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Effect of viscosity and dielectric properties on the polymer fiber composite

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Abstract (row height 0.8 cm)

Polymer-fiber-based composites were classified as "high" (real permittivity), "magnetic," and "superconducting," with "high" composites supporting the all-dielectric approach to wave manipulation.The goal of this research is to develop a processable dielectric material with a relatively large real part of the relative permittivity (ε'). The magnetic and dielectric performance, as well as the thermal properties, of polymer fibre composites based on polyvinylidene fluoride (PVDF) can be improved by the addition of various materials, such as graphene, which has excellent electrical and dielectric properties. The magnetic and dielectric properties of such a composite material are affected by shape, filler concentration, and size. The PVDF polymer fibres were created using solvent-induced phase separation and electrospinning. 1g of graphene was mixed with 30g of ethanol and added to 199ml of PVDF polymer dope solution. The effectiveness of graphene as a dielectric material was investigated using the X-band 8.2–12.4 GHz regions of the key sight ENA series Network Analyzer E5071C on polymer fibre composite materials. According to the results, the graphene fibre has a higher real permittivity of 6.08F/M than the conversional polymer fibre composite, which has a permittivity of 2.0F/M. The addition of graphene successfully polarised the polymer fibre composite based on the results obtained; this is due to graphene's dielectric field dependence. Graphene, on the other hand, is a material with a distinct behaviour due to its electronic structure and linear dispersion near the fermi level. Also, graphene is a superconducting – insulating transition material that can be driven by electric fields; it was discovered that increasing the viscosity of the PVDF dope solution resulted in brittleness of the polymer-fiber, which has a negative effect on the mechanical properties of the fibre.

1. Introduction

A well-organized Organic and inorganic composite have been thoroughly investigated. Because inorganic materials have mechanical strength, electrical, thermal stability, and magnetic properties, while organic polymers have dielectric, flexibility, and ductility, which are difficult to obtain from individual components. [1]. When designing an electromagnetic absorber, it is critical to select materials that have significant control over some dielectric and magnetic properties. The dielectric and magnetic properties of the materials must correspond with the frequency of the radiation, which must cover a broad range of frequencies. Materials used must be designed in such a way that their magnetic and dielectric properties vary in frequency in an exceptional procedure. [2] There are four different electromagnetic parameters that must be independently manipulated: real and imaginary parts of effective permittivity and magnetic permeability. [3]. Insulating matrix materials such as magnetic absorption which are made by dispersing magnetic filler remain to play a prominent part in the study and application of microwave absorption materials [4, 5]. Carbon black polymer composites have been studied by many researchers due to their excellent performance in condense matter physics as well as engineering applications such as electromagnetic interference, shielding wave absorption, and electronic packaging.[6-8] The dielectric absorption, electrical, mechanical, effective permittivity and effective permeability of a material can be improved with low amount of carbon nanotube (CNTs) as well as their thermal properties of the composites in the microwave range of frequencies [9, 10]. For the last epoch, the use of intensive conductive polymer material (ICPM) has been a great concern and significant because of their numerous diversities of physical and electrical/conductive properties. These conducting polymer composite have been projecting in application ranging from organic transistor [11] Polyvinylidene fluoride (PVDF) is an electrically conductive polymer that has received a lot of attention in recent years. PVDF is a risky application that requires a lot of chemical resistance, a high degree of purity, and excellent mechanical properties. It has superior creep resistance to other fluoropolymers and a low density of about 1.78 (g/cm3). Also, because the molecular chains are mechanically stretched and poled under tension. Conductive polymerization on fibres such as wool has previously been achieved in previous research work. [12] cotton [13] and nylon [14] even the use of electrochemical and chemical oxidation, and in rare cases, vapour phase polymerization[15] . The electrical properties have been achieved through this procedure and it has been with the extent of significant degradation in mechanical properties [13] it was identified that in the pure state polymer are excellent electrical insulators: though polymer can be rehabilitated to be a good electrical conductors by mixing them with a good conductive materials. Different conductive filler has been used to give good conductive properties to polymers, such as carbon nanotube (CNTs), Carbon black (CB) and carbon fibers (CF) have been employed as conductive fillers.

The first self-supporting 2D crystal is graphene [16]. One of the most important nanomaterials is graphene and it has gain attraction in the area of fundamental condensed matter physics and materials ranging from the nano to macroscopic scale [17-19]. Graphene has exceptional mechanical properties, including a record tensile strength (~130 GPa), elastic modulus (1.1 TPa) and prominent flexibility, and brilliant electronic transport performances such as extremely high electric conductivity (~10^8 S/m), carrier mobility (200,000 cm^2 /V s) and capacity (1–2 GA/cm^2) [20]. It was record that graphene have high thermal conductivity of (5000 W/m K), high temperatures, good stability against chemicals, atomic thickness and valuable others. These new improvements have streamlined the accepting of graphitic materials, together with their fabrication. For example, starting from solvated graphene, graphene films/papers can be easily fabricated by many sophisticated solution-processing approaches, and they exhibited many good properties in mechanics and electronics. Graphene papers are much stronger than commercial graphite die-cast foils [21, 22]. Additionally, graphene gave a fresh concept for the field of 3D frameworks. A typical example is graphene aerogel, which is created by bridging these thinnest building blocks and exhibits the extremely low density of a gas but in a solid state [23].

2. Experimental Details

A) Chemical and instruments

Poly(vinylidene fluoride) (PVDF) pellet was purchased from sigma-Aldrich (63103) St. Louis USA with 99% purity without further purification, 1-methyl-2-pyrrolidinone (NMP) reagent plus of 99% purity was also purchased from Sigma-Aldrich international GMBH C/O Aldrich chemical co LLC, 600 North Teutonia Avenue Milwaukee, Wl 53209 USA. With Mw: 99.13g/mol, Mp: -240C(lit), bp: 2020 C (lit), bp: 81-820 C/10mmHg (lit), Fp: 1.4 (lit), Vapor pressure: 0.2gmmHg (200C) and assay 99%. Graphene were provided by Cambridge University London, smith electric stirrer and the polymer were used as received.

B) Preparation of PVDF polymer fiber

The PVDF polymer fibers were prepared by solvent induced phase separation through the spinning equipment, as shown in figure 1. Table 1 show the list of spinning parameters. The PVDF pellet was dissolved in 1-methy1-2pryrrolidinone (NMP) followed by stirring at temperature between 60 – 700C until the solution became homogeneous. Then 1g of graphene was dispersed into 30g of ethanol and then added into 69g of polymer dope solution, it was stirred at 150rpm using electric stirrer and degas for about 30mintes. Spinning solution with different polymer concentrations (20 -25wt.%) were formulated. All the polymer solution prepared was clear and homogeneous at room temperature. Water is used as the external coagulant; the spinneret with orifice diameter/inner diameter of the tube 0.6mm was used. In spinning polymer fibers the take up velocity (8-9m/min) and the air gas was in the range of 5 to 25cm, FESEM technique was used to study the surface morphology of polymer fiber composite and polymer fiber composite with addition of graphene.

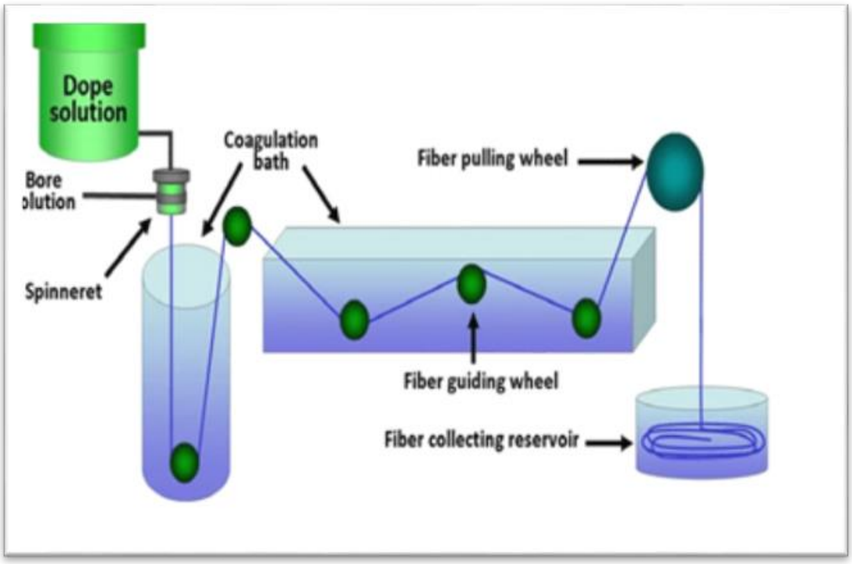

Figure 1: The Schematic diagram of spinning equipment 1. Dope tanks; 2, Bore solution; 3, Spinneret; 4, Coagulation bath; 5 Fiber guiding wheel; 6, Fiber pulling wheel; 7, Fiber collecting reservoir; 8, Nitrogen Cylinder.

3. Result and Discussion

The effectiveness of graphene as a dielectric material was investigated using the X-band 8.2 – 12.4 GHz regions of key sight ENA series Network Analyzer E5071C on polymer fibres composite materials. The dielectric properties (' and ") of two different samples were measured using a network analyzer connected to an open-ended coaxial line (probe) via a cable attached to the holder and used as a sensor in the dielectric property measurement. The samples were laid flat on the probe's surface, and the technique was based on the coaxial line's reflection coefficient values versus the composite samples. At room temperature, real and imaginary permittivity measurements were taken, and permittivity was calculated using the equation (1).

$$\varepsilon = K = \varepsilon' + j\varepsilon'' \qquad (1)$$

Where is the true permittivity, is the imaginary permittivity, and K is the frequency? The obtained results revealed the high performance of dielectric properties, the real permittivity of polymer fibre composite with graphene is to investigate the possible mechanism of dielectric absorption, the real and imaginary parts of permittivity (ε', ε") and magnetic permittivity were determined from scattering parameters using Network analyser E5071C material measurement software. The amount of energy stored in a material by an external electric field is measured by real permittivity, and " is the imaginary permittivity, which measures how much energy is dissipated or lost in the material.

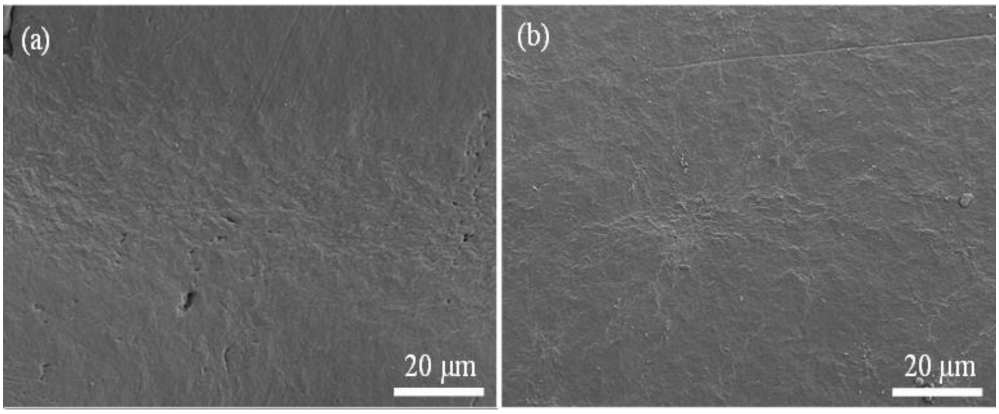

Figure 2: FESEM images of (a) Polymer fiber Composite without graphene (b) Polymer fiber Composite with addition of graphene

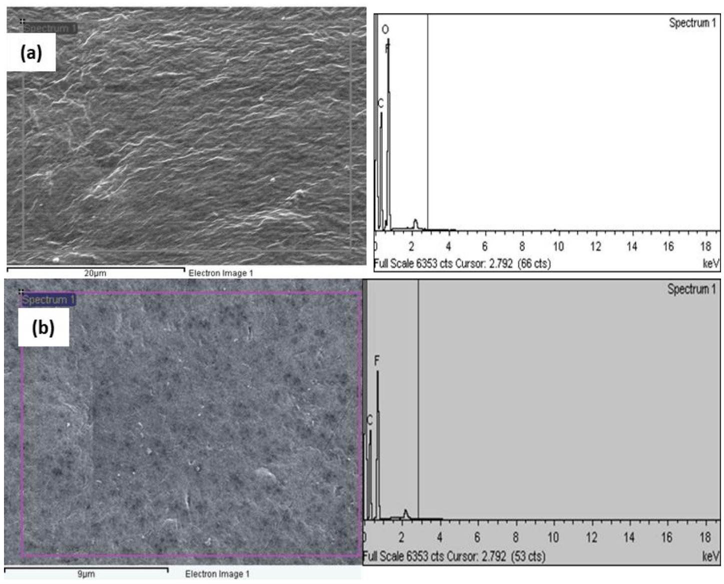

Figure 3: EDX morphology analysis of polymer fiber (a) and polymer fiber with graphene (b)

Figure 4 and 5 explain the variation of the ε' with the load percentage of graphene on the polymer fiber and without graphene at room temperature at random frequencies 8, 9, 10, 11, 12 and 13 GHz respectively. The effective medium theory clearly explains the increment of effective of real permittivity and the imaginary permittivity values in compliance to the additive [20, 21], where higher real permittivity of polymer fiber composite can be obtained by adding filler to the conversional polymer fiber composite matrices and vice versa. It is clear that the value of ε' increase three times with the addition of graphene compared to the conversional polymer fiber.

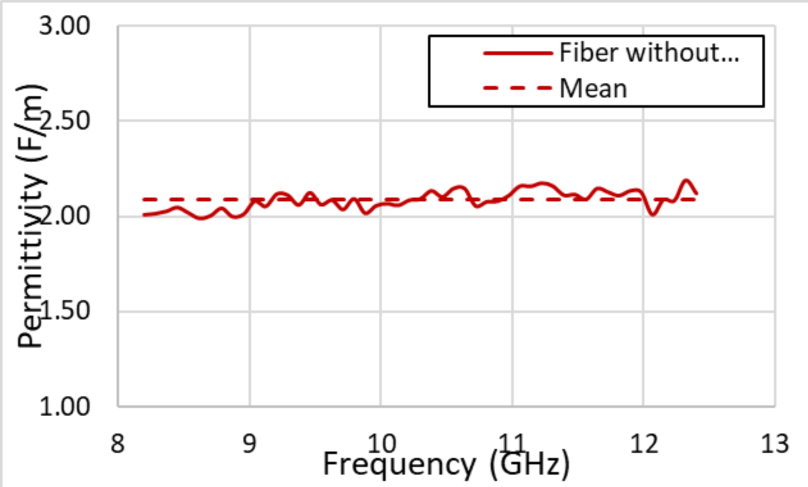

Figure 4: Plot of real permittivity of conversional polymer fiber without graphene

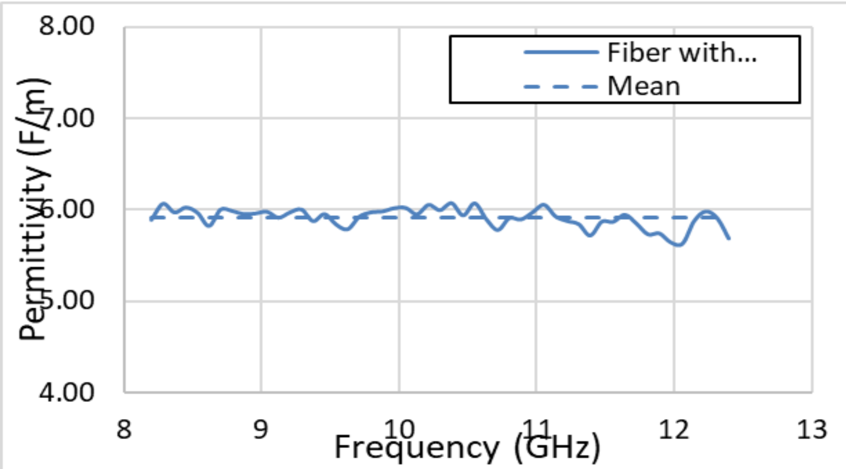

Figure 5: Plot of real permittivity of Polymer fiber composite with Graphene

The dielectric field energy changes quickly at higher frequencies, the value of graphene in the polymer fiber composite resulted in the higher dielectric properties effects that subsidized to the increase in real permittivity result and this is due to the electric field dependence of graphene, graphene is a material with unique behaviour due to its electronic structure and linear dispersion near the fermi level, also graphene is a superconducting – insulating transition materials which can be driven by electric fields (Figure 6).

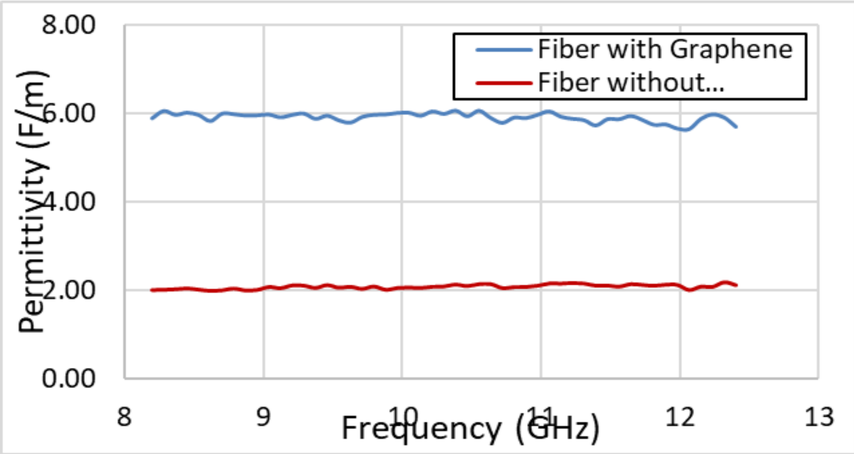

Figure 6: Plot of real permittivity of conversional polymer fiber and real permittivity of polymer fiber with graphene

Based on the result obtain from the experiment it is clear that the reinforcement of graphene on the polymer fiber composite have shown a promising result in enhancing the dielectric properties of conversional polymer fiber composite at a low percolation threshold. Graphene as Nano filler has opened a new breadth for the production low cost, light weight and high performing composite materials for a range of applications. Graphene as a nanocomposite have been widely used for making various sensors, energy storage, memory, EMI and antistatic coatings etc. graphene flexible electrode has some commercial application in LED, transportation conducting coatings for solar cells and displays. Figure 2 (a, b) shows the FESEM images of polymer fiber composite without graphene and polymer fiber composite with addition of graphene respectively. It is clear from images that the polymer with graphene has a smooth surface and there is no pore on the surface.

4. CONCLUSIONS

Based on the result attained from the experiment, graphene polymer fiber was successfully prepared through the spinning method. PVDF pellet was dissolved with NMP solvent at 60 – 700 C, dielectric properties of the material were analysis using network analyser of the frequency range 8.2 – 12.4GHz. The sample was measured through an open- ended cable revealed a proportional relation between the obtained results of real permittivity with the addition of graphene. The permittivity was successfully measured as a function of frequency using network analyser. Dielectric properties of the polymer fibers increase due to the addition of graphene. It was observed from the experiment that the higher the viscosity of the dope solution the higher the brittleness of the fiber. Graphene was able to increase the dielectric properties of the conversional polymer fiber composite because of its electric field dependence and its unique behaviour due to electronic structure and linear dispersion near the fermi level, also as superconducting – insulating transition materials which can drives by electric fields. The improvement of a Nano-level distribution of graphene particles in a polymer composite matrix has opened a new and exciting area in materials science in recent years. Its distinctive properties make it suitable to improve the dielectric properties of polymer fiber composites. This part reviews the dielectric properties of different polymer/graphene composites and the different factors affecting dielectric materials. We deliberated on the percolation threshold based on filler volume fraction, processing methods, aspect ratio, surface area, orientation etc. In order to improve dielectric properties, the dispersion of graphene in polymer matrices and the graphene–polymer interaction needs to be improved, which are achieved by the surface modification of graphene. Finally, a few electronic applications of these high-performance graphene composite materials are mentioned.

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