Dynamic mechanical analysis, electrical properties and water sorption behaviour, of phenol formaldehyde nanocomposite reinforced with multiwalled carbon nanotubes

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ABSTRACT

The goal of this research is to synthesise Phenol-formaldehyde nanocomposites containing pure multi-walled carbon nanotubes using an in-situ polymerisation process. The impact of filler loadings (MWCNT) with various weight percentages in the composite was explored in this research. The visco-elastic, electrical, morphological, and water sorption behaviour of the nanocomposites were investigated. The influence of MWCNT loading on the dynamic mechanical analysis, water uptake, electrical behaviour was examined. Using in-situ polymerisation, an effort was made to generate non agglomerated and homogenius dispersion of multiwalled carbon nanotubes (MWCNT) in the PF composite. The influence of MWCNT dispersion on the viscoelastic characteristics, electrical, morphological, and water sorption behaviour of PF-MWCNT nanocomposites has been thoroughly investigated. When compared to neat PF, lower filler loading (0.05 wt%, 0.08 wt percent) resulted in greater AC conductivity. According to DMA investigation of PF-MWCNT, 0.15 wt% has a greater storage modulus and 0.05 has a higher glass transition temperature. The addition of MWCNT has effectively reduced the water uptake of the entire nanocomposite.

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1. Introduction

Phenol formaldehyde resin (PF) is a kind of resin containing phenol and formaldehyde. A synthetic polymer produced from phenol or substituted phenol reacting with formaldehyde in the presence of a catalyst is known as resin. Billiard balls, lab tables, as well as coatings and adhesives, have all been made using them. When it comes to commercial polymeric resin systems, phenolic resins are among the oldest and most well-known, and they are frequently associated with the birth of the plastics industry. This response was initially documented by Von Baeyer in 1872 [1]. He noticed that the reaction between phenol and formaldehyde catalysed by acid resulted in the development of a resinous substance that he had not anticipated. He made resins that were either commercially or technically useful. Due of its poor mechanical

strength, PF's range of uses was limited. Because of the rapid growth of global businesses, the quest for new renewable raw materials has become a critical concern for researchers. As a result, researchers are increasingly interested in reinforcing PF and improving its mechanical strength. Specific ways have been investigated, such as adding fibres and particles or chemically altering the PF basic resin. The disadvantages of composite can be addressed by incorporating nanoparticles. The phenolic resins are extremely fragile, numerous tougheners such as natural fibres, carbon nanotubes (CNT), graphene and others are employed to minimise brittleness [2]. Carbon nanotubes especially multiwalled carbon nanotubes can be considered as group of cylindrical tubes of graphite sheets similar to fullerene end caps [3]. It exhibits higher Young's modulus [1 TPa] with few millimetres of length, diameter (1–100 nm) and density ranging from 1 and 2 g/cm³. These unusual properties offers a wide variety of scientific and technological possibilities. Due to their special one-dimensional nanostructures, carbon nanotubes (CNTs) has been extensively used in polymer nanocomposites [4]. The observations, however,

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do not always meet as wishes, because CNTs are difficult to process, due to their low dispersibility, and aggregating tendency. In addition, owing to their low solubility in both aqueous and non-aqueous solvents, processing the tubes are often found to be difficult. These are mainly used as a perfect reinforcement for polymers to enhance thermal, mechanical and electrical properties.

Carbon allotropes have outstanding features, such as strong thermal and electrical conductivities, flame retardancy, and exceptional mechanical properties, make them potentially appealing fillers for advanced composites manufacture [5,6]. Carbon nanotubes (CNTs) have gotten a lot of interest since even small amounts of CNTs may offer significant electrical conductivity and improve the mechanical characteristics of nanocomposites [7].To convert non-conductive polymers to conductive polymer, carbon allotropes (CNT, Graphene, Carbon black etc) are widely used [7–10]. It is interesting to note that the addition of MWCNT increased the conductivity of the nanocomposite [11]. The electrical properties of nanocomposites rely on the filler-filler interaction, geometry of the filler, interaction of the filler with the host matrix and dispersion of the filler [12]. The dispersion of MWCNT is crucial since the geometry and interaction of MWCNT is almost same. CNT is employed as an ideal reinforcement in this work to improve the dynamic mechanical and electrical characteristics of the PF system.

By integrating nanofillers like reactive rubber nanoparticles (RRNP) and nanoclay in the phenol–formaldehyde resin Solyman et al. [13] developed PF nanocomposite. By the addition of reactive rubber nanoparticles (RRNP) and modified nanoclay, Phenol formaldehyde nanocomposites were prepared before curing. The functional groups present in nano clay and PF matrix interacted well which attributes enhancement in mechanical properties. Furthermore, there was an enhancement in thermal stability of the fabricated PF nanocomposite by 10–20%. The characteristics of the produced PF-Graphene oxide (GO) nano composite were considerably improved by the addition of graphene oxide [14]. The non-conducting graphene oxide was reduced in the presence of phenol during in-situ polymerisation, and the reduced graphene oxide (RGO) produced by this approach had a high conductivity. The percolation threshold of the resulting nanocomposite was 0.17 vol%. The inclusion of 2.3 vol% graphene oxide resulted in a 76 °C reduction in decomposition temperature.

P.K Sandhya et al., [15] conducted a recent investigation of water sorption behaviour of phenol formaldehyde resin reinforcing with reduced graphene oxide and ZnO adorned graphene oxide. At various temperatures, the influence of two distinct fillers on the water uptake behaviour of was examined. The researchers discovered that the presence of RGO improves water absorption, but the presence of ZnO-RGO filler limits the water sorption abilities. The estimation of the activation energy was done using Arrhenius equation in order to study the effect of temperature on water sorption. The water sorption of the PF nanocomposites follows a first order response, according to the kinetic investigations. Smolen et al., [16] has fabricated carbon nanotubes - epoxy nanocomposites and investigated the mechanical and electrical properties. The percolation threshold was achieved for all materials with a 1% of multiwalled carbon nanotubes, and improved its conductivity. They got better tensile strength and a higher strain percentage but the young's modulus got reduced.

The functionalization of CNT surfaces increases the mechanical and morphological behaviour of PF nanocomposites, according to previous research [2]. The sophisticated surface modification process of CNTs, on the other hand, destroys their side walls, thereby lowering the entire properties of nanocomposites. As a result, CNT surface modification is not always beneficial. It has been found that mechanical and thermal features of CNT-nanocomposites have a considerable influence on the dispersion of carbon nanotubes in the matrix and their interaction with it, as well as the processing

procedures employed to synthesise polymer nanocomposites. In this study. the dynamic mechanical analysis, electrical properties, water sorption behaviour were used to evaluate the PF-MWCNT nanocomposite. TEM was used to investigate the structural morphology of MWCNT in PF matrix.

2. Materials and methods

2.1. Materials

Merck (India) provided phenol, formaldehyde solution (37 %), and sodium hydroxide pellets. Ad-Nano Technologies Private Limited, India, provided multiwalled carbon nanotubes with a diameter of 10–15 nm and length of $\sim$ 10 μm on average.

2.2. Methods

2.2.1. Synthesis of Phenol-formaldehyde -MWCNT nanocomposite

Phenol-formaldehyde resole type resin is prepared by condensation polymerization of phenol and formaldehyde in the presence of sodium hydroxide as a catalyst. Primarily 0.5 mol% of NaOH solution is homogenised with various weight percentage of MWCNT (0.05, 0.08, 0.12, 0.15 wt%) for one hour. The reaction is allowed to cool before being neutralised with glacial acetic acid to eliminate any leftover sodium hydroxide. Kept overnight and the A stage resin cured at different temperatures.

2.2.2. Step cured at different temperatures

- 60 °C for 2 hrs
- 70 °C for 12 hrs
- 80 °C for 3 hrs
- 90 °C for 2 hrs
- 100 °C for 1 hr
- 110 °C for 1hr
- 120 °C for 3 hrs

2.2.3. Experimental method

Square specimens of side 1*1 cm are cut from neat sample 0, 0.08, 0.15, 0.20 and 0.25% of PF/CNT composites. Specimens of known weight are immersed in distilled water at a particular temperature. The samples were periodically removed from solvents, dried of any solvent adhering to the surface using a tissue paper and weighed immediately. During the initial stage of a diffusion experiment, the solvent is absorbed by the sample at relatively fast. It is necessary to weigh them every 10 min for the first day, 30 min for second day. Then as the experiment progress, it becomes necessary to weigh the sample only once an hour and then once a day. Weighing was continued at frequent intervals until equilibrium swelling was reached. The results of diffusion are expressed in diffusion curves, where mole% uptake of solvent is plotted against the square root of time in minutes.

2.2.4. Estimation of Qt (mol % uptake of the solvent)

The mol% uptake of the solvent, Qt for the composite samples was determined using equation

$$Qt = \frac{\frac{W2-W1}{Ms} * 100}{W1}$$

The weight of the specimen before and after swelling are w1 and w2, respectively. The molar mass of the solvent is Ms.

3. Characterisation techniques used

3.1. Specific gravity

A specific gravity bottle was used to determine the resin's specific gravity according to ASTM D 792.

3.2. Total solid content (TSC)

TSC was calculated by drying a precisely weighed sample (approximately 0.5 g) at 170 °C for 30 min.

3.3. Dynamic mechanical analysis (DMA)

A thin film c lamp was used to do dynamic mechanical analysis on a TAQ 800 thermal analyser (Q800DMA,TA Instruments, New Castle, Delaware, United States). The dynamic mechanical characteristics were tested in a temperature range of 120 °C to 70 °C at a frequency of 1 Hz and a strain amplitude of 5 μm. The temperature was raised at a rate of 2 °C each minute.

3.4. AC and DC conductivity

With a frequency range of 20 Hz to 30 MHz, the AC conductivity of the specimens were examined using a Wayne Kerr 600B accuracy LCR metre. The DC conductivity of the samples were taken from Keithely Source Meter 2450.

4. Results and discussions

4.1. Specific gravity

The specific gravity of the PF resin is 1.14.

4.2. Total solid content (TSC)

The Total solid content of PF resin is 78%.

4.3. Dynamic mechanical analysis (DMA) of PF-MWCNT nanocomposite

Figure 1.a) shows the storage modulus and b) shows loss modulus and c) shows the tan delta of the prepared PF-MWCNT nanocomposite. The degree of dispersion of filler, matrix- filler interaction can be confirmed from the DMA analysis [17]. Among the five samples (neat, 0.05, 0.08, 0.12, 0.15), 0.15 wt% exhibits higher storage modulus. The storage modulus of 0.15 wt% is 2938 MPa at 25 °C, while for 0.12 wt% is 2383 MPa, 0.08 wt% is 2386 MPa, 0.05 wt% is 2041 MPa and for neat is 1824 MPa. The incorporation of MWCNT has increased the storage modulus considerably. By increasing temperature, the storage modulus decreases. This phenomenon can be explained as the addition of MWCNT into PF matrix has brought good interfacial interaction and rigidity to the nanocomposite. The molecular chain mobility is the reason for damping factor (Tan delta). The addition of MWCNT has pronounced effect on the segmental mobility of molecular chains in the PF matrix. 0.08 wt% and 0.12 wt% have lower tan delta than the neat PF [10]. This shows that these loadings restricted the chain mobility. The peak in tan delta shows the glass transition temperature (the maximum temperature showing whether the material can found application as structural component). Here T_g for neat, 0.05 wt%, 0.08 wt%, 0.12 wt%, 0.15 wt% is 93.7 °C, 109.49 °C, 103.67 °C, 91.04 °C, and 90.2 °C respectively. Because of the excellent interfacial connection between MWCNT and PF matrix, the increase in Tg is related to decreased segmental

mobility. The higher concentration of MWCNT has decreased the glass transition temperature due to agglomeration.

The covalent link between the polymer matrix and CNT has been found in certain experiments to provide an increase in storage modulus when MWCNT is added [18]. The interfacial slippage between the MWCNT and the PF matrix causes the damping in PF-MWCNT nanocomposites. When there is strong interfacial adhesion between polymer and filler. There will be less interfacial slippage. As the MWCNT content increases, the interfacial slippage increases owing to agglomeration of MWCNT. The damping qualities of polymer nanocomposites are influenced by the filler fraction, critical shear stress, adhesion of nanofillers with the polymer matrix. MWCNT has a high aspect, which improves the damping properties of polymer nanocomposites. High storage modulus and low loss factor can only be achieved if the MWCNT is dispersed uniformly and efficiently interacts with the PF matrix.

The Tg decreased as the amount of MWCNTs increased. This might be because the presence of MWCNT allows the polymer chain to be more flexible. MWCNT at a loading of 0.15 wt% has the maximum mechanical damping. Because of the inadequate interfacial adhesion between the polymer and nanomaterial, a larger damping factor implies more friction among the mobile polymer chains. Fang et al. [19], observed a similar trend by the incorporation of CNT in polyurethane- polyethylene terephthalate blends Fig. 1.

4.4. Electrical properties of phenol formaldehyde- multiwalled carbon nanotubes (PF-MWCNT) nanocomposite

4.4.1. DC conductivity of PF/MWCNT nanocomposites

The DC conductance, conductivity and resistivity of MWCNT-PF nanocomposites are given in the Table 1 Fig. 2. Shows that for 0.05 wt% the conductivity is same as neat and it suddenly increases for 0.08 wt% and then shows a decreasing trend for 0.12 and 0.15 wt%. The electrical conductivity of polymer composites containing fillers is widely recognised to be influenced by characteristics like uniform dispersion, filler shape, and interfacial adhesion with the host matrix and with itself. The development of an efficient network for electron conduction can be aided by good MWCNT distribution in the PF matrix. The uniform distribution of filler in the MWCNT-PF composite resulted in 0.08 percent MWCNT showing maximum electrical properties. At higher weight percentage of MWCNT, the conductivity decreases due to the van der waals force of attraction among MWCNT leading to agglomeration. Agglomeration adversely affects conductivity. Fig. 2. Shows Conductivity vs Weight percentage of MWCNT.

4.4.2. AC conductivity of PF-MWCNT nanocomposite

Fig. 3a) shows the dielectric constant and dielectric loss of PF-MWCNT nanocomposites. By the addition of MWCNT the dielectric constant increased initially and then decreased with increasing frequency. The results are similar to the previous reports [17,20,21]. The electronic properties of MWCNT is due to the presence of sp^2 graphene sheets [22]. The pi electrons are free to move under magnetic field. Thus, MWCNT can act as minicapacitors inside the Phenolic resin. By the application of electric field these minicapacitors accumulates charges on the MWCNT [23]. The homogenious dispersion increases the formation of minicapacitors thereby increasing the dielectric constant [24]. Here 0.08 wt% shows higher dielectric constant. Meanwhile the dielectric constant decreased with increasing frequency due to the development of inner dipoles which hinders the change in applied electric field at higher frequency. Fig. 3 b) shows the dielectric loss of PF-MWCNT nanocomposites. Here also the dielectric loss increased with increased MWCNT loading. The agglomeration at higher loading and conductive networks formed among the fillers are the reason for this phe-
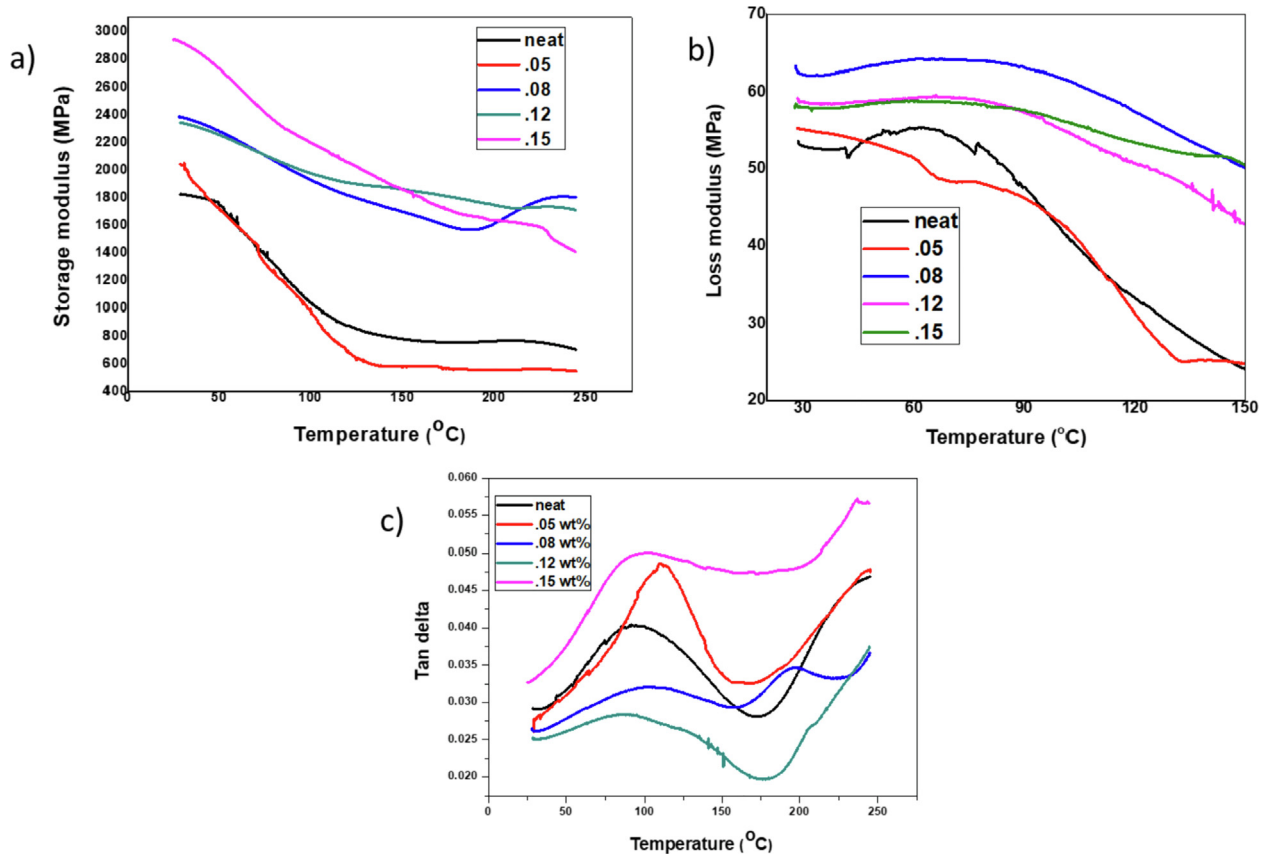
Fig. 1. a) Storage modulus b) Loss modulus c) Tan delta of PF-MWCNT nanocomposite.

Table 1
DC conductivity measurements of PF /MWCNT nanocomposites.

Sample	Resistance(R) (Ohm)	Area(A)	Thickness	Conductivity	Resistivity (Ohm^{-1})
Neat PF	1.638	668.8	4.5	0.04440	22.5225
0.05%	1.74123	649.445	3.996	0.042667	23.43695
0.08%	0.02918	688.3902	2.9875	2.409989	0.4149395
0.12%	0.176	670.894	3.696	0.4102395	2.4376
0.15%	3.93992	680.6135	3.66	0.0181424	55.11948

nomenon. Some portion of electrical energy is converted into thermal energy by the current leakage at higher loading. This may lead
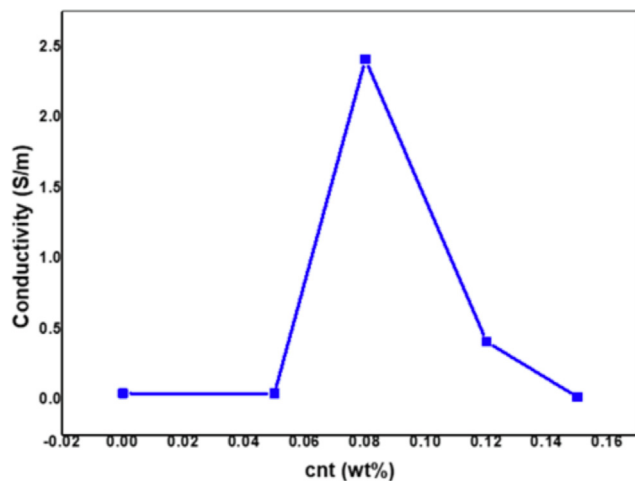

Fig. 2. Conductivity vs Weight percentage of MWCNT.

to increase in dielectric loss due to energy dissipation at higher MWCNT concentration. Fig. 3 c) represents the AC conductivity of PF-MWCNT nanocomposites with different loadings of MWCNT. The figure shows that the as the frequency increases conductivity increases compared to the neat resin. 0.05 wt% addition of MWCNT showed higher conductivity than all other weight percentages. From the results it is clear that 0.05 wt% exhibits higher conductivity. So, we suggest that 0.05 wt% loading have homogenious dispersion and ordered arrangement which enhances the electrical conductivity by the formation of conductive networks.

Logakis et al. [25], got improvement in AC conductivity by the incorporation of MWCNT in polyamide composite. They found that temperature dependence of electrical conductivity shows that rather than hopping, conduction occurs by charge carriers tunnelling through a potential barrier produced by a thin polymer layer intervening between the carbon nanotubes. The percolation threshold of multiwalled carbon nanotubes/polypropylene (PP) was discovered to be between 1.0 and 1.5 wt% of multiwalled carbon nanotubes by Seo et al. [26]. Long et al. [27] used in situ chemical oxidative polymerization to develop multiwalled carbon nanotube/polyaniline composite. They discovered that increasing
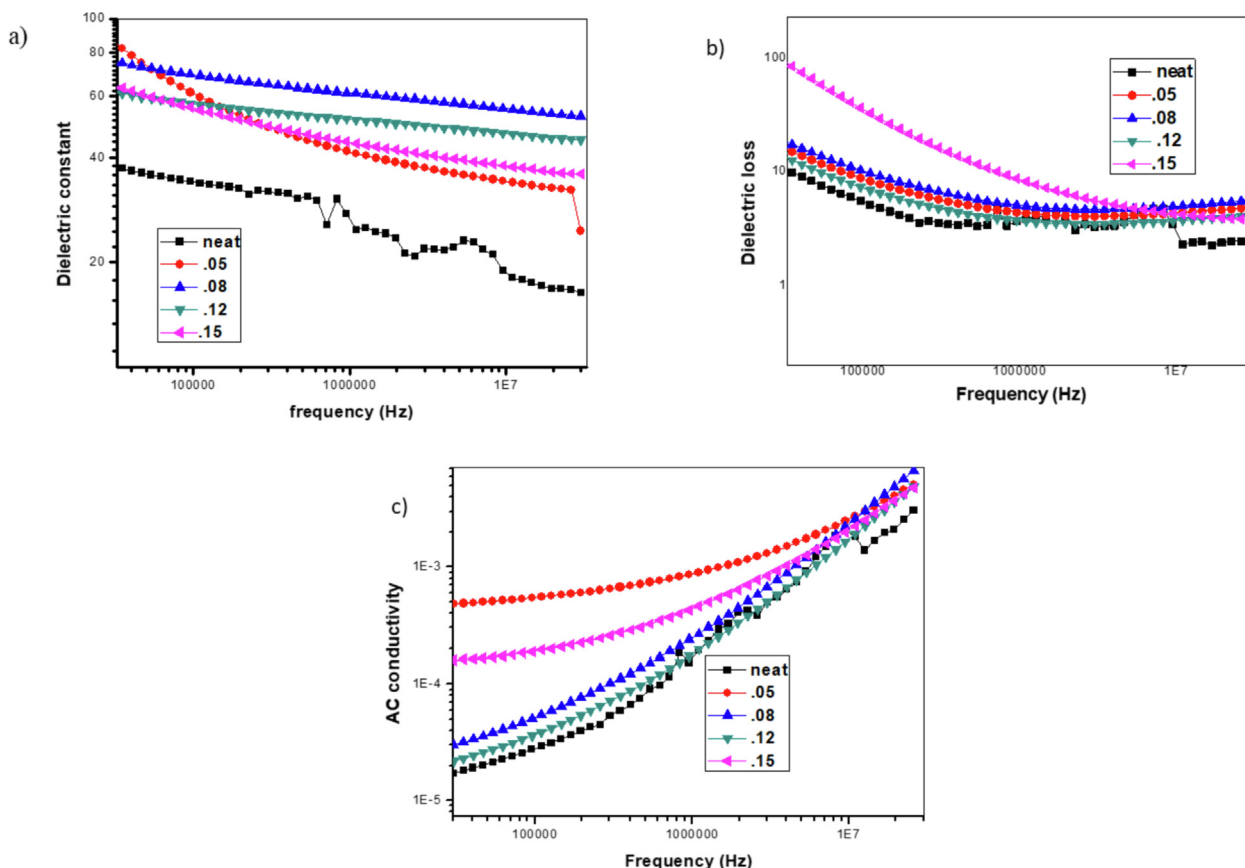
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Fig. 3. a) dielectric constant b) dielectric loss c) AC conductivity of PF-MWCNT nanocomposite.

the carbon nanotube loading from 0 to 24.8 wt% boosts the conductivity of the composites by two orders of magnitude.

4.5. Transmission electron microscopy of PF-MWCNT nanocomposite

Fig. 4 shows TEM pictures of PF-MWCNT at a concentration of 0.05 wt%. Phenolic resin containing MWCNT is efficiently distributed inside the matrix. The uniform dispersion of MWCNT facilitates the property improvements of corresponding nanocomposites.
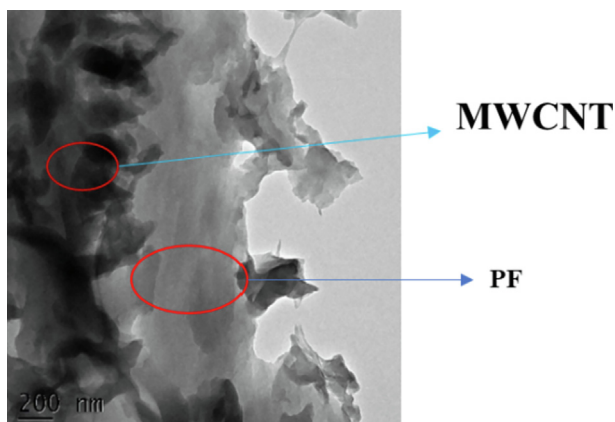

Fig. 4. Transmission electron microscopy of PF-MWCNT nanocomposite.

4.6. Water uptake behaviour of PF-MWCNT nanocomposite at different temperatures

One of the factors that affects the sorption of solvents in polymer nanocomposites is temperature. The open spaces between entangled polymer chains give rise to free volume, which is an intrinsic characteristic of the polymer matrix. Direct monitoring of these free spaces is impossible due to their molecular size. Because the size (and presence) of every particular free volume depends on the vibrations and translations of the surrounding polymer chains, free volume pores are dynamic and transitory in nature. The translation of the polymer chains can open and close, generating open/close channels and providing "pathways" for diffusion jumps. Eyring was the first to define the concept of free volume in polymers and to connect the viscosity of hydrocarbon liquids to activation energy [28]. Diffusion of the solvent molecule through polymer composites is influenced by the kind of filler, its adherence and compatibility with the polymer matrix, and the filler penetrant interaction. Fillers, such as carbon-based nanofillers, change the sorption and permeability of matrices by changing the polymer's transport properties. The transport behaviour of filler polymer systems is influenced by their size, free volume, aggregation stage, quantity of filler, and interaction between the filler and the matrix.

The behaviour of different weight % of MWCNT composites (0, 0.05, 0.08, 0.12 and 0.15%) at three different temperatures was studied and the results are shown in Fig. 5. Photo graphic image of experimental section is shown in Fig. 6.From the result it is found that temperature has significant effect on the sorption of
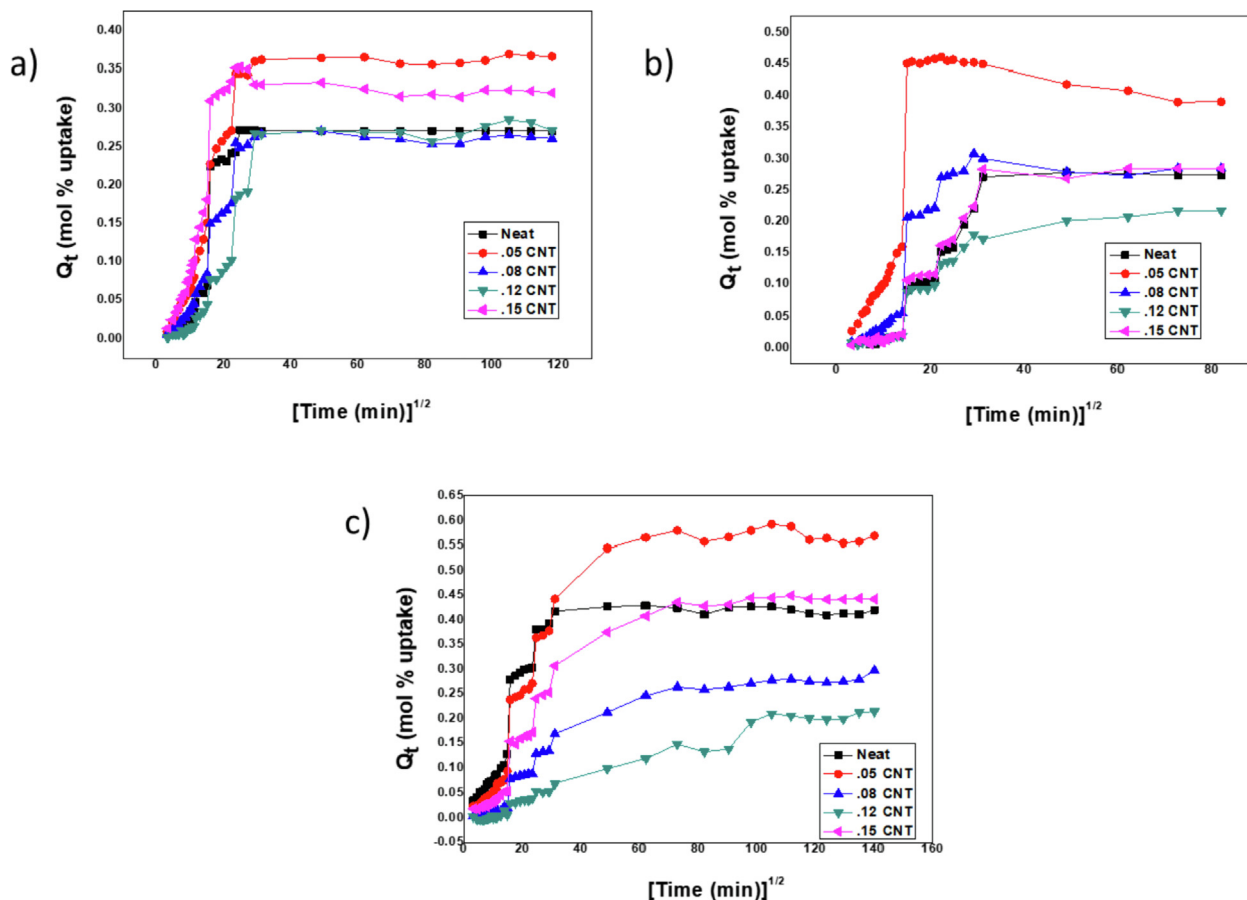
Fig. 5. Mol % uptake of water of PF-MWCNT nanocomposites a) 30 °C b) 50 °C c) 70 °C.

Fig. 6. Samples immersed in solvent.

water in various composites. At 30 °C, the mol percent absorption of water falls as the weight percent of MWCNT increases. In the case of 0.05 % and 0.15% MWCNT, agglomeration and free volume is the result of higher water uptake. The sorption properties of matrix composites with fillers have been shown to be influenced by variables like dispersion level, morphology of filler, and filler-filler relationship [15,29]. The distribution rate of MWCNT is crucial in determining the sorption behaviour of MWCNT − PF composites. As a result, the mol% uptake decreases with increase in weight% of MWCNT. Mol % uptake of water is highest for 0.05 %

MWCNT and lowest for 0.12 % MWCNT. At 50 °C 0.05 % have highest water uptake and 0.12 % have the least. 0.08 and 0.15 have almost similar water uptake like the neat. The capacity of the polymer to create routes for the solvent to advance in the form of randomly produced voids is linked to the diffusion process. The solvent absorption reduces as the void generation decreases with filler addition. Fig. 5c indicates mol % uptake of water with different grades of PF-MWCNT nanocomposites at 70 °C is plotted. The plot shows that temperature has significant effect on water uptake. Mol % uptake of water is highest for 0.05% MWCNT, 0.08 % and 0.12 % have lesser water uptake than the neat. The solvent absorption reduces as the void generation decreases with filler addition. But the existence of tiny fractures and voids etc. in the sample may be possible during the preparation of sample, which result in easy sorption of molecules in 0.15% MWCNT at 70 °C.

4.7. Diffusion, sorption and permeability coefficient

It is generally agreed that the coefficients of diffusion and sorption, as well as the permeability of the medium, are the most significant characteristics to measure and understand when it comes to the effectiveness of the diffusion process. The diffusion coefficient is related to the segmental mobility of the polymer.

The given below equation is be used to determine the diffusion coefficient (D).

$$D = \pi \left(\frac{h\theta}{4Q_\infty} \right)^2 \qquad (4.7.1)$$

h - initial thickness of the sample,

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Table 4.7
a (D), (S) and (P) of PF-MWCNT nanocomposites with varying MWCNT content at 30 °C, 50 °C, 70 °C.

MWCNT content (wt %)	D (cm² S⁻¹)	S	P (cm²S⁻¹)
At 30 °C			
0	1.15×10^{-4}	0.0489	5.62×10^{-6}
0.05	9.98×10^{-4}	0.0524	5.23×10^{-5}
0.08	1.14×10^{-4}	0.0381	4.32×10^{-6}
0.12	1.11×10^{-4}	0.0794	8.88×10^{-6}
0.15	6.57×10^{-4}	0.0731	4.84×10^{-5}
At 50 °C			
0	1.17×10^{-4}	0.0557	6.43×10^{-6}
0.05	10.13×10^{-4}	0.0581	5.88×10^{-5}
0.08	1.22×10^{-4}	0.0511	6.26×10^{-6}
0.12	1.65×10^{-4}	0.0789	13.01×10^{-6}
0.15	1.25×10^{-4}	0.0480	6.01×10^{-6}
At 70 °C			
0	4.17×10^{-4}	0.0486	2.02×10^{-5}
0.05	1.85×10^{-3}	0.0995	1.84×10^{-5}
0.08	3.91×10^{-4}	0.0469	1.83×10^{-5}
0.12	3.67×10^{-4}	0.0487	1.78×10^{-5}
0.15	4.18×10^{-4}	0.0659	2.75×10^{-5}

θ - slope of the initial linear portion of the sorption curve. In order to get the slope, we plot Q_t versus $\sqrt{t}$.

Q_∞ - equilibrium mol% uptake.

When the polymer and the penetrant molecule are in close proximity, this coefficient (S) is calculated.

$$S = \frac{M_\infty}{M_0} \qquad (4.7.2)$$

M_∞ - mass of water taken up at equilibrium
M_0 - initial mass of the polymer sample.

Table 4.7**a** lists the estimated diffusion, sorption, and permeability coefficients for PF hybrid composites. As seen in the table, the D value of PF-MWCNT composites rose with temperature.

The permeability coefficient of a sample may be used to gather information about the amount of water that penetrates through a uniform region of the sample in one second by measuring the amount of water that permeates through a uniform region of the sample in one second (P). Permeation through a matrix is mostly determined by the diffusivity and sorption of the penetrant in the polymer used to construct the matrix. It may be calculated by multiplying the diffusion and sorption coefficients together.

$$P = D \times S \qquad (4.7.3)$$

All the three coefficients (D, S, P) of composites are computed using equations (4.7.1) to (4.7.3), and the results are presented in Table 4.7a. at various temperatures.

Diffusion, sorption, and permeability coefficient all increase as temperature rises. The influence of temperature on the mobility of polymer chains is the reason for this phenomena.

5. Conclusions

By analysing the AC conductivity of PF-MWCNT, lower filler loading (0.05 wt%, 0.08 wt%) exhibited better conductivity. The creation of conductive networks increased the DC conductivity of PF-MWCNT by 0.08 wt%, resulting in greater conductivity. DMA analysis of PF-MWCNT indicates that 0.15 wt% have higher storage modulus and 0.05 exhibited higher glass transition temperature. The produced nanocomposite's morphological examination (TEM) indicates that the integrated MWCNT was evenly disseminated in the host matrix. The water sorption behaviour (at 30 °C, 50 °C, and 70 °C) also attributes the MWCNT addition reduced the sorption efficiency. Diffusion coefficient, sorption coefficient and permeation coefficient have calculated and found to be increasing with increasing temperature.

Given the random orientation and frequent agglomerating tendency of the MWNTs used in this study satisfactory results were achieved in terms of storage modulus, water uptake and electric conductivity enhancement. The processing is simple, straightforward, and inexpensive. The goal of future research should be to improve the dispersion and alignment of carbon nanotubes in the matrix, as well as the interfacial bonding between the CNTs and the PF matrix.

CRediT authorship contribution statement

Lakshmipriya Ravindran: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization. **M.S Sreekala:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration. **S. Anilkumar:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Sabu Thomas:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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