

Study the Effect of Nanoparticle SiO₂ On Some Mechanical Properties for Epoxy/ Reinforced With 6 Layers of WRE-Glass Fibers Composites

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ABSTRACT: In this study, the neat epoxy and nanocomposites with volume fraction (1, 3, 5, 7 and 10%) of SiO₂ nanoparticles reinforced with six layers of woven roving WRE-glass fibers specimens were prepared by molding method. The results show an increase of Impact strengths with increasing the SiO₂ nanoparticles volume fraction at 1% Vol. of SiO₂ nanoparticles, then decreases with increasing volume fraction at 3% Vol. of SiO₂ nanoparticles, then the Impact strength increases with increasing volume fraction of SiO₂ nanoparticles until the Impact strength reach to maximum values (382.36 KJ/m²) at 5% Vol. of SiO₂ nanoparticles. And then Impact strength decreases with increasing volume fraction at 7% and 10% Vol. of SiO₂ nanoparticles. Also the results of Shore D hardness of EP/SiO₂ nanocomposites reinforced with 6 layers of woven roving WRE-glass fibers showed that Hardness No. values decrease with increasing the volume fraction of SiO₂ nanoparticles until the Hardness No. values reach to Minimum value (81.6) at 10% Vol. fraction of SiO₂ nanoparticles.

KEYWORDS: - Silica nanoparticles, woven roving WRE-glass fibers, Impact strength, Shore D hardness.

I. INTRODUCTION

Inorganic nanoscale fillers include nanotubes, layered silicates (e.g., montmorillonite, saponite), nanoparticles of metals (e.g., Au, Ag), metal oxides, nonmetal oxides (e.g., TiO₂, Al₂O₃, SiO₂), semiconductors (e.g., PbS, CdS), and so forth, where the nanoparticle has at least one dimension in nanometer scale, consequence, polymer nanocomposites are described as follows: zero-dimensional nanocomposites refers to isolated 0-D nanoparticles in a continuous polymer matrix; one-dimensional nanocomposites refers to 1-D nanotubes in a polymer matrix; two-dimensional nanocomposites refers to 2-D sheets exfoliated in a polymer matrix (e.g., polymer/layered silicate hybrids); and three-dimensional nanocomposites refers to interpenetrating polymer networks [1]. Epoxy is the most widely employed thermoset polymer, wide variety of composites can be made using epoxy as a matrix. They can be broadly grouped into fiber reinforced plastic (FRP) composites, particulate composites and is one of the most important polymer nanocomposites and has wide variety applications in industry, low density of epoxy resin around 1.05 - 1.3 g/cm³, good adhesive of epoxy resin. Epoxies are amorphous and highly cross-linked polymers, the structure of cross-linked polymer also leads to undesirable properties such as; relatively brittle materials, a poor resistance to crack initiation and growth. One way to improve these disadvantages can be done by filling with nanoparticles where the special properties of nanoparticles leading to improve the material properties [2]. Some advantages expected from the reinforcement of nanoparticles are: (i) nanoparticles complete suppression of sedimentation caused by lower viscosity of the resin formulation compared to common reinforcing fillers which lead to filler sedimentation, (ii) improved some mechanical properties such as; fracture toughness, impact strength, and modulus, scratch and abrasion resistance, (iii) improved dielectric properties, (iv) improvement of heat distortion (v) chemical resistance (vi) durability and weathering stability, (vii) no adverse influence on the processing characteristics of the basic resin [1,3].

computer chip packaging (insulation), protective coatings, adhesives and advanced aerospace composites, based on their great strength, high temperature stability, good processability, and good chemical resistance these are the important applications for polymer nanocomposites. Also polymer nanocomposites show major improvements in mechanical properties, gas barrier properties, thermal stability, fire retardancy, insulating properties with good mechanical properties and other fields [4-6].

II. EXPERIMENTAL WORKS

The raw materials used to prepare the samples are; Epoxy as a matrix (Nitofill, EPLV with Nitofill EPLV hardener from Fosroc Company), the weight ratio of the epoxy resin to the hardener was 3:1 and gelling time 40 minutes at 35°C, mixed viscosity 1.0 poise at 35°C and density 1.04g/cm³. The fillers are SiO₂ nanoparticles (Aerosil-200) from Aerosilpharma (hydrophilic silica) with mean diameter of 12nm, a specific surface area of 200±25m²/g, Atomic force microscopy (AFM) was used (CSPM scanning probe microscope) to measure the particles size of SiO₂ nanoparticles, the particles size distribution is shown in Fig.(1).

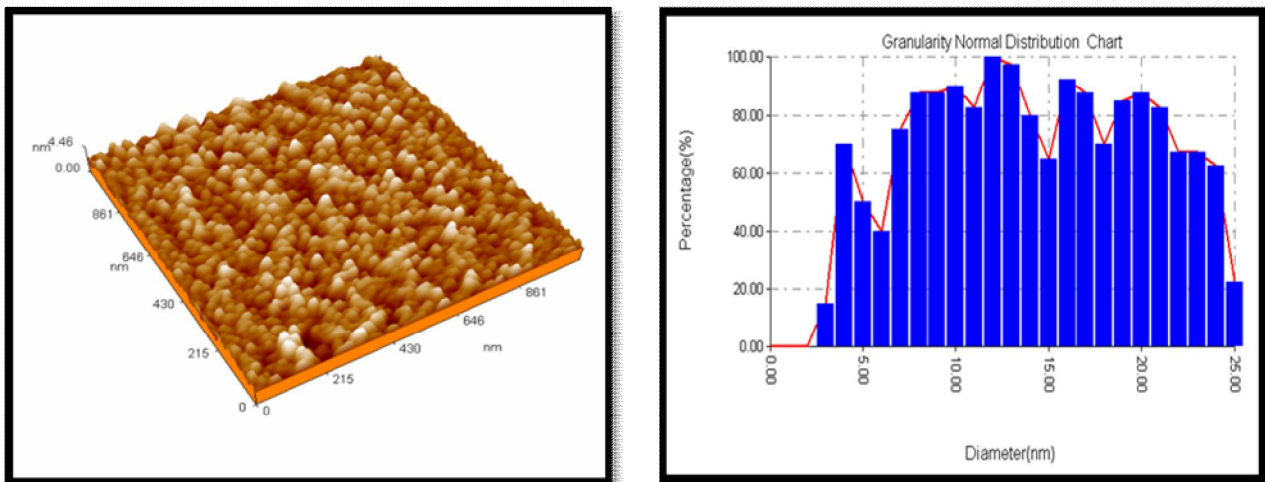


Figure 1. AFM of silica nanoparticles

E-glass fibers type bidirectional woven roving as reinforcements of surface density 400 g/cm² are used in this work with properties: good wetting characteristics, excellent mechanical properties, easy air release and Low fuzz, width (900, 3600) mm. The fiber material used in this work is shown in figure (2). Table (1) shows some of the raw materials properties.

Table 1 Some raw materials and some of their properties

Materials	Density g/cm ³	Particle Size	Surface area (m ² /g)	Purity%
Epoxy (EPLV)	1.04	-----	-----	-----
Nano-Silica (SiO ₂)	0.05	12 (nm)	200±25	99.8
E-Glass fiber	2.55			

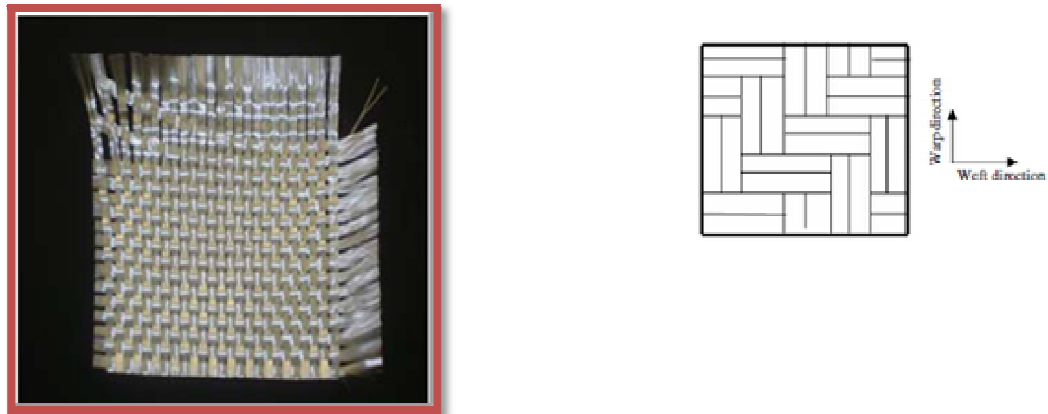


Figure 2. Woven roving Mat glass fiber or mat (M)

Impact test and Shore D hardness test specimens were prepared by hand lay-up technique and mixing process which can be summarized by the following steps:

Specimens of neat epoxy and its nanocomposites with different volume fraction (1, 3, 5, 7 and 10%) of SiO₂ nanoparticles reinforced with six layers of woven roving E-glass fibers were prepared by molding method, mass for a given volume fraction of SiO₂ was determined from the volumes of individual components matrix and SiO₂ fillers by using:

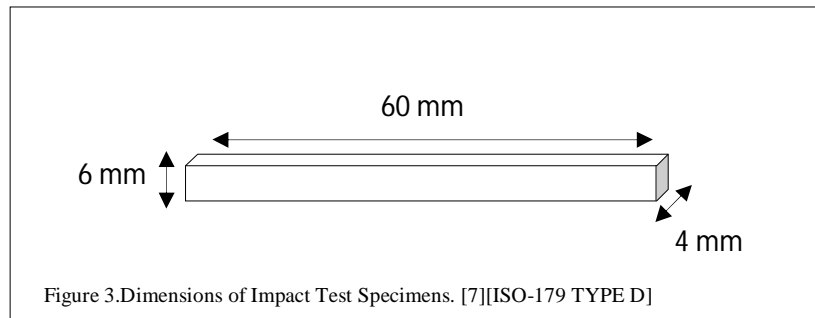
$$V_f + V_m = 1 \quad \dots \dots \dots (1)$$

$$V_f = W_f / \left[W_f + W_m \left(\frac{\rho_f}{\rho_m} \right) \right] \quad \dots \dots \dots (2)$$

Where V_f is the volume fraction of SiO₂ fillers, V_m is the volume fraction of epoxy matrix, W_f & ρ_f is the mass and density of fillers for the prepared composite, W_m & ρ_m is the mass and density of epoxy matrix for the prepared composite.

The nanocomposites were prepared in more complicated method such that; the nanoparticles were preheated at 120 for 2h in order to eliminate possible absorbed water on their surface, so that to prepare homogenous mixture of epoxy and nanocomposites, a volume fraction percent of nanoSiO₂ particles weighted with electronic balance of four digits type (Sartorius H51) then mixed with epoxy resin, the mixture put inside a container, an oil bath was used to heat up the mixture to desired 75 temperatures so the viscosity of epoxy base is reduced. Proper mechanical stirring for 2h at this stage resulted better dispersion of nanoparticles, then the mixture was cooled to room temperature after that the hardener was added to the formulation and mixed by mechanical stirring for 10 minutes, nanocomposite reinforced with E-glass fiber, they were prepared by pouring, the mixture of epoxy and SiO₂ nanoparticles on 6 laminates of the woven roving E-glass fiber uniformly using hand lay-up method, paint brush and aluminum notched roller to maintain uniformly mixture with the fibers sheet. Sheets were left at room temperature for 24 hours for curing, and was cast in an oven for 1 hour at 50 °C for post curing, it was left for 48 hours before pulling out from molds and left for 7 days before any test to get better curing conditions and kept then in vacuum chambers.

The sheets of the nanocomposites reinforced with six layers of woven roving WRE-glass fibers are cutting into specimens, by using a circular iron saw, plus from the samples were removed by using the iron rasp, the samples were polished by using abrasive emery papers of grade 400. The shape and dimension of the samples cut for impact test according to [ISO-179 TYPE D] shown at Figure (3).



➤ **CHARPY IMPACT TEST**

This instrument consists mainly of pendulum and energy gauge. Charpy impact test consists of standard test piece that would be broken with one flow of a swinging hammer. The test piece is supported at both its ends in a way that the hammer strikes it at the middle. The testing method of this instrument includes lifting of the pendulum to its maximum height and fixing it firmly. The specimen is fixed in its pertaining place, and then the energy gauge is initialized (on zero position), after that, the pendulum is freed whereas its potential energy would be changed to kinetic energy. Some of this kinetic energy is utilized to fracture the specimen, while the energy gauge reads the value of fracture energy (U_c) for the sample under test. Impact strength (I.S) is calculated by applying the relationship [8].

$$I.S = U_c/A(KJ/m^2).....(3)$$

Where U_c : is the fracture energy (Joule) which is determined from charpy impact test instrument. A : is the cross-sectional area of the specimen.

➤ **HARDNESS TEST**

Shore D Durometer Hardness instrument, fabricated by TIME GROUP INC Company, and was used to carry out the hardness test by using pointed dibbing tool. The pointed dibbing tool penetrate the material surface by the pressure applied on the instrument where the dibbing tool head touching quite the surface of the samples then calculate the hardness values for the samples.

II. RESULTS AND DISCUSSIONS

The results of Impact strengths of EP/SiO₂nanocomposites reinforced with 6 layers of woven roving WRE-glass fibers in Table (2) showed that Impact strength has a randombehaviour with increasing volume fraction of SiO₂nanoparticles of EP/SiO₂nanocomposites reinforced with 6 layers of WRE-glass fibers. The results show an increase of Impact strengths with increasing the SiO₂nanoparticles volume fraction at1% Vol. of SiO₂ nanoparticles,then decreases with increasing volume fraction at3% Vol. of SiO₂ nanoparticles, then the Impact strength increases with increasing volume fraction of SiO₂ nanoparticles until the Impact strength reach to maximum values (382.36KJ/m²) at5% Vol. of SiO₂nanoparticles.And thenImpact strength decreases with increasing volume fraction at7% and 10% Vol. of SiO₂ nanoparticles.

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Table (2) the values of Impact Strength of epoxy and EP/SiO₂nanocomposites reinforced with 6 layers of WRE-glass fibers.

Sample	Impact Strength (I.S), KJ/m ²
EP	3.30
EP / 0% nanoSiO ₂ reinforced with 6 layers of WRE-glass fibers.	101.2
EP / 1% nanoSiO ₂ % reinforced with 6 layers of WRE -glass fibers.	208.86
EP / 3% nanoSiO ₂ % reinforced with 6 layers of WRE -glass fibers.	101.27
EP / 5% nanoSiO ₂ % reinforced with 6 layers of WRE -glass fibers.	382.36
EP / 7% nanoSiO ₂ % reinforced with 6 layers of WRE -glass fibers.	125.39
EP / 10% nanoSiO ₂ % reinforced with 6 layers of WRE -glass fibers.	156.39

Photographs of specimens before, after test show damage of 10Vol. % SiO₂ for nanocomposites reinforced 6 Layers of (WR) E-glass fiber was shown in Figure (4).

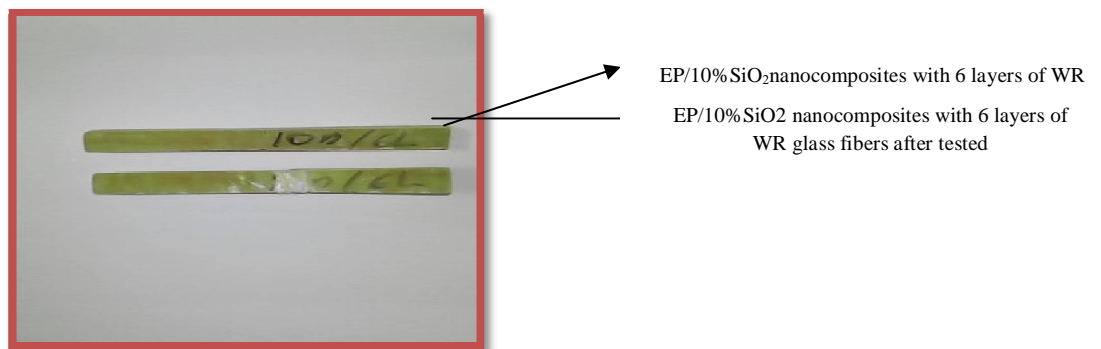


Figure.4. Photographs of specimens before and after tested to show damage of 10Vol. % SiO₂ for nanocomposites reinforced 6 Layers of (WR) E-glass fiber

In general all the results obtained still higher than the neat epoxy and the neat composites specimen. Figure (5) shows the variation of Impact strengths of EP/SiO₂nanocomposites reinforced with 6 layers of WRE-glass fibers vs. SiO₂nanoparticles volume fraction.

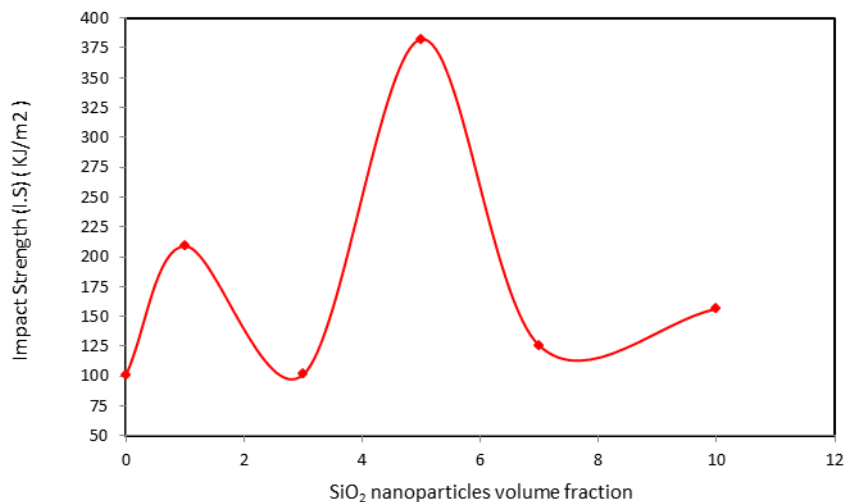


Figure 5. Charpy impact strength vs. the volume fraction for EP/SiO₂nanocomposites reinforced with 6 layers of WRE -glass fibers

The results of Shore D hardness of EP/SiO₂nanocompositesreinforced with 6 layers ofwoven rovingWRE-glass fibers showed in Table (3).Where the Hardness No. values decrease with increasing the volume fraction of SiO₂nanoparticles.This type of behavior indicates increasing brittle properties of the nanocomposites.Minimum value was (81.6) at 10% Vol. fraction of SiO₂nanoparticles, several mechanisms were responsible of decreasing Hardness No. such as; nanoparticles size that increased space distance between epoxy chains, decreasing epoxy chains length over certain critical chains length due to distribution nanopaticles inside epoxy matrix, low porosity of nanoparticles surface lead to de-bonding and cavitationsappears. Figure (6) shows the variation of Hardness No. of EP/SiO₂nanocomposites reinforced with 6 layers of WRE-glass fibers vs. SiO₂ nanoparticles volume fraction.

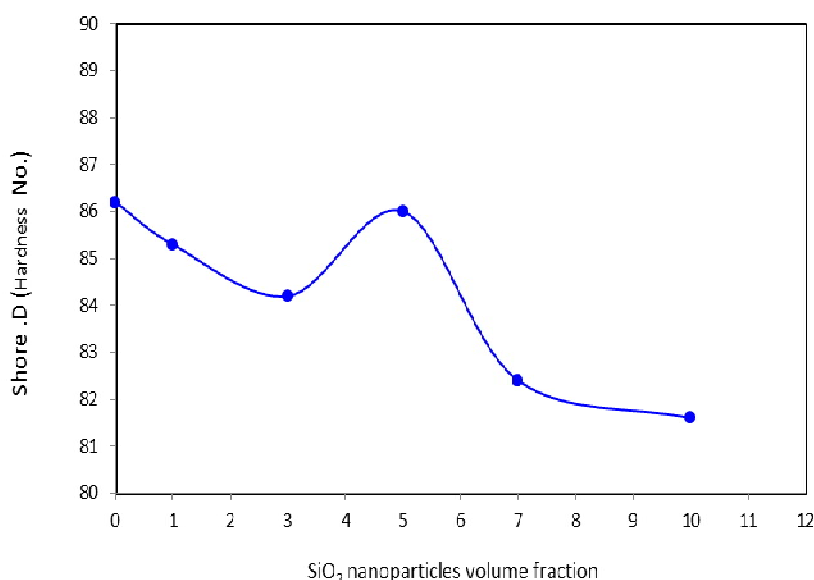


Figure 6.Hardness No.vs. the volume fraction for EP/SiO₂nanocompositesreinforced with 6 layers of WRE-glass fibers

Table (3): The values of Shore D hardness for epoxy and EP/SiO₂ nanocompositesreinforced with 6 layers of WRE –glassfibers

Sample	Hardness No.
EP	79.7
EP / 0% nanoSiO ₂ reinforced with 6 layers of WRE -glass fibers.	86.2
EP / 1% nanoSiO ₂ reinforced with 6 layers of WRE -glass fibers.	85.3
EP / 3% nanoSiO ₂ reinforced with 6 layers of WRE -glass fibers.	84.2
EP / 5% nanoSiO ₂ reinforced with 6 layers of WRE -glass fibers.	86
EP / 7% nanoSiO ₂ reinforced with 6 layers of WRE -glass fibers.	82.4
EP / 10% nanoSiO ₂ reinforced with 6 layers of WRE -glass fibers.	81.6

IV. CONCLUSION

- ❖ SiO₂ nanoparticles improve Impact strength of epoxy matrix in EP/SiO₂nanocomposites reinforced with 6 layers of WRE-glass fibers.
- ❖ Impact strength of EP/SiO₂nanocompositesincrease with increasing volume fraction of SiO₂nanoparticles in the epoxy matrix of EP/ SiO₂nanocomposites reinforced with 6 layers of WRE-glass fibers.

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