FABRICATION AND EXPERIMENTAL INVESTIGATION OF MECHANICAL PROPERTIES OF GRAPHENE/SILICA EPOXY NANOCOMPOSITES

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Abstract - *The attractive properties of graphene and its composites have led to the study of numerous applications such as transistors, biosensors, energy storage devices, nano-electro-mechanical systems and others; the past decade has witnessed the rapid growth of carbon nanotechnology. More research in the area will help the development of next generation graphene based composites and hybrid materials. In this study, samples composite materials used for manufacturing by hand stirring technique which casted into rectangular plate. The matrix materials of these composites are: epoxy resin, reinforced with graphene particles which are added in constant percentage 6% wt and nano silica which are added in percentages of (0,4,8,12 and 16)% to the matrix. Tests of Shor-D hardness, Tensile strength and Bending strength for all the samples are conducted. It is found from the results there is improvement in tensile strength and hardness, with the tensile strength increasing up to the 12% wt and the hardness increasing for all the % wt of the samples that were reinforced with graphene and nano silica*.

Key Words: **Graphene, Epoxy, Reinforcement, Tensile, Hardness.**

1. INTRODUCTION

A composite material is defined as a material which is composed of two or more materials at a microscopic scale and has chemically distinct phases. Thus, a composite material is heterogeneous at a microscopic scale but statistically homogeneous at macroscopic scale.

In general, the following conditions must be satisfied to be called a composite material:

1. The combination of materials should result in significant changes in property. One can see significant changes when one of the constituent material is in fibrous or platelet from.

2. The content of the constituents is generally more than 10% (by volume).

3. In general, property of one constituent is much greater (>5 times) than the corresponding property of the other constituent.

The matrix material experiences combined effects of strength and low weight. Most commercially produced composites use a polymer matrix material often called a resin solution. There are many polymers available depending upon the starting raw ingredients. The most common are known as polyester, vinyl ester, epoxy resin, phenolic, polyamide, polypropylene, and others.

In matrix-based composites, the matrix has two functions namely binding the reinforcement material in fixed position and deforming to distribute the developed stresses among the constituent reinforcement materials under the influence of the forces applied.

Graphite is available in large quantities as in the form of both normal and synthetic sources and is economical. The main graphite derivatives include EG, graphite oxide, graphene Nano platelets (GNP), graphene oxide (GO), reduced graphene oxide (RGO), and graphene.

Silicon dioxide, also known as silica (from the Latin silex), is a chemical compound that is an oxide of silicon with the chemical formula SiO_2. Silica is one of the most complex and most abundant families of materials, existing both as several minerals and being produced synthetically. Notable examples include silica gel, fused quartz, fumed silica, and aerogels.

In this paper, the way in which the mechanical properties of epoxy composite materials were affected by addition of graphene and nano silica was studied. The same epoxy resin (Araldite LY556) and graphene was used in all experiments, while other parameters were changed.

1.1 Materials and Specimen Preparation

The materials used in preparation of specimens are graphene particles (10nm size), nano silica of the fumed type (35nm size). The epoxy resin used is Araldite- LY 556 and hardener used is Amine-HY 951. Epoxy resin and hardener are mixed in the ratio of 10:1. Graphene is kept constant at 6% wt in all the samples, owing to the fact that graphene provides very good dispersion characteristic and good mechanical properties at the taken % wt. This was the chosen value upon studying of the past research and investigations.

Firstly, the graphene particles and nano silica powder is weighed accordingly. Epoxy is also weighed. The graphene, nano silica mixture is poured into the epoxy polymer. Now, this mixture is stirred constantly for about 10 minutes. Hardener in the ratio 10:1 wt% of epoxy is added to this mixture. Finally, the entire mixture is stirred for about 2-3 minutes and poured into the mould cavity which was priorly prepared with mould releasing wax spread on the top plate and bottom plate of the mould cavity. After the samples were completely cured it is more suitable to start testing after keeping them at room temperature for a whole day.

1.2 Material Characterization

Tensile Test - Tensile testing was carried out using Tensometer instrument according to the ASTM D638 test standard. The sample size was 165mm x 19mm x 3mm. The test specimen before and after fracture is as shown in Fig -1 and Fig -2.

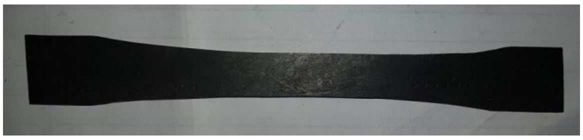

Fig -1: Tensile Test Specimen

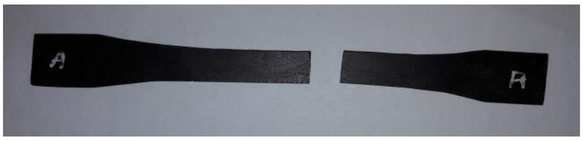

Fig -2: Tensile Test Specimen after fracture

Bending Test - Three point flexure properties were also according to ASTM D790 with dimensions (100mm x 12.7mm x 3mm). Here the specimen is supported on two knife edges as a simple beam and load is applied at its mid-point. The test specimen before and after fracture is as shown in Fig -3 and Fig -4

Fig -3: Bending Test Specimen

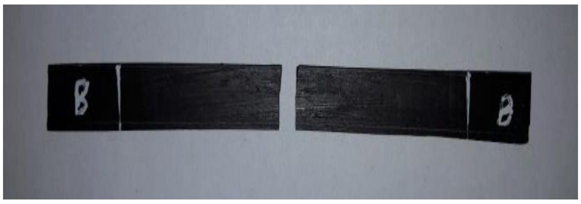

Fig -4: Bending Test Specimen after fracture

Hardness Test - Shore D hardness test was conducted as per ASTM standards (ASTM D2240). Durometer is one of several measuring instrument of the hardness of a material. Durometer is typically used as a measure of hardness in elastomers , polymers, and even rubbers. Durometer, like many other hardness tests, measures the depth of an indentation in the material created by a given force on a standardized presser foot. The standard applied load being 4.55 kg. The test specimen is as shown in Fig -5.

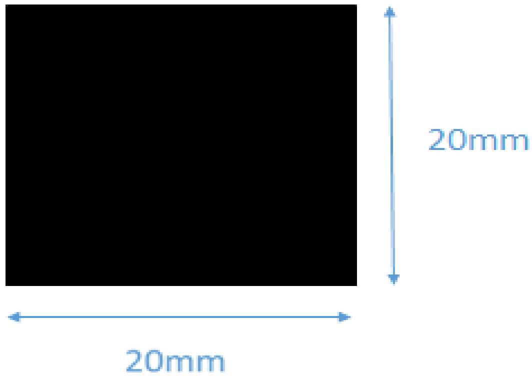

Fig -5: Hardness Test Specimen

2. RESULTS AND DISCUSSION

The following table shows the results of the Graphene Silica reinforced Epoxy Nano Composite.

Table-1: Composition of the test specimens and the corresponding results obtained

Specimen	Combination(Epoxy-Graphene-Nano Silica) in %	Tensile Strength (MPa)	Flexural Strength(MPa)	Hardness
A	94-6-0	91	176.6	57
B	90-6-4	93.6	167.2	60
C	86-6-8	96.3	154.3	63
D	82-6-12	104.7	147.7	70
E	78-6-16	91	141.1	72

2.1 Tensile Test Results

Table -2: Tensile strength and the elastic modulus results of the tensile test specimens

Specimen	Tensile Strength (MPa)	Elastic Modulus (MPa)
A	91	2600
B	93.6	2750
C	96.3	2879
D	104.7	3012
E	91	2996

It was observed that the tensile strength of the specimen increased up to the 12% wt of nano silica. This was expected and attributed to the distribution of graphene in the resin matrix. Being immiscible, the graphene powder acted as interference in the longitudinal continuity of the polymer, thus resulting in decreasing the overall tensile strength of the component at 16% wt. The graphene powder still had some agglomerated particles, which leads us to conclude that mechanical mixing is not the appropriate way to mix Nano-particles in a resin matrix. Ultra-Sonication method is suggested as it will achieve much more homogeneity and proper distribution of particle size.

2.2 Bending test results

Table -3: Flexural strength and the Flexural modulus results of the tensile test specimens

Specimen	Flexural Strength (MPa)	Flexural Modulus (MPa)
A	176.6	3200
B	167.2	3050
C	154.3	2900
D	147.7	2850
E	141.1	2725

The flexural strength of the specimen decreases for all the % wt nano silica composition. Proper mixing should increase this margin further. However, decrease in the bending strength was observed. Also, crack formation took place in the test samples; which leads us to conclude that the sample aren't flexible and had no malleability.

2.3 Hardness test results

Table -3: Hardness test results

Applied mass in kg	Specimen	Resulting force in N
4.55	A	57
	B	60
	C	63
	D	72
	E	72

The Shore-D hardness value of the sample increased by a very good margin. Good surface finish was observed. The hardness value of 57 for the pure graphene sample increased up to 72 for the 16% wt sample. This indicates that with the increase in addition of the nano silica, better bonding has taken place resulting in an increase in hardness

3. CONCLUSIONS

The graphene-epoxy-nanosilica specimens prepared as per ASTM standards subjected to mechanical characterization results were analyzed and compared. The present investigation revealed that different composition of Nano silica influences the improved or enhanced properties of composites.

To go over the main points, the experimental data promising role of graphene in polymer-matrix composites:

• Graphene and Nano silica powder are typically more effective in enhancement of the mechanical characteristics (Shore-D hardness and tensile Strength) of epoxy - matrix composites, as compared to pure graphene sample

• 12 % wt.Nano silica / epoxy composite exhibit the highest enhancement in tensile strength which is means of geometrical shape of graphene and optimum mix of graphene.The maximum Tensile strength is 176 N/mm^2.

• Adding of Nano silica resulted in a decrease in the bending strength of the samples. This was due to the poor dispersion of the particles in the matrix in higher % wt. The maximum Flexural strength is 57.93 N/mm^2

• Adding Nano silica to epoxy matrix increases the hardness due to the dispersion state of Nano silica in the polymer matrix and its interfacial interactions affect on the properties of Graphene/Epoxy/Nano silica composites. The maximum Shore D hardness number obtained for composites reinforced with 16% Wt.Nano silica i.e. 72.

The molding properties of the composite were excellent and 90% of the mold area was filled without any additional help. The composite had a medium viscosity. The polymer resin was easy to handle as it was in liquid state at room temperature.

It can be concluded that addition of graphene powder in such small quantity and increase in nano silica has caused noticeable changes in the mechanical properties of the polymer. With proper mixing using better techniques of manufacturing and processing at the Nano-scale, one can expect more enhancements.

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