Investigation of Addition Titanium Dioxide on General Properties of Polycarbonate

Najim A. Saad, Esraa Rzaq Jwad

Polymer and Petrochemical Industries Department, College of Materials Engineering, Babylon University, Babylon, Iraq
Email: jasim_910@yahoo.com, esraraqaq1993@gmail.com

Abstract

Polycarbonate is a transparent commercial engineering polymer used in many applications especially in mobile protector screen for its good properties. In the present paper, nano composite material composed of polycarbonate sheet and nano titanium dioxide particles was prepared. Three ratios of TiO₂ (0.01-0.03-0.05 g) were employed with polycarbonate by using pressing technique. Different mechanical, chemical, thermal and morphology tests were characterized as hardness, impact, FTIR, UV, XRD, DSC, tensile strength, contact angle and smoothness test. The results were shown that the hardness decreased in about 15% and the impact resistance increased in about 10% with TiO₂ level increasing. FTIR showed there were no new peaks appearing and that indicated physical interactions between the nano filler and the polycarbonate matrix, also transparency reduced in about 5%. UV showed the absorption of polycarbonate to radiation after added TiO₂. DSC showed decreasing in the Tg level and increasing in the crystallinity of material after processing. Contact angle test showed that the wettability increased at first but retained decreasing with adding more TiO₂ to the surface. Surface roughness test and AFM test show decrease in smoothness with adding TiO₂ to polycarbonate sheet.

Subject Areas

Mechanical Engineering

Keywords

Nanocomposite, Titanium Dioxide Particles, Polycarbonate, Physical, Chemical and Morphology Properties

1. Introduction

Polycarbonate is a transparent commercial engineering polymer used in many applications due to its properties such as high shock resistance, thermal stability,
toughness and good optical properties as well as other mechanical properties [1].
According to the physical and mechanical properties of polycarbonate making it
important in many industries, it replaces the glasses in different applications as
display panels of electrical tools, low weight eyewear lenses and compact disks,
but metal is better than polycarbonate in electrical and thermal properties [2].

Polycarbonates are mainly used in electrical insulators also used in production
of Blu-ray Discs and DVDs [3]. Polycarbonate is showing incompatibility with
acetone and ammonia which can dissolve it, but alcohol used to clean the surface
of polycarbonate sheet after used [4]. Polycarbonate is improved by using nano-
particles to obtain polycarbonate nanocomposite with new physical, electrical
and mechanical properties. Thin transparent layers contain TiO₂ studied and the
interest in them has increased in recent years intensively because of application
potential including Photocatalytic and Water Air Purification [5]. The surface
antifogging and easily washable result from super-hydrophilic property of the
surface allow the water to spread through the surface. Titanium dioxide is the
most nanoparticles that used in many applications involving photocatalytic, opt-
toelectronic activities and electrochromic application [6].

TiO₂ is considered as one of the important environmentally friendly materials
to be used to create new applications for renewable energy [7]. Thin film of TiO₂
describes as antifogging effect, self-cleaning and it’s widely used in glass indus-
try. Super hydrophilicity of the of TiO₂, thin film obtains the antifogging effect to
the surface. Polycarbonate-TiO₂ nanocomposite could be prepared by different
coating methods such as spray ion beam evaporation, plasma enhanced, spin
coating, dipping, chemical vapor deposition and pressing method [8].

The introduction of nanoparticle had been widely investigated and reported to
be the most efficient method to improve the properties of polycarbonate. The
self-cleaning coating has been used in new applications including buildings,
sculptures, cars and machinery. This coating is based on TiO₂ optical stimula-
tion. TiO₂ self-cleaning with polycarbonate material shows better scratch resis-
tance and hardness. Perfect mechanical properties of self-cleaning coating make
them useful in many applications [9].

Houman et al. [10] prepared self-cleaning coating from TiO₂ on polycarbon-
ate surface by using dip coating process and treating the surface with chemical
solution to obtain hydrophilic groups on surface in ultrasonic device and wash-
ing then with DI. The results showed improvement in mechanical properties af-
after coating included increases in hardness in about 2.5 time and scratch resis-
tance increases in about 6.4 time then PC substrates. The transparency of
PC-TiO₂ decreased in about 10% - 15%.

Nima et al. [11] improve the properties of polycarbonate by prepared films of
polycarbonate—TiO₂ nano composite. The film formed by using Solvent eva-
poration method and studied the mechanical properties of nanocomposite films by
conducting tensile tests and hardness measurement. The result from tensile test
showed that stress-strain peak had increased with increased TiO₂ nano particles
content and elastic modulus increased with TiO₂ nanoparticle weight fraction.
Al-Shammary, Z. R. [12] prepared PC-TiO₂ and PS-TiO₂ composites at room temperature and studied the effect of TiO₂ on tensile properties. The results showed reducing in ultimate stress and young modulus compared to PC and PS pure. Also, the toughness became stabilized because TiO₂ particle made these chains interlocked and mobility of chains became restrict.

The aim of this paper is to improve the surface properties of polycarbonate by addition TiO₂ nanoparticles. The pressing technique used to insert nanoparticles on the surface. This sample latter if needed excellent properties and homogenous in structure, they reformed by cutting them and extrude through twin-screw extruder device.

2. Experimental Part

2.1. Materials

The used materials in this research are polycarbonate (PC) and titanium dioxide nano particles (TiO₂). The used polycarbonate sheet is as Table 1 and TiO₂ nanoparticles as Table 2 by used pressing method with temperatures and pressure as Table 3.

<table>
<thead>
<tr>
<th>Table 1. Mechanical and physical properties of PC.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Property</td>
</tr>
<tr>
<td>Tensile Strength</td>
</tr>
<tr>
<td>Tensile Modulus of Elasticity</td>
</tr>
<tr>
<td>Melting Point</td>
</tr>
<tr>
<td>Processes Temperature</td>
</tr>
<tr>
<td>Impact Strength</td>
</tr>
<tr>
<td>Density</td>
</tr>
<tr>
<td>Hardness</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2. The specification of titanium dioxide nanoparticles.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product name</td>
</tr>
<tr>
<td>Color</td>
</tr>
<tr>
<td>Particle size</td>
</tr>
<tr>
<td>TiO₂ content</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 3. Pressing information.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polycarbonate</td>
</tr>
<tr>
<td>TiO₂ powder</td>
</tr>
<tr>
<td>Temperature</td>
</tr>
<tr>
<td>Temperature</td>
</tr>
<tr>
<td>Time</td>
</tr>
</tbody>
</table>
2.2. Samples Preparation

At first cleaning the surface of polycarbonate sheets (5 cm × 5 cm) with thickness of 2mm with ethanol and washed with Distilled water then dried in electrical oven for 2 hours. After cleaning, dispersed TiO₂ powder on the surface. Cover PC-TiO₂ with a piece of sulfone to prevent the adhesion of the powder with the piston plates and for the interference of the nanoparticles to the cavities that cannot see in the surface. The large particle remain on the surface, therefore after pressing washed the sheet again with ethanol and Distilled water then dried.

Tests: Mechanical tests have been conducted (hardness, surface roughness and impact test) Includes standard specifications: for impact test-ASTMD256-87 by used charpy type instrument. Hardness of polycarbonate prepared according to ASTM D 2240. Tensile strength for PC with addition was performed by using (Bongshin model WDW-SE) instrument according to ASTM D-638-IV. Also used microstructure test as contact angle test used device was SL 200C—Optical Dynamic I Static Interfacial Tensiometer & Contact Angle Meter which manufactured in KINO Industry Co., Ltd., USA with contact angle range from 0 o to 180 o. FTIR—test also used to characterize the structure performed by using (FT-IR–OPUS_7.0 manufacturing by Bruker Company). UV-Vis double beam spectrophotometers, (SHIMADZU, UV-1800, Japan) used to check the absorbance of nanocomposite for different energy. DSC test was performed according to ASTM D3418-03 manufacturing by japan. AFM-Test was carried by tapping mode SPM model AA3000 ANGSTROM ADVANCED INC., USA, 2008 (AFM-Contact Mode). This test was performed using XRD 6000 instrument, manufactured by (SHIMADZU)—Japan.

3. Results and Discussion

3.1. Mechanical Test

3.1.1. Hardness Test

The hardness for pure and nanocomposite material measure are by using shore hardness (D). The result of this test appear decreased in the hardness compared to pure that indicate to increase the flexibility with decreased the rigidity of material after addition of TiO₂ as Figure 1.

3.1.2. Toughness

Showed from this test impact strength of material and it consider one of the ways to known the flexibility of polycarbonate pure and polycarbonate with TiO₂. In which the impact improved after addition 3% of TiO₂ make them better when the nanocomposite subjected to shock or loads as in Figure 2.

3.1.3. Tensile Strength Test

The Tensile strength of PC nanocomposite decreased with increasing the proportion of TiO₂ nanoparticles from 1 to 5 wt% as shown in Figure 3. The maximum tensile strength was obtained with PC-pure Figure 4, while the nanocomposite
with 1, 3 and 5 wt% occurs decreased in the tensile strength. Also, the modulus of elasticity decreases with addition TiO$_2$ nanoparticles. The results in this work agree with Z. Shammary [12].

3.2. Microstructure Test

3.2.1. Wettability
The wettability of material measured by using contact angle test in which the
The wettability decreases with addition TiO$_2$ nanoparticles as seen in Figure 5. The increase in wettability in a specific range better for self-cleaning properties in the surface to remove the contaminated. In this case, the TiO$_2$ works as an automatic cleaning agent in the material. Contact angle changed with surface tension of the liquid, surface topography (surface roughness), level of interaction (between the liquid and solid) and surface energy of the substrate.

3.2.2. Surface Roughness Test

From this, the smoothness for polycarbonate-pure and nanocomposite was measured as in Figure 6. The roughness of the surface increased with addition of TiO$_2$ to polycarbonate sheet in pressing technique. The increases of roughness in polycarbonate are due to low-efficiency devices. The roughness also affects the wettability properties as we said earlier.

3.2.3. Chemical Structure

The chemical structure of nanocomposite clarifies by using FTIR-test. The result showed that no new peak appear and that indicate to physical interaction between the polycarbonate structure and TiO$_2$ powder. It is noted from Figure 7 for FTIR curve of PC and PC material with titanium oxide at 1%, 3% and 5%. The peaks PC are observed in the wave numbers 3670 cm$^{-1}$ (O-H), at 3498 cm$^{-1}$ (O-H), at 2715 cm$^{-1}$ (C-H) and at 1604 cm$^{-1}$ (C=C) after addition TiO$_2$ by 1%, there is an increase in transmittance. The transmittance value of the pure polymer increased very little and the (Ti-O-Ti) showed at 634 cm$^{-1}$. After increasing the ratio of TiO$_2$ to 3% and 5%, it is obvious that titanium oxide reduces the amount of radiation due to increased particle size that increases the absorption of the material and its reflection. Moreover, this leads to less permeability.

![Figure 5](image5.png) **Figure 5.** Representing contact angle test at 1 min (According to young Laplace).

![Figure 6](image6.png) **Figure 6.** Representing the surface roughness test.
3.2.4. UV-Test
The use of TiO₂ is to avoid the photo-degradation of polycarbonate because TiO₂ have ability to absorb ultraviolet radiation as shows in Figure 8. Uv-vis give the amount of absorption when added TiO₂. It is also noticed from Figure that there are a slight decrease in absorption as the percentage of addition increase and formation of a more cohesive membrane due to filling the blanks. Also noted through the form, the randomness or confusion in the curve decreases as the proportion of titanium dioxide increases. While, at 5% of titanium, there is a clear decrease in the absorption curve in area of UV. This happen due to addition of high ratio of titanium to the polymer material obtained transparent so that the ultraviolet light passes through them. This considered an undesirable proportion because the ultraviolet rays harmful to the human eye. Therefore, the best rate is less than this ratio (5% TiO₂) to prevent the crystallization that occurs in this ratio.

3.2.5. DSC-Test
This test shows Tg and Tm for polycarbonate before and after addition of TiO₂ in different level. TiO₂ decreased Tg with decreased hardness of polycarbonate that mean the flexibility of material increases and this better for the flexible screen as Figure 9. Tg decreased from 152°C for pure to 144°C and 143°C for nanocomposite.

3.2.6. Morphology Test
From this test describe the roughness of the surface after addition TiO₂ to the polycarbonate sheet; also know the size of TiO₂ particle. With increases the grain size of particle, reduces the light transmission due to increases the crystallinity of nanocomposite as shown in Figure 10. In addition, the distribution of nanoparticle was good on the polycarbonate surface.
3.2.7. XRD Test

XRD Patterns of PC and PC with (1, 3 and 5 wt%) TiO₂ shown in Figure 11. PC shows single peak that related to amorphous structure of it. Addition, TiO₂ to PC matrix appears change in the peak of PC matrix as in $2\theta = 25.2^\circ$ related to (101) plans of anatase with level 1 wt% of TiO₂ and this agree with Nima et al. [11].
When increasing the amount of TiO$_2$ in PC matrix causes physical interface as shows in test. The peak from X-ray diffraction showed that amorphous matrix decreased with increasing the intensity of TiO$_2$ peak after addition titanium dioxide.

### 4. Conclusion

We can conclude that better impact resistance, contact angle, hardness from this work in 0.03 TiO$_2$ compared to other levels. FTIR for samples showed physical interaction occurred for polycarbonate; TiO$_2$ also showed that all levels of TiO$_2$ gave the same proportions of transparency. Reducing in tensile and elastic modulus indicated to increase the flexibility of composite with reduced Tg and increased the crystallinity of material after addition of TiO$_2$. The transparency of polycarbonate sheet decreased with addition of TiO$_2$ and this depended on constriction of powder that used. XRD showed no chemical interaction that oc-

---

**Figure 11.** XRD polycarbonate-TiO$_2$ nanocomposite (a) Pure-polycarbonate; (b) PC-0.01 TiO$_2$; (c) PC-0.03 TiO$_2$; (d) PC-0.05 TiO$_2$. 
curred between polycarbonate and TiO2 nanoparticles.

5. Summary

Studies have shown the resistance of scratching, hardness and other mechanical properties of polycarbonate are improved by using TiO2 nano-particles. The present work aims to improve the mechanical properties and morphology of the surface without effect on the physical properties as transparency of polycarbonate.

References


