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Dielectric Properties of Multi-Wall Carbon Nanotubes / Polystyrene Composites

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Abstract: Multi-Wall Carbon Nanotubes (MWCNTs)/Polystyrene (PS) composites were prepared by solution casting method. The effects weight percentage of carbon nanotubes on dielectric properties of the composites studied using (LCR)meter as a function of frequency over the range (50Hz-5MHz) at room temperature were studied. The experimental results showedthat dielectric constant, dissipation factor and dielectric loss of composites increased with increasing the weight percentage of carbon nanotubes and decreases with increase in frequencies.

Keywords: PS, MWCNTs, Dielectric properties, Polymer nanocomposite

INTRODUCTION

Carbon nanotubes (CNTs)attract high attention as perspective material due totheiruniquemechanical, electrical,thermal and optical properties. One of the most interesting ways of application of multiwall carbon nanotubes (MWCNTs) is their usage for synthesis of (MWCNTs-reinforced) composite materials. Introduction of carbon nanotubes in polymer matrix leads to significant increase of material's properties, such as mechanical strength, electrical conductivity, fracture toughness and electromagnetic shielding properties [1-3]. In recent decade many works were done in the field of the development of preparation techniques and investigation of properties of (MWCNTs-reinforced) plastic composites, based on such matrices as epoxy resin [4], polymethylmethacrylate [5], polyurethanes [6]andpolystyrene [7].The effective performance of the carbon nanotubes in composites for a variety of applications strongly depends on the ability to disperse the carbon nanotubes homogenously throughout the matrix[8].Good interfacial bonding and interactions between nanotubes and polymers are necessary conditions for improving properties of the composites.Various approaches for the fabrication of (CNTs/polymer) composites were shown including different functionalization and dispersion methods of nanotubes[9]. The most important are: Solution processing of composites [9], Melt processing of bulk composites[10], Melt processing of composite fibers[11], Layer-by-layer assembly (LBL)[12]and In-situ polymerization[13].

The addition of carbon nanotubes as a conductive filler to a dielectric host (e.g. polymer) has attracted much interest due to the excellent electrical properties of carbon nanotubes and their very large aspect ratio (>1000). The use of carbon nanotubes as filler in a polymer host opens up possibilities for the fabrication of a new class of reinforced antistatic films, electromagnetic shielding materials and conductive polymers at very low filler content. It was reported that the effective conductivity of such composites drastically increases with increasing concentration of the carbon nanotubes [14]. The aim of this work is to study the dielectric properties of (Multi-Wall Carbon Nanotubes (MWCNTs)/Polystyrene (PS))composites with different weight percentages(wt.%)of (MWCNTs).

Experimental

To prepare ((MWCNTs)-PS) compositeswith different weight percentages(0,1,1.5,2,2.5 and3)wt.% of (MWCNTs),the required amounts of (MWCNTs)and (PS) mixed with chloroform separately and placed in the ultrasonic unit to remove aggregates and to ensure a better dispersion in the solvent. The solutions were then cast into clean and dry glass Petri dish and allowed to evaporate at room temperature until solvent free films were obtained. The samples were made in the form of circular discs and smooth surfaces. Samples with a diameter of (20 mm) and thicknesses (1mm) were placed between two parallel plated electrodes, in order to examine the dielectric properties of samples by (LCR) meter (Agilent Impedance Analyzes 4294A). The (LCR) meter, was connected with the computer and the data was collected as a function of different frequencies. The measurement was carried out at frequencies from (50Hz) to (5MHz) at room temperature.

Results and Discussion

The dielectric properties of(MWCNTs/PS) composites are studied as a function ofweight percentage (wt.%) of (MWCNTs)and applied frequency at room temperature. The values of dielectric constant (ε′) and dissipation factor (D) (loss of tangent(tanδ)) and dielectric loss (ε") are obtained from the measured values of capacitance (c) using following equations [15]:

$\varepsilon' = c\, d / \square_o A$(1)

$\varepsilon'' = \varepsilon' \tan\delta$ (2)

where (d) is sample thickness and (A) is surface area of the sample.

The variation of dielectric constant with respect to frequency for the (Ps) composites with differentweight percentages(wt.%)of (CNTs) are shown in figure (1). It can be seen from the figure that the dielectric constant of (Ps)composites decreased with increasingthe frequency. This is due to that at lower frequencies of applied voltage, all the free dipolar functional groups in the (Ps) chain can orient themselves resulting in a higher dielectric constant values at these frequencies.As the electric field frequency increases, the bigger dipolar groups find it difficult to orient at the same place as the alternating field, so the contributions of these dipolar groups to the dielectric constant goes on reducing resulting in a continuously decreasing dielectric constant of the (PS) system at higher frequencies[16-18], this behavior is in agreement with[19].

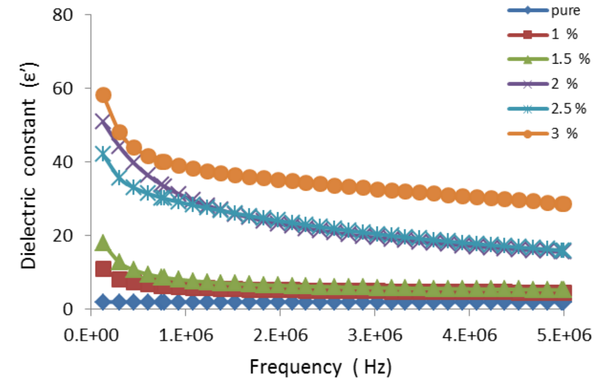

Fig.(1): Variation of dielectric constant with frequency at different CNTs (wt.%)

Also we have noticedfrom figure (2) that the values of dielectric constant of (Ps) composites at different frequencies have been found to be slowly increasing with weight percentages(wt.%) of (CNTs), this result agreement with [20].

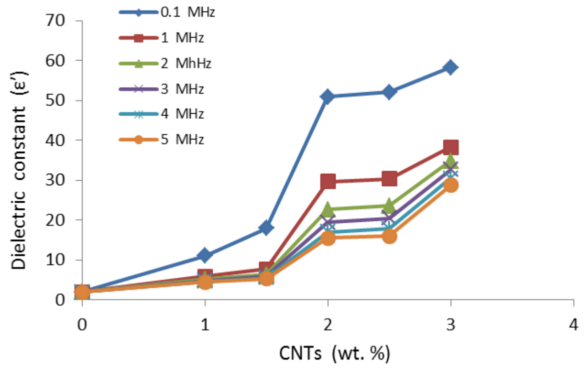

Fig. (2): Varation of dielectric constant with CNTs (wt.%) at different frequency

The dissipation factor of (PS) compositeswith different weight percentages(wt.%)of (CNTs)are obtained as a functionof different frequencies given in figure (3).It is found that the dissipation factor decreases as the frequency increases up to around (3MHz) for all samples whereas at higher frequencies the dissipation factor remains same and is independent of the frequencies and we have noticed from figure (4) that the values of dissipation factor of(PS)compositesat different frequencies have been found to be increasing at (0.1MHz) with (3%)of (CNTs).

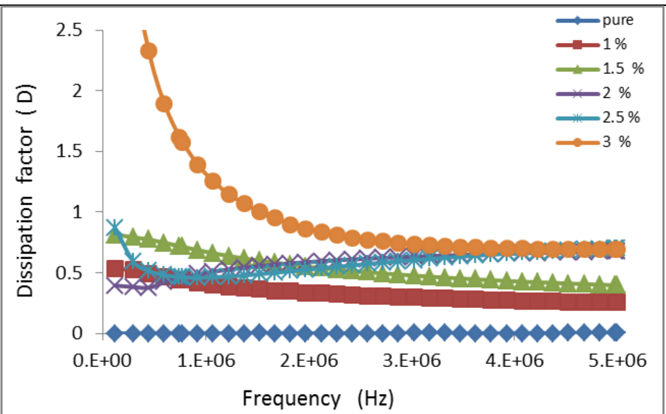

Fig.(3): Varation of dissipation factor with frequency at different CNTs (wt.%)

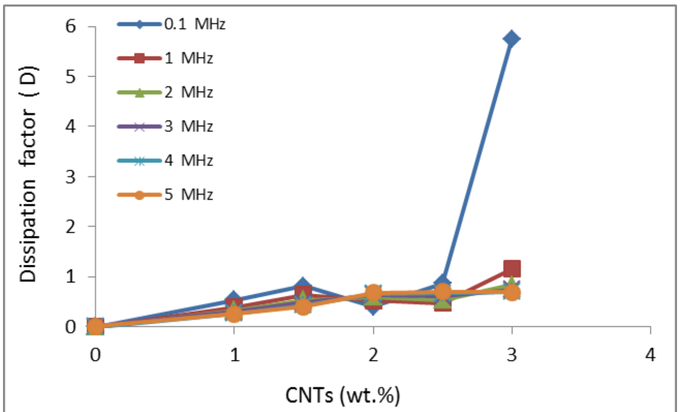

Fig.(4): Varation of dissipation factor with CNTs (wt.%) at diferent frequency

The dielectric loss of (PS) and its composites with different weight percentages(wt.%)of (CNTs) are obtained as a function of different frequencies given in figure (5).It is found that the dielectric loss of all these composites decrease at low frequency range (50Hz - 3MHz) and afterwards it nearly remains same at higher frequency range. Also it is clear in figure (6) at different frequencies when the weight percentage of (CNTs) increases dielectric loss of (PS) compositesincreases.

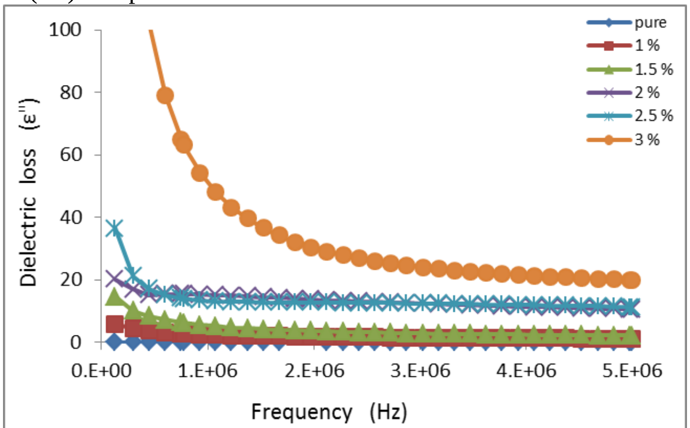

Fig.(5): Varation of dielectric loss with frequency at different CNTs (wt.%)

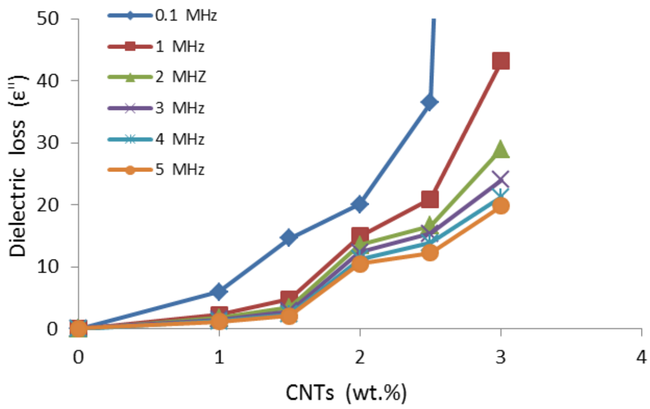

Fig.(6): Varation of dielectric loss with CNTs (wt.%) at different frequency

Conclusions

MWCNTs/PScomposites were prepared successfullyby solution casting method. The dielectric properties of the polymer composites were measured. The dielectric constant,dielectric loss anddissipation factordecreased with the increasing of frequency. This is due to the electronic, ionic, dipolar and surface charge polarizations which depend on the frequencies. The large values of dielectric constant at lower frequencies may be due space charge polarization arising at the grain boundary interfaces**.** All these dielectric parameters are increased with increasing the weight percentage of carbon nanotubes.

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