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Preparation of Epoxy Nanocomposites and Studying Their Mechanical, Thermal and Morphology Properties

تحضير متراكبات الايبوكسي النانوية و دراسة خواصها الميكانيكية و الحرارية و المظهرية

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Abstract:

Epoxy resin was used as a matrix , reinforced by nanosilica as a filler in different percentages (1, 3, 5, 7 and 10) % to prepare epoxy nanocomposites and a comparison between manual mixing and ultrasonic mixing by studying mechanical properties (tensile strength) , thermal properties (Limiting Oxygen Index (LOI)) and morphology (Scanning Electron Microscope (SEM)) to get the best improvement results .

The best results were for ultrasonic mixing , at additive content 5% for tensile strength, and noticeable increment in all limiting oxygen index measurements.

الخلاصة:

تم استخدام راتنج الايبوكسي كمصفوفة مدعم بالسيليكا النانوية كمادة مالئة بنسب مختلفة (1 ، 3 ، 5 ، 7 و 10) % لتحضير متراكبات الايبوكسي النانوية و إجراء مقارنة بين المزج اليدوي و المزج بواسطة جهاز الامواج فوق الصوتية و ذلك بدراسة الخواص الميكانيكية (قوة الشد) و الخواص الحرارية (معامل الأوكسجين المحدد) و الشكل الظاهري (مجهر المسح الالكتروني).

و بعد إجراء القياسات وجد إن أفضل النتائج كانت بالمزج بجهاز الموجات فوق الصوتية ، عند النسبة 5 % لقياس قوة الشد ، و زيادة ملحوظة في جميع قياسات معامل الأوكسجين المحدد.

Key words: Epoxy resin, Nanocomposites, ultrasonic, nanosilica.

Introduction

Epoxy is formed from two different chemicals; these are referred to as the "resin" and the "hardener". (1)

Among the thermoset materials, epoxy resins show special chemical characteristics such as absence of byproducts or volatiles during curing reactions, low shrinkage up on curing, curing over a wide temperature range and the control of degree of cross-linking.(2)

A polymer composite is made by the combination of a polymer and synthetic or natural inorganic filler. Fillers are employed to improve the desired properties of the polymer or simply reduce the cost. Polymer composites with improved mechanical, thermal, barrier and fire retardant properties are widely used in very large quantities in variety of applications, using conventional fillers such as talc, calcium carbonate, fibers, etc.(3)

The primary reasons for using additives are:

1. Property modification or enhancement.
2. Overall cost reduction.
3. Improving and controlling of processing characteristics.(4)

Nanotechnologies are the design, characterization, production and application of structures, devices and systems by controlling shape and size at nanometer scale. The nanometer scale is conventionally defined as 1 to 100 nm. (5)

Nanocomposites are a new class of materials that have high physical , thermal and mechanical properties compared with conventional composites (micro composites) due to the much stronger interfacial interactions between dispersed nanosized particles and matrix.(6)

Nanoparticles can be classified as:

1. One dimension; nanorods, nanowires …etc.
2. Two dimensions; tubes, fibers, platelets … etc.
3. Zero or three dimensions; particles, quantum dots, hollow spheres … etc.(7)

Nanocomposites are a type of composite in which the scale of the dispersed phase is within the nanometer scale at least in one dimension. Polymer nanocomposites consist of a polymeric material (thermosets or thermoplastics) and a reinforcing nanoscale material (nanoparticles). (8)

Due to the nanoscale dispersion of the nanoparticles, polymer nanocomposites exhibit light-weight, good dimensional stability, enhanced heat and flame resistance, and improvements of strength, stiffness, and barrier properties with far less clay loading than conventional composite counterparts . Of course, many factors may affect the properties of polymer nanocomposites :

• Type of nanoparticles and their surface treatments;
• Polymer matrix, such as molecular weight, crystallinity, and polymer chemistry;
• Synthesis methods, such as in-situ polymerization, melt compounding, and solution blending;
• Polymer nanocomposite morphology, such as nanoparticle dispersion.

Several studies of nanosilica as filler in composites materials were carried out to improve the strength, reduce the production cost, adjust the viscosity and to make smooth surface. (6)

Nanocomposites used in many fields such as defense application, corrosion protection, actuators, diffusion barriers, sensors(9), flammability (10), dielectric properties (11).

Experimental Part

Materials

The polymer matrix was consisted of part (A) epoxy resin (Quickmast105) and part B hardener (polyamine). Epoxy polymer matrix was prepared by mixing 3:1 parts by volume epoxy resin to hardener.

The additive is Silicon Oxide (SiO_2) nanopowder provided from (NANOSHEL LLC), atomic particle size 15-20 nm, and spherical particles.

Preparation of nanocomposites

Epoxy/ Silica nanocomposites were prepared by adding different percentage of nanosilica as filler (1, 3, 5, 7 and 10) % to epoxy resin, mixed manually for 30 minutes, then adding the hardener and mix well, molding the mixture in a glass mold prepared previously with insulating material to easy remove after dry. For the same percentage of filler, epoxy and filler were mixed by ultrasonic mixer for 20 minutes at 45^{o} C then adding the hardener and continue the above steps.

Mechanical Properties Analysis

Tensile Strength

Using (2L 203_2000 KG JIANQIAO testing equipment to execution sample test according to ASTM D412 in which the highest load was determined.

Thermal Properties

Limiting Oxygen Index (LOI)

Using oxygen Index tester YES_100 (ALEZZ CO.) according to ASTM D 2863 to determine minimum O_2 concentration required to sustain combustion of polymer sample in the presence of gases mixture (nitrogen and oxygen).

Morphology Properties

Scanning Electron Microscope (SEM)

Using Tescan VEGA 3SB to study morphology of sample surface, accelerating voltage 200V to 30 KV.

Results and Discussion

Results indicated that tensile strength increased with increasing additive content until 5% of nanosilica because of decreasing in space distance between chain crosslink by adding nanoparticles which are polar, creating Van der Waals bonding between chains and particles, lead to increase constrained between particles/polymer chains and polymer chains itself, with continuous adding of fillers, tensile strength began to decrease as (7 and 10) % because of agglomeration effect. [12, 13]

Generally the well dispersion of silica particles in the polymer matrix yields enhanced tensile strength with increasing silica content, according to two cases of in situ polymerization, the increasing noticed in 5 % but in ultrasonic mixer more enhancements was happened, as in Table (1) :

Table (1) : Tensile test values in (MPa) for epoxy/silica nanocomposite by manual and ultrasonic mixer

Additive Type % / Of mixing	1	3	5	7	10
Manual mixing	32.50	33.26	37.64	32.34	31.71
Ultrasonic mixer	43.09	49.86	50.36	27.15	18.63

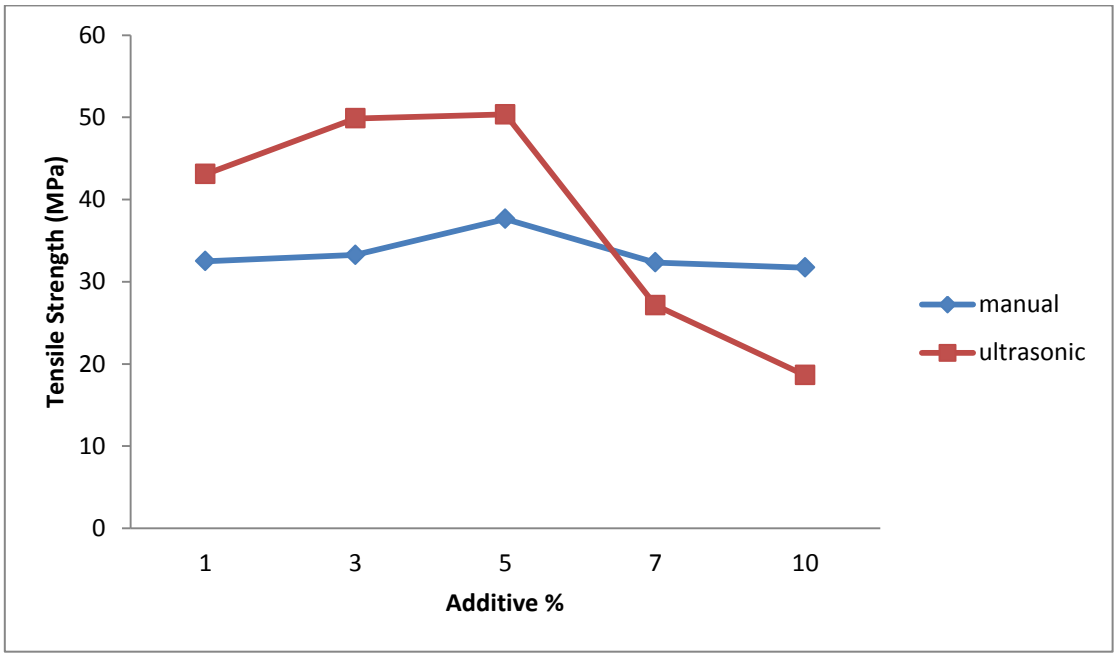

Figure 1 : Tensile strength of epoxy / silica nanocomposites.

Epoxy resin containing low weight percentages of nanosilica have greatly improved fire resistance which increased with increasing the additive weight percentage. More enhancement of limiting oxygen index results happened by using ultrasonic mixer, as shown in Table (2). This is due to the best dispersion of nanosilica in the composite structure , which effects the flammability and combustion of the polymer.

Table (2): Limiting Oxygen Index (LOI) values for epoxy/silica nanocomposite by manual and ultrasonic mixer.

Additive% / Type of mixing	1	3	5	7	10
Manual mixing	21.25	22.48	23.07	23.80	24.7
Ultrasonic mixer	23.80	24.17	24.81	25.23	25.71

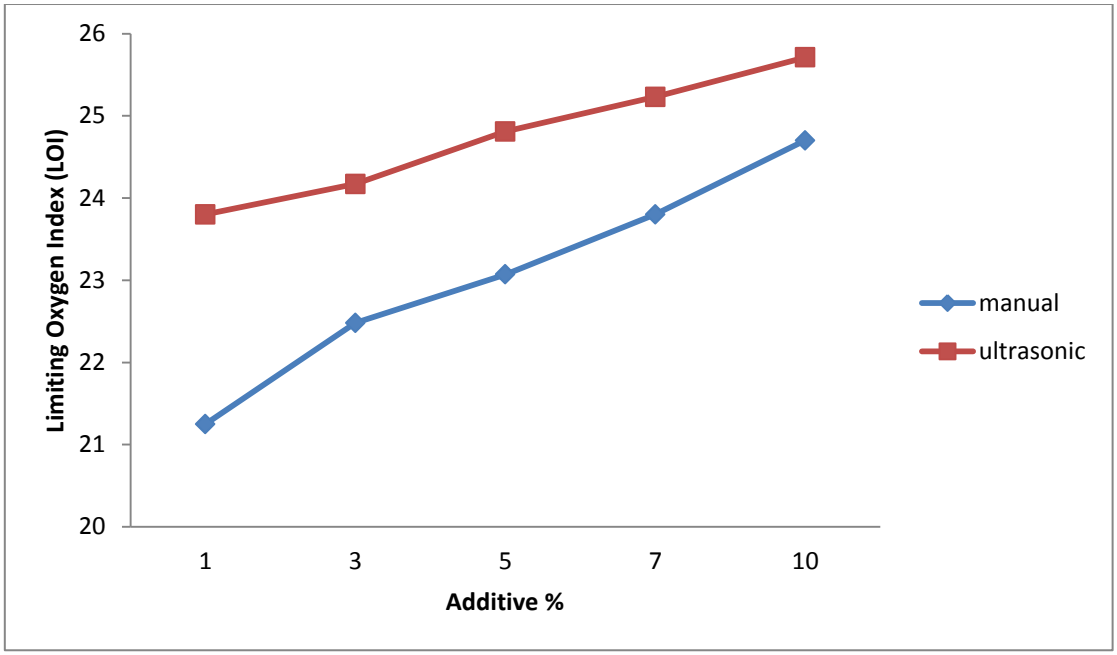

Figure 2 : Limiting Oxygen Index of epoxy / silica nanocomposites.

Scanning Electron Microscope (SEM) was used to evaluate nanosilica dispersion within epoxy matrix. The sample has 5% filler content showed higher dispersion because of high compatibility of silica with epoxy resin and effect of ultrasonic mixer achieving good dispersion of filler , as in Figure (3).

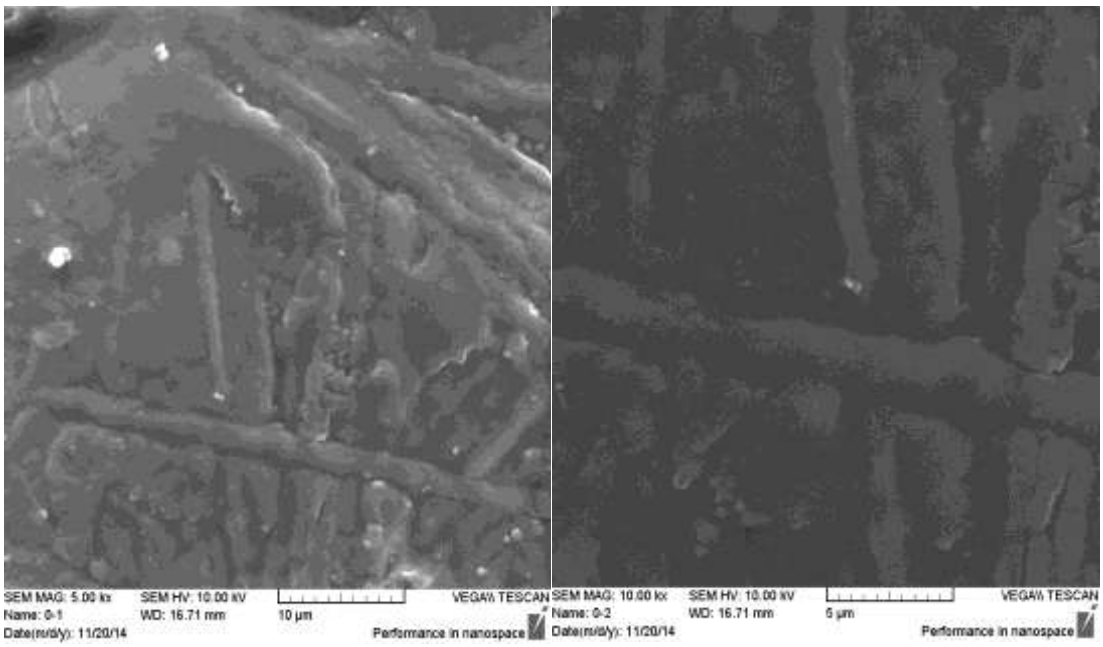

Figure 3 : SEM images of epoxy/ silica nanocomposites at 5% .

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