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Study of the Effect of UV Radiation on the Impact Test of Epoxy-Polyurethane Blend Reinforced with Micro and Nano Silicon Carbide

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Abstract

This research includes use epoxy and polyurethane resins to form a blend of Epoxy/Polyurethane with different ratios of (90–10)%, (80–20)%, (70–30)%, and (60–40)% to find the best ratio for impact strength as a function of material toughness; and strengthened with micro and nano silicon carbide at weight fractions of 2, 4, 6 and 8%. The impact test was studied in natural conditions and after exposure to UV irradiation for 24h. Results showed that the "polymer blend/nano silicon carbide" composite has better properties compared with the micro-silicon carbide containing composite. The values of impact strength decrease with increasing the weight ratio for all samples. Values in the case of UV radiation are generally higher than values in natural conditions.

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1. Introduction

Given the rapid development the world is witnessing, the world cannot be imagined without polymer used in many industrial applications because it possesses special advantages that other types of materials (mineral and ceramic) do not own. The important features of polymer are ease of manufacture, oxidation resistance, and lightweight [1]. Nanocomposites are polymer e.g., thermoplastics, thermosets, or elastomers composites with nanoscale building blocks. They combine the advantages of the filler materials (e.g., thermal, stability rigidity) and the advantages of polymer (e.g., dielectric, flexibility, and ductility). Moreover, when fillers become nanosized the composites usually contain special properties of nanofillers leading to improved materials properties [2,3]. Silicon Carbide is the only chemical compound of silicon and carbon. It was originally produced by a high temperature electro-chemical reaction of carbon and sand. Silicon carbide is an excellent abrasive and is used in grinding wheels and other abrasive products for over one hundred years, it has Molar mass (40.10 g·mol^{-1}), Density (3.16 g·cm^{-3}), Melting point (2830 °C). Today the material is developed into a high-quality technical ceramic with very good mechanical properties. It is used in abrasives, ceramics, refractories, and numerous high-performance applications. The material can also be made an electrical conductor and has applications in electronic components, flame igniters, and resistance heating. Structural and wear applications are constantly developing [4].

Nanoparticle research has provided many innovative and unexpected solutions in the field of ceramics, electronics, pharmaceuticals and optics. Silicon carbide (SiC) nanoparticles exhibit characteristics like high thermal conductivity, high stability, high purity, good wear resistance and a small thermal expansion coefficient. These particles are also resistant to oxidation at high temperatures. An important point to be noted about their storage is that they must be kept away from moisture, heat, and stress [5]. The material toughness is associated with its ability to absorb shock or impact loads without fracture. Two standardized tests, the Charpy and Izod, were designed and are still used to measure impact energy, sometimes termed notch toughness.

This test is very important in the practical side because it shows the strength of polymeric materials by calculation of the energy required to fracture the sample of polymer under specific conditions of moisture, temperature and others. The materials will behave as ductile when exposed to a static load, and brittle when exposed to dynamic load. The measure of impact strength of polymers is a very complex test for several reasons, including many tests of impact and the different basic which depend on the dimensions and different shapes of the samples used in the test and the different types of loads in each test and different the speed of applied load on the sample under test. The temperature effect is limited in thermoset resins, while its effect is greater in thermoplastic resins. The impact strength values are increased by increasing the temperature due to the loosening of the bonds and the molecular bonding forces, allowing greater energy absorption in the soft behavior [6,7]. In 2008, Vaezi M. R. et al., different contents composite coatings of SiC (nano and micro) and studied nano and micro SiC dependence in the coatings of nano composition the concentration of SiC in bath, rate of stir, density of current, and plating bath temperature. The deposition efficiency also studied with SiC and without it, the behavior of wear, and corrosion for the coatings of the nanocomposite. The result shows that the cathodic potential polarization increasing with increasing the concentration of SiC in the way. The wear, microhardness, and corrosion resistance of the coatings of nanocomposite are increased also with increasing nano and micro SiC material in the bath [8].

In 2010, Ban A. Y. used Epoxy and Novolac resins mixed with either polyurethane (PU) or polysulphide (PSR) rubbers to compose blends of ternary polymer. These polymeric blends are the matrix, which is reinforced with (TiO_2) powder type with volume fraction of (10%). Ten polymeric blends were prepared from (Epoxy + Novolac) resins and either polyurethane or polysulphide. Results showed that samples of blends reinforced with (TiO_2) powder possess better impact strength, tensile strength, compression strength, hardness, and wear resistance [9]. In (2012), Muhannad M . A, used Epoxy with different ratios of volume fractions (1, 2, 3, 4, 5, 7, 10, 15) and 20% of SiO2, TiO2 nanoparticles, and microparticles to prepare epoxy nanocomposites and micro-composites to examine and study some of their mechanical properties (Young modulus, flexural strength, and fracture toughness) and dielectric properties (relative permittivity and tan delta). Results found the mechanical properties of nanocomposites were increased with increasing volume fractions [10]. In (2017), Rana M. S, studied some physical and mechanical properties (i.e. the impact strength, hardness, flexural strength, thermal conductivity, and diffusion coefficient) of (epoxy/polyurethane) blend reinforced with nano silica powder (2%wt.). Results showed that the water had affected the bending flexural strength and hardness, while impact strength increased and the thermal conductivity decreased [11].

2. Materials and methodology

By using impact fracture testing, normalized tests, like the Charpy and Izod tests measure the impact energy required to fracture a sample with a hammer mounted on a pendulum. Energy is measured by the change in potential energy (height) of the pendulum. this energy is called (notch toughness). The impact strength is calculated from the following relation [7].

$$Impact\ strength = \frac{U(J)}{A\ (m^2)} \quad ...(1)$$

where I.S is impact strength, U is the energy of fracture, and A is the area of the cross-section. The Epoxy resin used in this work was Sikadur - 105 which is a two-component, low-viscosity epoxy resin system in the form of transparent liquid (which transforms into a solid state after adding the hardener to it in a percentage of (2:1). Polyurethane (PU) were used in this study has two components composed of a base resin and curing agent (hardener), the low viscosity of polyurethane system in the form of a transparent liquid, which transforms into a solid state after adding the hardener to it in a ratio (1:2). It is supplied from Fosroc Company, UK. It has a density equal to (1.1-1.3) gm/cm^3. Micro Silicon Carbide powder (SiC), supplied by a company (Struers Co, USA), with the specifications shown in Table 1.

Table 1: Specifications of micro–Silicon Carbide

Property	micro SiC
Density	3.22 [g/cm^3]
Young's Moduls	430 [GPa]
Flexural Strength	490 [MPa]
Fracture Toughss	3 [$MPa \cdot m^{1/2}$]
Thermal Conductivty	140 [W/mK]
Purity	99.5%
Particle Size	10 µm

Table 2: Specifications of nano Silicon Carbide

Property	Nano SiC
Density	3.216 g/cm^3
Crystal Phase	cubic
Specific surface area	90m^2/gm
Decomposition point	2973(K)
Combustion heat	30.343(KJ/Mol)
Linear expansion coefficient(373K):	$6.58 \times 10^{-6} k^{-1}$
Purity	99%
Particle Size	50 nm
color	Gray green

Silicon Carbide Nano powder (SiC Nano Powder) supplied from a company (HEFFI EV NANO TECNOLOGY, China), powder and the specifications show in the Table 2. Hand Lay-Up method was used to prepare the samples. The epoxy was mixed with the hardener by ratio (2:1) by mixer for (7-10 min.) and mixing the polyurethane with the hardener (2:1) during the same time, then mixing the materials to form Polymer blends prepared with different ratios (90 -10, 80 - 20, 70 -30 and 60 -40) %, and selected the optimum ratio (80-20) % by using the impact test and reinforced with nano and micro silicon carbide with weight ratio (2, 4, 6 and 8) %.

3. Results and Discussion

The Charpy impact test instrument is used to calculate the impact strength of the samples under test using equation (1) to measure the impact strength of samples in natural conditions and after exposure (24 hours) to UV irradiation. Figures 1 and 2 and Tables (3) and (4), show the experimental results in a natural condition (N.C) and (UV) case respectively. The experimental results of Charpy hardness for micro and nanocomposites in Natural condition and UV Irradiation decreased with increasing weight fraction for all samples. The reason is due to increased material fragility and therefore reduced durability under fast mechanical movements which makes the samples easy to break. The blend chains length decreasing over a certain length of the critical chains due to distribution of particles inside the blend. Low porosity for the microparticles surface leads to de-bonding and cavitation appears, increasing volume fraction of particles leads to create new crack path near to the surface of microparticles and lead to decrease plastic deformation inside matrix where interfacial space between particles and matrix is consider as a weak region which is weaker than the blend this agree with [12].

Table 3: Impact strength value for particle and Nano of (SiC) samples at natural condition

Weight Fraction		**Impact Strength (KJ/m^2)**
Wt%	**µSiC**	**Nano SiC**
(2 +98 Blend)	11.23	12.85
(4 + 96 Blend)	11.09	11.91
(6 + 94 Blend)	10.60	10.87
(8 + 92 Blend)	9.79	10.36

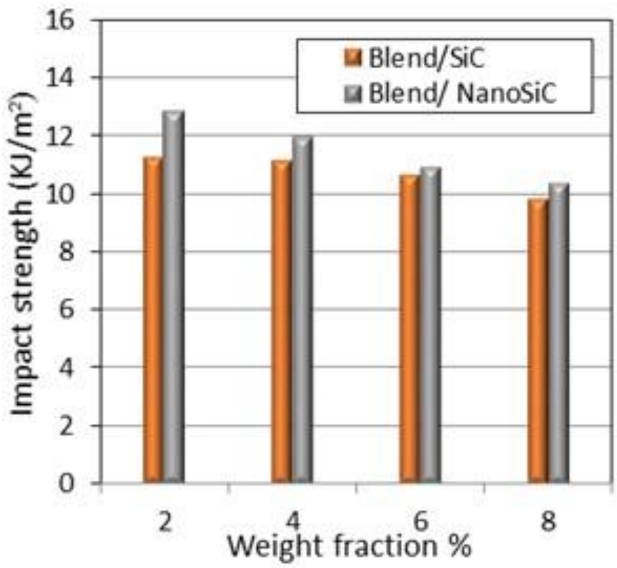

Figure 1: The behavior of impact strength with weight fraction for micro and nano SiC + blend at natural conditions.

In the case of (UV) irradiation for the time interval (24 h). From Table 4 and Figure 2, it is clear that the impact strength values for all samples with exposure to UV irradiation were less than that in natural condition. The values of hardness have increased after irradiation and this is due to the ultraviolet radiation function, lead to reforming and recombination of polymer chain polarization and reorientation, where it increases polymers hardness and reduces elasticity and become brittle, therefore easy to be broken [13].

Table 4. Impact strength value for particle and Nano of SiC samples with exposure to UV

Weight Fraction Wt%	μSiC	Impact Strength (KJ/m²) Nano SiC
(2 +98 Blend)	10.52	12.55
(4 + 96 Blend)	10.82	11.65
(6 + 94 Blend)	10.16	10.54
(8 + 92 Blend)	9.45	9.81

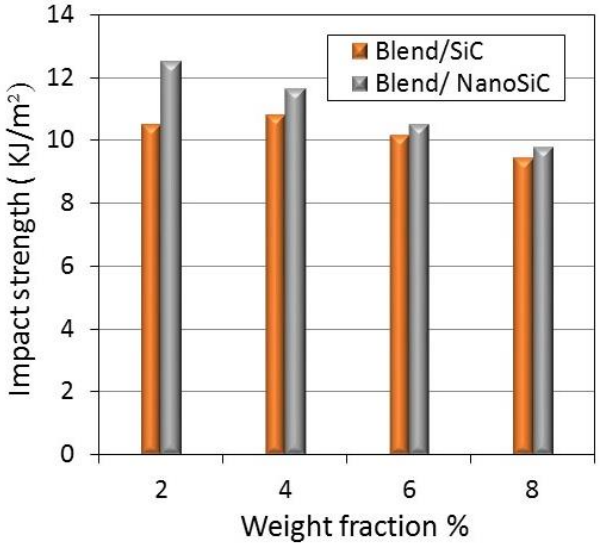

Figure 2: The Impact Strength value relation with weight fraction for particles and nano (SiC + Blend) exposure to UV

4. Conclusions

This research includes using epoxy and polyurethane resins to form a blend with different ratios to find the best ratio for impact strength as a function of material toughness; and strengthened with micro and nano (Silicon Carbide) and with weight fraction (2, 4, 6 and 8) %. Impact test was studied in natural condition and after exposure to UV irradiation for (24h). Results showed that the composite (polymer blend - nano Silicon Carbide) has better properties compared with (micro Silicon Carbide + blend) composite. Also, values of Impact strength decrease with increasing the weight fraction for (nano and micro SiC/blend) in natural condition and after (UV) irradiation, values of impact strength for (Nano SiC) samples are larger than that of micro (SiC) for the same weight fraction. The Impact strenghth values in the case of UV radiation are lower than values in natural condition.

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