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Study on Mechanical Behavior of Graphene Based Polymer Composites

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Abstract*: Addition of Graphene in the matrix improves the mechanical properties, which makes it potentially good reinforcement in polymer composites. Graphene possess unique mechanical properties, which makes it attractive filler for producing multi-functional composites for a wide range of applications. It is an overview on the state of the art of graphene, including material synthesis and characterization. It helps in identifying its influence on the multi-functional and mechanical properties of the composites. Graphene was synthesized by a simple method (Hummer's Method). Characterization is done by X-Ray Diffraction, SEM images for the prepared graphene. It is found that mechanical properties are improved tensile strength, flexural strength and heat distortion temperature of the glass epoxy laminated composite when the small amount of grapheme added to the epoxy matrix material.

Index Terms*: Epoxy Nano Composites, Graphene, Mechanical properties.

I. INTRODUCTION

Graphene nano platelets (GNPs) are a novel nano fillers including single or multi layers of a graphite plane which possesses exceptional functionalities, high mechanical strength, and chemical stability, for the following reasons: their abundance in nature and thus their cost effectiveness and their extremely high-specific surface area, which carries high levels of transferring stress across interface and provides higher reinforcement than carbon nanotubes [1]. The dispersion state of graphene is crucial to determine the final performance of the graphene/polymer composites, and it is necessary to understand the effect of graphene dispersion on the properties of the composites [2]. Unfortunately, whether the different dispersionstates of graphene can lead to a different impact on the mechanical properties remains an important open question in polymer composites [3]. Graphene may find use in various applications including sensors, ultra capacitors, liquid crystal displays, organic light emitting diodes, solar cells,and polymer and ceramic composites [4]. In polymers there has been a considerable amount of research on graphene composites, which have low electrical percolation thresholds and good mechanical properties and thermal conductivity. Graphene has similar electrical, mechanical and thermal properties compared to CNTs. The main advantages of using graphene over CNTs are a higher specific surface area and fewer tendencies to tangle, which makes it easier to disperse graphene into a matrix, whereas CNTs usually require surface modification in order to process them [5]. It is also relatively easy to produce, inexpensive and potentially has less health hazards compared to CNT.

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II. EXPERIMENTAL PROCEDURE

A. Materials and synthesis

In this study, graphene oxide was synthesized and characterized. In a typical synthesis process, natural graphite powders were oxidized to graphite oxide using a modified Hummers method [6]. Figure 2.1 shows 1.5 g of graphite powders were first oxidized by reacting them in a mixture of 35 ml concentrated nitric acid and 70ml of concentrated sulphuric acid in an ice bath.

Fig 2.1 Magnetic stirring of Graphite with H2SO4 at ice bath (0-5°C)

Then, 9gm of potassium permanganate was added to the container slowly shown in figure 2.2. After reaction at 650 C for 120h, 100ml deionized water was added drop wise to the container carefully.

Fig 2.2 Grapheneoxide, after completion of reaction

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Then the reaction was allowed at 900 C for 2 h to fully oxidize graphite into graphite oxide, figure 2.3 shows the graphite oxide was washed with dilute hydrochloric acid and deionized water [7].

Fig 2.3Adding monohydrate to graphene oxide and then heated

Graphite oxide was dispersed in a mixture of deionized water and exfoliated through ultrasonification for 1 h. The final GO dispersion was reduced by hydrazine hydrate at 1000 C for 24h [8].

III. CHARACTERIZATION

Graphene oxide and graphene formation are characterized by X-Ray Diffraction, Scanning Electron Microscope, U-V Spectroscopy and Fourier Transform Infra-Red . Figure 2.4 and 2.5 shows the SEM image of Graphite oxide and graphene. SEM images show the presence of ultra-thin layers with wrinkled paper like structure

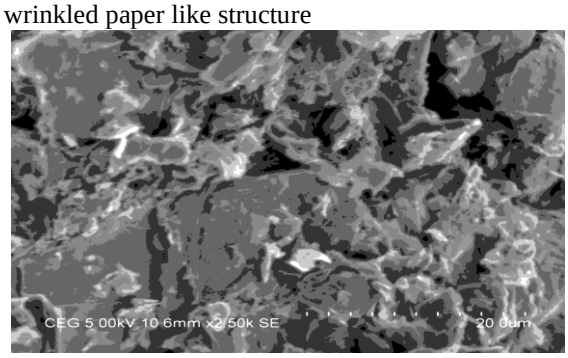

Figure 2.4 SEM Image of Graphite

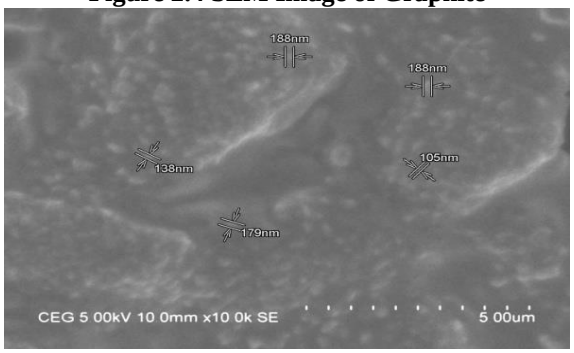

Figure 2.5 SEM Image of Graphene

IV. DISPERSION OF GRAPHENE WITH EPOXY MATRIX

Graphene powder flakes of irregular shapes with an average size of 179 nm and epoxy resin (100 % of resin weight) were used as conducting fillers and insulating matrix respectively. In a typical fabrication process, the 260 ml of epoxy was dissolved in 100 ml of acetone, followed by adding graphene powders. The suspension was sonicated for 2 hrs to ensure homogeneous dispersion of the graphene powders [9]. Then the solution was kept at 50°C for 6 hrs for fully removal of acetone. Finally dispersed graphene epoxy resin was prepared.

V. SPECIMEN PREPARATION

A. Figures and Tables

Glass fibre graphene epoxy composite is prepared using Bi-directional glass fibre along with epoxy resin (LY 556) &graphene and hardener (HY 951). Bi-directional glass fibre of 205 gsm is used to prepare laminates using hand lay-up method [10]. The Bi-directional glass fibres are cut into 30cm × 30cm. Two plies are weighed in the Electronic weighing machine (12 layers). A layer of wax is applied over it for easy removal of the laminate once the curing is over. Over the layer of wax, a Teflon sheet is placed to the size little larger than the ply size and wax is applied over the Teflon sheet also. The dispersed Epoxy resin (LY556) and graphene is taken in a small container and hardener (HY951) is taken as 10% of the resin weight [11]. Now the resin and hardener is stirred well and using a brush resin is applied over the wax coated Teflon sheet. The resin need to be applied gently and evenly in all the regions over the Teflon sheet so that the chances of void formation are ruled out.The 0° ply is taken and placed over the region where resin is applied and using a roller the fibre layer is rolled evenly.Similarly all the 12 layers are done by repeating the above steps. Over the final ply, again the resin is applied. Then a Teflon sheet coated with wax is taken and placed over the final ply. The laminate is allowed to cure in atmospheric condition for next 4 hours [12,13].

Table 2.1 specimen preparation in different graphene ratios

S. No	Glass Fibre(%)	Epoxy(%)	Graphene(%)
1	50	49	1
2	50	48	2
3	50	46	4
4	50	44	6
5	50	42	8

. ASTM Specimen Standard

For mechanical testing of glass fibre reinforced graphene composites, ASTM has given specific standards for various testing. In the ASTM D 3039 standards, the dimensions of the specimens for various orientations of the glass fibres are given [14]. Glass fibre epoxy composite laminate prepared using hand lay-up method and compressed in compression moulding machine should be cut as per the dimension given in the standards. Following are the dimensions for tensile test as given in ASTM D3039 standard. According to the ASTM standard D790, the specimen dimensions for flexural tests depends on the thickness of the specimen. Tensile Test : 300 mm x 25 mm x 3 mm. Similarly for the flexural tests, specimen dimension. Flextural Test: 100 mm x 12.7 mm x 3 mm [15,16].

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VI. Results and Discussion

A. Characterization of graphene

The observed peaks in XRD pattern of as prepared and heated samples confirm the crystalline nature of the samples. A sharp intensive peak observed at diffraction angle (2Θ) of 260 is highly specific for crystalline nature of graphene.

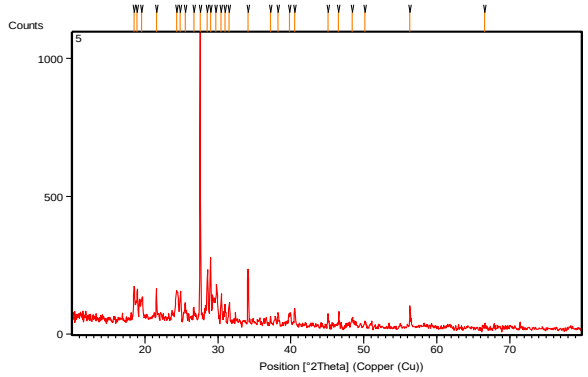

Fig. 3.1. XRD imageof graphene

B. Tensile strength

To find the tensile values, Young's modulus along axial and lateral fibre direction, Poisson ratio along axial and lateral direction and Rigidity modulus, the tensile test need to be done with strain gauges attached to the specimens [17].

The strain gauges are fixed to glass fibre epoxy composite specimens and then the strain gauges are attached to the strain meter while conducting the tensile test in standards. Tensile test is performed glass fiber grapheme epoxy composites with different ratios and stress value obtained during the test is given below.

Stress σ = Load / Lateral Area
Young's Modulus = σ /ε
Poisson's ratio = ε2 / ε1

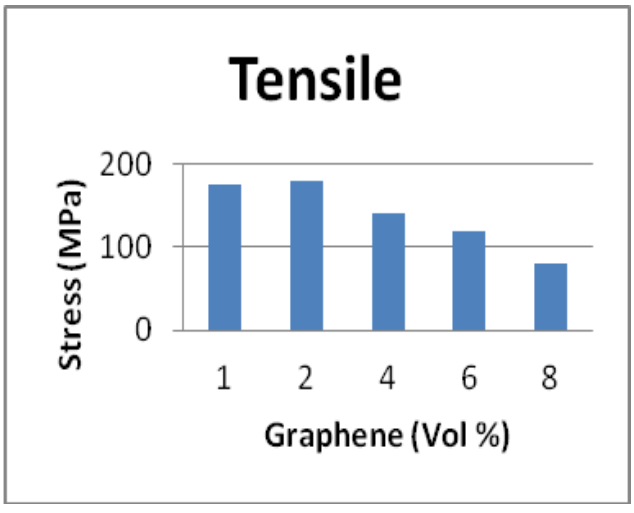

Figure 3.2 Tensile values for different ratios of graphene

C. Flexural properties

Flexural test is performed glass fiber grapheme epoxy composites with different ratios and load displacement value obtained during the test is given below

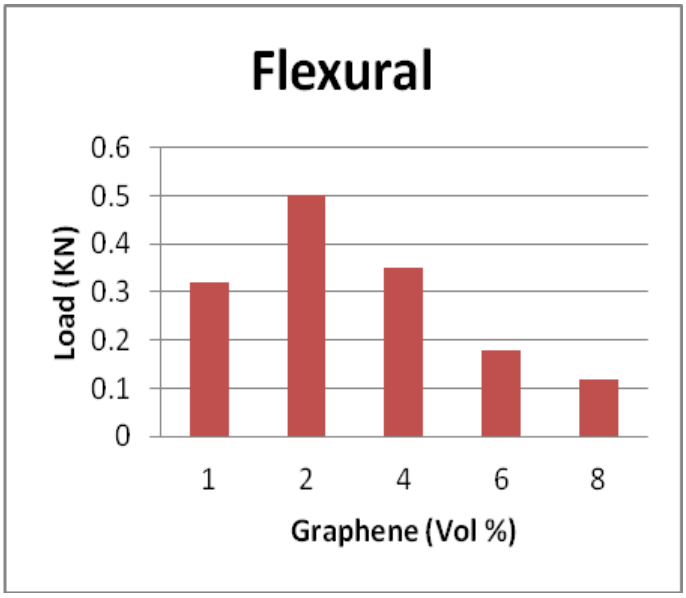

Figure 3.3 Flexural values for different ratios of graphene

D. Tensile and Flexural test Analysis

The mobility of polymer chains was restricted because of the dispersion of nano fillers under low content. The high aspect ratio, high modulus, strength ofnano fillers and matrix. However, the decrease in strength with high nano filler content can be attributed to the following two effects. 1) non uniform dispersion of the nano fillers in high loading systems,acoustic cavitation is one parameter for nano particle dispersion under low content. 2) voids might also have decreased the strength.

E. Heat Distortion Temperature Test

The results of the Heat distortion temperature tests are presented in Table 3.1.Three specimens were used for each laminate at different ratios of graphene [18].

Table 3.1 HDT values for different ratios of graphene

S. No	Graphene vol %	Sample 1 (^{0}C)	Sample 2 (^{0}C)	Sample 3 (^{0}C)	Temperature (^{0}C)
1	1	179	180	178	180 ̊c
2	2	195	192	193	195 ̊c
3	4	210	207	209	210 ̊c
4	6	218	219	220	220 ̊c
5	8	240	237	238	240 ̊c

With graphene addition, the withstand temperature increased from 1800C to 2400C at a graphene content of 8 vol.% is given in Fig 3.4.

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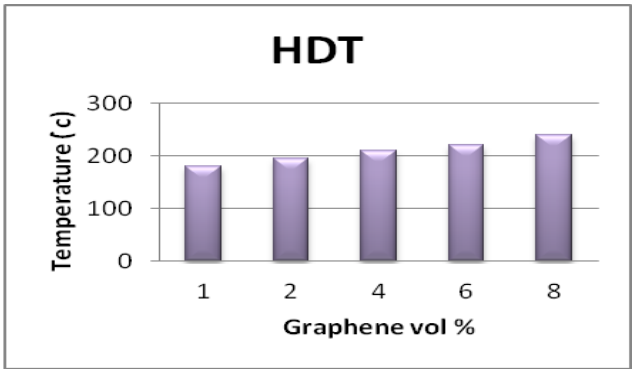

Figure 3.4 HDT values for different ratios of graphene

VII. CONCLUSIONS

In this study, the synthesis and characterization allows us to define the critical steps for processing Graphene based glass fibre reinforced plastics and identify its influence on mechanical property of the composites.

- Synthesis of graphene was successfully carried out by Hummer's method. Graphene oxide and graphene were obtained by this method followed by characterization.
- Characterization was done by XRD analysis, SEM images, and UV Spectra Analysis.
- From XRD, structural nature has been examined, the surface morphology of graphene have hexagonal shape is confirmed by SEM image .
- From tension result, when graphene increased from 1% to 2% in a epoxy along with acetone as dispersion medium, stress increased from 186 MPa to 195 MPa. It is found to be 5% improvement in strength due tothe addition of graphene. Further increase of graphene from 2% to up to 8% resulted in decreasing of the strength of the laminate.
- From flexural result, when graphene increased from 1% to 2%, load increased from 0.32 kN to 0.5 kN.Further increase of graphene from 2% to up to 8% resulted in decreasing of the strength of the laminate.
- Heat distortion temperature test was carried out on various specimen of graphene of 1%, 2%,4%, 6% and 8% of volume. In this test we see from thee graph that the withstand temperature is maximum for 8 % volume of graphene and least for 1% of volume.

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