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MODIFICATION POLYMER MATRIX COMPOSITES BY ADDITION GRAPHENE

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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 layout technique which casted into cylindrical pellets. The matrix materials of these composites are: epoxy resin, reinforced with graphene particles which are added in three percentages (1, 3, and 6) % wt to the matrix. Additionally there are pellet without reinforced with graphene particles, then measured Shor-D hardness, diametrical compressive strength and thermal conductivity for all the samples, its found from the results there is improvement in mechanical properties and thermal conductivity of the samples that reinforced with graphene specially at 6%wt.

KEYWORDS: Modification Polymer Matrix Composites, Transistors, Biosensors, Energy Storage Devices, Nano-electro-mechanical Systems and Others

INTRODUCTION

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

2-D graphene possesses improved electrical, mechanical and thermal properties as well as other character, including higher aspect ratio and well-built specific surface area as compare to other reinforcements such as CNTs and carbon and Kevlar fibres. It is sensible to expect some major improvement in a variety of properties in the composites with graphene as nanofiller. [(1)]

The modern success in synthesis of large amount of graphene further promotes the progress of graphene based composite and hybrid materials.

Since the electronic, photonic, mechanical, and thermal properties of graphene depend on the number of layers, [although the monolayer (ML), bi-layer (BL), and tri-layer (TL) graphemes' have practical significance] and its crystalline structure, the controlled synthesis of graphene with defined layers is rather significant so graphene with its excellent mechanical property as a good applicant for these aim.

The development of strong, durable and cost efficient polymer-matrix composite materials for current and future technologies is still an unsolved problem. In this search for original materials as reinforcing fillers in polymer-matrix composites is of crucial significance. [1, 2]

Polymer matrix composites with graphene One of the most hopeful applications of material which the interface of graphene materials and polymer chains merge to develop the most technologically capable nano devices, and its derivatives as fillers have shown a great possible for various important applications, such as electronics, green energy, automotive industries, and biomedical applications biosensors, energy storage devices, nanoelectro-mechanical systems and aerospace. [3]

The processing conditions, dispersion, aggregation, modification and aspect ratio of graphene on the properties of the graphene/polymer nanocomposites are effect.

By using conventional processing methods, graphene composites can be easily Made-up into intricately shaped components with excellent safeguarding of the Structure and properties; this is significant to make full employ of the exceptional properties of graphene. Compare with carbon nanotubes (CNTs), graphene has a higher surface-to-volume ratio as of the inaccessibility of the CNT's inner surface to polymer. This makes graphene more favorable for getting better the properties of polymer matrices. [4]

EXPERIMENTAL

Material Second-Hand

Epoxy resin (EP) used as matrix in this work supplied by Don Construction Products (DCP), commercially known as Quick mast 105 Saudi Arabia, Metaphenylen Diamine (MPDA) that used with (EP) resin as hardener. The graphene nanopowder (12) nm flakes obtain from graphene supermarket Co.

Preparation of Composites

In this work preparation the samples by mixing Epoxy resin (EP) with graphene powder which had particle size (5nm) in varying weight percentage as (0.1, 0.3, 0.6) % wt were sonicated for 1 h for better dispersion then after that The addition ratio of hardener Metaphenylen Diamine (MPDA) to (epoxy+ graphene)system is (1:3)

These mixtures were cast in a mould with diameter (5cm) at room temperature, After solidification samples of epoxy resin reinforced with varying amounts of graphene powder i.e. 1%, 3%, 6%, (by weight of resin) were prepared and The samples were cut to the standard dimensions for each test.

TESTING TECHNIQUES

Hardness Test

Shore hardness is tested with device called Durometer. This utilizes an indenter loaded by a calibrated spring. The measured is determined by the penetration depth of the indenter in the load so this test is performed by Shore hardness (D) and according to (ASTM D 2240). [5]

Diametral Compression Strength (Dc)

Essentially the method used loading disc-shaped samples in Compression across their diameter. Such loading generates a tensile stress at the center of the disc in a direction perpendicular to the direction of applied load that is according to (ASTM standard D 3967).

It was measured by Hertz equation calculating the tensile strength (σ_1) from the following [6]

$$\sigma_1 = \frac{2P}{\pi\, t\, D} \tag{1}$$

Where:

- ***P*:** is the maximum compressive load recorded during the test (N).
- ***t*:** is the thickness of the test specimen (mm). ***D:*** is the diameter (mm).

Thermal Conductivity

The thermal conductivity of samples was measured by a lee's disc device; this process was base on a heat balance in the steady state between the sample and the three disks of the device that allowed estimating the thermal conductivity of the solid sample.[7]

$$k\frac{(T_B - T_A)}{ds} = e\left(T_A + \frac{2}{r}\left(d_A + \frac{1}{2}ds\right)T_A + \frac{1}{r}ds\,T_B\right) \tag{2}$$

To calculate (e) from the equation (3)

$$IV = \pi r^2 e(T_C - T_A) + 2\pi r e\left(d_A T_A + d_S \frac{1}{2}(T_A + T_B) + d_B T_B + d_S T_C\right) \tag{3}$$

RESULTS AND DISCUSSIONS

Hardness Test

It can be observed from the figure (1) which represents the relation between the hardness and graphene percentages, which the addition of graphene to epoxy matrix' can significantly improves the hardness; which increase with graphene addition.

The increase of hardness of these composites in present study can be attributed to (i) superior mechanical properties of graphene; its intrinsic strength (~1.0 TPa) and elastic modulus (125 GP) (ii) Graphene has a higher surface-to-volume ratio, makes graphene favourable for getting better the hardness of polymer matrices.[8]

Graphene is its ability to reconstruct the atom arrangement by forming non-hexagonal rings; this order is of critical importance in passing the nanoscale interlayer interactions to their macroscopic mechanical properties

This can be cross linked by various chemicals to establish both intralayer, i.e. graphene particles are bridged on the edges, and interlayer load transfer from matrix to graphene, so it's dramatically improves the hardness of epoxy under applied hardness load.[9]

Diametral Compression Strength (Dc)

The results of the samples practical that the diametric compression increase with graphene presence as show in the figure (2)

In general, stress can affect behaviour of (epoxy-graphene) system with respect to stress which can be easily reorganized in terms of Le Chatelier principle: "when perturbed, a system in equilibrium tends to react in order to minimize the perturbation".[10]

On the other hand, the graphene dispersed in epoxy matrix may create creased structures that have a tendency to unfold rather than stretch under applied loading; these indicate that graphene are highly effective in suppressing crack propagation in epoxy matrix; may be due to homogeneity dispersion of graphene inclusions within epoxy matrix; [11, 12] So graphene is capable to stabilize the structure and establish a uniform crosslink pattern, which further enhance diametric strength of epoxy.

Thermal Conductivity

Figure (3) illustrate that epoxy resin showed very poor thermal conductivity but the samples reinforcement with graphene in different percentage showed a significant enhancement. At 0.6 %wt graphene- epoxy resin showed higher thermal conductivity than that of the epoxy resin. Thus, graphene composites are promising thermal interface material for heat dissipation

It observes an abnormal development of thermal conductivity. This behaviour could be related to two belongings. The first is the existence of an organized structure of the molecules in the liquid state at the solid/liquid interface that facilities the coupling between the graphene particles and the epoxy before addition hardener (fluid).[8,10,11] The second could be contributions from the Brownian motions of the particles that modify the heat transfer in the (epoxy) fluid.(As well as it can't forget that the graphene is predicted to have a remarkable performance, it's high thermal conductivity about 5,000 W/mK that make it to addition this property strongly to epoxy matrix [12]

The increasing trend promises higher thermal conductivity at larger graphene concentrations. As efficient heat propagation in samples is mainly due to acoustic phonons, a uniform dispersion in the epoxy matrix may give to the steady increase in thermal conductivity in the composites. [13]

When thermal conductivity depends both on temperature and porosity so part of the conductivity increase may be due to the density increase by graphene addition so improving the interface filler-polymer without harming the reticulation reaction between the resin and the curing agent, producing materials with improve properties[3]

CONCLUSIONS

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

- Graphene powder are typically more effective in enhancement of the mechanical characteristics (Shor-D hardness and Diametral Compression Strength) of epoxy - matrix composites, as compared to pure epoxy sample
- Adding 6 % wt graphene to epoxy matrix increases the hardness due to The dispersion state of graphene in the polymer matrix and its interfacial interactions affect on the properties of graphene/epoxy composites

- increase in Compression Strength value of epoxy –graphene composite with increasing graphene weight percentage (wt%) because of that graphene are helpful in suppressing crack propagation in epoxy matrix
- 0.6 %wt graphene / epoxy composite exhibit the highest enhancement in thermal conductivity which is means of high intrinsic thermal conductivity and geometrical shape of graphene, low thermal resistance at the graphene/matrix interface, and optimum mix of graphene

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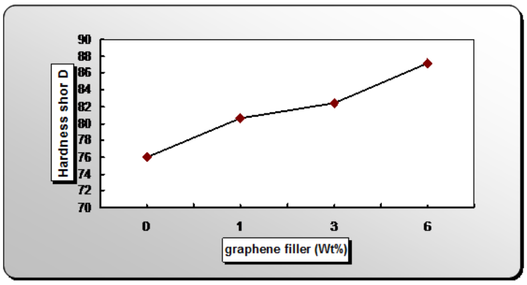

Figure 1: Represent the Relation between the Hardness Shor D And the Weight Percentage of Graphene (Wt %)

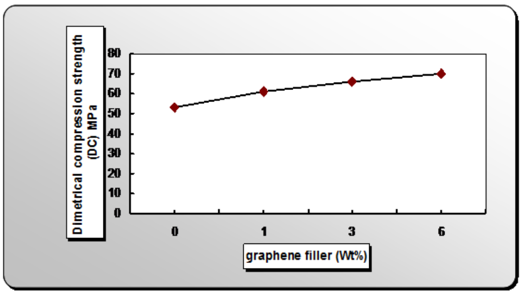

Figure 2: Represent the Relation between the Diametral Compression Strength (DC) and the Weight Percentage of Graphene (Wt %)

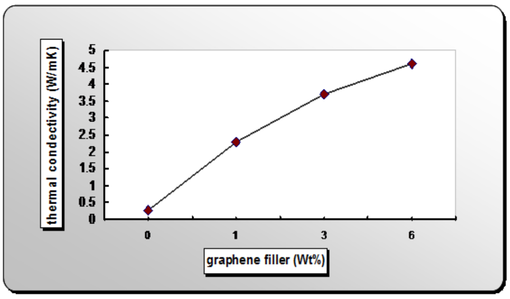

Figure 3: Represent the Relation between Thermal Conductivity and the Weight Percentage of Graphene (Wt %)