Mechanical properties of glass fibre reinforced Unsaturated Polyester toughened epoxy/ siliconized iron (III) oxide nanocomposites

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Abstract: In this work we studied the mechanical properties of the glass fibre reinforced siliconized iron (III) oxide nanoparticles filled Unsaturated Polyester (UP) toughened epoxy nanocomposites. Glass fibre reinforced UP toughened epoxy filled with iron (III) oxide nanoparticles composites were prepared with eight layers. The morphology of the composites was studied by SEM. The mechanical properties (tensile and flexural) of the composites were observed by the addition of siliconized iron (III) oxide nanoparticles. The measurement shows the enhanced mechanical properties at 3 wt % siliconized iron (III) oxide nanoparticles loading.

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1. Introduction

Composite materials are being used more and more instead of steels and other metals because of their high strength at low specific weight. The unusual use of composites material and manufacturing glass-fibre-reinforced polymer (GFRP) still need a lot of handwork. The composites material is not expensive making them for engineering applications (Sampathkumaran P Kishore, Seetharamu 2000, and Tayep, Gadelrap, 1996). Due to their good combination of properties, glass fibre-reinforced polymer composites are used in various fields particularly in the automobile, space industries and sea vehicles (Pihtili, Tosun, 2002 and Pihtili, Tosun 2002). As compared with other composites glass fiber reinforced composites are the most reliable engineering materials (Mallick 1993). Nowadays large numbers of epoxy are available varying from viscous liquids to high-melting solids. The major of epoxy resins prepared from epiclorohydrin and bisphenol. Epoxy resins are also modified with plasticizers. Due to their good mechanical properties and chemical resistance, epoxies are generally used in structural component, paints, and protective plating. The shrinkage of epoxy is too low and during the curing reaction by-products are not formed like water or volatile materials. However these epoxy resins are reinforced with glass fibre, (Srivastava, 1996 and Ramesh 1983) the obtained composites is used in structural applications which require high hardness and lightness (Piggot, 1980 and Vishwanath, Verma, 1992). In this work we prepared and studied the mechanical properties and morphology of siliconized iron (III) oxide nanoparticles with glass fibre reinforced UP toughened epoxy composites.

2. Experimental

2.1 Materials

Iron (III) oxide nanopowder average size <50 nm and 3-aminopropyltrimethoxysilane as silane grafting agent were obtained from Sigma Aldrich India. Diglycidyl ether of bisphenol-A (DGEBA) based epoxy resin LY556 and 4,4'diaminodiphenylmethane (DDM), epoxy curing agent is obtained from Ciba-Geigy Ltd., India. Unsaturated polyester (UP) resin was obtained from Naptha Resins and chemicals, India. Benzoyl peroxide was purchased from Merck India Ltd. Glass fibre purchased from Ceat Ltd., India.

2.2 Preparation of Composites

100 g of epoxy resin was toughened with 10 wt% of UP. The siliconized iron (III) oxide nanoparticles were prepared sol gel (Julyes, 2012) methods. The nanoparticles was mixed with UP toughened epoxy (1, 3, 5 wt %) respectively using mechanical stirring followed by sonication process. The obtained epoxy mixture was reinforced with glass fibre. The epoxy resin mixture was applied on the both sides of the glass fibre. All samples were prepared using eight layers of glass fibre. In samples resin/fibre ratio was between 0.5 and 0.7. The obtained sample was placed in aluminum plates and clamped. Finally the sample was cured at 100 ℃ for 4 h and post cured at 140 ℃ for 3 h.

3. Characterization

3.1 Tensile test

The tensile testing was performed as per ASTM-D-638 using Universal Testing Machine. The test specimens were prepared by machining operation. Five specimens were tested for each composition.

3.2 Flexural test

Flexural test of the sample was studied as per the ASTM D790 using Universal Testing Machine (Instron, Model 6025 UK). Five samples were tested for each composition.

3.3 Scanning Electron Microscopy

Scanning Electron Microscopy (SEM) was used to study the surfaces of the fractured specimens. SEM samples were coated with a thin layer of gold before examination to protect the fracture surfaces from beam damage and also to prevent charge build up.

4. Result and discussion

4.1 Tensile properties

Figure 1. and 2. shows the tensile strength and modulus of the composites. The incorporation of siliconized iron (III) oxide nanoparticles into glass fibre reinforced UP toughened epoxy composites increases the values of tensile strength (12% and 64%) and modulus (8% and 22%) by the addition of 1 and 3 wt % nanoparticles respectively. Increasing of tensile strength and modulus are due to effective dispersion of nanoparticles into their epoxy matrix (Naureen Shahid, Villate, 2005). However the tensile strength and modulus decreases with addition of nanoparticles above 3 wt % due to the agglomeration of nanoparticles in epoxy matrix.

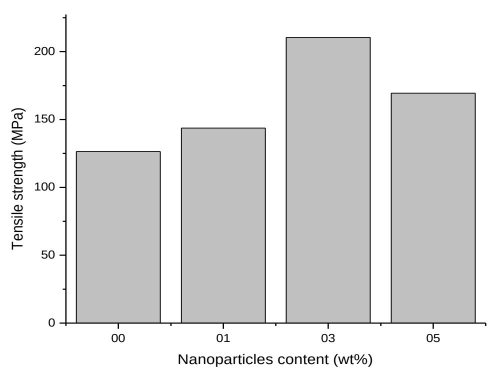

Figure 1. Plot of tensile strength for composites

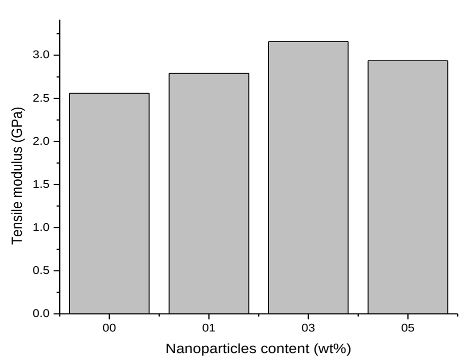

Figure 2. Plot of tensile modulus for composites

4.2 Flexural properties

Flexural strength and modulus of composites were shown in figure 3 and 4. Flexural strength and modulus of glass fibre reinforced epoxy composites were increased by the addition of nanoparticles up to 3 wt %. The values of flexural strength (4% and 23%) and modulus (10% and 19%) increases by the addition of nanoparticles 1, 3 wt% respectively which causes by the formation of nanocomposites. Addition of nanoparticles above 3 wt% was not uniformly dispersed into epoxy which decreases the flexural strength (Liu 2000).

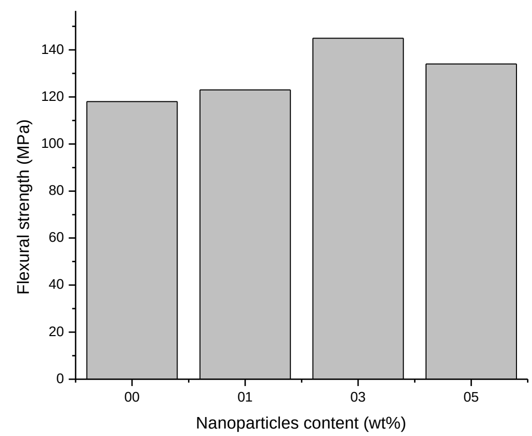

Figure 3. Plot of flexural strength for composites

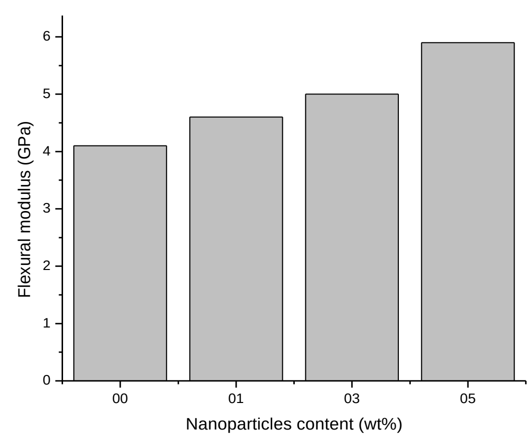

Figure 4. Plot of flexural modulus of composites

4.3 Morphology

Dispersion of nanoparticles in composites were studied by SEM. Figure 5, 6, 7 and 8 shows the SEM images (0, 1, 3, 5 wt. %) of siliconized iron (III) oxide nanoparticles with glass fibre reinforced epoxy composites respectively. Figure 6 and 7 shows the nanoparticles (1 and 3 wt %) were well dispersed into the composites and it explains nanoparticles increases the reinforcement of composites (Manjunatha 2010).

The addition of 5 wt% nanoparticles in epoxy shown figure 8 which exhibits the nanoparticles were not dispersed into composites.

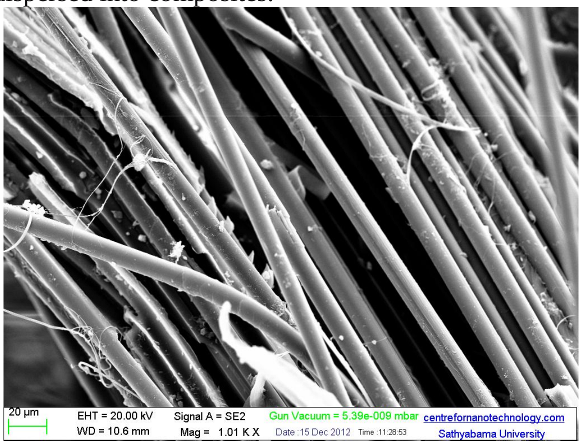

Figure 5. SEM image of glass fibre with 0 wt % nanoparticles

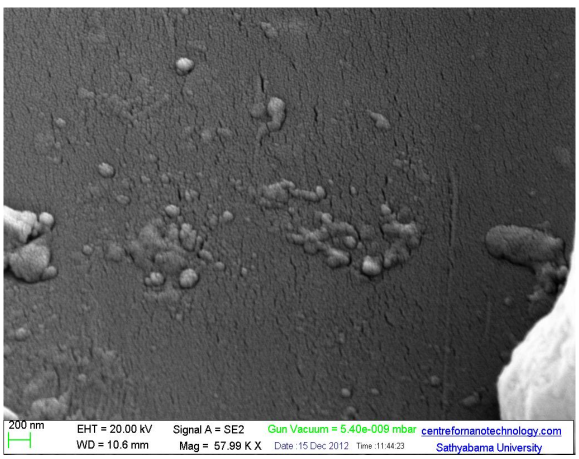

Figure 6. SEM image of glass fibre with 1 wt % nanoparticles

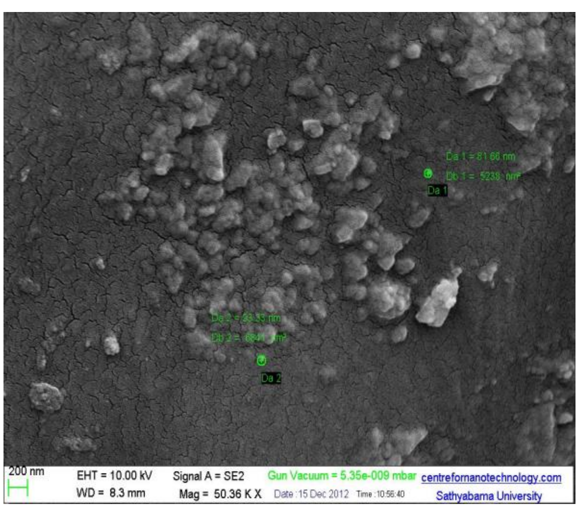

Figure 7. SEM image of glass fibre with 3 wt% nanoparticles

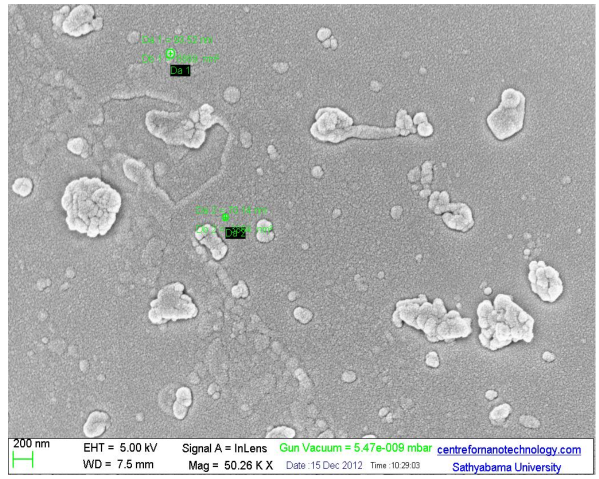

Figure 8. SEM image of glass fibre with 5 wt% of nanoparticles

5. Conclusion

The various concentrations of siliconized iron (III) oxide nanoparticles with glass fibre reinforced UP toughened epoxy composites were developed. The addition of siliconized iron (III) oxide nanoparticles in the glass fibre reinforced UP toughened epoxy increases the tensile strength, tensile modulus and flexural strength and modulus. However the addition of nanoparticles above 3 wt % decreases the mechanical properties. Morphology of composites explains lower amount of nanoparticles were well dispersed in composites. Higher amount of nanoparticles in composites were formed clusters. These results showed that the enhanced mechanical properties for composites at relatively low nanoparticles loading.

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