Fabrication of Aluminium Polymer Nano Composite by In-Situ Technique

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Abstract

In the present work, In-situ polymerization technique synthesized epoxy alumina polymer nanocomposite. Dispersion of alumina nanoparticle of rod shaped and spherical shape with size 20nm-50nm, were achieved by ultra-sonication processing technique. Effect on mechanical properties (Tensile and viscoelastic properties) because of the post curing temperature on nanocomposites were determined. Postcuring temperatures 60, 80, 100, 120 and 1500 ^{0}C were selected. Tensile strength with young's modulus, and storage modulus of neat epoxy specimen as well as nanocomposite with different wt.% of nanoparticle showed decrement with increase in temperature, while glass transition temperature increased. Mechanical properties were maximum for nanocomposite with 0.1 wt. % nanoparticle for all Postcuring temperature. It was observed that Nanocomposite with rod shape showed good mechanical properties.

1. Introduction

Polymers are large molecules composed of many subunits, known as monomers having high molar mass. The known two types of polymers are naturally occurring polymers and Synthetic polymers. The polymers occurring naturally are shellac, starch, wool, silk, protein and cellulose. While the production of synthetic polymers for commercial purpose is done over large scale with wide range of uses depending on the properties. Some of the major examples are synthetic rubber, phenol formaldehyde resin, neoprene, nylon, polyvinyl chloride (PVC or vinyl), polystyrene, polyethylene, polypropylene etc. Polymers show some good factors like they have low weight, Good compressive strength, well damping capacity, high resistance towards environmental and chemical degradation. With all these good factors there are some loop holes such as they lack of strength and stiffness, they have low resistance to wear and crack initiation and propagation, they are seemed to be prone towards UV degradation. Polymers take a long time to decompose and cause pollution.

With all those good and evil factors, the demand of polymers is increasing day by day, they can be used for many applications such as carry bags for different small and big work, and they are used for packing, storing food items and other products. Nylon is used for various uses such as school bags, luggage cases, purses, school bags. Polyvinylchloride is mostly

used for waste water pipes, pipes used for electric wirings, polyvinyl acetate is used for producing plastic bottles with variety of utensils and other daily used things. These are also used for making parts of aircraft such as internal parts of passenger compartment which are mostly made of backlit plastics. Electrical instruments such as switches, iron, water heater, etc.

2. Composite Materials

Most of the composite materials are designed and developed to improve the mechanical properties like wear strength, hardness, stiffness, toughness, and performance on working at elevated temperatures. The strengthening mechanism of the composite material highly depends on the geometry and selection of reinforcement in the matrix. Therefore, the composite materials are classified on the grounds of geometry for a representative unit of reinforcement.

2.1 Nanocomposite Material

A nanocomposite is considered as a multiphase solid material in which one phase can have one, two or three dimensions in the range of 1-100 nm. Nanocomposites are named as advanced, multi-phase polymer composites with nanometer-scale which often shows variety of enhanced physical properties (i.e. strength, stiffness, hardness, durability, thermal, and viscoelastic properties).

2.2 Polymer Nanocomposite

Polymer Nanocomposites are made up of small number of units widely known as monomers of nano size which are dispersed in the polymer matrix. These are of different size and shape like platelets, fibers, spheroids and must be having at least one dimension below 100nm depending on the requirement and purpose. The systems need controlled compounding, stabilization of dispersion with uniformity, dispersed phase orientation, and various strategies for different multi-phase systems, including polymer Nanocomposites. The transition of micro to nanoparticle leads to bring change in physical and chemical properties. The major factors are ratio of the surface area to volume and the size of the particle. On increasing the surface area-to-volume ratio, particles size gets reduced which leads to increasing dominance of atoms on the particle surface area over interior the particles. In result the properties are enhanced by the reaction of particles in between.

Fu et al. (2008) did study on particle size and their effect with particle/matrix interface adhesion and particle loading on mechanical properties of particulate–polymer composites. Montazeri et al. (2010) studied about the viscoelastic properties of multi-walled carbon nanotube/epoxy composites by two different curing cycles. In another work Montazeri and Montazeri (2011) studied about Viscoelastic and mechanical properties of multi walled carbon nanotube/epoxy composites with different nanotube content. Montazeri et al. (2012) used dynamic mechanical thermal analysis to study the Viscoelastic properties of free volume

fraction for multi-walled carbon nanotube/epoxy composite. Rahman et al. (2012) used amino functionalized MWCNTs and worked on improving the mechanical and thermo-mechanical properties of e-glass/epoxy composites. Cui et al. (2013) studied the Effect of functionalization of multi-walled carbon nanotube on the curing behavior and mechanical property of multi-walled carbon nanotube/epoxy composites.

3. Synthesis of Polymer Nanocomposite

In the present study thermosetting polymer, epoxy was used as the matrix material. The matrix material was taken from Bisphenol-A for the present study and the based epoxy was prepared by using Araldite LY556 having density density of 1.17 gm/cc at 25°C procured from Huntsman advance materials (India) Pvt. Ltd. The epoxide groups took part in cross-linking when mixed with hardener at both the ends. Alumina (Al_2O_3) nanoparticles of spherical and cylindrical shapes shown in Figure 1 and Figure 2 were taken and used as reinforcement material to synthesize the polymer nanocomposites. The effect of shape of reinforcement on tensile and viscoelastic properties of nanocomposites was observed. Diameter of spherical alumina nanoparticles were of 27-43 nm with density of 3.5-3.9 g/cm^3.

3.1 Synthesis of Neat Epoxy Samples

For the synthesis of neat epoxy samples epoxy resin (LY556) and hardener (HY951) were selected and were mixed in ratio 10:1 by weight. Mixing was done gently to avoid the formation of bubbles in the mixture. After mixing the mixture was gushed in the vertical acrylic mold and maintained at room temperature for around 24 hours for curing. After curing the sheet sheet was removed out of the mold and was kept in air circulating oven at different temperature (i.e. 60^0C, 80^0C, 100^0C, 120^0C, 150^0C) for four hours for post curing. After four hours oven was switched off and the specimen was allowed to cool in the oven to the room temperature. Required samples were prepared by these sheets.

3.2 Synthesis of Polymer Nanocomposite

Required amount of nanoparticle was heated at 150^0C for four hours to withdraw water content as moisture. These particles were mixed with acetone and was sonicated for an hour in a bath sonicator the sonicated mixture was mixed with epoxy and was again sonicated. Then acetone was removed from the mixture by the process of partial distillation with the help of hot plate with stirrer, for the removal of entrapped gas, the obtained mixture was kept in vacuum for around half an hour. Later hardener was introduced in and mixed to obtain the nanocomposite sheets which were casted in the similar way that of neat epoxy.

4. Result and Discussions

4.1 Dispersion of Al Nanoparticle

The dispersion of particles in acetone was examined by Transmission Electron Microscope (TEM) images of the composites at accelerating voltage 5-120 KV which is shown in Figure 3. Transmission electron micrographs were taken at the two stages of polymer

nanocomposites formation process. First, the dispersion alumina nanoparticles were checked after the sonication of nanoparticles / acetone mixture. In the second stage, dispersion of nanoparticles was checked in the solid polymer nanocomposite sheets. There was no agglomeration of particles in micrograph. The micro graph was taken for spherical alumina nanoparticle and it was assumed that there was no agglomeration present in other composition of composites. The nanocomposite formed is shown in Figure 4.

4.2 DSC Results

Differential Scanning Calorimetry (DSC) is used to calculate the amount of heat needed to raise the sample temperature and reference is measured as a function of temperature. It is a thermo-analytical technique. DSC curve of neat epoxy was used to select the postcuring temperatures for neat epoxy and Nanocomposites with varying wt. % of nanoparticle. The graph obtained is shown in Figure 5 and 6, shows that there was increase in post curing temperature with increase in loss modulus and fall in the storage modulus of epoxy material. The $\tan \delta$ peak comes down and moves to high temperature due to rise in post curing temperature. The glass transition temperature increases from 81℃ to 111.58℃ due to increase in post curing temperature from 60℃ to 150℃. From the curves it is clear that an optimum post curing temperature 80℃ can be selected for optimum properties.

4.3 Tensile Properties

Dynamic Mechanical Analysis (DMA) of neat epoxy and nanocomposites with different shape and size of alumina (Al_2O_3) particle and with different post curing temperature were determined according through ASTM standard D4065.Tensile test produced tensile strength and young's modulus of polymer. Increase in post curing temperature, showed decrement in the tensile strength and Young's modulus, Figure 7 describes the behavior of the tensile test. From the curves it is clear that tensile strength and Young's modulus is maximum for 60℃ and minimum for 150℃.

5. Conclusion and Future Work

Epoxy-alumina Nanocomposites having different weight percent (0.5wt%, 1wt%, and 1.5 wt%) of alumina particles of an average size of 20- 50 nm and of different shape such as rod shape and spherical were prepared through Ultrasonication technique and were post cured at different temperatures. The following conclusions can be drawn from the results of material characterization. Storage modulus of neat epoxy specimen and nanocomposite was maximum for 60^0C postcuring temperature and was minimum for 150^0C. Glass transition temperature of neat epoxy specimen and nanocomposite was maximum for 150^0C postcuring temperature and was minimum for 60^0C post curing temperature. Tensile strength and young's modulus has same effect of increase in post curing temperature as storage modulus, and decrease was observed with increase in postcuring temperature. There is a huge possibility of doing this thing by different a processing methods with performing other tests which are not been done in this study work. This work was explored for epoxy/hardener ratio 10:1 variation of

hardener can be done for different possibilities. This work explored the effect of nanoparticles on thermosetting epoxy matrix. Effect of addition of alumina nanoparticles on thermoplastic can be explored.
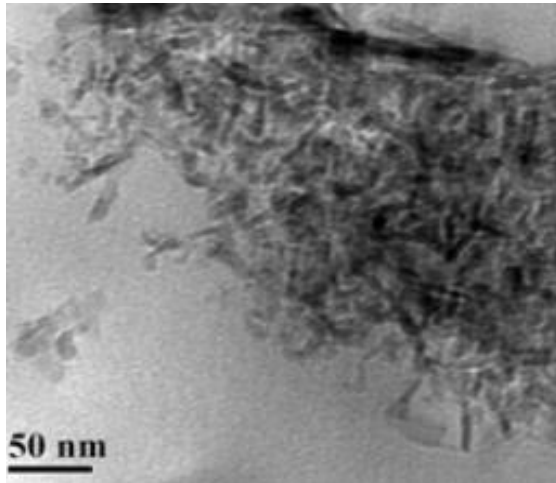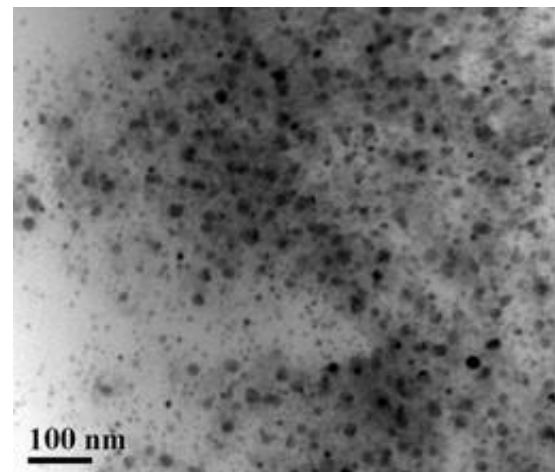

Figure 1. Cylindrical shape Al nanoparticles

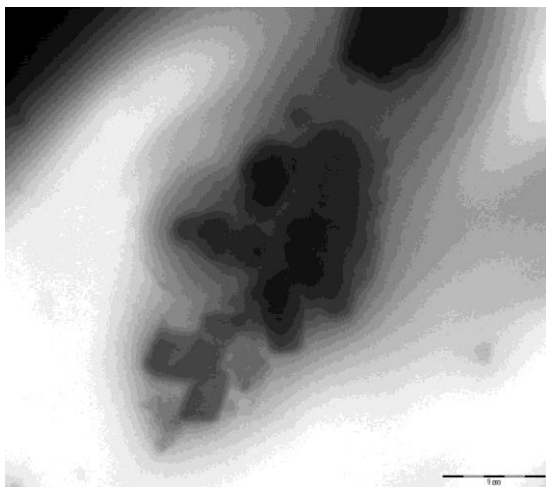**Figure 2. Spherical shape Al nanoparticles**
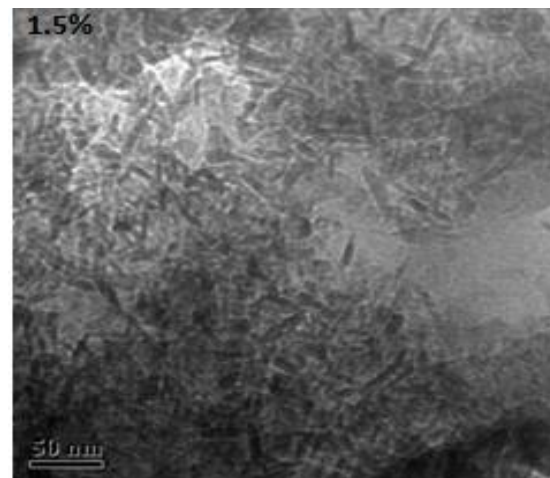

Figure 3. Dispersion mixture (acetone + particle)

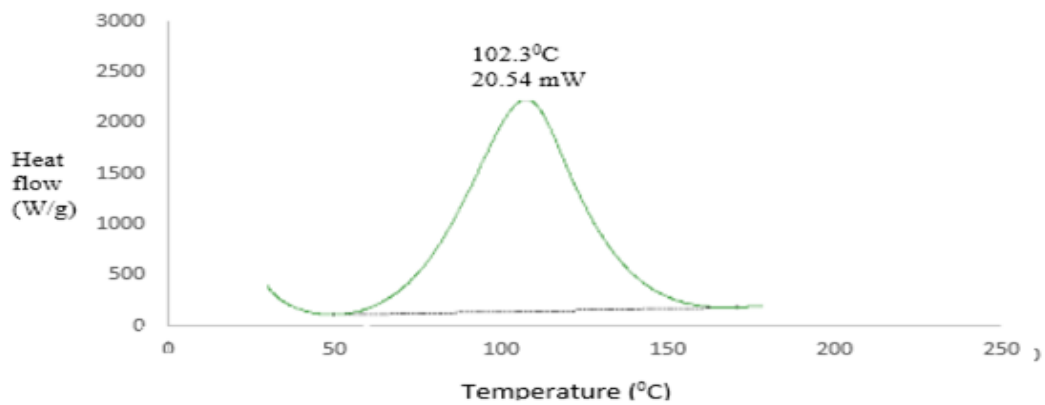**Figure 4. Dispersion of nanoparticle composite**
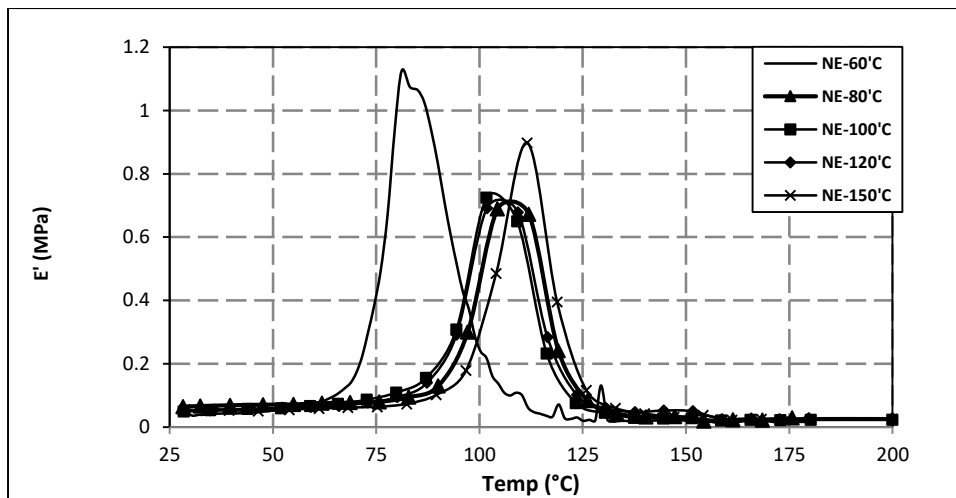

Figure 5. DSC scans of neat epoxy

Figure 6. Tan δ of neat post cured at different temperature as a function of temperature
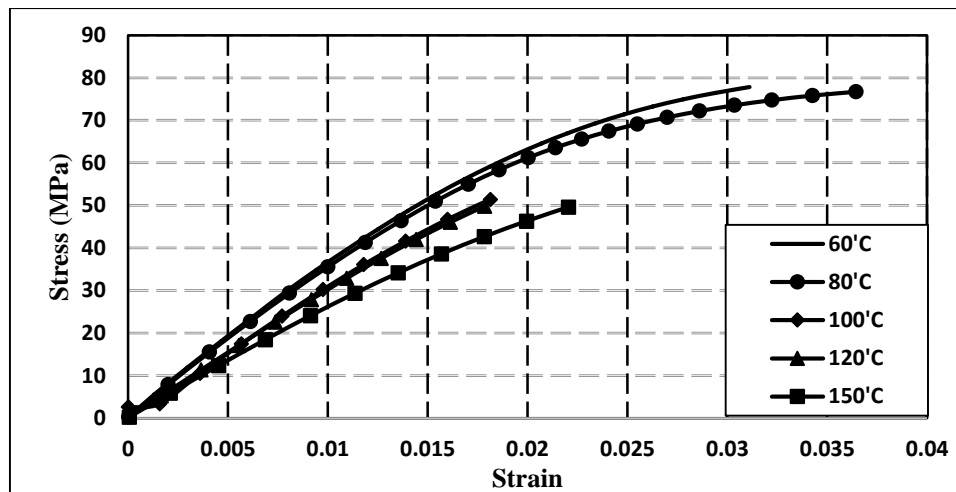

Figure 7. Stress-Strain curve for neat epoxy for different post curing temperature

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