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PREPARATION AND MECHANICAL PROPERTIES OF NANOCLAY-MWCNT/EPOXY HYBRID NANOCOMPOSITES

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Abstract:

Among the various kinds of reinforcing element, Multi Wall Carbon Nano-tubes (MWCNT) and Nanoclay have found much more attention as a filler element to upgrade the mechanical properties of polymer composite material. In this paper, production of hybrid nanocomposites and the effect of MWCNT and nanoclay on mechanical properties of hybrid nanocomposites have been evaluated. In hybrid nanocomposites, MWCNT and nanoclay are embedded in epoxy resin. The processing of hybrid nanocomposite is always been a difficult task for researcher to prepare defects free samples. Here, the processing of Epoxy/Nanoclay-MWCNT hybrid composites has been done by using homogenizer and ultrasonic techniques for complete dispersion of nanoparticles into epoxy resin. The MWCNT and nanoclay were embedded into epoxy resin in different weight fractions and mixtures were used for tensile test and hardness specimen production. The tensile modulus and tensile strength values have been calculated via tensile tests. The test result shows that tensile modulus of samples increases as the filler content increase up to certain extent but then start decreasing. Also the elongation reduces as the filler content rises in the epoxy which shows the brittleness present in the samples. Rockwell hardness on B-scale was conducted on Nanocomposite samples and found that increasing the filler content excessively does not improve hardness as much.

Keywords: nanoclay; hybrid nanocomposites; mechanical properties; multi wall carbon nano-tubes.

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1. Introduction

In the recent eras, Polymer based nanocomposite materials have found much more attention in research and industries due to simple processing techniques, high strength to weight ratio, diverse functional application and minimum cost (Karatas et al., 2007; Rozenberg & Tenne, 2008; Zhou et al., 2011; Alsafee et al., 2014; Mahesh Hosur et al., 2018). A nanocomposite generally belongs to composite material in which filler particles are used in nano or molecular form which are mixed into the matrix phase in less concentration, which enhances the performance of nanocomposites. Hybridization in nanocomposites with inorganic compounds were used to intensify their physical, thermal, and mechanical properties (Liu et al., 2007; Ayatollahi et al., 2011a; Kim et al., 2011; Mahesh Hosur et al., 2017).

Carbon Nano-tubes (CNT) generally have unique atomic structure, high tensile modulus and excellent thermal and electrical conductivities (Gojny et al., 2005; Ayatollahi et al., 2011a; Lee et al., 2013; Mahesh Hosur et al., 2017). Due to conductive nature of multiwall carbon nanotubes (MWCNT) is has been used by many researcher to improve the electrical properties of polymer composite material. Nanoclay is naturally found product, in large quantity at minimum cost. Nanoclay has the large surface area, ion-exchange capacity and strong adsorption that's why it has many industrial and research oriented application. Nanoclay is being used as catalyst and sometime catalytic support over the years. Nanoclay also intensifies the mechanical properties, thermal stability and dimensional stability. (Ho et al., 2006; Lakshmi et al., 2008; Sun et al., 2010; Mat Yazik et al., 2020). Recently Nanoclay when being used as filler content has shown improvement in tensile modulus and tensile strength, barrier properties, flame resistance, and thermal properties of many polymer materials. (Gojny et al., 2005). The concurrent presence of MWCNT and Nanoclay in polymer might give benefit of both fillers and lead to a multifunctional material. Only few researchers have evaluated the simultaneous effect both MWCNT and Nanoclay (as filler) on different properties of polymer composite materials.

Mat Yazik (2020), studied the effect of montmorillonite (MMT) and multi-walled carbon nanotube (MWCNT) when disperse in shape memory epoxy (SMEP) at different loading condition. In his study tensile and flexural strength by embedment of MMT and MWCNT hybrid nanofiller into shape memory epoxy was studied and found that his study may be implemented to choose the optimum loading condition in various applications of mechanical requirements.

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Bhuvaneshwaran Mylsamy et al. (2019) studied the consequence of nanoclay filled chemically treated *Coccinia Indica* fibre embedded into epoxy composites on mechanical properties and morphological characterizations and compared with the unfilled composite. He examine experimentally that by enhancing in weight percentage of nanoclay into epoxy leads to intensify tensile, flexural and impact strength of the treated *Coccinia Indica* fibre embedded epoxy composites. Ayatollahi et al. (2011b) studied effect of Multi Walled Carbon Nano-tube and Nanoclay on the Epoxy. Electrical and mechanical characterisations of composite system were evaluated by using the ultrasonic technique for dispersion of nanoparticles. He concluded that nanocomposite when reinforced with 0.5 wt. % MWNTs shows better elastic modulus as compared with a nanocomposite enriched with 5 wt. % Nanoclay. He found that a lower amount of MWCNTs enhance higher young's modulus. His study also noticed that simultaneous presence of MWCNTs and Nanoclay can enhance impact strength, but at the same time reduces the ultimate tensile strength. Also on introducing Nanoclay into the MWCNT/Epoxy nanocomposites leads to deteriorate the electrical conductivity. In this paper, production of nanocomposites and effect of MWCNT and Nanoclay on mechanical characterisation of hybrid nanocomposites have been evaluated. Nanoclay and Multiwall Carbon Nano-tubes (MWCNT) were embedded into epoxy resin using homogenizer and ultrasonic technique for the production of hybrid nanocomposites. The mechanical properties such as tensile strength, elastic modulus and hardness of obtained hybrid nanocomposites were evaluated by tensile test and Rockwell hardness test on B-scale

2. Materials

Materials which were used in the production of nanocomposite are G4-250 Epoxy grade resin and hardener from Northern polymer India private limited and Silicon oil from scientific fisher and all the chemicals are used without any further purification. Multiwall Carbon nanotubes brought from Nanoshell (95%) having average size 20-30 nm. Nanoclay (montmorillonite clay surface with 25-30 wt. % trimethyl stearyl ammonium) was brought from Sigma-Aldrich (India) Average size 20-80 nm. Hardener was used as a binder material for matrix and filler element. The confirmation of MWCNT and Nanoclay was done by the scanning electron microscope photographs as shown in Figure 1 and Figure 2.

3. Production of hybrid nanocomposites

In order to analyze the effect of reinforcing element into the Epoxy resin, these reinforcing element MWCNT, Nanoclay and hardener in given wt. % were mixed in required amount into Epoxy resin. The hybrid composites were prepared on the basis of mechanical characterization of Epoxy/MWCNTs, Epoxy/Nanoclay and Epoxy/MWCNT-Nanoclay composites. The mixture was stirred with the help of Homogenizer (Figure 3) at 8000 RPM and followed by the ultrasonic probe sonicator (Figure 4) where it was sonicate for around 1 hour at 110 V. Then the hardener was mixed in it and the mixture was put into the mould boxes for 48 hours.

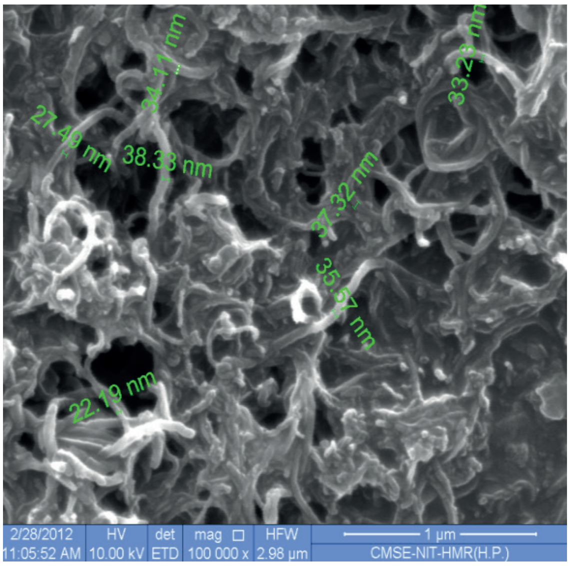

Figure 1: SEM image of MWCNT.

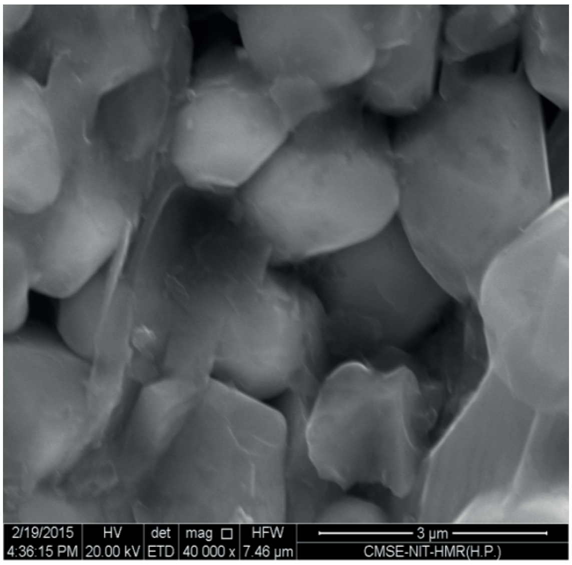

Figure 2: SEM image of Nanoclay.

Figure 3: Homogenizer.

Figure 4: Ultrasonic probe Sonicator.

Rectangular and round moulds of aluminum sheet were prepared. Silicone oil was used for inner coating of foil paper in order to prevent the problem of stickiness. The prepared solution was put into the mould and was kept undisturbed for 48 hours. After 48 hours, solid samples were taken out from the mould and shaped into rectangular size as per tensile testing (Figure 5).

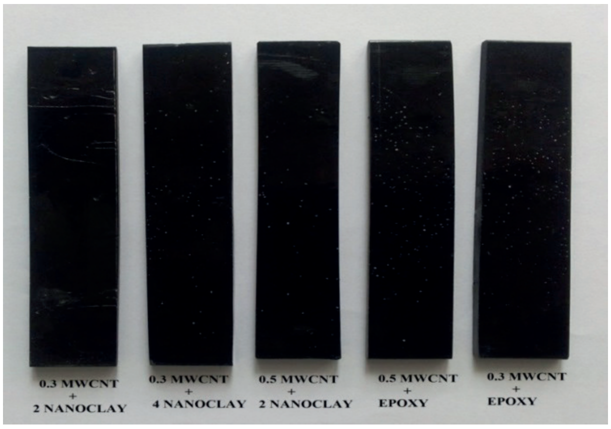

Figure 5: Rectangular sample tensile testing.

4. Results and discussions

The tensile testing and Rockwell hardness were used to investigate the mechanical properties of hybrid nanocomposites. Tensile strength of flat specimens of 100×20×3 mm size was used on the universal testing machine (Figure 6). The hardness of the composites samples is obtained by Rockwell hardness machine on B scale (Figure 7)

Tensile testing on all the samples were performed at the speed of 2 mm/min and gauge length of 30 mm. Figure 8 represents the tensile strengths of epoxy resin with filler content of Nanoclay and MWCNT and concludes that, by inclusion of filler content increment in tensile strength by

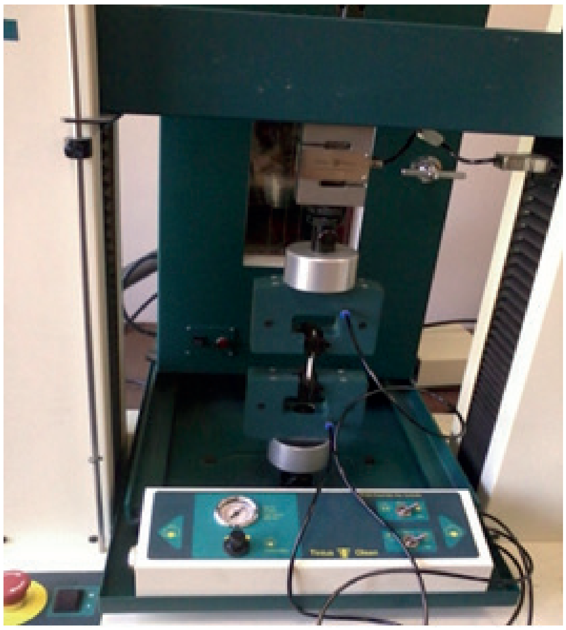

Figure 6: Universal testing machine.

Figure 7: Rockwell hardness machine.

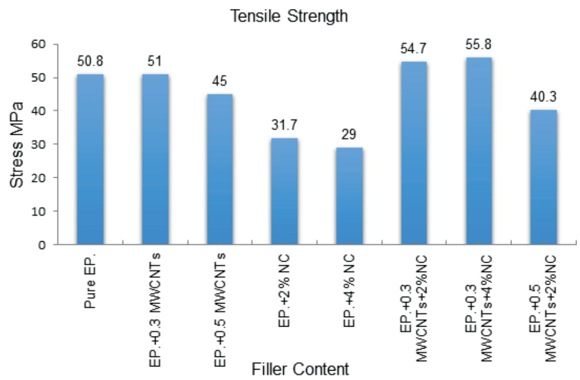

Figure 8: Tensile strength of various samples.

very less amounts. The value of tensile strength is found highest for 0.3 wt. % MWCNT and 4% NC content hybrid composite, tensile strength is increased from 50.5 MPa to 55.5 MPa (9.4% increases). However, with the excessive addition of MWCNT & Nanoclay, tensile strength reduces and in case of 2 wt. % and 4 % wt of NC or more the value of tensile strength is reduced in relation to neat epoxy. The reason for decrease in tensile strength can be concluded due to worse distribution of nanoparticles in the epoxy resin, due to which possibility for the formation of pores, cavity, imperfection and imprudent stress concentration points can form.

Figure 9 represents elasticity modulus of neat epoxy, Epoxy/Nanoclay, Epoxy/MWCNT and EpoxyMWCNT-Nanoclay hybrid nanocomposites. It can be concluded from Figure 9 that addition of filler element improve the elastic moduli. The value of elastic modulus was obtained higher when Nanoclay and MWCNT nanoparticles were used together (as shown in Figure 9). For the composition 0.3 wt. % MWCNT-4 wt. % Nanoclay the value of elastic modulus was found about 68 % higher when compare with neat epoxy.

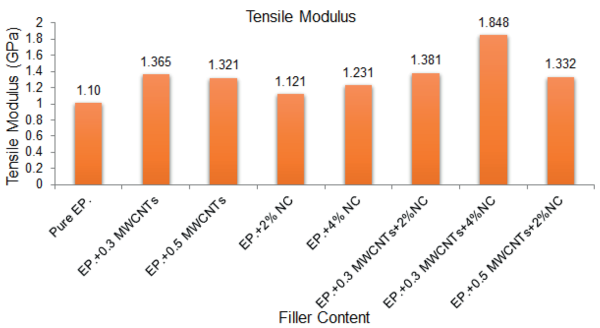

Figure 9: Tensile modulus of various samples.

Figure 10 shows the stress-strain behavior of Epoxy/MWCNTs/Nanoclay, which emphasis that initially it was a linear relationship followed by nonlinear portion. It is also found that resin when modified by nanoparticles, elasticity modulus and strength increases considerably but strain % is decrease at the same time. So, it can be concluded that modification by nanoparticles introduces some brittleness in the samples.

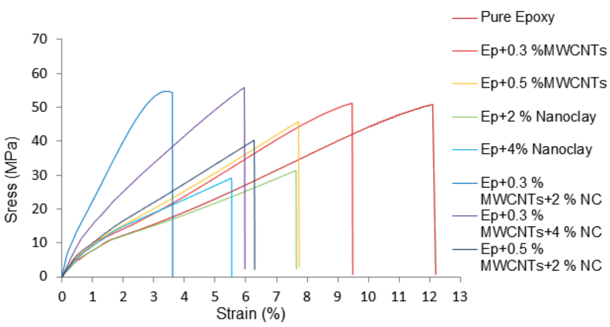

Figure 10: Strain-strain diagram for Hybrid Nanocomposites.

Figure 11 shows the Rockwell hardness result of samples on B-scale. The maximum hardness is found in 0.5 wt. % MWCNT/epoxy resin which is 12.5 % higher than neat epoxy. It can also be concluded from hardness test that by increasing the filler content excessively does not improve hardness.

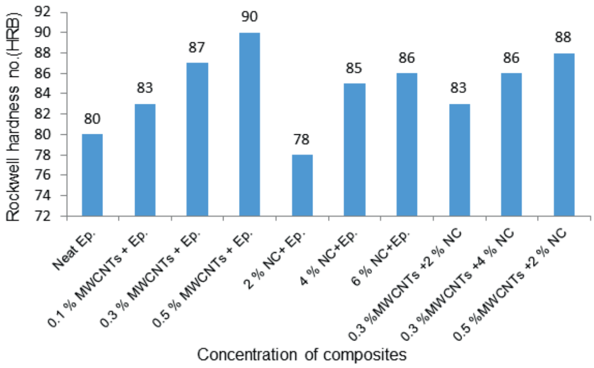

Figure 11: Rockwell hardness of various sample on B scale.

5. Conclusions

Epoxy/MWCNTs, Epoxy/Nanoclay and Epoxy/MWCNTs/Nanoclay hybrid based polymer composites were successfully prepared using Homogenizer and ultrasonic process to analyze the mechanical properties. The mechanical properties have been studied with Tensile Testing Machine. Rockwell hardness machine was used to calculate hardness of the composites samples.

- This study found that to by introducing MWCNTs as filler content in Epoxy resin composites, enhancement in the mechanical properties (tensile strength and Rockwell hardness) was seen, this emphasizes the importance of filler material to enhance performance of the nanocomposites.
- The tensile strength for the 0.3 wt. % of MWCNTs and 4 % NC has shown 9.48 % improvement and the tensile modulus for 0.3 wt. % MWCNTs and 4 % Nanoclay has shown 35 % and 27 % improvement respectively.
- The Rockwell hardness (HRB) was found maximum for the 0.5 wt. % MWCNT/epoxy resin which was 12.5 % higher than neat epoxy.

6. Scope for Future Work

In future following other characterization on Nanocomposite can be perform as listed below.

- In present work preparation of Epoxy/MWCNTs, Epoxy/Nanoclay and Epoxy/ MWCNTs /Nanoclay hybrid nanocomposites by using Homogenizer and sonicator. In future, production method of hybrid composites can be improved with alternative technique with different filler element.
- As MWCNT is conductive in nature, so in future, the electrical characterization of Epoxy/Nanoclay and Epoxy/ MWCNTs /Nanoclay hybrid nanocomposites can be studied.
- Thermal Analysis of hybrid composites like TGA and DSC Nanocomposites may be conducted.
- Tribological characterization of Epoxy /MWCNTs / Nanoclay composites can also be studied in the future.

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