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Effect of Graphene and Silica Fillers on Mechanical Properties of Polymer Nano Composites

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ABSTRACT

In the recent years Polymer Nano composites have become promising materials in all engineering materials for transportation, automotive, and biomedical applications. This paper presents various combinations of Nano fillers and matrix materials which were used to develop the Nano composite material by means of simple compression molding technique and characterization of mechanical properties. The effect of Nano Silica (0-25% by weight) and these properties was studied. The silica Nano filler has received much attention due to their ordered structure and high surface area. The Graphene has attracted considerable interest over recent years due to its intrinsic mechanical properties. Finally, Nano composites were subjected to tensile, flexural, impact and hardness testing to analyze the mechanical properties.

Key words: *Polymer Nano composites, Nano Silica, Graphene, Nano fillers.*

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1. NANO COMPOSITES (NC_S)

Nano composites are a class of materials in which one or more phases with Nano scale dimensions (0-D, 1D, and 2-D) are embedded in a metal, ceramic, or polymer matrix. The general idea behind the addition of the Nano scale second phase is to create a synergy between the various constituents, such that novel between the various constituents, such that novel properties capable of meeting or exceeding design expectations can be achieved. The properties of Nano composites rely on a range of variables, particularly the matrix material, which can exhibit Nano scale dimensions, loading, degree of dispersion, size, shape, and orientation of the Nano scale second phase and interactions between the matrix and the second phase.

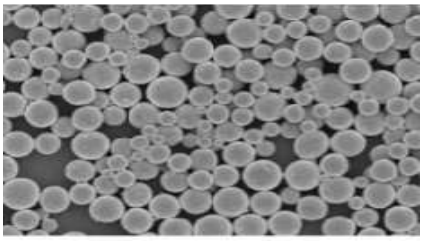

Figure 1: Nano particles

Polymer Nano composites are defined as polymers in which small amount of Nanometer size fillers are homogeneously dispersed and will have potential significant impact on materials mechanical, electrical and thermal properties etc. Therefore in recent years polymer based Nano composites with excellent mechanical, thermal and properties have drawn more and more attention to the research and industry peoples. Polymeric Nano composites can be broadly classified as:

1. Nano clay-reinforced composites.
2. Carbon nanostructures (Graphene, carbon nanotubes and carbon Nano diamonds) -reinforced composites.
3. Nano fiber-reinforced composites.

4. Inorganic particle reinforced composites.

1.1 Graphene-Polymer Nano composites

Graphene has demonstrated a variety of intriguing properties including high electron mobility at room temperature, exceptional thermal conductivity and superior mechanical properties with Young's modulus of 1 TPa. Graphene and its derivatives filled polymer Nano composites have shown immense potential applications in the fields of electronics, aerospace, automobile, defense industries, green energy, etc., due to its exceptional reinforcement in composites Graphene has a higher surface-to-volume ratio, makes Graphene potentially more favorable for improving the properties of polymer matrices, such as mechanical, electrical, thermal, gas permeability and microwave absorption properties

2. EXPERIMENTAL DETAILS

2.1 Materials:

Graphene particles with a size of 20 nm were used. A medium viscosity epoxy resin (LY556) and a room temperature curing polyamine hardener (HY951) both supplied by zenith industrial suppliers, Bangalore. composed the matrix system investigated. Silica particulates with a size of 40 nm were used as fillers to fabricate the composite .Silica particles normally exist in a form of a fine, white amorphous powder or colloid suspension. Its most important characteristic is an extremely large surface area and a smooth nonporous surface, which can promote a strong physical contact when embedded in a polymer matrix.

2.2 Equipment's:

1. A mold
2. Mold releasing spray/wax
3. Mixing container
4. Hand gloves
5. Weighing Machine
6. Stirring stick

2.2.1 Preparation of mold:

The mold used to produce epoxyNano composites consists of two metal plates of size

Figure 1: Mold plates

2.3 Fabrication:

Direct mixing of matrix polymer and Nano fillers is a top-down approach based on the breakdown of aggregated fillers during the mixing process. This type of method is suitable for fabricating polymer-based composites containing Nano or sub-micron sized fillers. There are two general ways of mixing the polymer and fillers. The first is mixing a polymer, in the absence of any solvents, with nano fillers above the softening point of the polymer (melt-compounding method). The second is mixing the polymer and fillers as in a solution. In this study first method was used and test specimens were prepared by compression molding process.

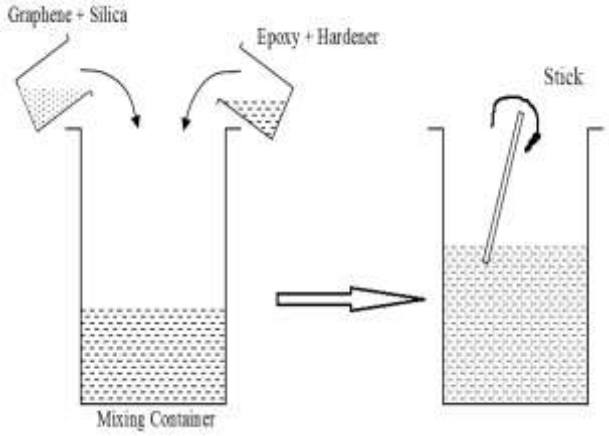

Figure 2: Mixing of epoxy, graphene and silica

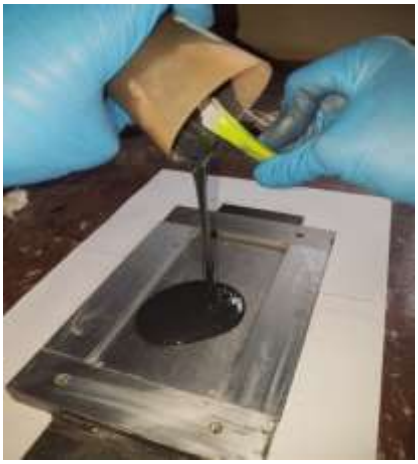

Figure 3: Pouring mixture into the mold

Figure 4: Composite plate

1. The mold inside surface was cleaned with acetone or any cleaning solution and a release agent (spray/wax) coat was then applied to the surface of the table to aid easy removal of the composite laminate.
2. A weighted amount of Epoxy and hardener were mixed in a container in the ratio of 10:1to initiate the reaction.
3. A weighted amount Graphene and silica were added to the previous mixture and stirred for 10-15 minutes.
4. The mixture was poured into the mold carefully and closed by tightening the nuts slowly.
5. The part was left to cure for 24 hours and later post cured at room temperature for 12 hours.

3. EXPERIMENTAL DETAILS

Four test specimens L_o, L_1, L_2 and L_3 with different volume fractions 0%, 5%, 10% and 15% of filler materials of five samples of each were made and average value was considered.

Specimen nomenclature	Graphene (%)	Silica (%)	Epoxy resin (%)
L_o	6	0	94
L_1	6	4	90
L_2	6	8	86
L_3	6	12	82
L_4	6	16	78

3.1 Tensile testing:

Figure 4: Tensile test specimen

The tensile tests were conducted in the universal testing machine (UTM) on flat specimens cut from the laminates as per ASTM D638 standard and are shown in figure. The most commonly used specimen geometries are the straight-sided specimen with end tabs. Uni-axial load is applied through the ends. The tensile strength and tensile modulus with different weight fraction of epoxy-silica was compared in below table.

Specimen	Tensile strength(MPa)	Elastic modulus(MPa)
L_o	91	2600
L_1	93.6	2750
L_2	96.3	2879
L_3	104.7	3012
L_4	91	2996

3.2 Flexural strength:

Figure 4: Flexural test specimen

The determination of flexural strength is an important property of any structural material. It is the ability of the composite material to withstand bending before reaching the breaking point. Generally, three point bend test is conducted for finding out flexural strength in the universal testing machine (UTM).The flexural test was performed on all the three samples as per ASTM D790 test standards. The flexural strength and flexural modulus with different weight fraction of epoxy-silica was compared in below table.

Specimen	Flexural strength(MPa)	Flexural modulus(MPa)
L_o	176.6	3200
L_1	167.2	3050
L_2	154.3	2900
L_3	147.7	2850
L_4	141.1	2725

3.3 Impact test:

Figure 4: Impact test specimen

For analyzing the impact property of the different specimens an impact test is carried out. The test involves striking the standard specimen with a specified weight pendulum dropped from the specified height. The amount of energy absorbed in fracturing the test piece is measured and this gives an indication of the toughness of the test material. Impact test specimens are prepared as per ASTM D256.

Specimen	Impact Strength(J/mm2
L_o	18
L_1	16
L_2	13
L_3	12
L_4	12

3.4 Hardness test:

Hardness test the term hardness of a material is defined as, resistance to permanent deformation such as indentation, abrasion, scratching and machining. For determining the Hardness value in Rockwell Hardness machine suitable load, scale, ball size has to be selected.

Specimen	Hardness(Shore-D)
L_o	57
L_1	60
L_2	63
L_3	70
L_4	72

4. CONCLUSION

The experimental investigations on mechanical properties of Graphene-silica reinforced epoxy composites with different weight fractions have been carried out. The conclusions drawn from the present work are:

1. The tensile strength varied from 91Mpa to 104.7Mpa and the maximum is obtained for composite specimen L_4.
2. The flexural strength and impact strength of the composite decreasing due to increase in hardness.

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