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Effect of temperature on Electrical conductivity of Multi Walled Carbon nano Tube / Epoxy Nano Composites

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ABSTRACT

In this research prepared composites from epoxy – carbon nano tube using hand lay method with different volume ratios of carbon nano tube (CNT) (0,1,2,3,4,5)% To weight carbon nano tube different ratio (1,2,3,4,5%) by using sensitive electrical balance (0.001gm) added CNT with epoxy with stirrer at 60c one hour after that added hardener and stirrer five minute. Make electrical tests to find the electrical conductivity increased with increased ratio of CNT and activation energy decreased with increasing ratio of CNT . dielectric constant and dielectric loss decrease with increasing frequency . Dielectric constant measure the electric properties of a material as a function of frequency the frequency dependence of dielectric constant 'ε at two temperature 20 and 60 °c .

Keywords: *Carbon nano tube; Epoxy; Electrical conductivity*

1. INTRODUCTION

Epoxy resin is a cross-linked polymer widely used as a matrix for advanced composites given its specific strength, good stiffness, chemical resistance and dimensional stability. The main drawback of epoxy resin for structural applications may be its inherent brittleness. The several research works have recently been reinforcement of epoxy matrices with CNTs [1]. Carbon nanotubes are unique nanostructures that can be considered conceptually as a prototype one-dimensional (1D) quantum wire. The fundamental building block of carbon nanotubes is the very long all-carbon cylindrical single wall carbon nanotube (SWNT), one atom in wall thickness and tens of atoms around the circumference (typical diameter 1.4 nm). Initially, carbon nanotubes aroused great interest in the research community because of their exotic electronic properties, and this interest continues as other remarkable properties are discovered and promises for practical applications develop [2].A composite material can be defined as a combination of two or more materials that results in better properties than those of the individual components used alone. In contrast to metallic alloys, each material retains its separate chemical, physical, and mechanical properties. The two constituents are reinforcement and a matrix. The main advantages of composite materials are their high strength and stiffness, combined with low density, when compared with bulk materials [3].

2. PREPARATION OF CARBON NANOTUBE/POLYMER COMPOSITES

2.1 Solution mixing

Perhaps the simplest method for preparing nanotube/polymer composites involves mixing nanotube dispersions with solutions of the polymer and then evaporating the solvents in a controlled way. This method has been used with a range of polymers, including polyvinyl alcohol, polystyrene, polycarbonate and poly (methyl methacrylate) [4]

2.2 Melt processing

The solution mixing approach is limited to polymers that freely dissolve in common solvents. An alternative is to use thermoplastic polymers (i.e. polymers that soften and melt when heated), and then apply melt processing techniques. The downside is that achieving homogeneous dispersions of nanotubes in melts is generally more difficult than with solutions, and high concentrations of tubes are hard to achieve, due to the high viscosities of the mixtures. However, the dispersion of nanotubes can be improved using shear mixing. The electrical conductivity of the composites were found to be more than 16 orders of magnitude higher than that of PE. Good mechanical properties were also observed, although these began to fall off above a certain loading of tubes[4].

2.3 In situ polymerization

An alternative method for preparing nanotube/polymer composites is to use the monomer rather than the polymer as a starting material, and then carry out in situ polymerization. Wolfgang Maser and co-workers were among the first to use this method, to prepare a MWNT/polyaniline composite [4].

3. Composite Material

It is a material composed of two or more distinct phases (matrix phase and dispersed phase) and having bulk properties significantly different from those of any of the constituents [5].

3. EXPERIMENTAL PART

1. Materials

Epoxy : epoxy (105) Don construction products (DCP) , Amman –Jordan The ratio of hardener to epoxy used in this study was approximately 3:1. Carbon nano tube (MWCNTs > 95% ,OD = 5-15nm) , US Research Nanomaterials, Inc. USA .

2. Preparation of MWCNTs / Epoxy Nano composites

To weight carbon nano tube different ratio (1,2,3,4,5%) by using sensitive electrical balance (0.001gm) added CNT with epoxy with stirrer at 60c one hour after that added hardener and stirrer five minute.The competent casting using glass mold (dimension 10*10*0.4 cm) . the samples were stored at room temperature for 24 hours to dry .show in table (1)

Table (1) composition of MWCNT/Epoxy composited

Sample	S1	S2	S3	S4	S5	S6
By volume ratio MWCNTs %	0	1	2	3	4	**5**

3. Electrical conductivity (A.C)

A.C conductivity measurements were made by using A computerized LRC bridge (model). The dielectric constant for the investigated samples was studied from room temperature and 60°C at different frequencies ranging from 10kHz up to 10 MHz. The samples used in the dielectric measurements were in disk form, having 30 mm in diameter and 4 mm in thickness. Silver paste was coated to form electrodes on both sides of the sintered ceramic specimens in order to ensure good contacting. The electrical measurements were carried out by inserting the sample between two parallel plate conductors forming cell capacitor. Then, the whole arrangement was placed in to non-inductive furnace for heating the samples with constant rate [6].

$$\varepsilon' = c\, d / \epsilon_\circ A \quad \text{........(1)}$$

$$\varepsilon'' = \varepsilon \tan \delta \quad \text{.........(2)}$$

ε' is the permittivity , $\epsilon_\circ = 8.85 \times 10^{-12}$ F/m is the permittivity of free space.ε'' is the dielectric loss, and $\tan\delta$ is the loss tangent and A is the area of the electrode. The A.C. resistivity of the prepared samples was estimated from the dielectric parameters. As long as the pure charge transport mechanism is the major contributor to the loss mechanism, the resistivity (ρ) can be calculated using the following relation:

$(\rho) = 1 / (\tan\delta\ \varepsilon\ '\varepsilon\omega)$ (Ω Cm)….. (3) is the angular frequency and f is the $\omega = 2\pi f$, ω where frequency of the applied electric field in Hertz.

$\sigma = 2\pi f\ d\ C \tan\delta\ A$ ……(4)

where σ is the A.C. conductivity, f is the operating frequency, d is the thickness of the dielectrics, $\tan\delta$ is the dielectric loss, C is the capacitance and A is the area of the electrode.

4. RESULTS AND DISCUSSION

1. Effect of percentage weight of carbon nano tube on electrical conductivity :-

Figure (1) show the electric conductivity increase according to increase in frequency .that the conductivity of the composites CNT-EP increases in comparison to EP pure .there is an increases in charge transport and by heat treatment the conductive grains of CNT expand due to which mobility of carrier increases between the grains and hence a.c conductivity .

The conductivity of the chemically functionalized MWCNT/EP composites increases slowly with increasing the MWCNT weight ratio. The reason for the electrical properties of these composites can be attributed to the tunnelling conduction mechanism. Which agree with [7].

The dielectric constant will decrease with further increasing MWCNT concentration. The dielectric properties of the composites can be understood by the percolation theory and interfacial polarization effect

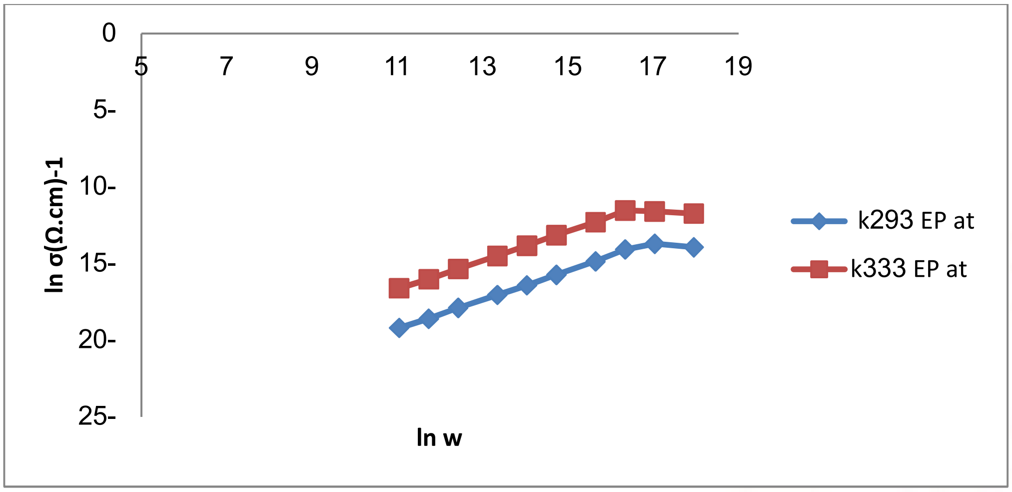
2. Effect of Frequency and temperature on electrical conductivity

The variation of σ a.c(ω) with frequency in the range 10KHz- 10MHz for the investigated compositions (with similarly the same thickness) was studied through the temperature range 20 and 60° c. The obtained results are plotted as ln σ a.c(ω) versus ln ω at different elevated temperature values .Figure (2) shows the frequency dependence for the composites . It is clear from this figure that σ a.c(ω) increases linearly with increasing frequency. Values of the frequency exponent S were calculated from the slope of the straight lines of the data in Figure(2).When increases the temperature will increasing the electric conductivity because the electrons will capture more energy when the temperature increases, and they can overcome the potential barrier easily [7].

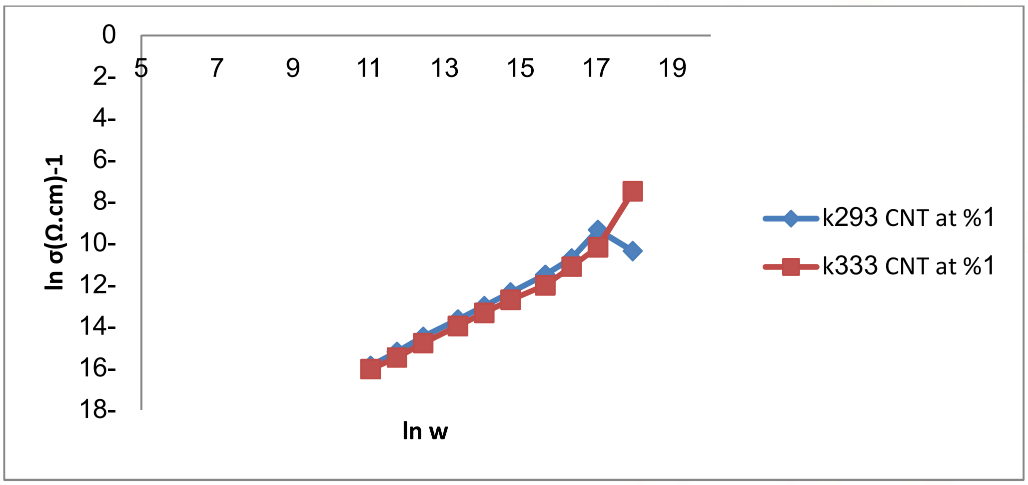
Table (2) observed values of the exponent S are somehow frequency dependent. It decreases with increasing temperature from 0.852 to 0.799 for the epoxy pure and from 1.099 to 0.919 for the 1% CNT and from 0.99-0.819 for the 5%CNT. This can be attributed to hoping conduction of mobile charge carriers over barrier between two sites.

Table (2) values of exponent factor (S)

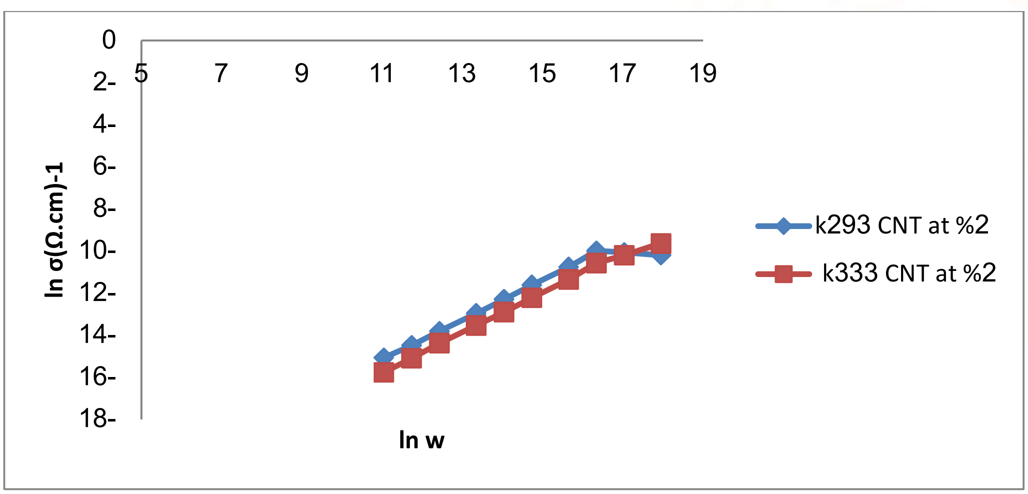
Samples	Temperature k	Value of S
epoxy	293 333	0.852 0.799
1% CNT	293 333	1.009 0.919
2%CNT	293 333	0.914 0.799
3% CNT	293 333	1.009 0.913
4% CNT	293 333	1.003 0.828
5% CNT	293 333	0.99 0.819



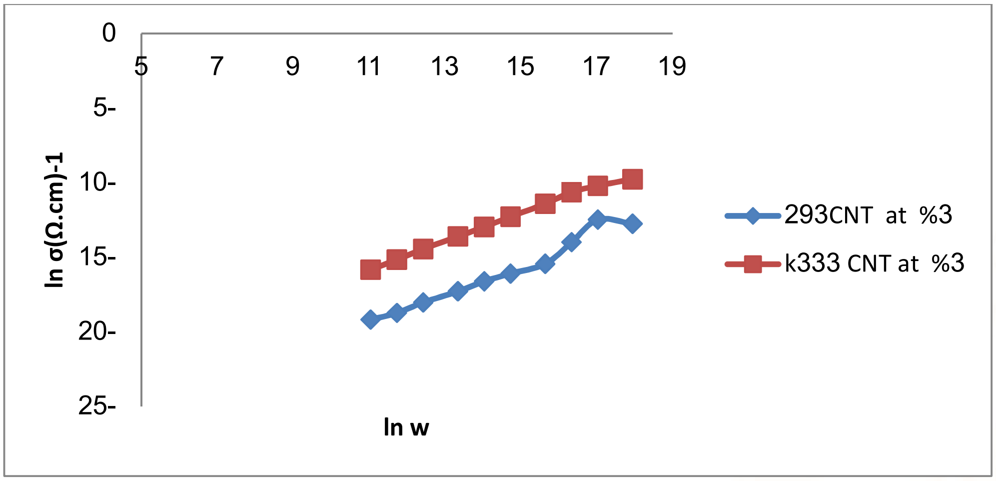
a) A.C conductivity of epoxy pure



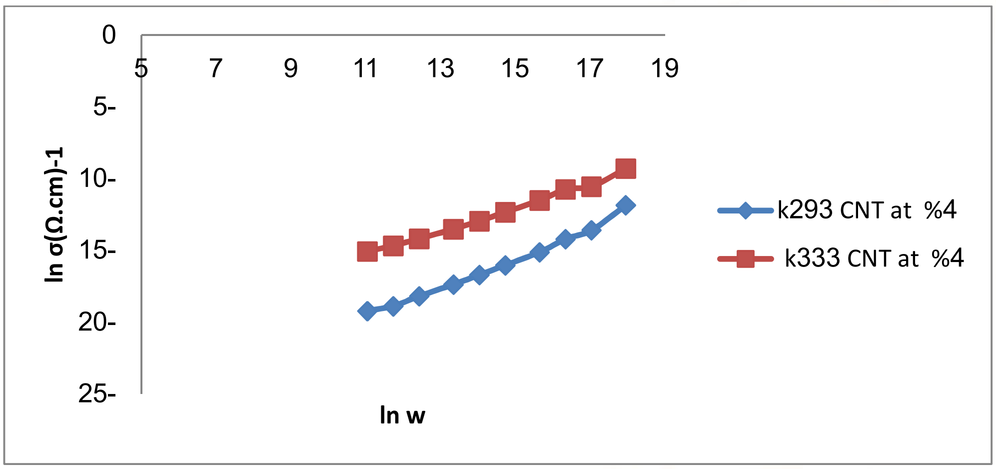
b) A.C conductivity of 1% CNT



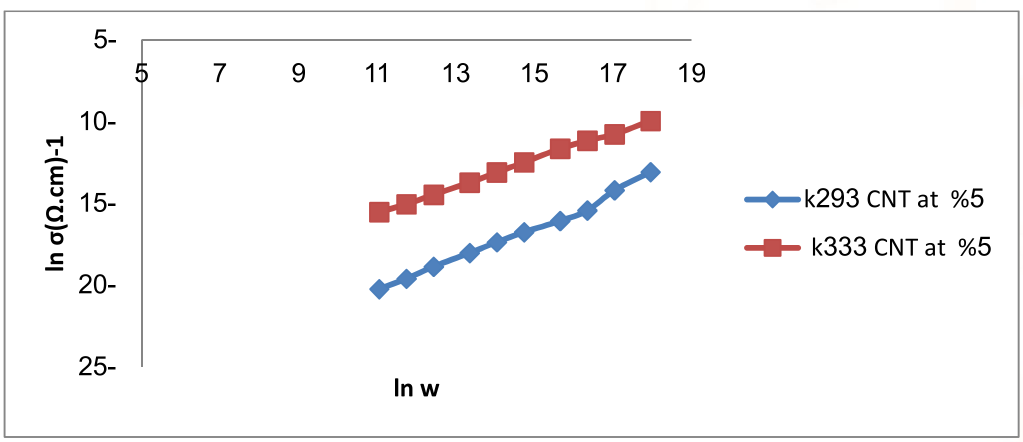
c) A.C conductivity of 2% CNT



d) **A.C conductivity of 3% CNT**



e) **A.C conductivity of 4% CNT**

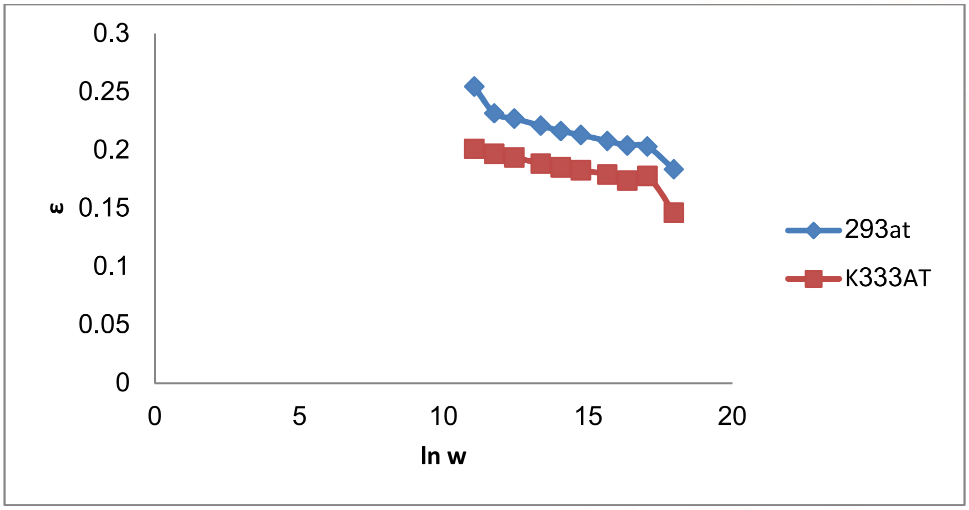


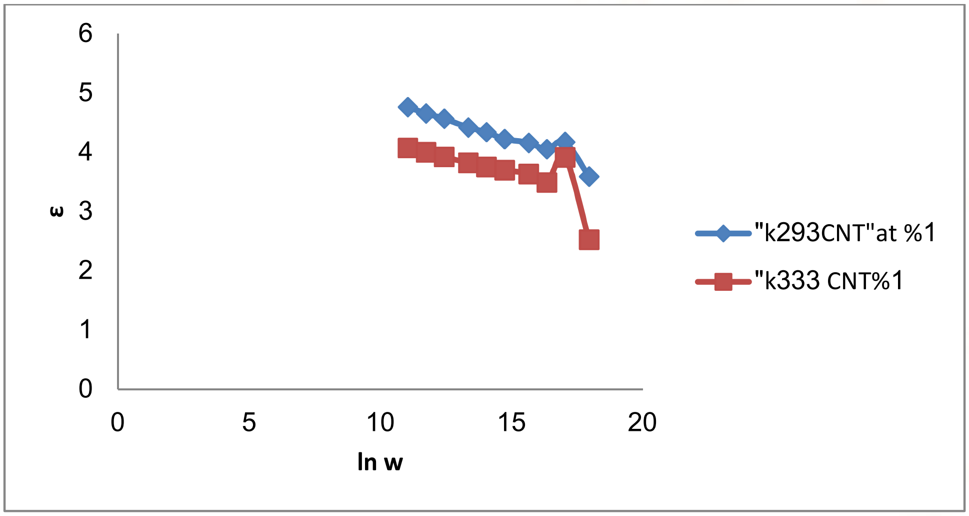
f) **A.C conductivity of 5% CNT**

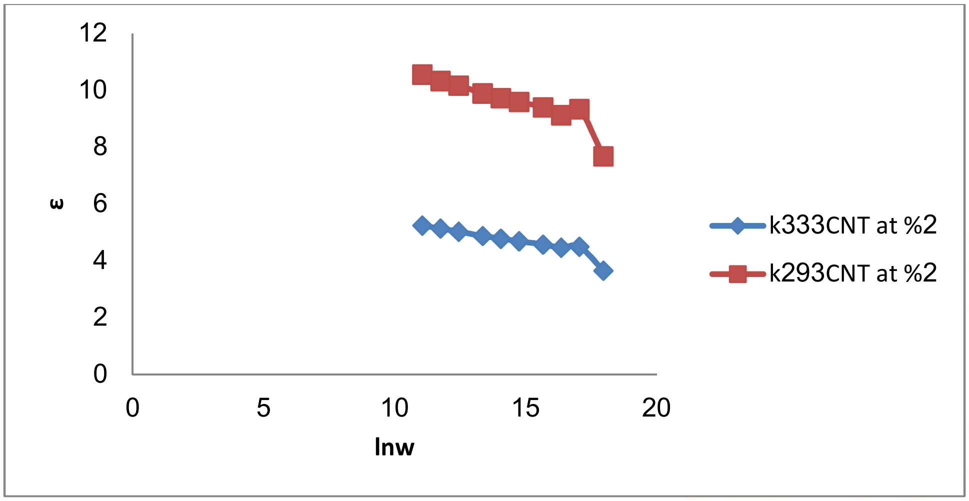
Figure (1) variation of A.C conductivity of CNT /EP composites of different weight at room temperature and 333k

3. Effect of Frequency and temperature on Dielectric constant and dielectric loss

Dielectric constant measure the electric properties of a material as a function of frequency .Figure (2) shows the frequency dependence of dielectric constant 'ε at two temperature 20 and 60 c . It is clear from this figure that 'ε decrease with frequency and increase with temperature . In case of polymers and composites materials (epoxy +carbon nano tube) , the orientation polarization and interfacial polarization play an important role. Interfacial polarization arises for electrically heterogeneous materials where two phases differ from each other in dielectric constant and conductivity . In such materials , the mobility of the charge carrier occurs more easily and randomly through one phase and therefore is constricted at phase boundaries [8] .Figure (3) show the dielectric loss "ε for epoxy and epoxy / CNT at 20 c and 60 c and different frequency . the dielectric loss decrease with increasing in frequency and increase in temperature.







12
10
8
6
4
2
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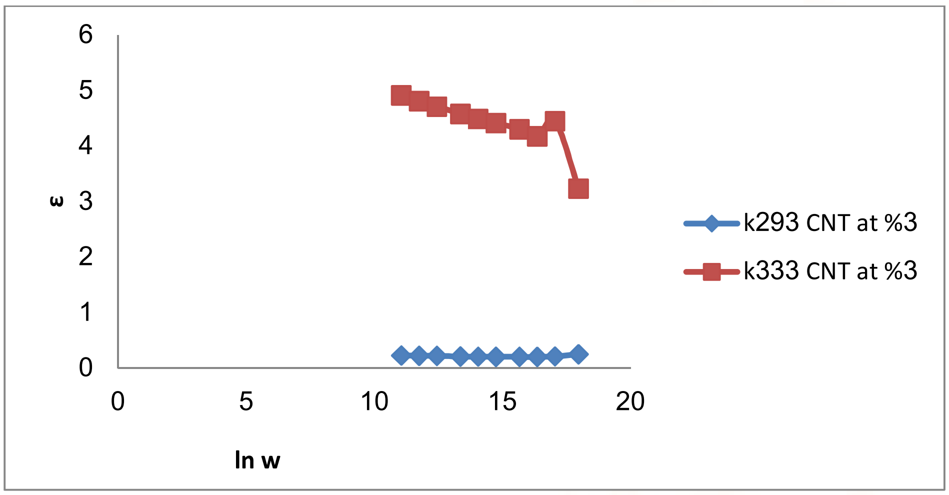
ε
0
5
10
15
20
lnw
k333CNT at %2
k293CNT at %2



6
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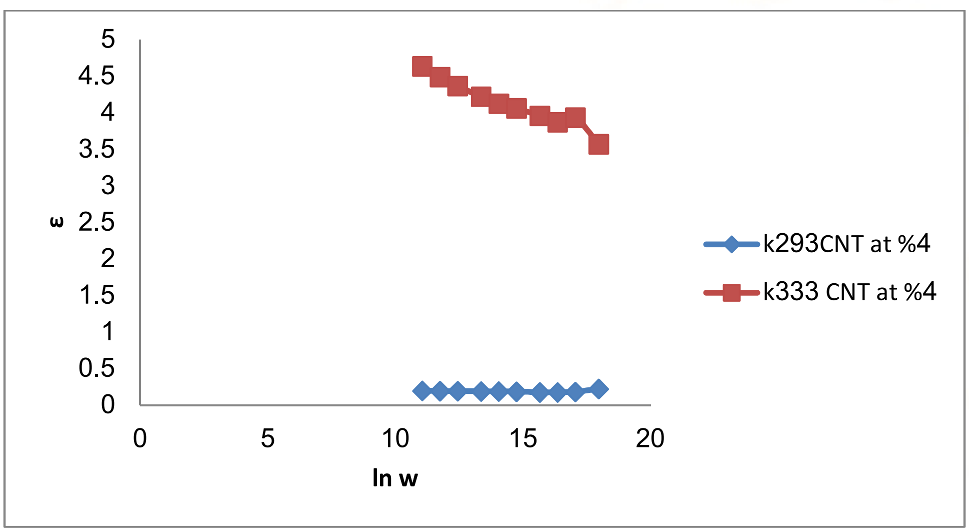
k293 CNT at %3
k333 CNT at %3



5
4.5
4
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3
2.5
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ε
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5
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ln w
k293CNT at %4
k333 CNT at %4

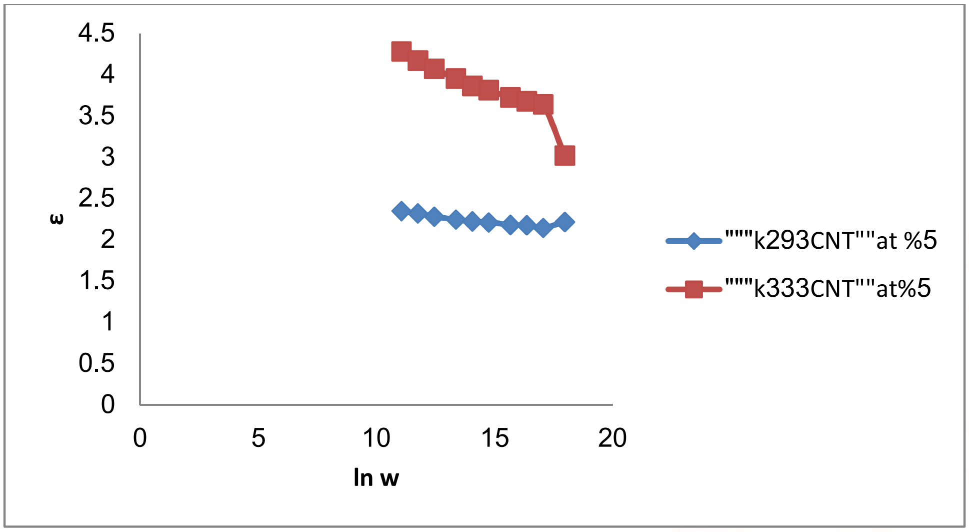
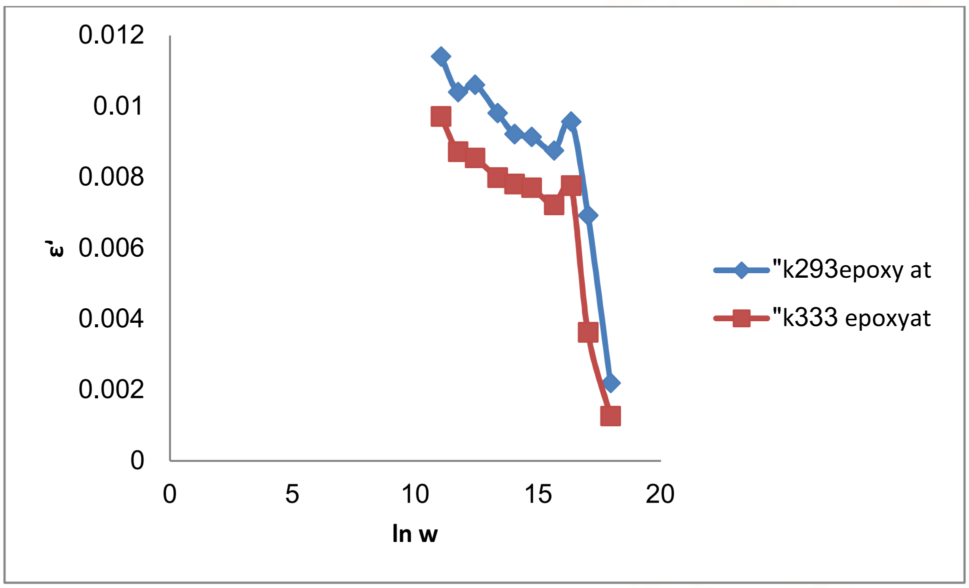
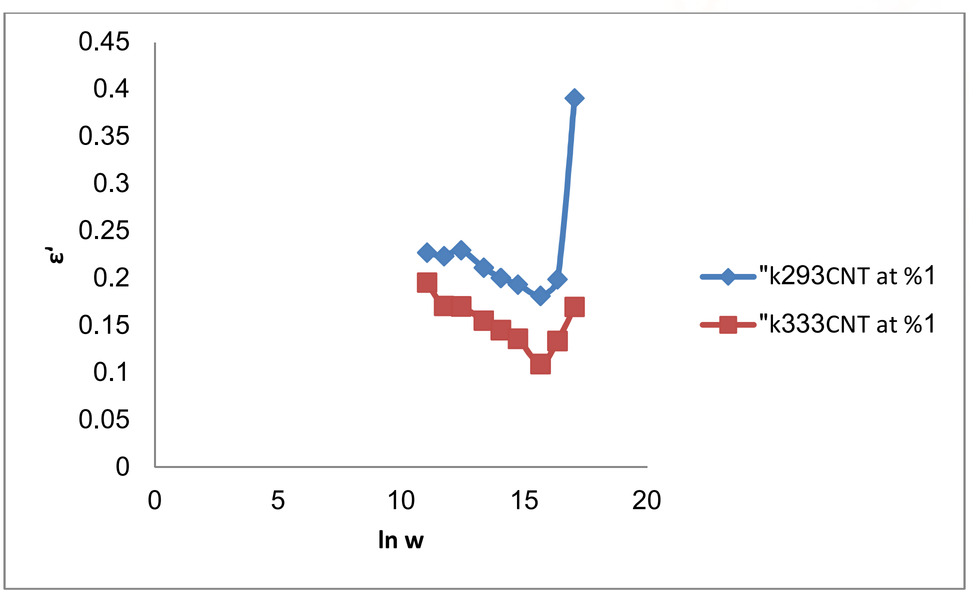
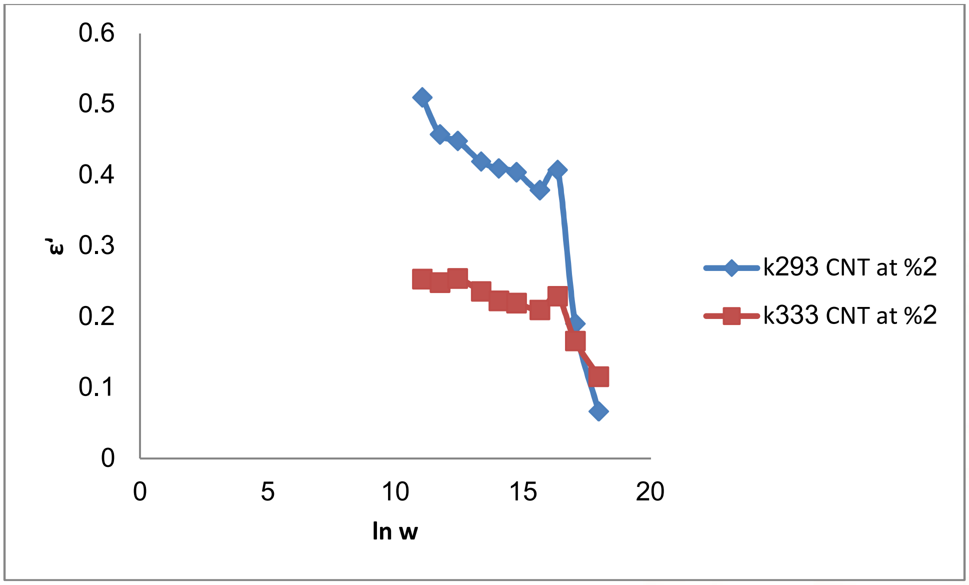


Figure (2) dielectric constant as a function of angular frequency for epoxy –CNT) nano composites






0.6
0.5
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ε′
0.3
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0
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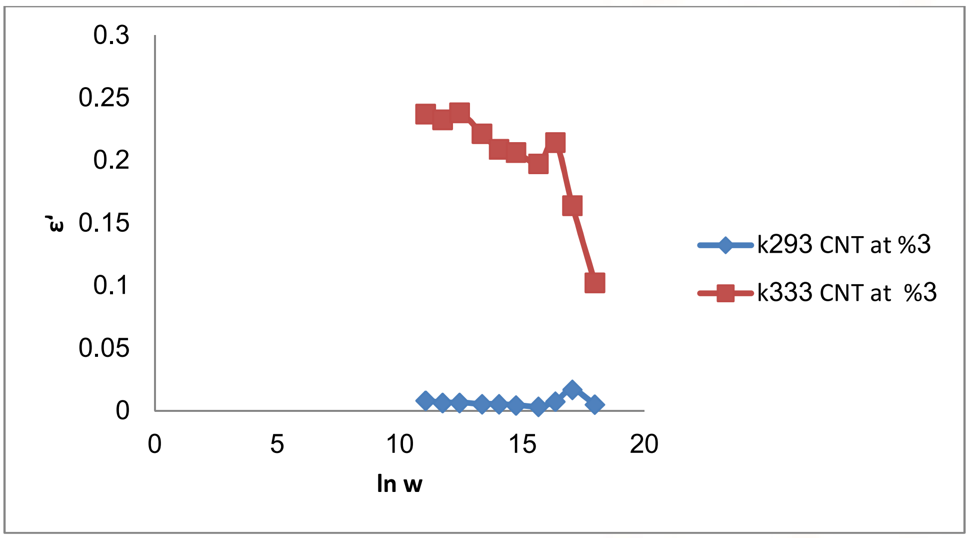
5
10
15
20
ln w
k293 CNT at %2
k333 CNT at %2


0.3
0.25
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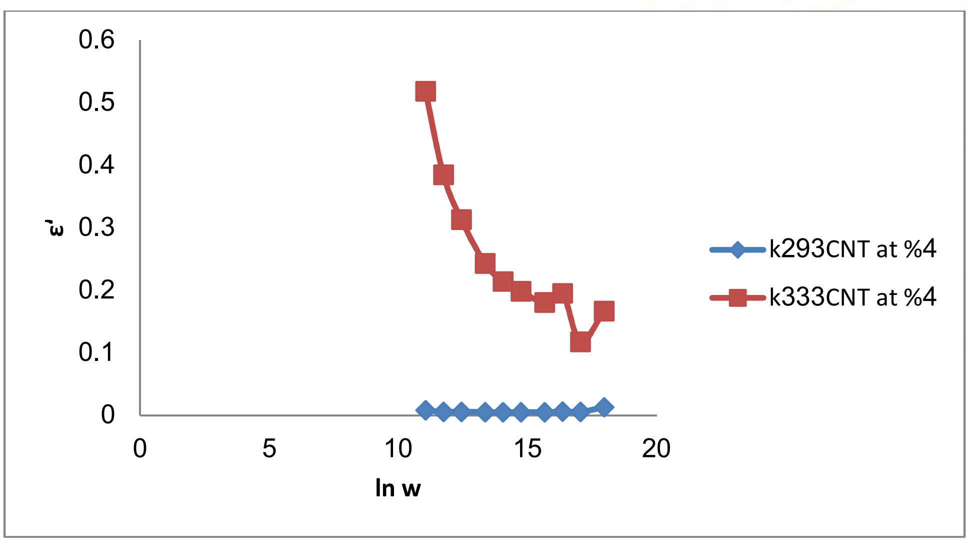
20
ln w
k293 CNT at %3
k333 CNT at %3


0.6
0.5
0.4
ε′
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0.1
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15
20
ln w
k293CNT at %4
k333CNT at %4

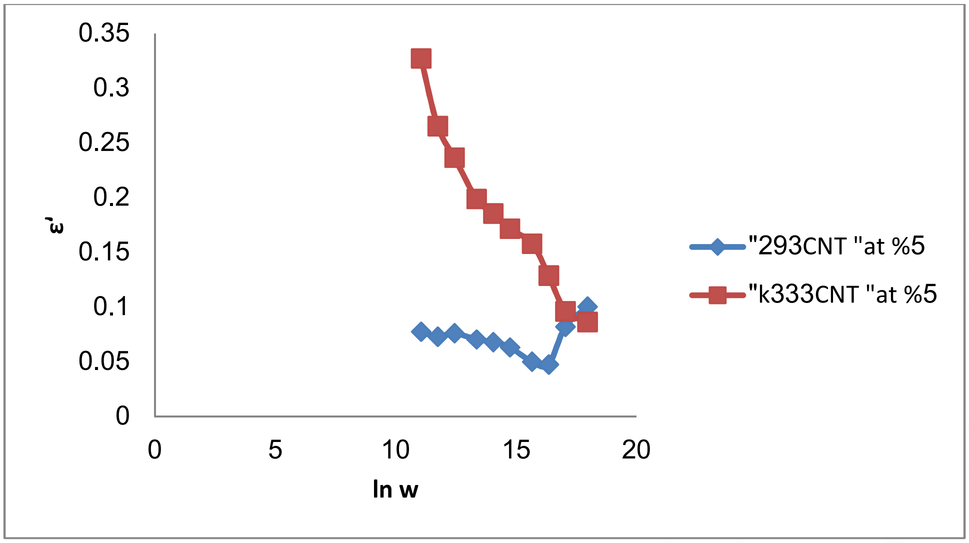

Figure (3) dielectric loss as a function of angular frequency for epoxy –CNT) nano composites

CONCLUSION

1. Electrical conductivity increase with increasing frequency and with increase ratio of carbon nano tube.
2. Activation energy decrease with increasing ratio of CNT
3. Dielectric constant and dielectric loss decrease with increase frequency.

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