strongly enhanced Compared to the respective polymer. In PVA-Na⁺ montmorillonite nanocomposites The water vapour transmission rates were Measured for the pure polymer and several of its low MMT nanocomposites. The Permeability decreased to about 40 % of The pure water vapour transmission values For silicate loadings of only 4–6-wt %. This Decrease is attributed to the increased path Tortuosity of the penetrant molecules and To the enhanced modulus of the polymer Matrix [33]. Very recently, Stephen et al. [36,37] studied The gas transport behaviour of Nano and micro composites of natural rubber and their Blends with carboxylated styrene butadiene rubber latex membranes.

2.6.3 Dielectric properties

Dielectric spectroscopy (DEA) is a powerful tool in studying relaxation phenomena in polymers and composites. It provides information about the location and activation energy of relaxation transitions, the dipole moments of the subunits involved, concentration and mobility of charge carriers and so on. Dielectric measurements in polyurethane-nanosilica composites showed that both the nonfilled and the filled composites exhibit an overlapping transition consisting of two subrelaxations, which become resolved only at the highest frequencies. Wei et al. [38] studied the effect of poling on the dielectric properties of PT-PEK-C

nanocomposite films. The difference between the dielectric constants of the components is very large. Plasticisation should be considered in order to determine the poling temperature of the nanocomposite thin films. Besides, the viscosity of the polymer descends and the alignment of PT ultra fine particles is easy at high temperature. But the conductivity of PT-PEK-C composite thin films increases rapidly with temperature, i.e., the thin films are broken down easily at high temperature.

2.7 Polypropylene Plastic

Polypropylene (PP) is one of the most commonly used thermoplastics in the world. Polypropylene uses range from plastic packaging, plastic parts for machinery and equipment and even fibres and textiles. It is a rigid, semi-crystalline thermoplastic that was first polymerised in 1951 and is used widely today in a range of domestic and industrial applications. Today, global demand for polypropylene is estimated at around 45 metric tons and this figure continues to rise exponentially [39].

2.7.1 Uses for polypropylene

Polypropylene has a slippery, tactile surface, making it ideal for

- plastic furniture
- low friction applications, such as gears in machinery and vehicles.



Figure (2) :- Application of polypropylene plastic [39].

It is highly resistant to chemical corrosion, making it an excellent choice for packaging for:

- Cleaning products
- bleaches and first-aid products

It offers excellent fatigue resistance and elasticity, securing it a well-deserved reputation for toughness and durability. Polypropylene has high insulation properties too, making it safe to use for plastic casing in electrical goods and cables. In its fiber form, polypropylene uses are not limited to not only useful for tote bags but also encompass a much wider range of other products, including ropes, twine, tape, carpets, upholstery, clothing and camping equipment. Its waterproof properties make it especially effective for the marine sector. In the automotive industry,

polypropylene is also used widely, for example in for battery casings, trays and drink holders, bumpers, interior details, instrumental panels and door trims.

Finally, the medical world appreciates the waterproof properties of polypropylene too, as well as its flexible strength, resistance to mould, bacteria and chemical corrosion. It cleans well a sit can stand up to steam sterilisation methods.

Some medical applications include:

- Syringes
- medical vials
- Petri dishes
- pill containers
- specimen bottles

2.7.2 Material properties and types of polypropylene

This versatile thermoplastic and polymer are popular due to its highly flexible properties,[40] lighter density and ability to adapt to a range of fabrication techniques. The different variations in polypropylene have led the material to be known as the ‘steel’ of the plastic industry, as it can be used and manipulated a number of ways.

➤ **There are two main types of polypropylene thermoplastics:**

- Homopolymers
- Copolymers



Homopolymers contain only propylene monomers in semi-crystalline form. Main uses include textiles, packaging, pipes, medical components and electrical applications.

Copolymers are divided into random copolymers and block copolymers, produced by polymerising propene and ethene together. Copolymers contain higher amounts of ethylene, which result in an increase in desirable properties within the polypropylene. They are softer than homopolymers but have better impact strength. Polypropylene can function as both a plastic and fibre type of thermoplastic. This allows for a vastly increased range of uses. It can be used as a fibre, such as in the manufacture of promotional tote bags and ‘bag for life’ shopping carriers. It is soft, malleable and has a relatively low melting point, making it very easy to be used in the injection moulding process, where it is supplied in pellets. It flows well too, due to its low melt viscosity.

2.7.3 POLYPROPYLENE AS AN INJECTION MOLDING PLASTIC

Polypropylene is a very popular material in the injection molding world; this popularity is due to it being a very ‘moldable’ material. Its versatility, wide range of uses, and unique properties are among those reasons. Polypropylene is easy to mold despite its semi-crystalline nature, and it flows very well because of its low melt viscosity. This property significantly enhances the rate at which you can fill up a mold with the material. The rate should not be set too high, however, to ensure good surface finish and to avoid defects such as voids, weld lines, and flow fronts. The melt temperature of polypropylene can be anywhere between 200oC (392oF) to 250oC (482oF),[\[41\]](#) although it can go higher depending on the grade of polypropylene and the kind of additives it contains. Shrinkage in polypropylene is about 1% but can vary based on a number of factors, including holding pressure, holding time, melt temperature, mold wall thickness, mold temperature, and the percentage and type of additives.

2.7.4 POLYPROPYLENE AS A CNC MACHINABLE PLASTIC

Polypropylene has gained a reputation as a material that cannot be machined. This is because it has a low annealing temperature, which means that it starts to deform under heat. Because it is a very soft material in general, it requires an extremely high skill level to be cut with precision; Creative Mechanisms has been successful in doing so. Our teams can use a CNC machine and cut the polypropylene cleanly and with extremely great detail. In addition, we are able to create living hinges with polypropylene that have thickness as little as .010 inches. Making living hinges is a difficult endeavor on its own, which makes using a difficult material like polypropylene even more impressive.

2.7.5 Advantages to Polypropylene

Due to the fact that polypropylene adapts well to the injection moulding process, it can be used to make incredibly thin layers of plastic. It is very suited to applications such as:

- **Hinges on medication pots**
- **Lids on shampoo bottles**
- **And other containers that will be bent and manipulated a lot and mustn't break.**



Polypropylene can even withstand twisting motions of up to 360 degrees without snapping and is very hard to snap as a result. It is relatively low cost and straightforward to produce and readily available in multiple countries and communities. High chemical and fatigue resistance add to its durability and versatility as a packaging material and option for hinges and bottle tops attached to the main bottle by a thin layer of plastic. It can offer great versatility in colour, as it can be produced as an opaque or transparent thermoplastic and used when some transfer of light is desired. Its lighter density allows it to be used in applications where weight saving has to be a key consideration.

Polypropylene is waterproof and extremely resistant to moisture absorption, which adds to its packaging benefits and flexibility as a packaging material. Its semi-crystalline nature offers high flexural strength too, making it resilient to general wear and tear and ideal for items that must undergo higher levels of physical stress. It is also resilient against mildew, mould, rot and bacteria.

2.7.6 Polypropylene disadvantages

One key disadvantage when it comes to the wider environment and preservation of global resources is the fact that polypropylene is not conducive to being easily recycled. When it burns, it produces a chemical change that cannot be reversed. If you tried to re-heat polypropylene that has already been melted and formed, it would simply burn, rather than liquify for a second time. Other recycling or re-conditioning methods must be considered, at a significantly higher cost.

This low melting point also means that polypropylene is highly flammable and limited in its ability to withstand higher temperatures and it is also susceptible to UV degradation and oxidation. Finally, while polypropylene's glossy finish makes it aesthetically pleasing and easy to handle, this exact same property also makes it harder to bond to other surfaces and materials, such as paints and glues. Alternative bonding methods, such as welding must be introduced when using polypropylene to make a joint or hinge.

2.7.7 Is polypropylene safe?

While some potentially toxic chemicals are used in the manufacture of polypropylene, it is generally regarded as a safe finished product and is commonly used in plastic packaging that includes food and drink products and medical supplies. While it is not considered very eco-friendly, due to difficulties in the recycling process, items made from polypropylene can be re-used safely and are strong enough to resist normal wear and tear for several uses. Another point that points towards the safety of polypropylene is that the thermoplastic is frequently used to make

- **Disposable cups**
- **Plates**
- **bottles**
- **Cutlery**
- **safely contain, package and protect hot beverages and warm foods.**



2.8 High-Density polyethylene (HDPE)

High-Density polyethylene, aka HDPE, is a trendy thermoplastic material made from petroleum. HDPE is known for its excellent tensile strength, high melting point, low cost, and good impact strength. HDPE can be used in various applications like milk jugs, plastic bottles, beach bottles, cutting boards, and piping's because of such impressive properties.

HDPE is also very easy to fabricate and weld using any standard thermoplastic welding equipment, mainly available in sheet and rod forms.

Easy welding properties and versatility in its nature make HDPE the right choice for manufacturing larger plastic products like water tanks and chemical tanks, difficult to manufacture without using high-graded plastic material.

HDPE is also available in multiple additional grades. It can be utilized to manufacture various products from many categories like FDA compliant for cutting boards, disinfectant for medical facilities, woodgrain texture for the outdoor environment, etc.

2.8.1 HDPE Properties

1. Enhanced Stiffness HDPE:

Conventionally, used for applications that are supposed to last for a long time (at least 8 to 10 years). It offers supreme flatness and consistency and is 25% thicker compared to the original HDPE material.

2. UV Stabilized grade HDPE:

It does exactly what it sounds like. Typically, 25% to 30% lighter than the original HDPE is mostly utilized to resist UV and water exposure.

Those properties and availability in the sheet form make this HDPE a prime choice for manufacturing marine products, water tanks, playgrounds, outdoor cabinetry, etc.

3. Cutting Board grade HDPE:

This HDPE Material is extensively used for manufacturing food-related products, mostly in food storage space. It meets all the FDA requirements to directly or indirectly contact food and related items. It is resistant to hot water, and cleaning chemicals come with no absorption ability for moisture. Those properties make it perfect for F&B Sector.

4. Antimicrobial HDPE:

Antimicrobial HDPE has a unique property of resistance towards bacteria, algae, and fungi. What makes it resistant to them is its unique molecular configuration.

This HDPE is bonded at a molecular level, so it retains its usefulness for a prolonged period of time. It also works and blends well with woodworking tools, which makes it strong and durable. The durability makes this HDPE a good choice to be implemented in hospitals, clinics, nursing homes, medical carts, etc. The unique property of resistance to bacteria and algae is helping this HDPE material steadily increase its presence in the retail industry, where showcasing and storing products for a long time is a crucial part of their business.

5. Engravable HDPE :

The UV-stabilized HDPE is durable, weather-resistant, and available in sheet form, which easily blends with machines. This HDPE material comes in multiple color options.

The colors are reliable, long-lasting, and don't need additional painting or refinishing. That color holding nature makes it applicable to produce carnival equipment, number plates, toys, and children's furniture.

6. WoodGrain HDPE :

WoodGrain HDPE is known for being easily operable with basic woodworking equipment and negligible maintenance. It comes with an authentic woodgrain color and is flexible enough to be shaped for desired objects.

Colors can be changed on every sheet. No worries about rotting, chipping, and eliminating. Suitable for outdoor applications construction and related products, furniture, and playgrounds.



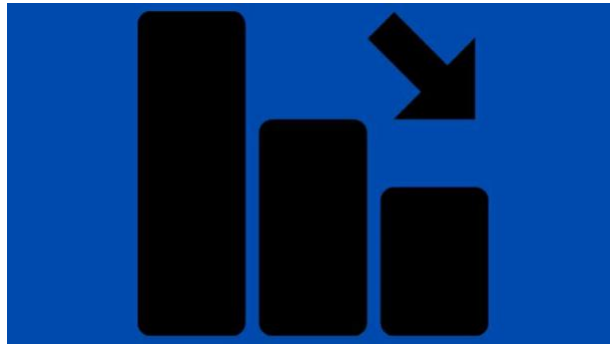
2.8.2 Advantages of HDPE Material



High-Density Polyethylene (HDPE) has quite a few benefits for both manufacturer and buyer. Let's discuss some of them.

1. HDPE is corrosion-resistant, making it suitable to produce essential public infrastructure like underground piping as it wouldn't rust by weather effects and is long-lasting. Sterilization of HDPE makes it perfect for food and beverage storage containers.
2. Easy malleability and moldability is another standout feature for HDPE material as it increases its applications substantially. The material is rigid and has an impressive melting point of 210 to 270°C. However, once it melts, it can be utilized in producing a lot of products like water tanks, cutting boards, detergent bottles, shampoo bottles, pilings, etc.
3. HDPE material has a fabulous strength to density ratio of 0.93 to 0.97 g (it might not seem a lot compared to LDPE, but there's a catch). When seen under a microscope, HDPE molecular structure differs from LDPE. It has a linear structure with little branching, which results in a stronger molecular structure and greater tensile strength. That's the reason why a 60 grams HDPE cup can hold about a gallon of liquid without any bending.
4. HDPE is an easily recyclable material. Recyclability is an essential factor, especially these days when the global carbon footprint is on the rise. Recycling HDPE can save up to 50% of your material cost, and no worries about quality as recycled HDPE material is said to be as good as "virgin" material.

2.8.3 Disadvantages of HDPE Material



Although there are very few HDPE disadvantages, I still would like to shed some light on them.

- **High flammability.**
- **Considerably, high thermal expansion.**
- **Non-resistant to chlorinated hydrocarbons.**
- **Non-resistant to oxidizing acids.**

2.8.4 Applications

Fantastic mechanical properties make HDPE suitable for many high-end applications across various industries.

- Consumer Goods
- Packaging Applications
- Fibers and Textiles

1. Consumer Goods:



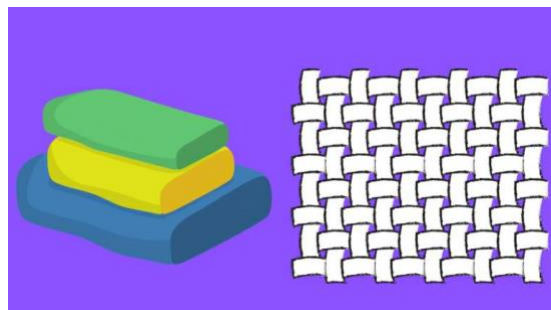
HDPE's inexpensiveness and easy process ability with injection molding and extrusion molding make it a highly usable consumer goods application.

2. Packaging Applications



Impact strength and reasonable chemicals resistance help HDPE polyethylene with applications in industrial bulk containers, jerry cans, drums, fruit juices, crates, bottles for keeping liquid foods, etc.

3. Fibers and Textiles:



High tensile strength and easy processability boost HDPE's competitiveness for manufacturing products like industrial and decorative fabrics, fishing and sports net, ropes, nets, etc .

Other applications include fuel tanks – the automobile industry, wires, and cables, pipes for drainage, industrial uses, cable protection, large inspection chambers, gas, water, sea downspout, etc.

2.9 Effect Addition Nanoparticles On The Properties Of (PP/Nano ZnO)

Semi crystalline polypropylene (PP), a useful and Versatile commodity thermoplastic, could be the Most popular matrix for Nano composites study. To Date, PP is widely used in packaging, automotive And aerospace industries. Among the main reasons For the popularity of PP are its structural flexibility, High isotacticity, good mechanical performance, Narrow molecular weight distribution and good op-Tical translucence [42-43]. In recent years, the incorpo-Ration of nanoparticles in PP matrix has generated Intense enthusiasm among polymer scientists due to Its promising industrial applications in many facets Of technology. Nano composites with good filler dis-Persion offer significant improvements in mechanical, thermal, electrical, optical and physico-chemical properties even at relatively low filler content [45-44].

2.9.1 CRYSTAL STRUCTURE OF ZnO

Crystalline ZnO has a wurtzite (B4) crystal structure at ambient conditions. The ZnO Wurtzite structure has a hexagonal unit cell with two lattice parameters, a and c, and Belongs to the space group of C46V or P63mc. Figure 4 clearly shows that the structure is Composed of two interpenetrating hexagonal closed packed (hcp) sublattices, in which Each consist of one type of atom (Zn or O) displaced with respect to each other along The threefold c-axis. It can be simply explained schematically as a number of alternating Planes stacked layer-by-layer along the c-axis direction and composed of tetrahedrally Coordinated Zn²⁺ and O²⁻. The tetrahedral coordination of ZnO gives rise to the non-Centrosymmetric structure. In wurtzite hexagonal ZnO, each anion is surrounded by four Cations at the corners of the tetrahedron, which shows the tetrahedral coordination and Hence exhibits the sp³ covalent-bonding.

2.9.2 NANOPARTICLES OF ZnO

Due to its vast areas of application, various synthetic methods have been employed to Grow a variety of ZnO nanostructures, including nanoparticles, nanowires, nanorods,

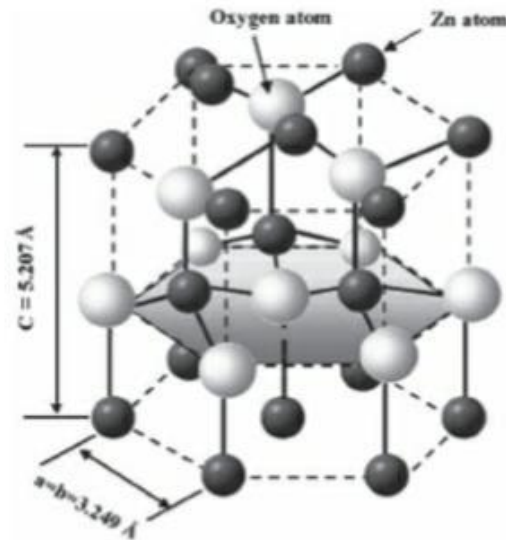


Figure (3) :- The hexagonal wurtzite structure model of ZnO. The tetrahedral coordination of Zn-O is shown. O atoms are shown as larger white spheres while the Zn atoms are smaller brown spheres.

Nanotubes, nanobelts, and other complex morphologies [46–47]. In the present chapter, We mainly focus on ZnO nanoparticles synthesized by either the sol–gel method (solution method) or the hydrothermal method. As the solution method presents a low cost And environmentally friendly synthetic route, most of the literature for ZnO nanoparticles is based on the solution method. In addition, synthesis of ZnO nanoparticles in thecSolution requires a well defined shape and size of ZnO nanoparticles. In this regards, Monge et al. [48] reported room-temperature organometallic synthesis of ZnO nanoparti-Cles of controlled shape and size in solution.

2.9.3 Interaction and risk

Zinc oxide is a stable, non-flammable compound that does not show any incompatibility with other chemical compounds, but when heated, it emits toxic fumes. The compound is not toxic or dangerous when ingested or in contact with the skin or eyes, however the compound presents an inhalation hazard. Harmful concentration of particles in the air can be reached quickly, especially for zinc oxide particles.

2.9.4 Applications

1- Medicine

Zinc oxide is a product widely used topically in dermatology for skin care. In the United States, it is the main ingredient in sunscreens due to its reflective properties. Zinc oxide is one of the safest ingredients to protect the skin from the harmful effects of UV rays. Ultraviolet rays penetrate the skin and damage tissues, accelerating the aging process and drying the skin. These rays also increase the risk of skin cancer. Sunscreens containing zinc oxide filter UV rays, preventing them from penetrating the skin and causing cell damage. Zinc oxide is also effective in healing the skin. It can be used to treat wounds, reduce sensitivity associated with sunburn, and soften chapped skin. People with zinc deficiency tend to experience slow wound healing cycles. When zinc oxide is applied to the wound area, it provides the body with the extra zinc it needs to repair skin cells. Zinc oxide helps keep the wound area moist and clean. Lotions and creams containing zinc oxide are effective skin care products. Zinc oxide can be applied to prevent excess oil from forming on the surface.

2- Rubber industry

More than 50% of zinc oxide is used in the rubber industry. Through the vulcanization process, the finish has high tensile strength, resistance to swelling and abrasion, and is flexible in a wider temperature range. In its simplest form, vulcanization is produced by heating rubber with sulphur. The two components that play an important role in the chemistry of vulcanization are known as "doping", and they are zinc oxide and citric acid. These compounds react together and with accelerators to form the zinc sulfide complex, which in turn is the main intermediate in adding sulfur to elastic elastomers and creating sulfur bonds to produce items such as tires.

3- Dyes and paints

Along with linseed oil (a drying oil useful as a compound), zinc oxide has been used as a pigment since the 18th century, leading to the rapid expansion of the European paint industry. Basic white pigments include zinc oxide, zinc sulfide, lithopone, and titanium dioxide.

4- Piezoelectric

Zinc oxide (ZnO) is an interesting substance with regard to conductivity. It crystallizes in the structure of wurtzite, and its union is a mixture of ionic and covalent. Monocrystals of high purity are insulators. Zinc oxide is the most piezoelectric of all materials and is widely used as a transducer in electronic devices.



Reference

- [1] Paul, D.R. (1989) Control of phase structure In polymer blends, in Functional Polymers (eds D.E. Bergbreiter and C.R. Martin), Plenum Press, New York, p. 1–18.
- [2] Scobbo, J.J, Jr and Goettler, L.A. (2003) Applications of polymer alloys and blends, In Polymer Blends Handbook (ed. L.A. Utracki), Kluwer Academic Publishers, pp. 951–976.
- [3] White, J.L. and Bumm, S.H. (2011) Polymer Blend compounding and processing, in Encyclopedia of Polymer Blends (eds A.I. Isayev and S. Palsule), Wiley-VCH, Weinheim, pp. 1–26.
- [4] ang, R., Quirk, R.P., White, J.L., and Min, K. (1991) Polycarbonate-polystyrene block Copolymers and their application as Compatibilizing agents in polymer blends. *Polym. Eng. Sci.*, 31, 1545.
- [5] George, S.M., Puglia, D., Kenny, J.M., Causin, V., Parameswaranpillai, J., and Thomas, S. (2013) Morphological and Mechanical characterization of Nanostructured thermosets from epoxy and Styrene-block-butadiene-block-styrene Triblock copolymer. *Ind. Eng. Chem. Res.*, 52 (26), 9121–9129.
- [6] Chen, C.C. and White, J.L. (1993) Compatibilizing agents in polymer blends: Interfacial tension, phase morphology, and Mechanical properties. *Polym. Eng. Sci.*, 33, 923–930.
- [8] Y. Roiter and S. Minko, AFM Single Molecule Experiments at the Solid-Liquid Interface: In Situ Conformation of Adsorbed Flexible Polyelectrolyte Chains, *Journal of the American Chemical Society*, vol. 127, iss. 45, p. 15688-15689 (2005)
- [9] McGraw-Hill Encyclopedia of Science & Technology, 10th Edition, Volume 14 (PLAS-QUI), page.162
- [10] McCrum N. G., Buckley C. P., Bucknall C. B., Principles of Polymer Engineering, Oxford University Press, 1997, p1.
- [11] Painter P. C., Coleman M. M., Fundamentals of Polymer Science: an Introductory Text, CRC Press, 1997, p1.
- [12] The book "Chemistry in Our Lives", authored by "Dr. Adel Ahmed Jarrar", is published by Dar Al-Diaa for Publishing and Distribution.
- [13] A.F. JOHNSON. "Uses and applications of polymers". in book of Polymer Reactor Engineering (pp.1-43), printed by Springer Science+ Business Media, B.V. doi:10.1007/978-94-011-1338-0.

- [14] "The Basics: Polymer Definition and Properties", plastics.americanchemistry.com, Retrieved 13-7-2018. Edited.
- [15] P. Potschke and D. R. Paul, " J. Macromol. Sci. C43, 87 (2003).
- [16] J. Lyngaae-Jørgensen, K. Lunde Rasmussen, E. A. Chtcherbakova, and L. A. Utracki, Polym. Eng. Sci. 39, 1060 (1996).
- [17] D Boury and B. D. Favis, J. Polym. Sci., Part B: Polym. Phys. 36, 1889 (1998).
- [18] P. T. Hijetaoja, R. M. Holsti-Miettinen, J.V. Sepälä, and O. T. Ikkala, " J. Appl. Polym.Sci. 54, 1613 (1994).
- [19] I. Fortelny, D. Michálek, J. Hromádka, and F. Lednický, J. Appl. Polym. Sci. 81,570 (2001).
- [20] R. Fayt and P. Teyssie, Polym. Eng. Sci. 30, 937 (1990).
- [21] Van Puyvelde, S. Velankar, and P. Moldenaers, Curr. Opin. Colloid Interface Sci. 6,457 (2001).
- [22] I.Fortelny, J. Macromol. Sci.-Phys. B39, 67 (2000).
- [23] J.F. Palierne and F. Lequeux, J. Non-Newtonian Fluid Mech. 40, 289 (1991).
- [24] su Ping Lyu, T. D. Jones, F. S. Bates, and C. W. Macosko, Macromolecules 35, 7845 (2002).
- [25] Fortelny and A. Zivny, Polymer 41, 6865 (2000).
- [26] I. W. Carter, J. G. Hendricks and S. Bolley, Patent 2,531,396, November 28, 1950
- [27] S. Fujiwara and Sakamoto, Japanese Patent Application 109,998, September 29, 1976
- [28] A. Usuki, Y. Kojima, M. Kawasumi, A. Okada, T. Kurauchi and O. Kamigaito, "Synthesis of ny-Lon 6-clay hybrid", Journal of Materials Re-Search, Vol. 8, no.5, 1993 pp.1179
- [29] O. Okada, M. Kawasumi, A. Usuki, Y. Kojima and O. Kamigaito, "Swelling behaviour of montmo-Rillonite cation exchanged for ω -amino acid By ϵ -caprolactam", Journal of Materials Re-Search, Vol. 8, no.5, 1993 pp.1174
- [30] G. T. Schueneman, A. J. Lesser, T. R. Hobbs and C.M. Novak, "Evaluation of short term-high Intensity thermal degradation of graphite fiber Reinforced laminates via ultrasonic spectroscopy" Journal of Polymer Science Part B: Polymer Physics, Vol. 37, no. 18, 1999 pp.2601

- [31] Y. Kojima, A. Usuki, M. Kawasumi, A. Okada, Y. Fukushima, T. Kurauchi, O. Kamigaito, Mechanical properties of Nylon 6–clay hybrid, *Journal of Materials Science*, Vol. 6, no. 5, 1993 pp. 1185
- [32] Y. Kojima, A. Usuki, M. Kawasumi, A. Okada, T. Kurauchi and O. Kamigaito, “One-pot synthesis of Nylon-6–clay hybrid”, *Journal of Polymer Science A*, Vol. 31, no. 4, 1993 pp.1755
- [33] K. E. Strawhecker and E. Manias, “Structure And properties of poly(vinyl alcohol)/ Na⁺ Montmorillonite nanocomposites”, *Chemistry Of Materials* Vol. 12, no. 10, 2000 pp. 2943
- [34] M. Ganter, W. Gronski, P. Reichert and R. Mul-Haupt, “Rubber nanocomposites: morphology And mechanical properties of BR and SBR vulcanizates reinforced by organophilic layered Silicates”, *Rubber Chemistry and Technology*, Vol. 74, 2001 pp. 806
- [35] X. Zheng and C. A. Wilkie, “Flame retardancy of Polystyrene nanocomposites based on an oli-Gomeric organically-modified clay containing Phosphate”, *Polymer Degradation and Stability*, Vol. 81 2003 pp. 539
- [36] J. Li, L. Zhao and S. Guo, “Ultrasonic preparation of polymer/layered silicate nanocomposites During extrusion”, *Polymer Bulletin* Vol. 55, 2005 pp. 217
- [37] R. Stephen, C. Ranganathaiah, S. Varghese, K. Joseph and S. Thomas, “Gas transport Through nano and micro composites of natural Rubber (NR) and their blends with carboxylated Styrene butadiene rubber (XSBR) latex membranes”, *Polymer*, Vol. 47, 2006 pp. 858
- [38] S. Wei, G. Shiyi, F. Changshui, X. Dong and R. Quan, “Poling and properties of nano-composite thin film PT/PEK-C *Journal of Materials Science*, Vol. 34, no. 24, 1999 pp. 5995
- [39] "British Plastics Federation." Polypropylene (PP). N.p., n.d. Web. 13 Sep. 2011. <<http://www.bpf.co.uk/plastipedia/polyMers/pp.aspx>>.
- [40] Fortilene PP General Properties, supplier technical report Solvay Polymers, Inc., 1989 <https://adrecoplastics.co.uk/polypropylene-uses>.
- [41] E. Calahorra, M. Cortazar. And C. M. G~mnan. *J. PolymSci, Polym Lett.*, 23, 257 (1985) creativemechanisms.com/blog/all-you-need-to-know-about-polypropylene.-part-
- [42] Reddy C. S. and Das C. K., “Polypropylene-Nano-Silica-filled composites: Effects of epoxy-resin-Grafted nanosilica on the structural, thermal, and dynamic mechanical properties”, *J. Appl. Polym. Sci.*,102 (2006), 2117-2124.

- [43] Lin O. H., Akil H. M., and Ishak Z. A. M., “Characterization and properties of activated nanosilica/Polypropylene composites with coupling agents” *Polymer Composites* (2008), In Press.
- [44] Leng P. B., Akil H. M. and Lin O. H., “Thermal Properties of microsilica and nanosilica filled polyPropylene composite with epoxy as dispersing aid”, *J. Reinf. Plast. Compos.*, 26 (2007), 761-770.
- [45] Jordan J., Jacob K. I., Tannenbaum R., Sharaf M. A. and Jasiuk I., “Experimental trends in poly-Mer nanocomposites – A review”, *Mater. Sci. Eng. A*, 393 (2005) 1-11.
- [46] G. Q. Ding, W. Z. Shen, M. J. Zheng, and D. H. Fan, *Appl. Phys. Lett.* 88, 103106 (2006).
- [47] Polarz, A. V. Orlov, F. Schüth, and A. H. Lu, *Chem. Eur. J.* 13, 592 (2007).
- [48] M. Monge, M. L. Kahn, A. Maisonnat, and B. Chaudret, *Angew. Chem. Int. Ed.* 42, 5321 (2003).
- [49] In 2017, SitiNikmatin, et al, studied Physical, thermal, and mechanical properties of polypropylene composites filled with rattan nanoparticles.
- [50] Harekrushna Sutar^{1*}, Rabiranjana Murmu¹, Chiranjit Dutta¹, Mutlu Ozcan² And Subash Chandra Mishra³.
- [51] Isabella L. M. Costa¹ · Noelle C. Zanini² · Daniella R. Mulinar.