Dielectric studies of Graphene and Glass Fiber reinforced composites

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Abstract. Graphene and E-glass fibres are one of the key materials used currently due to their unique chemical and mechanical properties. Lately graphene has attracted many researchers across academic fraternity as it can yield better properties with lesser reinforcement percentages. The current research emphasizes on the development of graphene-based nanocomposites and its investigation on dielectric applications. The composites were fabricated by adding graphene reinforcements from 1%-3% by weight using conventional Hand-lay process. A thorough investigation was carried out to determine the dielectric behaviour of the nano-composites using impedance analyser according to ASTM standards. The dielectric measurements were carried out in the temperature range of 300K to 400K in a step of 20K. The current research proposes the material for application in capacitor industry as the sample of 2.5% weight fraction showed highest value of K with 14 at 26.1 Hz and 403K.

1. Introduction

In composites, materials are joined so as to empower us to improve utilization of their ethics while limiting to some degree the impacts of their lacks [1]. This procedure of streamlining can discharge a designer from the requirements related with the choice and produce of traditional materials. Composite materials are utilized broadly as their higher particular (properties per unit weight) of quality and strength, when contrasted with metals, offer intriguing open doors for new products [2]. The utilization of fiber strengthened composite materials in marine, space, aviation and car ventures have developed extensively as of late in view of their one of kind properties like lightweight, strength to weight ratio, great resistance against corrosion and show less expansion under the effect of temperature. The machining behaviour of composites has been widely investigated [3]. The advancement of a nano level scattering of graphene particles in a polymer based composites has opened another and fascinating range in materials science lately [4]. Its exceptional properties make it reasonable to enhance the electrical properties of polymer composites. It additionally talked about the threshold in view of filler volume, aspect ratio and material orientation. Keeping in mind the end goal to enhance conductivity, the scattering of graphene in polymer based matrix and the graphene–polymer association should be enhanced, which are accomplished by the modifications in the surface of graphene [5-7]. Graphene polymer interactions lead to better conductivity and also have wide electronic applications. Tensile Strength reaches maximum with a small amount of graphene fillers.
added beyond that strength decreases. Increase in high silica and E-Glass fibers gives higher tensile and compressive strength and also electrical insulation [7-9]. Nano composites with intercalated graphene exhibit higher young’s modulus high glass transition temp and low thermal expansion than with graphene flakes. Graphene bases polymer nanocomposites exhibit superior mechanical properties compared to neat polymer or conventional graphite based composites. Addition of graphene in composite increases the wear resistance considerably with increase in different filler composition. Composite polymer reveals that there is a good range of dielectric constants and dielectric losses and also proves as frequency increases dielectric constant decreases. Addition of graphene with epoxy shows stable coefficient of friction comparing with neat epoxy resin. In the current work, the effect on graphene on dielectric strength is investigated by varying the temperature and frequency.

2. Methodology
2.1 Fabrication of Laminates
The composites were fabricated by Hand Lay Process and have been evaluated by the addition of Graphene with 1, 1.5, 2, 2.5 and 3 by weight% as a reinforcement in composites. A stir bar mixes the solution on a combined hot plate magnetic stirrer. Stirring is done for the reduction of graphene lumps with the application of heat to lower the viscosity of the resin. The speed is varied from 300 to 1150 rpm. The stirring is done till a uniform swirl motion appears. Then sonication which is the application of sound energy to agitate particles in the sample is carried in order to get the even breakdown of the molecules Ultrasonic Frequency of 600Hz is maintained for a time period of 45 minutes to facilitate the breakdown of graphene particles in the resin.

A glass of size 300*300 mm is used as base upon which wax is applied and a plastic sheet is placed to facilitate easy removal of the laminate after curing. E-Glass fibre is cut into size of 300*300 mm. According to the calculation, 13 layer of E-Glass fibre is used for each laminate. Resin and hardener are mixed in the desired ratio and the mixture is then applied uni-directionally using blades. Hand Lay-up process is adopted, fibres and resin are alternatively layered one after the other. After completing lay up of laminates, a pressure of 5kg/sq. ft. is applied onto the laminate and it is then left to cure for 2 days. After the adequate curing, the laminate is taken off from the glass.

![Figure 1. Stirring of graphene reinforced epoxy resin](image1.png)

![Figure 2. Ultra sonication of graphene reinforced epoxy resin.](image2.png)

2.1 Experimental Details
The fabricated composites reinforced in weight fraction 1%, 1.5%, 2%, 2.5% and 3% and these are nomenclature as laminate 1, 2, 3, 4 & 5 respectively. Dielectric measurements were carried out using an Electrochemical Work station available in the Battery Research lab as shown in figure below. A dielectric measurement provides information about the usability of laminates as dielectrics in a capacitor. Laminates as they don’t carry free charges are known to be electrically insulators, however, due to their dielectric nature, they can be employable in capacitors to enhance the capacitance without changing the dimensions of the electrodes. For testing the dielectric nature of the laminates, the specimen was taken as 1 cm diameter cylinder with 6 mm thickness and sandwiched between two silver electrodes. An electrical pulse of strength 0.5 V was used to stimulate the samples with varying frequency between 10 Hz to 1 MHz and the response of the specimen was recorded using a lab view program. The dielectric measurements were carried out in the temperature range of 300 K to 400 K in a step of 20 K.

3. Discussion
Dielectric measurements were carried out to study the sample’s employability in capacitors industry. Better the dielectric constant of the laminates, and stable the laminates thermally, higher would be the chances of the laminates being used as dielectrics in capacitors to enhance the capacitance of capacitors. Figure below shows the dielectric constant values of various laminates as a function of temperature inverse. It can be seen from the figures that the at high frequencies of the applied signal,
due to the lack of switching of dipoles with larger relaxation times, the dielectric constant of the system is lesser. However, at low frequencies of the applied signal, as all the available dipoles react to the signal, the net polarization of the system is large and hence the dielectric constant is also very high. This can be seen irrespective of the laminate composition. Highest value of $K$ was found for Sample 1 with a value of 14 at 26.1 Hz at 403K.

![Figure 5](image5.png)

Figure 5. Variation on Dielectric constant vs inverse of temperature for laminate 1

![Figure 6](image6.png)

Figure 6. Variation on Dielectric constant vs inverse of temperature for laminate 2

![Figure 7](image7.png)

Figure 7. Variation on Dielectric constant vs inverse of temperature for laminate 3
Figure 8. Variation on Dielectric constant vs inverse of temperature for laminate 4

Figure 9. Variation on Dielectric constant vs inverse of temperature for laminate 5

Figure 10. Variation on Dielectric constant vs Frequency for Laminate 1

Figure 11. Variation on Dielectric constant vs Frequency for Laminate 2
4. Conclusions

1. Graphene was reinforced in weight fraction of 1-3% using magnetic stirring and sonication and 5 different laminates were fabricated.

2. In present work, the changes in the dielectric strength of the Graphene reinforced polymer matrix nanocomposites fabricated have been reported.

3. The variation of dielectric strength was investigated by varying the frequency and temperature.

4. The addition of graphene and E-Glass fiber as reinforcement for the laminate has proved to be effective in increasing the K value of the laminate.

5. The Laminate of 2.5 weight % of graphene was found to exhibit superior properties in contrast to the other laminates of different weight percentages.

6. The laminate with 2.5% weight fraction of graphene can be used for capacitor applications.
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