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Evaluation of Modified Nanoparticles' Effects on Polypropylene Composites

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Abstract

Numerous sectors use nanoparticles and nanocomposites in a range of applications, including medicine, textiles, cosmetics, agriculture, optics, food packaging, optoelectronics, semiconductors, aerospace, building materials, and catalysis. Polymeric nanocomposites, which combine organic polymers with inorganic nanoparticles, are a novel family of materials that perform better than their microparticle counterparts. They should therefore enhance the field of engineering applications. A polymer matrix's characteristics can be drastically changed by the addition of inorganic nanoparticles. Nanoparticle reinforced polymer flexible composites, such as titanium dioxide ($nTiO_2$*) and zinc oxide (nZnO), open up new design possibilities with superior mechanical and chemical properties. This study examined the mechanical characteristics, morphological and thermal properties of composites made of polypropylene (PP) and filled with *$nTiO_2$* and nZnO. There were between 1 and 5 weight percent of nanoparticles in the matrix. Prior to melt mixing, silane and maleic anhydride-grafted styrene, ethylene butylene styrene (SEBS-g-MA) were applied to nanoparticles to improve fine dispersion and surface adherence. A twin-screw extruder and a heat press were used to create PP/nanoparticle nanocomposites in order to study the impact of modified and unmodified nanoparticles at various concentrations on the mechanical characteristics, morphological and thermal properties. Since nanoparticles have a rigid structure, all tensile properties-including yield strength, tensile strength, and tensile modulus-have increased while impact strength and elongation at break have decreased. Because of this, nanocomposites containing *$nTiO_2$* exhibited more elongation than those containing nZnO, despite *$nTiO_2$* having a higher hardness than nZnO. In comparison to SEBS-g-MA, the presence of silane in the PP/*$nTiO_2$* nanocomposite was more productive. The tensile characteristics of silane-modified *$nTiO_2$* nanocomposites, however, were higher than those of silane-modified nZnO nanocomposites. In this instance, the more refined structure of *$nTiO_2$* with PP has been induced, which ensures the outcome of reduced elongation at break. This is likely due to the superior compatibility of *$nTiO_2$* with silane. Thermal analysis was also carried out to determine the melt temperature, crystallization temperature, and crystallinity level.*

Keywords: Nanocomposites, Polypropylene, Nano-Tio_2, Nano-ZnO, Morphology, Mechanical Properties.

INTRODUCTION

Due to their favorable physical and chemical characteristics, as well as technological advancement, plastic materials are being used more and more frequently. Polymers have these benefits, which are why industrial applications like them. Reinforcements made of glass fiber, graphite, or metal oxide are applied to polymer surfaces to give products greater functional advantages than traditional polymers. These substances, known as composites, have begun to take the place of metal,

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ceramic, and glass components. They can be used in many different industrial contexts.

[1, 2]. Nanocomposite materials are used frequently and their production rates are increasing as nanotechnology advances. Nanocomposite is one of the phases in a multiphase material system with a 100 nm size. Because the filler particles in nanocomposite materials are so minute, they have a high area-to-volume ratio. The advantages of nanocomposite include its ability to resist chemical corrosion, mechanical strength, ease of production, and low weight. These fantastic assets have expanded the range of their applications [3–5].

Nanocomposite materials can be produced using a wide variety of techniquesThe most popular ones include in-situ polymerization, melt blending, and solution mixing. Melt mixing is the best technique. The process for creating polymer nanocomposites is melt mixing. Initially, the polymer is melted and combined with the required amount of nanoparticles using an extruder. As an alternative, the polymer and reinforcing elements are dry mixed before being heated in a mixer and sufficiently sheared to create the necessary polymer nanocomposites. In comparison to in situ polymerization or polymer solution mixing, melt blending has many advantages. Melt blending doesn't use organic solvents, making it environmentally friendly. The melt blending technique has gained popularity because it has the potential for use in industrial applications [6]. Compared to other methods, this one is also more cost-effective [7]. Such goods has qualities like antibacterial, high mechanical, high UV, and nonflammability [8, 9].

Because of their great qualities, including as flexible structures, simple manufacturing processes, superior shape, and mechanical behaviors, polymers are frequently employed in the production of nanocomposite materials [4, 10, 11]. Following various studies on nanocomposites that concentrated on the polymer to be used as the matrix phase, there is a noticeable improvement in the quality of the polymer even when very modest amounts of nanoparticles are introduced. The area-to-volume ratio of reinforcing nanoparticles is quite high and they are nanoscale, allowing for extensive phase contact [12]. Nanocomposites with polymer matrixes are more desirable than those with metal or ceramic matrixes [13]. Melt fiber spinning is a method used to create polymer nanocomposites. Nanoparticles are incorporated into the polymer matrix using this approach. Polymer matrix nanocomposites can be used to create composites with greater strength and useful features [4, 14, 15].

One of the most significant commercial polymers is polypropylene. It is widely utilized in the production of ordinary plastics, cars, cables, and packaging, among other things. [16–18]. At room temperature, it possesses excellent thermal and tensile qualities. Furthermore, it has a good chemical resistance rating [2, 19]. Polypropylene (PP) is used in the textile industry to give textile goods functionality. Its fiber structure appears to be flat and waxy. The manufacture of carpets, textiles, and technical textile goods all require polypropylene fibers. They are preferred due to its superior strength, low cost of production, and chemical resistance. In Table 1, the physical characteristics of polypropylene are listed.

Table 1. Characteristics of Polypropylene.

Properties	Value
Melting point (°C)	160–175
T_g (°C)	40
Density (gr/cm^3)	0.9
Degradation temperature (°C)	328–410

One of the key basic materials used in the textile industry is fiber, which can be made from a variety of substances. Although cotton fiber, which is made from natural sources, is the most widely used fiber in industry today, alternative fibers are gaining popularity. One of these types of fibers is polymer-based, and it is reinforced with reinforcing elements to produce practical textile goods. The major benefits of fiber matrix polymer nanocomposites are the reduction of production issues and the development of novel goods [20, 21].

It is crucial to keep in mind that nanoparticles give composite materials their unique qualities, which are subsequently enhanced and reinforced by reinforcing materials to make composites more durable and functional. To develop the mechanical properties of polymers, a variety of inorganic nanoparticles, including TiO_2, SiO_2, $CaCO_3$, and ZnO, are being employed [12, 22]. The primary benefit of using inorganic filler in polymer composites is cost reduction, but it can also improve the performance of mechanical qualities including rigidity, toughness, and dimensional stability [23]. To create a material with excellent qualities, numerous researchers in this area mixed zinc oxide with polymer composites. Although ZnO was added to polypropylene composite, Wacharawichanant et al reported that the tensile strength did not significantly enhance [24]. Similar results were found in related comprehensive tests carried out by other researchers, including a decline in the composite's elastic modulus, yield strength, and tensile strength [25]. A low value of tensile strength was similarly produced when $CaCO_3$ and other inorganic fillers were included into polypropylene composites [26]. TiO_2 has attracted a lot of interest among inorganic fillers since it is non-toxic. The chemical inertness, affordability, capacity to filter UV light, and high hardness of TiO_2 are some of its additional benefits. To enhance the physical and mechanical qualities of the composite, a number of researchers have looked into the usage of TiO_2 with PP. As a result, adding TiO_2 to PP composite also significantly improves its tensile strength [27–31].

Because of their enhanced mechanical strength and design flexibility in addition to their increased chemical, electrical, and optical properties, polymers reinforced with nano metal oxides are growing in popularity every day [32]. The characteristics of the nano composites may be weakened by agglomeration of the nanoparticles, on the other hand. Dispersant and coupling agents are employed in order to solve this issue [12]. Another issue that is frequently experienced is the impact strength diminishing as a result of the inorganic material's rigidity. Elastomeric natural materials are used by researchers to make composites more durable [33]. In this study, the mechanical characteristics, morphological and thermal properties of polypropylene reinforced with nanoscale titan dioxide and zinc oxide were examined. Improved tensile properties were obtained by using silane and SEBS-g-MA to increase the metal oxide's surface adherence and dispersion.

EXPERIMENTAL

The Nano Particles' Ingredients and Preparation

PP was bought from Lotte Chemical Titan Malaysia in pellet form, with a melt flow index of 14g/min and a density of 0.900g/cm3. ZnO and TiO2 were used as nanomaterials by the Chinese Nabond Company. For better surface adhesion and dispersion, the nanoparticles were coated with vinyltrimethoxysilane (VTMS, Aldrich) and SEBS-g-MA (FG1901X, Kraton, Shell Company).

They used SEBS-g-MA first, then silane, to cover the nano metal oxide particles. The coupling agent feature of SEBS-g-MA was anticipated to be more successful when it was coated onto the powders and employed as a compatibilizer. The SEBS-g-MA coated particles in the polymer matrix were better dispersed due to the silane coating. By melting together SEBS-g-MA and nanoparticles that had been dissolved in toluene over the course of 48 hours at 25°C, coating was applied. After drying the mixture at 50°C for 8 hours, SEBS-g-MA coated nano particles were ground. In order to apply the silane coating, a solution of 96% pure alcohol, 4% distilled water, and 1% silane was prepared. After three hours of mixing, SEBS-g-MA coated nanoparticles were gradually added to this solution. Following an eight-hour drying period at 50°C, the mixture was ground.

The nanocomposite samples were created using two types of compatibilizers (SEBS-g-MA and silane) and a predetermined amount of PP, along with variable amounts of nanoparticles (1, 3, and 5 wt%) and a fixed amount of 3 wt% of the nanoparticles. Nanocomposites that were both uncoated and coated have the following coding: For uncoated, PP/1 wt% $nTiO_2$ (marked as $PP/1UnTiO_2$), $PP/3UnTiO_2$, $PP/5UnTiO_2$ and PP/1UnZnO, PP/3UnZnO, PP/5UnZnO and for coated, PP/silane coated 1 wt% $nTiO_2$ (indicated as $PP/1SnTiO_2$), $PP/3SnTiO_2$, $PP/5SnTiO_2$ and PP/SEBS-g-MA coated 1 wt% nZnO (designated as PP/1SEnZnO), PP/3SEnZnO, PP/5SEnZnO.

The KraussMaffei Berstorff GmbH, Germany-based ZE-25A UTX twin-screw extruder, which has an L/D ratio of 44, was loaded with PP and nanoparticles. The operating temperature was between 180°C and 220°C, and the screw rotated at a speed of 100 rpm. The extruded strands were ground into tiny pellets, and the resulting pellets were employed in a hot press machine to create thin plates.

Characterizations

Fracture surfaces and nanoparticle dispersion were examined using TEM and SEM. We examined the fracture surfaces of nanocomposites using a SEM, JSM-6360LV from JEOL, Tokyo, Japan. In advance of imaging, the samples were gold-coated. The dispersion of PP and nanoparticles was assessed by transmission electron microscopy (TEM, JEM-2100F, JEOL).

The tensile test was measured with a Shimadzu Universal Testing Machine (type AG-1, Japan). Samples were 50 mm in gauge length, 10 mm broad, and 2 mm thick. We measured the yield strength, tensile strength, tensile modulus, and elongation at break at a crosshead speed of 10 mm/min. Using notched specimens and a 5.4 J pendulum hammer, the Izod impact test was carried out on a Zwick impact test machine. Five repeat tests were undertaken to get an average value for each sample during all experiments in accordance with ASTM-D 638-03 standard [34].

Differential Scanning Calorimetry (DSC)

A nitrogen environment was utilized to study the melting and crystallization behaviors using differential scanning calorimetry (DSC, Perkin Elmer DSC-7).

The samples (5-8 mg) were heated at a rate of 10°C/min from 40°C to 180°C, maintained there for 5 min, and then cooled back to 40°C at a rate of 10°C/min for 5 min. After that, a second heating cycle was carried out in order to erase the samples' thermal history. The melting temperature (Tm), the crystallization temperature (Tc), and the degree of crystallization (Xc) were all measured. The fusion enthalpy of the 100% crystalline phase of PP was used as 209 J/g to calculate the degree of crystallization of the blends [35].

FINAL RESULTS AND DISCUSSION

Mechanical Properties

The mechanical properties of the polymer matrix are improved by metal oxide nanoparticles [36]. Figure 1 (a) and (b) illustrates the variation of yield strength and tensile strength of PP, PP/uncoated $nTiO_2$ ($PP/UnTiO_2$), PP/uncoated nZnO (PP/UnZnO), PP/silane coated $nTiO_2$ ($PP/SnTiO_2$), PP/silane coated nZnO (PP/SnZnO), PP/SEBS-g-MA coated $nTiO_2$ ($PP/SEnTiO_2$) and PP/SEBS-g-MA coated nZnO (PP/SEnZnO) nanocomposites with nano-metal oxide contents varying from 0 to 5 wt%. It can be seen that the yield strength and tensile strength increased when the nano-metal oxide content was increased up to 3 wt% (yield strength increased by 16.9% and tensile strength increased by 20% for $PP/UnTiO_2$ nanocomposites and yield strength increased by 6% and tensile strength increased by 12% for PP/UnZnO nanocomposites compared to PP, respectively), and then decreased by 5 wt%. Since the agglomerated nanoparticles are quickly separated from the polymer in this situation, neither the yield strength nor the tensile strength of the material are ultimately affected by any portion of the external load. Zaman et al.'s findings were supported [37]. Silane and SEBS-g-MA enabled the modification of $PP/nTiO_2$ or PP/nZnO nanocomposites to improve the interfacial bonding between nano-metal oxide particles and PP. In comparison to $PP/UnTiO_2$ or PP/nZnO nanocomposites, the presence of silane in $PP/nTiO_2$ or PP/nZnO nanocomposites considerably enhanced the interfacial bonding between nano-metal oxide and PP. The highest yield strength and tensile strength of $PP/SnTiO_2$ and PP/SnZnO nanocomposite, which were roughly 32%, 31%, and 20%, 19% higher than

PP matrix, were 28.9, 33.4 MPa and 26.3, 30.3 MPa, respectively, at 3 wt% of nano-metal oxide content. The maximum yield and tensile strength were produced by PP/SnTiO$_2$, which was followed by PP/SnZnO. The stronger distribution that the compatibilizer creates and improved solid-state adhesion, which can transfer more stress from the matrix to the dispersion phase, are two ways that the compatibilized system's strength has increased. Although PP/SEnTiO$_2$ or PP/SEnZnO contains the same amount of nano-metal oxide as PP/SnTiO$_2$ and PP/SnZnO, it has a lower strength due to the presence of the elastomeric phase of SEBS-g-MA.

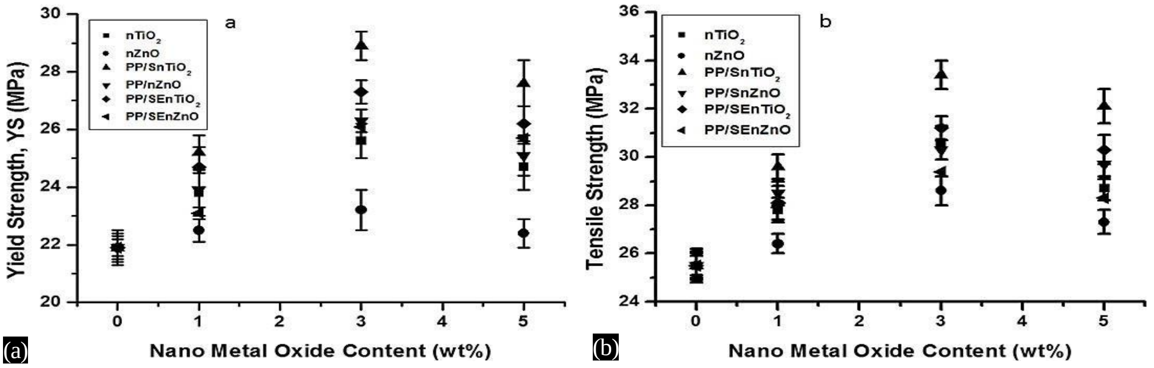
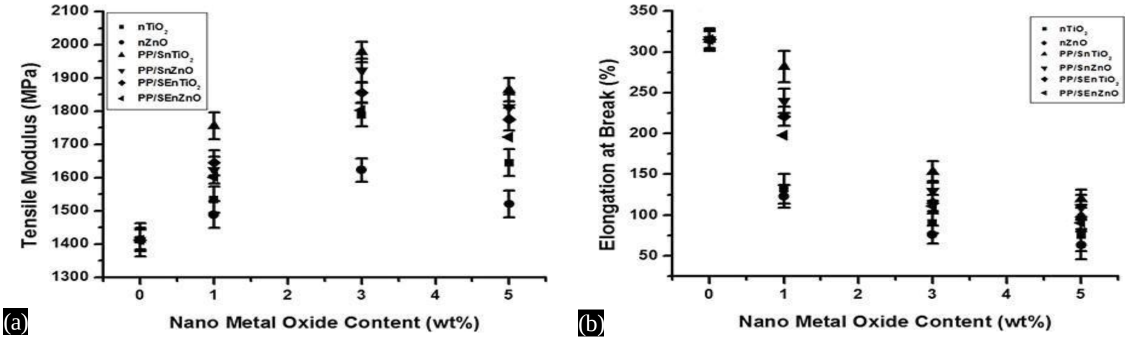


Figure 1. Tensile characteristics of PP nanocomposites reinforced with nTiO$_2$ and nZnO; (a) yield strength; and (b) tensile strength.

Tensile modulus and elongation at break of the nanocomposites as a function of nano-metal oxide content are shown in Figures 2(a) and (b). Tensile modulus increased steadily while elongation at break decreased progressively with the addition of nano-metal oxide. Through modulus development, the stress may be efficiently transferred from the PP to the nano-metal oxide particles. On the other side, the fact that elongation decreased when nano-metal oxide was added suggested that the material might interfere with or distort PP. This interference was caused by the PP being mechanically restrained and by physical interaction. Silane increased the tensile modulus, particularly when there was 5% nano-metal oxide content. The tensile modulus was enriched as a result of the silane-coated nano-metal oxide particles' fine dispersion and the PP and nano-metal oxide particles' strong adhesion, as will be discussed later. On the other hand, SEBS-g-MA nanocomposites produced strong tensile moduli with a nano-metal oxide level of 5 weight percent. However, according to the results of the tensile test, the nZnO particles coated on SEBS-g-MA were not disseminated as finely as nTiO$_2$ particles. Due to its rigid structure and greater hardness than nZnO, nTiO$_2$ has produced materials with higher yield strengths, tensile strengths, and tensile modulus. Comparing PP/nTiO$_2$ nanocomposites to nZnO-reinforced nanocomposites, however, was expected to result in lesser elongation; however, the contrary was actually shown to be the case to a greater than 1 wt% degree. According to this, silane or SEBS-g-MA may have worked with nTiO$_2$ more effectively than nZnO.



(c)

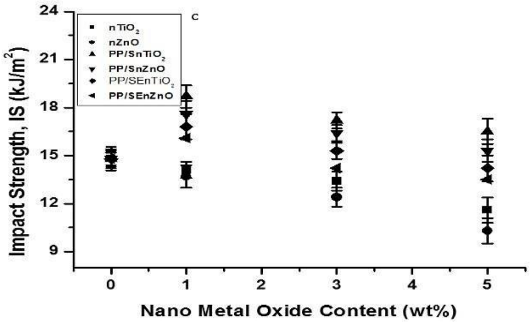


Figure 2. Tensile and impact characteristics of PP nanocomposites reinforced with $nTiO_2$ and nZnO, including (a) tensile modulus, (b) elongation at break, and (c) impact strength.

Figure 2(c) shows the impact features that were discovered during the impact test. Because of the particles' higher hardness, the addition of nano-metal oxide reduced the impact strength. But when the following nanocomposites with silane or SEBS-g-MA were compared: PP/SnTiO2 and PP/SEnTiO2, PP/SnZnO and PP/SEnZnO, the impact strength was improved by the addition of silane or SEBS-g-MA. Through the molecular flexibility of PP and increased impact strength, the presence of silane gives the nanocomposite toughness. Because of the existence of agglomerates, which will be covered later, the impact strength decreased with the increase in nano-metal oxide content. Because the SEBS-g-MA did not offer as good of a dispersion as it did in the silane as the nano-metal oxide content grew, agglomerates formed and the interfacial nano-metal oxide-PP adhesion dropped. Accordingly, poor impact strength has been observed in the nanocomposite of $PP/SEnTiO_2$ and PP/SEnZnO despite the elastomer phase's existence. Each agglomeration, as is well known, causes the effect of cracking and lowers its impact strength.

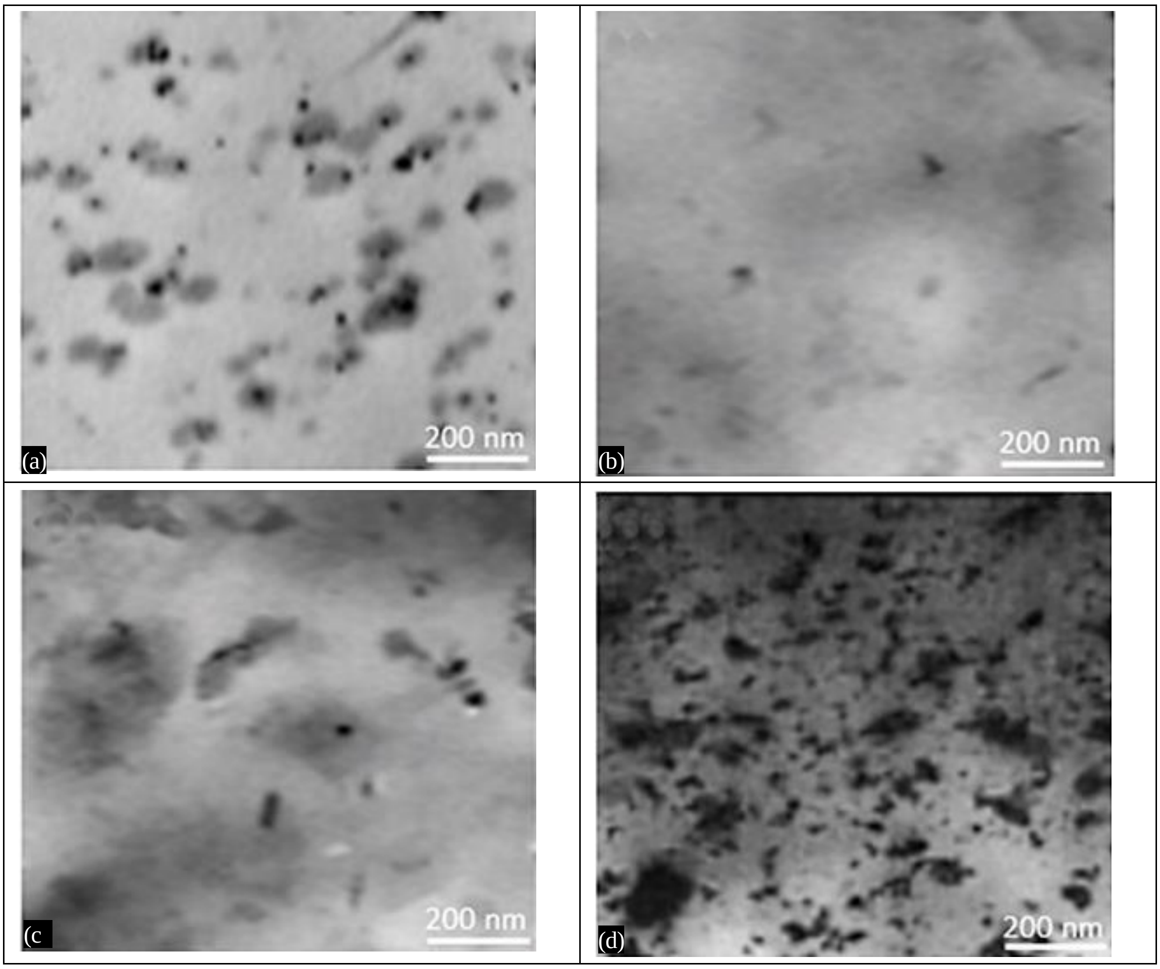
Dispersion of Particles and Surface Morphology

One of the most crucial components is regarded to be mechanical qualities, which are related to the uniformity of various morphologies, domain sizes, and forms to define the degree of dispersion of interactions between the two stages [38]. Figure 3(a-c) shows TEM photomicrographs of $PP/nTiO_2$ nanocomposites made of 3 weight percent $nTiO_2$ (designated as $PP/3UnTiO_2$), 3 weight percent $nTiO_2$ that has been coated with PP/silane (designated as $PP/3SnTiO_2$), or 3 weight percent $nTiO_2$ that has been coated with PP/SEBS-g-MA. Due to the absence of silane or SEBS-g-MA, the much larger $nTiO_2$ particles in Figure 3(a) are not intercalated and most likely form a "micro composite" structure. The rest of the area is an uninterrupted PP, and the black form shows the $nTiO_2$ tactoids. However, certain black shapes might represent some $nTiO_2$ particles with poor dispersion. Comparatively fewer $nTiO_2$ particles are visible in Figure 3(c) than in Figure 3(a), and they have been divided into lighter portions through blending. Nevertheless, silane, which acts as a compatibilizer and an intercalator between PP and $nTiO_2$ (Figure 3, b), might be added to get a better dispersion. Because silane's black shape is less prominent than in the $PP/3SEnTiO_2$ system, the $PP/3SnTiO_2$ systems exhibit better and more uniform $nTiO_2$ dispersion in the PP matrix. TEM images of the nanocomposites PP/3UnZnO, PP/3SnZnO, and PP/3SEnZnO are shown in Figures 3(d) through 3(f). Strong dispersion between PP and nZnO is indicated by the extraordinarily large nZnO particles in Figure 3(d) that are not intercalated. The nZnO particles were well disseminated and nearly embedded in the matrix in the TEM photomicrographs of the PP/3SnZnO indicated in Figure 3(e). This guarantees the strong connections formed between $nTiO_2$ and PP and the compatibility of the two materials. However, the dispersion of nZnO particles was smaller than in Figure 3(e) when the SEBS-g-MA coating was applied (Figure 3(f)), while some nanoparticles were divided into lighter sections during the mixing process. Additionally, the silane coating on nZnO particles improves surface adherence and fine dispersion in comparison to the silane coating on $nTiO_2$ particles.

Figure 4 shows SEM photomicrographs of the fracture surfaces of nanocomposites. Uncoated $nTiO_2$ or nZnO with nanocomposites were randomly positioned in the PP matrix, as shown in Figures

4(a) and (d), respectively, and several massive agglomerates bigger than 1 µm in size were exposed above the fracture surface. Since there is no functional polymer present and the interfaces appear to be individually moist and/or weak to the adherence of the components, large particles are dispersed throughout the PP to PP/3UnTiO$_2$ nanocomposite. This demonstrates the impact strength and low tensile characteristics of the nanocomposites explained above. Nanocomposites comprising 3SnTiO$_2$ and 3SnZnO particles, respectively, are shown in Figure 4(b) and (e). These nanoparticles diffused efficiently without agglomerating and were more evenly distributed throughout the PP matrix. This shows that TPE and nTiO$_2$/nZnO have a significant connection, adhesion, and direct contact due to wetting the nanoparticles. In the PP matrix, 3SnTiO$_2$ particles were more evenly distributed than 3SnZnO particles. This further supports the outcomes of the nanocomposites' better mechanical properties.

The morphological architectures of nanocomposites including 3SEnTiO$_2$ and 3SEnZnO particles are shown in Figures 4(c) and (f). In comparison to the PP/3UnTiO$_2$ or PP/3UnZnO systems, the PP/3SEnTiO$_2$ or PP/3SEnZnO systems have some big portions and smaller average particle sizes. This demonstrates that 3SEnTiO$_2$/3SEnZnO and SEBS-g-MA were more compatible than 3UnTiO$_2$/3UnZnO. The PP/3SEnTiO$_2$ or 3SEnZnO nanocomposites' tensile properties, however, were diminished by nanoparticle agglomerates that developed in some areas of the PP matrix. In contrast to 3SnZnO particles, 3SnTiO$_2$ particles offer higher surface adherence and fine structure to PP, which supports the f indings of the PP/3SnTiO$_2$ nanocomposite's superior tensile properties.



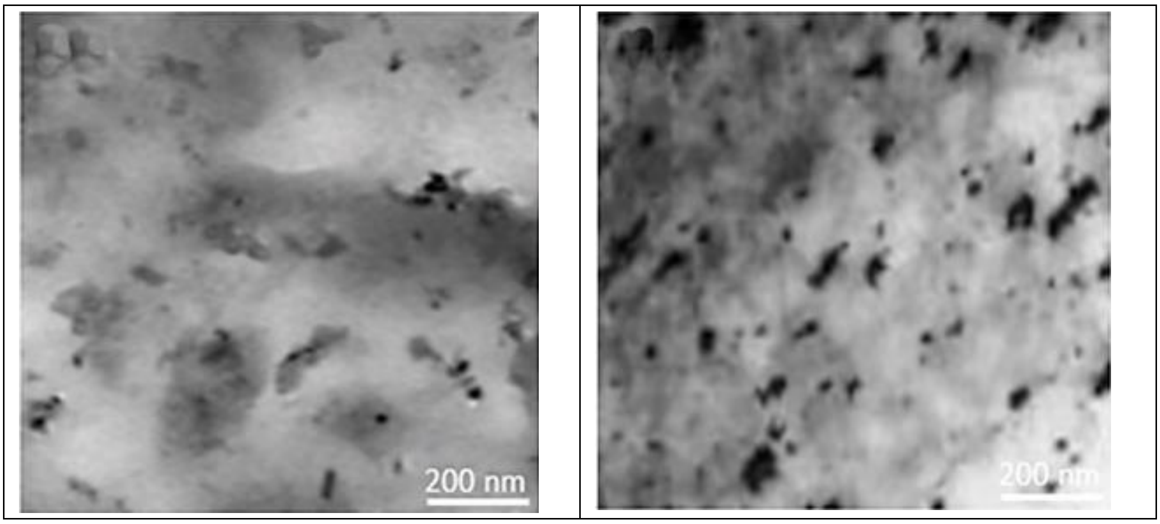
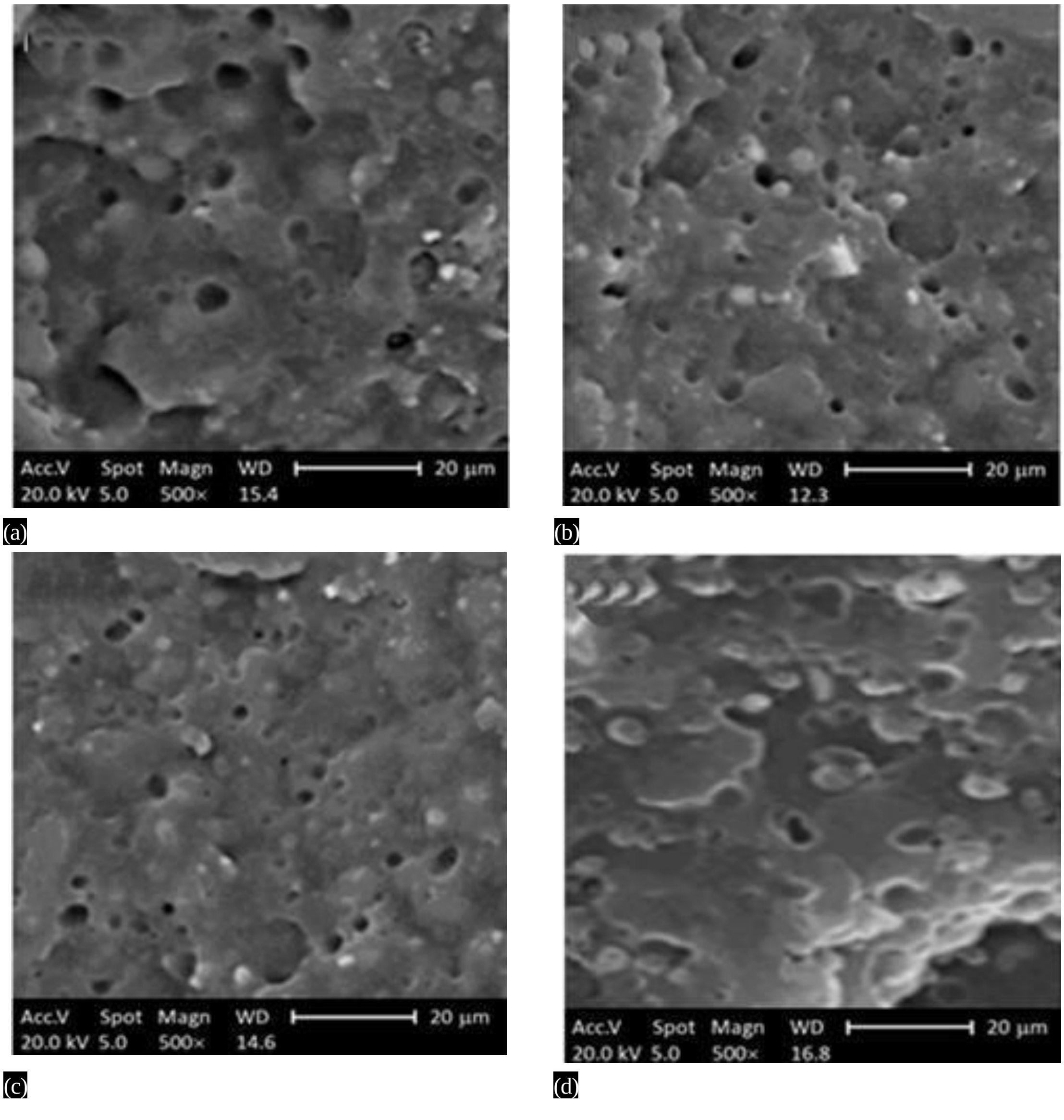


Figure 3. TEM photomicrographs of (a) PP/3UnTiO$_2$, (b) PP/3SnTiO$_2$, (c) PP/3SEnTiO$_2$, (d) PP/3UnZnO, (e) PP/3SnZnO, and (f) PP/3SEnZnO.



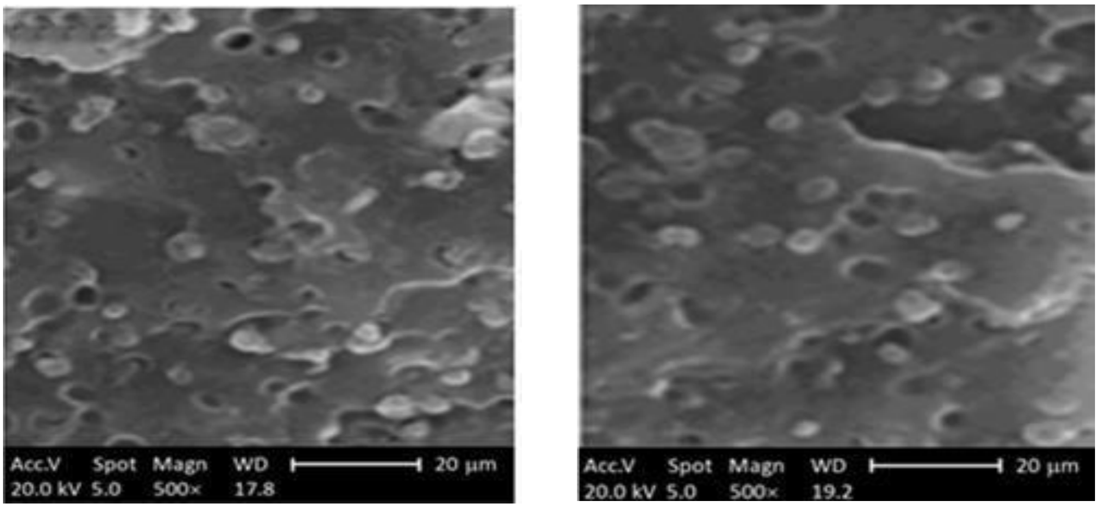


Figure 4. SEM pictures of (a) PP/3UnTiO$_2$, (b) PP/3SnTiO$_2$, (c) PP/3SEnTiO$_2$, (d) PP/3UnZnO, (e) PP/3SnZnO, and (f) PP/3SEnZnO.

Thermal Features

Table 2 provides the DSC results for the composites. The addition of nTiO$_2$ and nZnO did not significantly alter the melt temperature (T_m) or crystallization temperature (T_c). The addition of nZnO, on the other hand, lowered the degree of crystallization more than nTiO$_2$ did, indicating that nTiO$_2$ particles had no effect on the stability of the PP. In PP/nZnO composites, the physical impediment effect of nano-zinc oxide on the molecular chains and the retarding effect of nano-zinc oxide on the PP crystals were more noticeable. This result is presumably attributable to the finer dispersion of the nanoparticles and improved physical compatibility of nTiO2 with SEBS-g-MA. Several studies have looked into how nanoparticles affect the degree of crystallization. Various experimental observations produced varying results, and some of them acknowledged these particles as nucleating agents [39, 40]. For instance, in nano CaCO3 filled PP, the crystallinity was unaffected as the nanofiller quantity increased [39]. However, in additional research on clay/PP composites, crystallinity either rose or decreased [40, 41]. Additionally, Chandramaouleeswaran et al. [16] discovered a decrease in crystallinity of PP/nano ZnO composites that is consistent with the outcomes of this investigation. The majority of studies [42, 43] on nano titan dioxide reinforced composites concluded that nTiO$_2$ did not significantly impact the degree of crystallinity or act as a nucleating agent [25, 44].

Table 2. The nanocomposites' thermal characteristics.

Mixture	T_m (ºC)	T_c (ºC)	Enthalpy (J/g)	X_c(%)
Pure PP	166.5	126.7	87.3	42.4
PP/1 nTiO$_2$	165.7	124.9	84.5	41.3
PP/3 nTiO$_2$	166.3	126.5	83.6	40.7
PP/5 nTiO$_2$	166.5	127.3	85.2	41.8
PP/1 nZnO	166.6	125.4	69.5	33.5
PP/3 nZnO	165.8	125.7	67.5	31.6
PP/5 nZnO	165.8	125.4	68.2	31.9

CONCLUSIONS

Mechanical characteristics are improved by metal oxides, however each metal oxide behaves differently depending on its physical, mechanical, and chemical characteristics. The creation of PP/nano-metal oxide nanocomposites involved a melt mixing procedure monitored by a hot press machine mechanical properties of the polypropylene composites were improved by the addition of two nano metal oxides, nTiO$_2$ and nZnO. The mechanical, morphological, and thermal properties of

PP/nano metal oxide nanocomposites were investigated in this study along with the effects of surface-modified nano metal oxide particles. In contrast to pure PP matrix, PP/nano metal oxide nanocomposites have higher tensile properties due to the addition of metal oxide nanoparticles, whereas impact strength and elongation at break have decreased. PP's tensile properties, including as yield strength, tensile strength, and tensile modulus, are considerably altered by the addition of silane or SEBS-g-MA coated metal oxide nano-particles, however impact strength and elongation are decreased. In addition to fine dispersion with silane-coated nano metal oxide, SEBS-g-MA coated metal oxide nano-particles offered stronger surface bonding. Due to its rigid structure and higher hardness than nZnO, $nTiO_2$ has produced materials with higher yield strengths, tensile strengths, and tensile modulus. Comparing $PP/nTiO_2$ nanocomposites to nZnO-reinforced nanocomposites, however, was expected to result in lesser elongation; however, the contrary was actually shown to be the case to a greater than 1 wt% degree. This shows that silane or SEBS-g-MA was more compatible with $nTiO_2$ than nZnO. Additionally, the tensile characteristics of PP/nZnO nanocomposites are diminished by the presence of nano metal oxide agglomerates in specific regions of PP. Moreover, nZnO agglomerates that developed in some matrix locations decreased the PP/nZnO composites' tensile and crystallinity performances.

REFERENCES

1. Aydemir D, Gulsen U, et al. Nanocomposites of polypropylene/nano titanium dioxide: effect of loading rates of nano titanium dioxide. Materials Science. 2016;22:364–369.
2. Tang J, Wang Y, et al. Effects of organic nucleating agents and zinc oxide nanoparticles on isotactic polypropylene crystallization. Polymer. 2004;45:2081–2091.
3. Wang H, Xian G, et al. Grafting of nano-TiO2 onto flax fibers and the enhancement of the mechanical properties of the flax fiber and flax fiber/epoxy composite. Composites Part A: Applied Science and Manufacturing. 2015;76:172–180.
4. Zaman HU, Khan RA. Organically Modified Peanut Shell Flour-Reinforced Polypropylene Nanocomposites: Effect of Fiber Surface Treatment on Basic Properties. International Journal of Analytical and Applied Chemistry. 2022;8:19–30.
5. Zaman HU, Khan RA. A Review on Polymer Nanocomposites and Its Applications. International Journal of Advanced Science and Engineering. 2023;9:3006–3023.
6. Zhu J, Wilkie CA. Thermal and fire studies on polystyrene-clay nanocomposites. Polymer International. 2000;49:1158–1163.
7. Selvakumar V, Manoharan N. Mechanical and Morphological Properties of PP/MWNT/MMT Hybrid Nanocomposites. International Journal of Engineering and Technology. 2014;6:2351– 2356.
8. Montazer M, Morshedi S. Photo bleaching of wool using nano TiO_2 under daylight irradiation. Journal of Industrial and Engineering Chemistry. 2014;20:83–90.
9. Zhou J, Qiu K, et al. The surface modification of ZnOw and its effect on the mechanical properties of filled polypropylene composites. Journal of Composite Materials. 2005;39:1931– 1941.
10. Zaman HU, Khan RA. Investigation into Ultra-High Molecular Weight Polyethylene/Modified Nano-Zinc Oxide Nanocomposites. International Journal of Advanced Science and Engineering 2023;9:2848–2856.
11. Zaman HU, Khan RA. Effect of Coupling Agent on Organoclay Dispersion in Polyethylene/Organoclay Nanocomposites for Packaging Industry. International Journal of Nanobiotechnology. 2023;8:1–11.
12. Kruenate J, Tongpool R, et al. Optical and mechanical properties of polypropylene modified by metal oxides. Surface and Interface Analysis. 2004;36:1044–1047.
13. Gündoğan K, Öztürk DK. Investigation of Properties ZnO, CuO, and TiO_2 Reinforced Polypropylene Composites. NIScPR. 2021; 414–419.

14. Lin OH, Akil HM, et al. Effect of particle morphology on the properties of polypropylene/nanometric zinc oxide (pp/nanozno) composites. Advanced Composites Letters. 2009;18:096369350901800302.
15. Zaman HU, Khan RA. Mechanical and Thermal Properties of Extruded Thermoplastic Polyester Elastomer/TiO_2 Nano-Composites: Effect of Surface Modification. Advanced Journal of Science and Engineering;3:136–145.
16. Chandramouleeswaran S, Mhaske S, et al. Functional behaviour of polypropylene/ZnO-soluble starch nanocomposites. Nanotechnology. 2007;18:385702.
17. Zaman HU, Khan RA. Mechanical and Thermal Properties of Extruded Thermoplastic Polyester Elastomer/TiO_2 Nano-Composites: Effect of Surface Modification. Advanced Journal of Science and Engineering. 2022;3:136–145.
18. Zaman HU, Khan RA. Fabrication and Surface Modified Non-woven Calotropis Gigantea Fiber Mat Reinforced Polypropylene Composites by Film Stacking Method. Journal of Thin Films, Coating Science Technology and Application. 2022;9:10–21.
19. Awang M, Wan Mohd W: Comparative studies of Titanium Dioxide and Zinc Oxide as a potential filler in Polypropylene reinforced rice husk composite. in IOP Conference Series: Materials Science and Engineering, IOP Publishing; 2018. pp. 012046.
20. Demir H, Atikler U, et al. The effect of fiber surface treatments on the tensile and water sorption properties of polypropylene–luffa fiber composites. Composites Part A: Applied Science and Manufacturing. 2006;37:447–456.
21. Zaman HU, Khan RA. Study on Mechanical and Physical Properties of Wood-Plastic Nanocomposites after Fiber Surface Treatment. International Journal of Chemical Engineering and Processing. 2023;8:34–43.
22. Hashimoto M, Takadama H, et al. Mechanical properties and apatite forming ability of TiO 2 nanoparticles/high density polyethylene composite: Effect of filler content. Journal of Material Sci Mater Med. 2007;18:661–668.
23. Kubacka A, Fernández-García M, et al. Titanium dioxide-polymer nanocomposites with advanced properties. Nano-Antimicrobials: Progress and Prospects. 2012:119–149.
24. Wacharawichanant S, Phutphongsai A. The study of morphology and mechanical properties of compatibilized polypropylene/Zinc oxide composites. Journal of Solid Mechanics and Materials Engineering. 2007;1:1231–1237.
25. Altan M, Yildirim H, et al. Tensile properties of polypropylene/metal oxide nano composites. Tojsat. 2011;1:25–30.
26. Supaphol P, Harnsiri W, et al. Effects of calcium carbonate and its purity on crystallization and melting behavior, mechanical properties, and processability of syndiotactic polypropylene. Journal of Applied Polymer Science. 2004;92:201–212.
27. Esthappan SK, Kuttappan SK, et al. Thermal and mechanical properties of polypropylene/titanium dioxide nanocomposite fibers. Materials & Design. 2012;37:537–542.
28. Yang CP, Wu YJ, et al. Studies on crystallizations and mechanical properties of polypropylene/nano-TiO2 composites. Advanced Materials Research. 2013;690:494–498.
29. Selvin TP, Kuruvilla J, et al. Mechanical properties of titanium dioxide-filled polystyrene microcomposites. Materials Letters. 2004;58:281–289.
30. Altan M, Yildirim H. Mechanical and antibacterial properties of injection molded polypropylene/TiO_2 nano-composites: Effects of surface modification. Journal of Materials Science & Technology. 2012;28:686–692.
31. Mina MF, Seema S, et al. Improved performance of isotactic polypropylene/titanium dioxide composites: effect of processing conditions and filler content. Polymer Degradation and Stability. 2009;94:183–188.
32. Rong MZ, Zhang MQ, et al. Improvement of tensile properties of nano-SiO_2/PP composites in relation to percolation mechanism. Polymer. 2001;42:3301–3304.

33. Ishak ZM, Chow W, et al. Compatibilizing effect of SEBS-g-MA on the mechanical properties of different types of OMMT filled polyamide 6/polypropylene nanocomposites. Composites Part A: Applied Science and Manufacturing. 2008;39:1802–1814.
34. Ishida H, Campbell S, et al. General approach to nanocomposite preparation. Chemistry Material. 2000;12:1260–1267.
35. Setz S, Stricker F, et al. Morphology and mechanical properties of blends of isotactic or syndiotactic polypropylene with SEBS block copolymers. Journal of Applied Polymer Science. 1996;59:1117–1128.
36. Rahman M, Hoque MA, et al. Study on the mechanical, electrical and optical properties of metal-oxide nanoparticles dispersed unsaturated polyester resin nanocomposites. Results in Physics. 2019;13:102264.
37. Zaman HU, Hun PD, et al. Effect of surface-modified nanoparticles on the mechanical properties and crystallization behavior of PP/$CaCO_3$ nanocomposites. Journal of Thermoplastic Composite Materials. 2013;26:1057–1070.
38. Ghazy O, Freisinger B, et al. Tuning the size and morphology of P3HT/PCBM composite nanoparticles: Towards optimized water-processable organic solar cells. Nanoscale. 2020;12:22798–22807.
39. Chan C-M, Wu J, et al. Polypropylene/calcium carbonate nanocomposites. Polymer. 2002;43:2981–2992.
40. Ma J, Zhang S, et al. Crystallization behaviors of polypropylene/montmorillonite nanocomposites. Journal of Applied Polymer Science. 2002;83:1978–1985.
41. Li Y, Wei G-X, et al. Morphology and toughening mechanisms in clay-modified styrene- butadiene-styrene rubber-toughened polypropylene. Journal of Materials Science. 2002;37:2447– 2459.
42. Bahloul W, Bounor-Legaré V, et al. Morphology and viscoelasticity of PP/TiO_2 nanocomposites prepared by in situ sol-gel method. Journal of Polymer Science Part B: Polymer Physics. 2010;48:1213–1222.
43. Zebarjad SM, Sajjadi SA, et al. A study on thermal behaviour of HDPE/$CaCO_3$ nanocomposites. Journal of Achievements in Materials and Manufacturing Engineering. 2006;17:173–176.
44. Garcia M, Van Vliet G, et al. Polypropylene/SiO_2 nanocomposites with improved mechanical properties. Reviews on Advanced Materials Science. 2005;6:169–175.