



Study Of Some Mechanical Properties For Epoxy/ SiO₂ Nano Particles Reinforced With 6 Layers Of CM E-Glass Fibers Composites

¹Ahmed Jadah Farhan, ²Ruaa hilal

1Department of Physics, College of Science, University of Wasit, Kut, Wasit.
kutpc19@yahoo.com

2Department of Physics, College of Science, University of Wasit, Kut, Wasit.
Ruaahilal83@gmail.com

ABSTRACT

In this study, the neat epoxy and nanocomposites with volume fraction (1, 3, 5, 7 and 10%) of nano SiO₂ particles reinforced with six layers of chopped mat E-glass fibers (CM) specimens were prepared by molding method. The results of Impact strengths of EP/SiO₂ nanocomposites reinforced with 6 layers of CM E-glass fibers showed that Impact strength has a random behaviour with increasing volume fraction of SiO₂ nanoparticles. The results showed 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 (78.93KJ/m²) at 7% vol. of SiO₂ nanoparticles. And then Impact strength decreases with increasing volume fraction at 10% vol. of SiO₂ nanoparticles.

Also the results of shore D hardness of EP/SiO₂ nanocomposites reinforced with 6 layers of CM E-glass fibers showed that Hardness No. an increase 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 Hardness No. increases with increasing volume fraction of SiO₂ nanoparticles until the Hardness No. reach to maximum values (85.03) at 10% vol. of SiO₂ nanoparticles.

Keywords

Silica nanoparticles, chopped mat E-glass fibers, Impact strength, Shore D hardness.

1 INTRODUCTION

Polymer nanocomposites are defined as an interacting mixture of two phases, a polymer matrix and a solid phase which is in the nanometer size range in at least one dimension. Solid phase are fillers such as carbon nanotubes, layered graphite nanofillers, silica nanoparticles, titania nanoparticles etc. Very important feature of polymer nanocomposites is that the small size of the fillers leads to a dramatic increase in interfacial area as compared with traditional composites [1]. There are many factors that affect the polymer nanocomposite properties such as; (i) Types of nanoparticles and their surface treatments, dispersion and distribution of nanoparticles in the polymer matrix, shape and size. (ii) The types of synthesis methods. (iii) Polymer nanocomposite morphology. (iv) Polymer matrix such as degree of crystallinity, molecular weight, polymer chemistry and the type of polymer; thermoplastic, thermosetting or elastomers [2, 3, 4].

Sands cover a large quantity of the Earth and are the source from which most silica is made. The crystalline and non-crystalline forms of silicon dioxides are well known to be named as quartz and fused silica, respectively. Two methods have been used in preparing nano scale silica: the gas-phase (or the drying method) and the deposition preparation method (or the wet method). The particle sizes in both the gas-phase and the deposition methods are quite different in that the former produces silica with a smaller particle size than that produced by the latter method [5, 6].

Some characteristic of silica nanoparticles; (i) Swelling behavior and cation exchange performance. (ii) Porosity, particle porosity structure and pore distribution are of importance, the diameters of micropores and mesopores are all less than 50 nm, and the diameter of macropores or large pores is above 50 nm. Particles with pore diameter less than 100 nm should be thought of as nanomaterials. (iii) Dispersion phase and media, the smaller the particle size the more difficult is its dispersion into the polymer matrix [5, 7].

Nanocomposite materials have become increasingly important due to their extraordinary properties, which arise from the synergism between the properties of the parent components and their unique interfacial characteristics. These properties appear to be quite different from those of the conventional micrometer-sized composites. This mainly results from the nanometer-sized component which dramatically increases the available interacting surface area [20].

The general Applications of nanocomposite have recently attracted increasing interest because of the possibilities of synthesizing materials with unique physical-chemical properties. Highly sophisticated surface related properties, such as optical, magnetic, electronic, catalytic, mechanical, chemical and tri biological properties can be obtained by advanced nano structured manufacturing, making them attractive for industrial applications in high-speed machining, optical applications and magnetic storage devices because of their special mechanical, electronic, magnetic and optical properties due to size effect [9].

2 EXPERIMENTAL

2-1 RAW MATERIALS

Raw materials used in this experimental work are listed below:

2-1-1 MATRIX MATERIALS

Epoxy as a matrix (Nitofill, EPLV with Nitofill EPLV hardener from Fosroc Company) was used to prepare composites. 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. The properties of epoxy resin are given in Table (1).

Table (1): Properties of epoxy at 35°C

Property	Epoxy (EP)
Density (gm/cm ³)	1.04
Tensile strength (N/mm ²)	26.0
Compressive strength(N/mm ²)	93.0
Flexural strength(N/mm ²)	63.0
Young modulus in Compression (GPa)	10

2-1-2 FIBER MATERIAL

E-glass fibers were used as reinforcements, chopped mat E-glass fibers of surface density 300 g/cm². The fiber materials used in this work are shown in Figure (1). Table (2) show Properties of chopped mat random (CM) E-glass fibers.



Figure (1): Chopped mat (Random) glass fiber (CM) used in this work.

Table (2): Properties of chopped mat random (CM) E-glass fibers

Chopped mat random (CM)
Fast wet-out
Even thickness
Easy air release
High moisture content
Width(1040, 2080, 3120)mm

2-1-3 REINFORCING PARTICLE

SiO₂ nanoparticles (Aerosil-200) from Aerosil pharma (hydrophilic silica) with average diameter of 12nm, a specific surface area of 200±25m²/g. Atomic force microscopy (AFM) was used (CSPM scanning probe microscope) to measured the average particles size of SiO₂ nanoparticales, the particles size distribution is shown in Figure (2).Some properties of the reinforcing particulate are given in Table (3).

Table (3): properties of the particulate materials properties.

Particulate Materials	Density g/cm ³	Surface area m ² /g	Particle Size	Purity
Nano SiO ₂	0.05	200± 25	12 nm	99.8

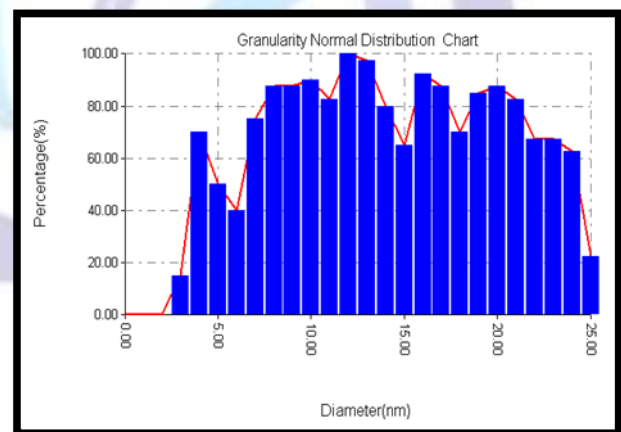
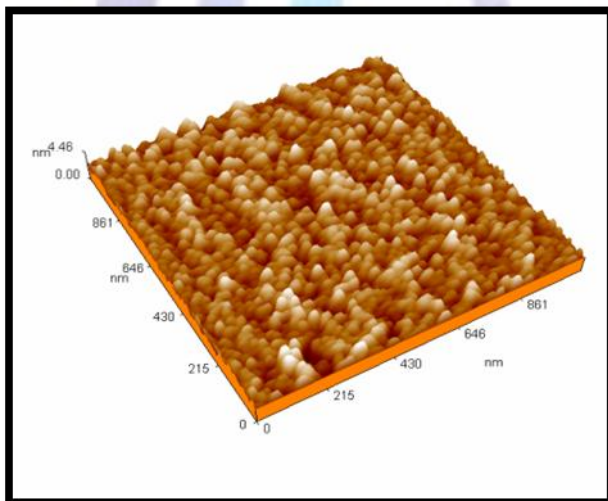


Figure (2): AFM of silica nanoparticles

2-2 PREPARATION METHOD

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:



2-2 -1 PREPARATION OF NEAT EPOXY

The neat epoxy specimens were prepared by simple direct mixing of epoxy resin with the hardener, epoxy resin and hardener are weighted for suitable mixing ratio by using electronic balance type (Sartorius BL 210S/Germany) with sensitivity of 10-4g and with rang up to 2Kg, and mixed in container by mechanical stirring for 15 minutes to get good homogeneity between epoxy resin and hardener before casting it as sheets (of dimensions 15x15cm²), by using clean glass mould (cleaned by distilled water to remove the dirt and dust present on the surfaces) were used for casting. The casting was cured at room temperature for 24 hours. Sheets were casted in an oven for 1hour with temperature 50 oC, it was left for 48 hours before pulling out from molds and then left at room temperature for 7 days before processing further and kept then in vacuum chambers.

2-2-2 PREPARATION OF THE LAMINATED COMPOSITES

Sheets of E-glass/epoxy composites were prepared from epoxy resin (as a matrix) and E-glass fibers(as reinforcement) with the chopped strand mat CM by using hand lay-up method sometimes called wet lay –up or contact moulding, is a simple method and the most widely used for fiber reinforced polymer (FRP) process. In its simplest form, the process consists of applying layers of reinforcing material against a single sided mould and working resin into the material with a brush and roller, after a suitable period of time to allow the resin to cure, the moulding with one smooth surface, is removed from the mould and trimmed to size, which can be summarized by the following steps:

The epoxy resin was mixed with the hardener in weight fraction of 3:1 both were thoroughly mixed to be ready to composite construction. Fiber glass sheets of dimensions 15 x 15cm² were cut from chopped mat.

The first layer of mat was laid and epoxy resin spread uniformly over it by means of a paint brush. A second layer of mat was laid and spread again with paint brush. After the second layer, to enhance wetting and impregnation, a teathed aluminum roller was used to roll over the fabric before applying resin. It was made sure that there is no air bubbles entrapped inside the mixture applied on sheet otherwise it would create a flow there. This process was repeated till all the six fabric layers were placed. The casting was cured at room temperature for 24 hours. The specimens were casted in an oven for 1hour with temperature 50°C and finally removed from the mold to get a fine finished composite sheet after 48 hours and then left at room temperature for 7 days before processing further and kept then in vacuum chambers.

2-2-3 PREPARATION OF EPOXY NANOCMPPOSITES

Nanocomposites with different volume fraction (1, 3, 5, 7 and10%) of nano SiO₂ particles and reinforced with six layers of E-glass fibers(CM) were prepared by molding method. Since properties of composite depend upon the volume fraction of reinforcement, 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,

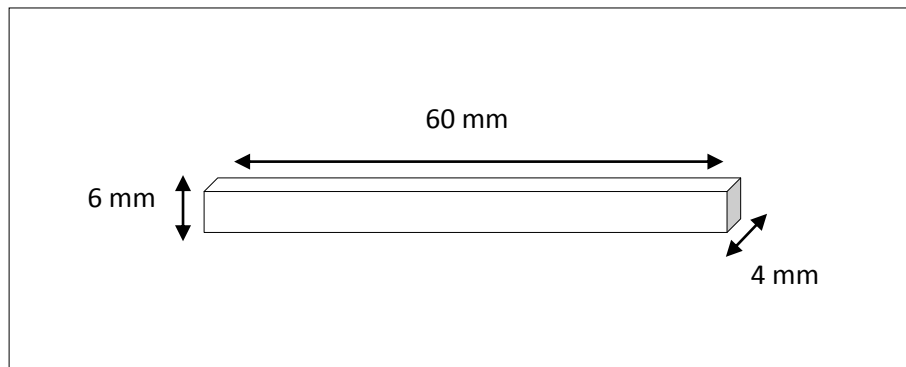
W_f & ρ_f is the mass and density of fillers for the prepared composite,

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 oC for 2 h in order to eliminate possible absorbed water on their surface, to prepare homogenous mixture of epoxy and the nanoparticles, 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 oC) temperature so the viscosity of epoxy base is reduced. Proper mechanical stirring (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 being mixed by mechanical stirring (10 minutes). Sheets were left at room temperature for 24hours for curing, and was cast in an oven for 1 hour at 50 oC 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.

3 IMPACT TEST SAMPLE CUTTING

The sheets of the nanocomposites reinforced with six layers of chopped mat E-glass fibers (CM) are cutting into specimens, by using a circular iron saw, pluses 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) .



**Figure (3): Dimensions of Impact Test Specimens. [10]
[ISO-179 TYPE D]**

4 CHARACTERISATION TECHNIQUE

4.1 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:[11]

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

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.

4-2 HARDNESS TEST

Shore D Durometer Hardness instrument, fabricated by TIME GROUP INC Company, 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.

5 RESULTS

5-1 IMPACT STRENGTH OF COMPOSITES

The results of Impact strengths of EP/SiO₂ nanocomposites reinforced with 6 layers of CM E-glass fibers in Table (4) showed that Impact strength has a random behaviour with increasing volume fraction of SiO₂ nanoparticles of EP/SiO₂ nanocomposites reinforced with 6 layers of CM E-glass fibers. 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 (78.93KJ/m²) at 7% vol. of SiO₂ nanoparticles. Increases Impact strength due to Increase of crack deflections (creating more than one crack propagation direction) which means crack propagation resistance and increase of chains supporting resulting from nanoparticles existence. And then Impact strength decreases with increasing volume fraction at 10% vol. of SiO₂ nanoparticles.

In general all the results obtained still higher than the neat epoxy and the neat composites specimen. Figure (4) shows the variation of Impact strengths of EP/SiO₂ nanocomposites reinforced with 6 layers of CM E-glass fibers vs. SiO₂ nanoparticles volume fraction.

Photographs under 40X magnification for Charpy Impact specimens of EP/SiO₂ nanocomposites with 1, 3, 5, 7and 10% volume fraction nanocomposites reinforced with 6 layers of CM E-glass fibers after the test showed in Figure (5).



Table (4) The values of Impact Strength of epoxy and EP/SiO₂ nanocomposites reinforced with 6 layers of CM E-glass fibers.

Sample	Impact Strength (I.S), KJ/m ²
EP	3.30
EP / 0% nanoSiO ₂ reinforced with 6 layers of CM E-glass fibers.	47.81
EP / 1% nanoSiO ₂ reinforced with 6 layers of CM E-glass fibers.	60.18
EP / 3% nanoSiO ₂ reinforced with 6 layers of CM E-glass fibers.	28.73
EP / 5% nanoSiO ₂ reinforced with 6 layers of CM E-glass fibers.	63.49
EP / 7% nanoSiO ₂ reinforced with 6 layers of CM E-glass fibers.	78.93
EP / 10% nanoSiO ₂ reinforced with 6 layers of CM E-glass fibers.	49.35

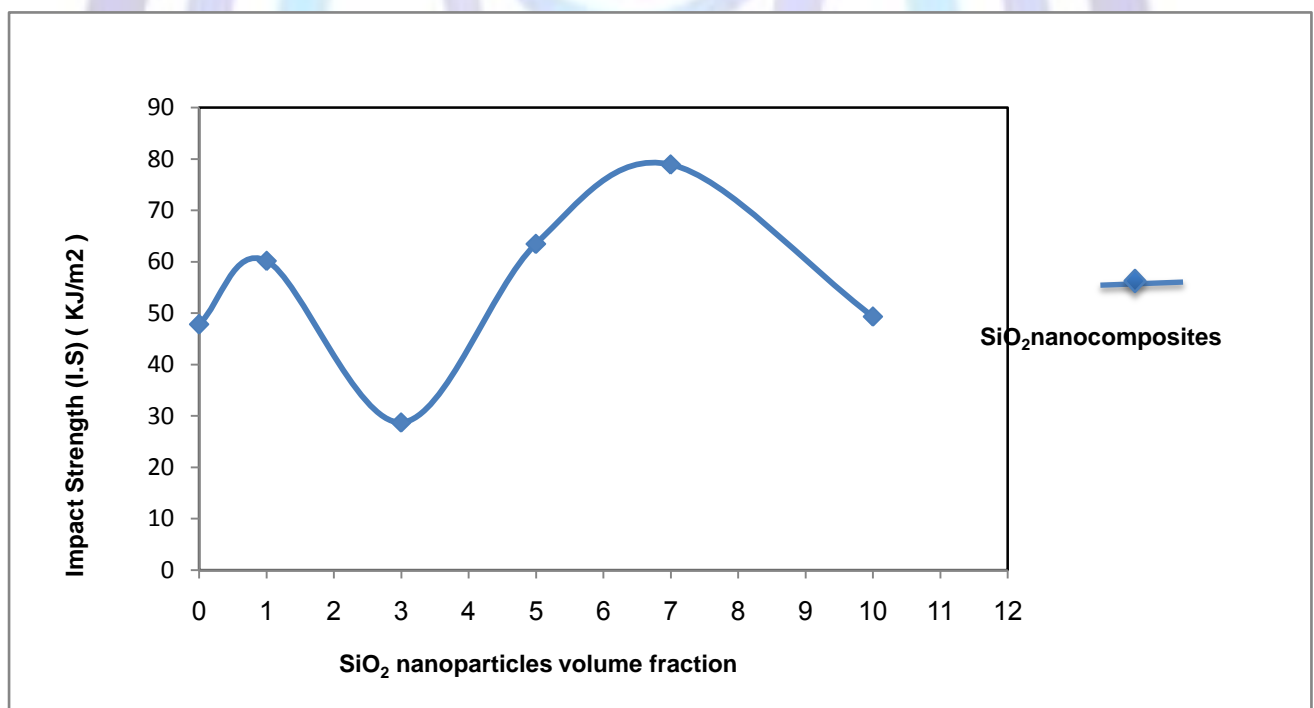


Fig. (4). Charpy impact strength vs. the volume fraction for EP/SiO₂ nanocomposites reinforced with 6 layers of CM E-glass fibers

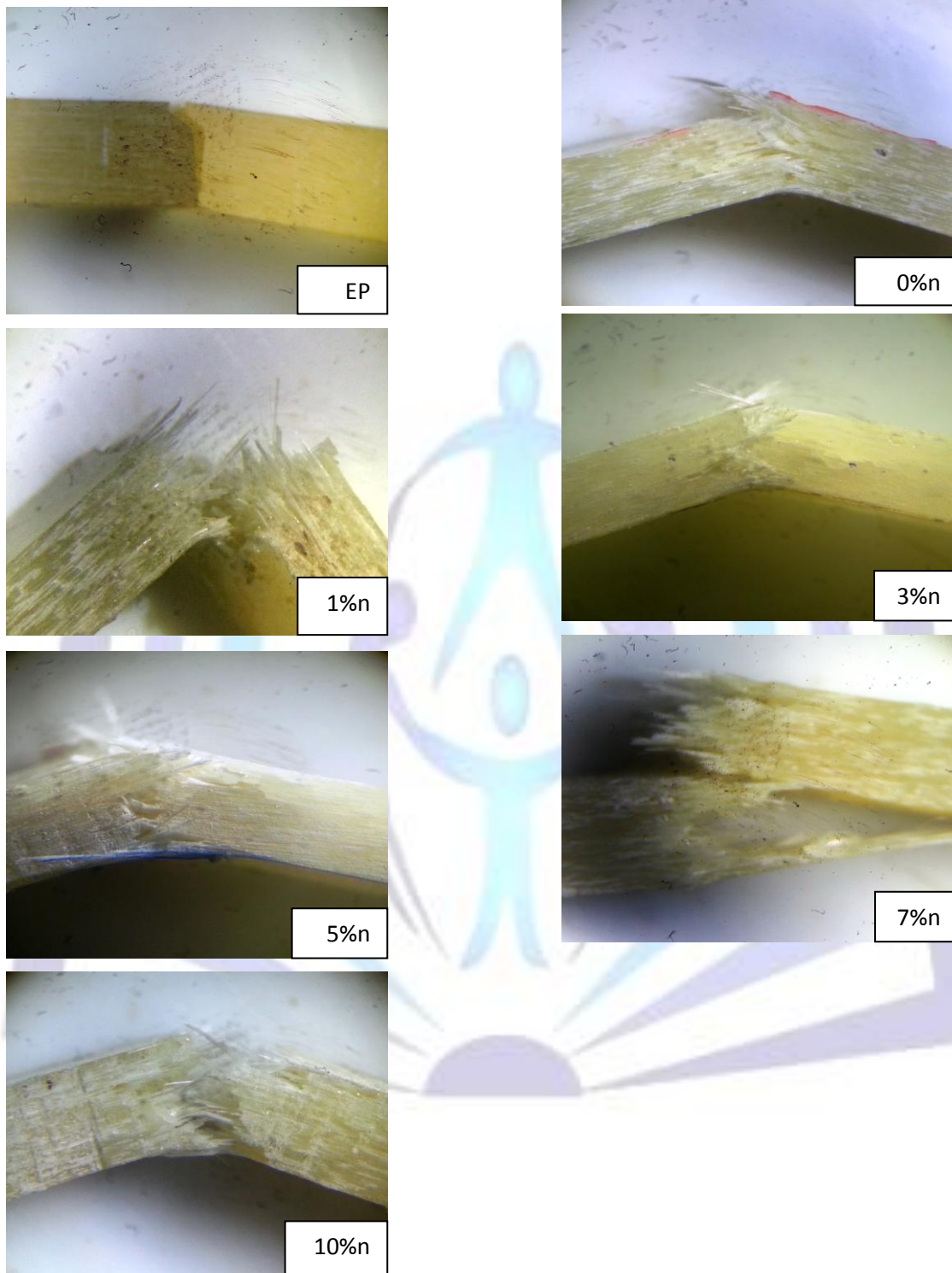


Fig. (5). Photographs under 40 X magnification for specimens of EP and EP/ SiO₂ nanocomposites with (1, 3, 5, 7 and 10%) vol . fraction nanocomposites reinforced with 6 layers of CME-glass fibers after test

5-2 HARDNESS TEST

The results of shore D hardness of EP/SiO₂ nanocomposites reinforced with 6 layers of CME-glass fibers showed in Table (5). It was noticed the Hardness No. an increase with increasing the SiO₂ nanoparticles volume fraction at 1% vol. of SiO₂ nanoparticles, this behaviour is due to existence SiO₂ microparticles in epoxy matrix causing an increase of the immobility of epoxy chains then decreases with increasing volume fraction at 3% vol. of SiO₂ nanoparticles, then the Hardness No. increases with increasing volume fraction of SiO₂ nanoparticles until the Hardness No. reach to maximum values (85.03) at 10% vol. of SiO₂ nanoparticles, this is because of particles size, where it leads to increasing the constraint between epoxy chains (chains immobility increase). So all the results of Hardness No. were higher than that of epoxy, figure (6) shows the variation of Hardness No. of EP/SiO₂ nanocomposites reinforced with 6 layers of CME-glass fibers vs. SiO₂ nanoparticles volume fraction.

Table (5): The values of Shore D hardness for epoxy and EP/SiO₂ nanocomposites reinforced with 6 layers of CME-glass fibers.

Sample	Hardness No.
EP	79.7
EP / 0% nanoSiO ₂ reinforced with 6 layers of CM E-glass fibers.	80.7
EP / 1% nanoSiO ₂ reinforced with 6 layers of CM E-glass fibers.	83.8
EP / 3% nanoSiO ₂ reinforced with 6 layers of CM E-glass fibers.	81.5
EP / 5% nanoSiO ₂ reinforced with 6 layers of CM E-glass fibers.	83.4
EP / 7% nanoSiO ₂ reinforced with 6 layers of CM E-glass fibers.	83.8
EP / 10% nanoSiO ₂ reinforced with 6 layers of CM E-glass fibers.	85.03

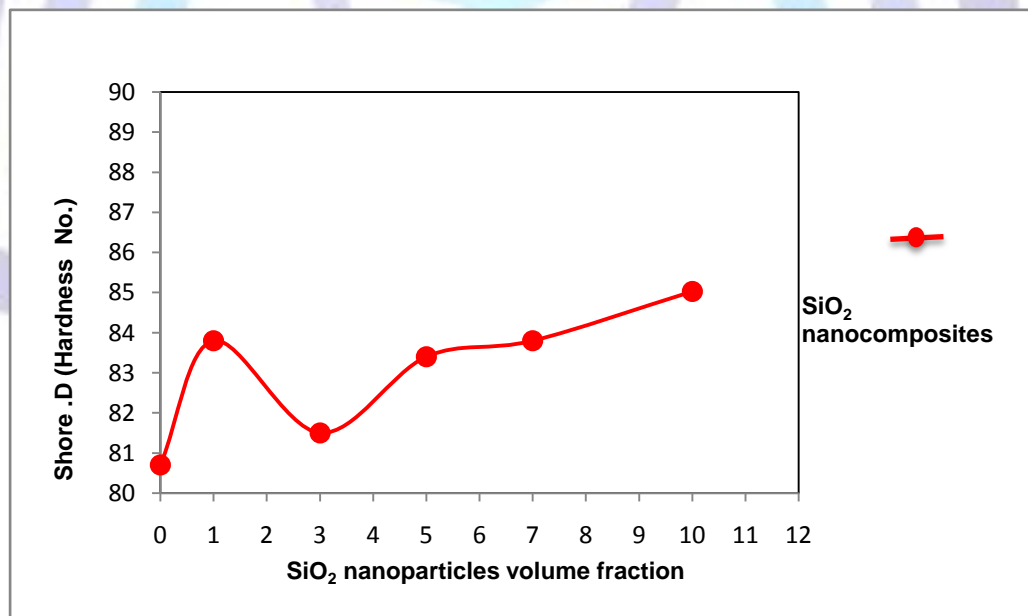


Fig. (6). Hardness No. vs. the volume fraction for EP/SiO₂ nanocomposites reinforced with 6 layers of CME-glass fibers



6 CONCLUSION

1. SiO₂ nanoparticles improve Impact strength and Hardness No. of epoxy matrix in EP/SiO₂ nanocomposites reinforced with 6 layers of CME-glass fibers.
2. Impact strength of EP/SiO₂ nanocomposites increase with increasing volume fraction of SiO₂ nanoparticles in the epoxy matrix of EP/ SiO₂ nanocomposites reinforced with 6 layers of CME-glass fibers.
3. Hardness No. of EP/ SiO₂ nanocomposites increase with increasing volume fraction of SiO₂ nanoparticles in the epoxy matrix of EP/ SiO₂ nanocomposites reinforced with 6 layers of CME-glass fibers.

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