Influence of the addition of nano-Silica particles as reinforcement on the tensile yield properties of the epoxy polymeric matrix used in medical applications

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Abstract: Epoxy is one of medical resins that are used in medical goods and devices and health goods and products such as dental composite materials, adhesive, other applications, etc. It is well known that the epoxy polymer matrix nanocomposites are one of the most important polymeric materials that exhibit very good mechanical and thermal properties. Herein, effect of silica nano particles on the yield mechanical properties of an epoxy polymer system has been investigated using a tensile test. It is reported that silica nanoparticles provided improvement in tensile Young's modulus of epoxy polymer matrix. Moreover, a considerable improvement in the ultimate strength of epoxy polymer matrix has been reported with increasing in the silica filler content. The addition of nanosilica is shown as a powerful method for improve the mechanical and physical properties of epoxy polymer that is used for production of medical goods, etc.

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1. Introduction

In recent decades, plastic and resin polymers are used as a common material in many health applications i.e. manufacturing medical equipment etc.. Specially, polymers are used as the composite matrix in composite materials. Composite materials are one of the main branches of science that nearly started at about half century ago. In these materials, combination of reinforcement part and matrix part forms a new composite material [1-6].

In the composite materials, combination of the properties of each ingredient caused the good performance. Moreover, for enhancing composite properties, reinforcing fillers can be added to composites. Among the reinforcing fillers, nano materials have been attended in recent years [7-9]. Nano materials are special effects on the composite materials due to their nano size. Nano size of these reinforcing fillers cause more surface area. Effective surface area of filler leads to good interactions with matrix. Therefore nanomaterials are used as the reinforcement in many researches by the previous investigators [10, 11].

Recently, epoxy polymers are used as glues and adhesives in medical applications. Since the hardened, finished polymers are almost non-toxic, they can used in many medical applications such as disposal medical devices, structural bonds, bone cement, prostheses, etc.. Moreover this resin has good mechanical properties that can bear mechanical loads which human bodies is imposed to. This resin also is used to manufacturing epoxy nanocomposites that has high potentials for medical applications and health goods.

Polymer nano-composites are of the main interest in recent decades. The superior mechanical and thermal properties that can be achieved at a much lower loading of nano-particles in comparison with the traditional micro-composites have played a major role in this shift of interests. They are interesting in both academic and industrial researches, due to the potentials for advanced properties at very low particle fraction than conventional ones. One of the polymers that are used for manufacturing nano-composites is Epoxy. Due to the high mechanical properties and low cost, epoxy resins are widely used in composites, electronic devices, medical devices and optical components as well as the medical applications and health goods fabrications.

However, it should be noted that unfortunately, the poor mechanical properties of the epoxy resines require the incorporation of improvement agents and reinforcing materials. Recently, with recent development of engineering, various effective strategies are examined i.e., use of glass beads, metal micro-particles, use of mineral particles, etc. for modification of yield properties and tensile characteristics of reinforced epoxy resines [12-16]. Another important technique for improvement and mechanical characteristics modification of epoxy

polymer is adding nano-silica. Adding nano-silica to epoxy for improving the mechanical properties of this polymer has been investigated by previous researchers [17-19].

In this work, use of silica nano-particles for improving the yield properties of epoxy polymer has been investigated via experimental test method. Therefore, the author has focused on investigating of the tensile yield characteristics i.e. yield strength and Young modulus of the neat and nano-silica modified epoxy mixtures (nanocomposite samples). The variation of the yield strength and the Young modulus as a function of nano-silica content has been investigated. It is shown that adding nano-silica is useful for improvement of epoxy polymers and could be used by engineers and manufactories.

2. Experiments

Materials

The compounds were made using Shell Epon 828 epoxy polymeric resin with diamino-3,5-diethyltoluene as the hardener, commercial sources of which were used, namely: Epikote DX6509 (Shell Chemicals from US).

The components were used in the ratio 100 parts by weight resin to 20 phr (phr: part per hundred parts resin by weight) hardener, which gives a 1:1 stoichiometric ratio of epoxy compound. Nano-silica used was with an average particle size of 20 nm were supplied by Walker Co.

The fumed silica nanoparticles had been chemically well-treated by the manufacturer to disperse well in epoxy.

Sample preparation

In order to manufacturing and preparing the test samples, the epoxy resin and Hardener were mixed at under vacuum. Then, 1, 2 3, 4 and 5 vol% of nano-silica reinforcement was added and mixed under vacuum. The mixture was cast into a mold, that had been preheated at 100 C. Curing was performed at 100 C for 6 h. Specimens were cut from the sheets prepared by this procedure.

For silica-modified formulations, first appropriate amount of nano-particle was weighted and then was mixed with the mixture for 2 hours before adding the hardener. Mixing was conducted to achieve a well-dispersed compound. The formulation of each sample has been shown in Table 1.

Table 1: Formulation used

	Epoxy (%)	Nano-silica (%)
E	100	0
E-1	100	1
E-2	100	2
E-3	100	3
E-4	100	4
E-5	100	5

Tensile Test

In this work we have focused on the investigation of uni-directional tensile characteristics of the polymeric samples. In this regards, Dumbbell tensile samples with a gauge length of 50 mm were made using a silicone rubber mold and both sides were polished by sand paper until all visible defects disappeared.

Tensile tests were performed at a strain rate of 0.5 mm/min at room temperature using an Instron tensile machine. The Instron extensometer was utilized to obtain accurate data to measure the modulus. The picture of test machine is shown in Fig.1. This precise instrument is able to produce the loading curves, i.e. strain vs, stress graphs.

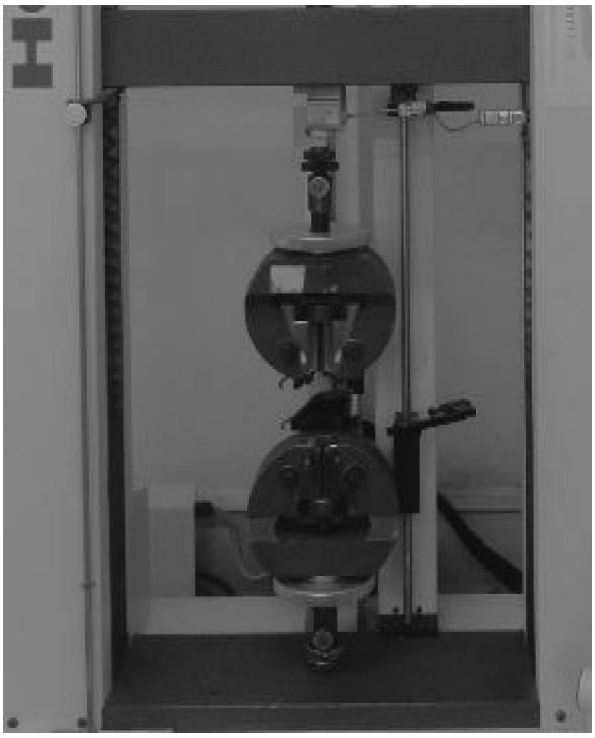

Fig. 1. Test machine used in this work.

3. Results and discussion

As we know, most of polymers have a low value of modulus and therefore they might be not useful for producing engineering products. In this cases, reinforcing agents is needed for increasing the mechanical performance of the material.

Similarly, low strength thermoset polymers can not be used for casting and production of high-performance goods.

In Table 2, Young's modulus of neat epoxy and the nano-silica filled epoxy is presented. As seen, the modulus increases significantly with the addition of nano-silica content.

Table 2: Young modulus of formulations

sample	Young Modulus (GPa)
E	4.7
E-1	4.9
E-2	5.1
E-3	5
E-4	5.4
E-5	5.6

In Table 3 Tensile strength of neat epoxy polymer and the nano-silica filled epoxy is presented. As seen, the strength of polymer increases significantly with the addition of nano-silica content.

Table 3: Tensile strength of formulations

sample	σ_u (MPa)
E	51
E-1	55
E-2	58
E-3	53
E-4	52
E-5	53

In Figures 1 and 2 the tensile behavior of neat and silica-modified epoxy samples has been presented. As seen from these figures, the addition of nano-silica reinforcing particles can slightly increase the tensile characteristics of the epoxy nanocomposites. This is due to the reinforcing effect of the solid nano-particles and load bearing characteristics of this nano-scale material.

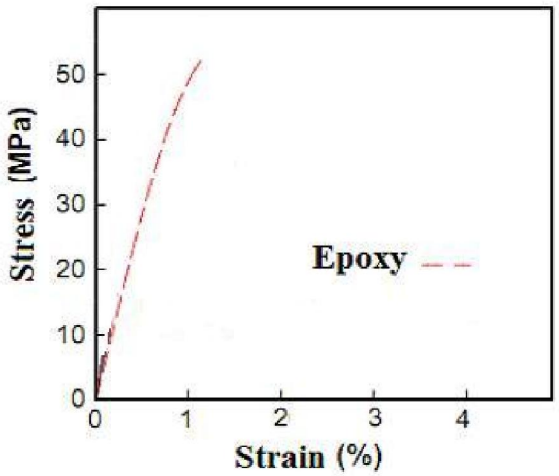

Fig. 2. Yield curve for neat epoxy.

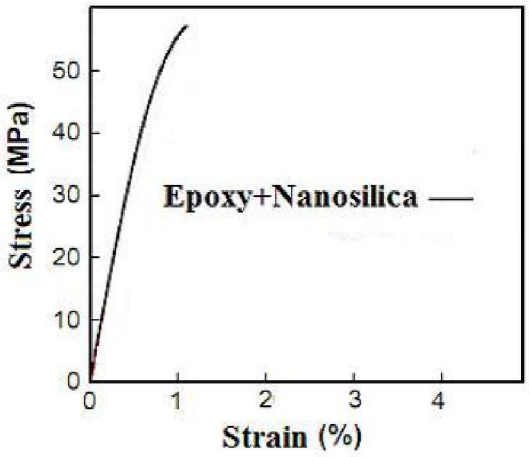

Fig. 3. Yield curve for epoxy containing 2 % nano-silica.

4. Conclusions

It is well established that the tensile behavior and characteristics of the nanocomposite have an important influence on the mechanical performance of the final goods made of these materials. In this regards, in this research paper, authors are focused on the evaluation of the tensile behavior of polymeric material reinforced with the nano-silica nanoparticles. The nanometric silica particles are added to epoxy matrix system. This modification yields in increased tensile strength and tensile Young's modules performance of the epoxy polymer matrix. Based on the measurement results presented in this study, a comprehensive improvement in elastic modulus and strength has been observed. It can be attributed to the higher rigidity of nano-silica particles. Based on the findings of this paper, one can conclude that the addition of nano-silica is a powerful

method for improve the properties of epoxy polymers.

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