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Studying and Measurements of an Introduced Composite Poly(1,2,3 trihydroxy 4,5 phenylene) Polymer

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Abstract-Polymers are one of the most important materials that have special chemical, thermal, magnetic and electrical properties that can be used in many fields nowadays. The goal of this paper is to focus on the electrical properties of an introduced polymer composite poly(1,2,3 trihydroxy 4,5 phenylene) polymer that was previously prepared by El-Garf et.al method [1].The samples of this polymer were prepared in two ways, with and without additives. The properties of the prepared samples are measured and are presented in this paper. The measurements show that additives drastically change the electrical parameters of this polymer.

Index Terms — Polymer , Composite ,Electrical Properties , Dielectric Constant , Dielectric Loss , Impedance , Tangent Loss , Glass transition point ,Optimum frequency.

1 Introduction

A material is defined as a substance that is intended to be used for certain applications [2]. Materials can generally be divided into two classes: crystalline and non-crystalline (amorphous).The traditional examples of materials are metals, ceramics and polymers. Semiconductors are being developed today to form highly complex systems. Their electrical properties are very sensitive to impurity concentrations. Radical material advances can drive creation of new products or even new industries, to make incremental improvements issues with currently used materials. The electrical behavior of engineering materials are diverse, and so are their uses in electrical applications [3].

2 Polymers

Polymers include the familiar plastic and rubber materials. Many of them are organic compounds that are chemically based on carbon, hydrogen, and other nonmetallic elements (viz. O, N, and Si). Furthermore, they have very large molecular structures, often chain-like in natures that have a backbone of carbon atoms. Some of the common and familiar polymers are polyethylene(PE),nylon,poly-vinylchloride(PVC),polycarbonate (PC), polystyrene (PS), and silicone rubber. These materials typically have low densities, whereas their mechanical characteristics are generally dissimilar to the metallic and ceramic materials. They are not as stiff nor as strong as these other material types. However, on the basis of their low densities, many times their stiffness and strengths on a per mass basis are comparable to the metals and ceramics [4].

2.1 Polymer additives

Most of the properties of polymers are intrinsic ones—that is, characteristic of or fundamental to the specific polymer. Some of these properties are related to and controlled by the molecular structure. Many times, additives are intentionally introduced to enhance or modify many of these properties, and thus render a polymer more serviceable. Typical additives include filler materials, plasticizers, stabilizers, colorants, and flame retardants [5, 6].

2.2 Material compounds (composites)

The design goal of a composite is to achieve a combination of properties that is not displayed by any single material, and also to incorporate the best characteristics of each of the component materials. A large number of composite types exist that are represented by different combinations of metals, ceramics, and polymers. Furthermore, some naturally-occurring materials are also considered to be composites—for example, wood and bone. However, most of those to be considered in the present discussions are synthetic (or man-made) composites [4].

2.3 The introduced polymer

The introduced polymer to be studied is the Poly (1,2,3 trihydroxy 4,5phenylene) prepared by El-Garf et.al method[1] . Poly means connection of the starting material 1,2,3, trihydroxy means that each benzene ring contains 3-OH groups(position of OH-group in benzene ring) and 4,5 means that the fourth position molecule is connected to another molecule in the fifth position.
Phenylene is the name of benzene ring after being connected to each other .Properties of Polyphenylene type polymers are as diverse as the methods for preparing their structure [7]. Electrical properties of Polyphenylene, as indicated by Huckel[8], has semi conducting properties .

3 Samples preparation and instruments used.

3.1 Pure pellet

The first sample is a pure pellet without any additives.

3.1.1 Sample-1 preparation:

First putting ¾ tea spoon (about 0.2319gm) from the Poly (1, 2, 3 trihydroxy 4,5 phenylene) polymer in the agate mortar to be grinded. Then put it in the mold (1 cm diameter) to be shaped as pill with weight 0.2319gm .The pill is then surrounded with aluminum paper and gold film on both sides forming a Shottky barrier suitable for use as a contact point .Then compress the pill with 200 K/cm2 compressor. Finally, the pill diameter is of 1 cm and thickness of 1.5mm.

3.1.2 Instruments used

The HIOKI 3520 LCR Hi Tester meter is used .It provides a wide range of frequency from (100Hz to 100 KHz) [9], applying a DC voltage at different temperature (25,45,65, 81,110,124,141and150)°C levels.

3.2 pellet with Additives

Sample-2 is a pellet with carbon as an additive element.

3.2.1 Sample-2 preparation:

First adding 0.2 gm of the Poly (1, 2, 3 trihydroxy 4, 5 phenylene) polymer to be dissolved in Dimethyl sulfoxide (DMSO) +6 ml black ink (Carbon) +20gm of jelly powder .This mixture is then heated and steer till it becomes a viscous solution .Put this solution in a small bill shape crucible then after two weeks the pellet is formed with thickness =2mm and a diameter =1.1cm . A magnetic stirrer (mixer) is a laboratory device that employs a rotating magnetic field to cause a stir bar (also called "flea") immersed in a liquid to spin very quickly, thus stirring it. The rotating field may be created either by a rotating magnet or a set of stationary electromagnets [10].
Carbon(C) is a unique material with many attractive engineering qualities. It is valuable for its lubricating properties, its electrical properties; the opportunity to improve the mechanical properties of such an important material and reduce its brittleness somewhat has been the driving force for the development of an invaluable material [11].

3.2.2 Instruments used

The Tinsley Prism LCR 6471 Data Bridge is used for measuring sample-2.First applying a DC voltage at different temperature (25,30,40,60,80,100 and 120°C) and different frequencies (100Hz, 1, 10 and 100 KHz).

4 Parameters to be measured

The capacitance (C) and Impedance (Z) are measured for the two samples.
From these measurements the followings are calculated:

(i)- The relative dielectric constant (permittivity)

$$€ = C/C_o \qquad (1)$$

where C is the sample capacitance measured in pf .

$$C_o = €_o A/d \ , \qquad (2)$$

Co is the capacitance of vacuum .

$€_o = 8.85*10^{-12}$ F/M , ,is the absolute value of vacuum ,

$$A = \pi r^2 \qquad (3)$$

A is the sample cross sectional area , r=0.5cm $*10^{-2}$ is the sample radius and d=1500 μm is the sample thickness .

(ii)-The real and imaginary components of the relative dielectric constant are

$$€' = € \cos\theta \ , \ €'' = € \sin\theta \qquad (4)$$

respectively and the tangent loss angle is

$$\tan\delta = €''/€' = Z''/Z' \qquad (5)$$

(iii)-The real and imaginary components of the sample impedance are [12]

$$Z' = Z \cos\theta \ , \ Z'' = Z \sin\theta \qquad (6)$$

5 Results and discussions

5.1 sample-1 measured parameters:

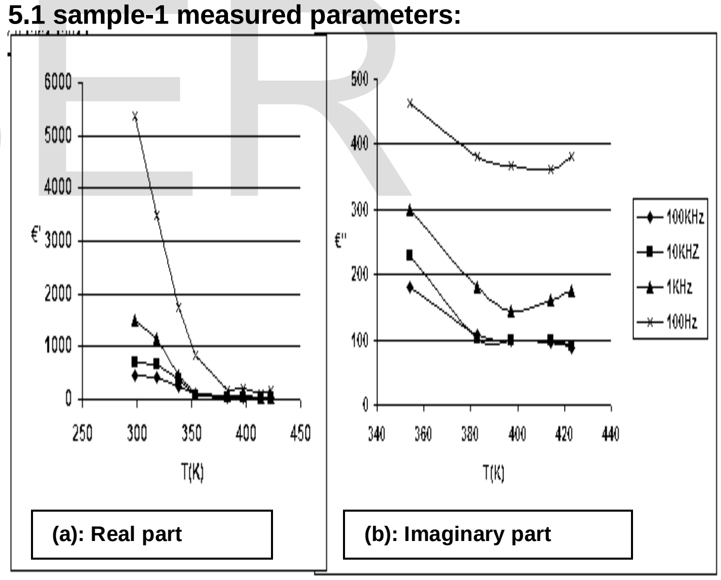

Fig.(1): The relation between temperature and dielectric for sample-1.

Figure (1-a and -b) shows the relation between the dielectric constant and temperature at different frequencies. It is seen that: from figure (1-a) the real part of the dielectric (€') decreases as the temperature and frequency increase. Also it is worth to note that the real part has a peak at temperature 397K which corresponds to a glass transition point (Tg) and a minimum at temperature 414K.
From figure (1-b) it is seen that the imaginary part of the dielectric (€'') decreases as the temperature increases and attains minimum of 397K. Also it is evident the dependence on

frequency, as the frequency decreases the dielectric (€″) increases.

In conclusion, the introduced polymer in its pellet form and at low frequency can polarize and store energy. Also it has a large capacitance to store the charge and can be used as a dielectric material .When comparing the introduced polymer dielectric constant to that of materials like carbon, silicon and germanium which have a dielectric constant of 5.5,11.68 and 16 respectively the introduced polymer as a powder has the higher dielectric constant values equals to 57.5 at room temperature and frequency =50Hz[1].It is worth to note that the frequency range 100Hz always shows higher dielectric loss which rapidly decreasing for temperatures greater than 350K.

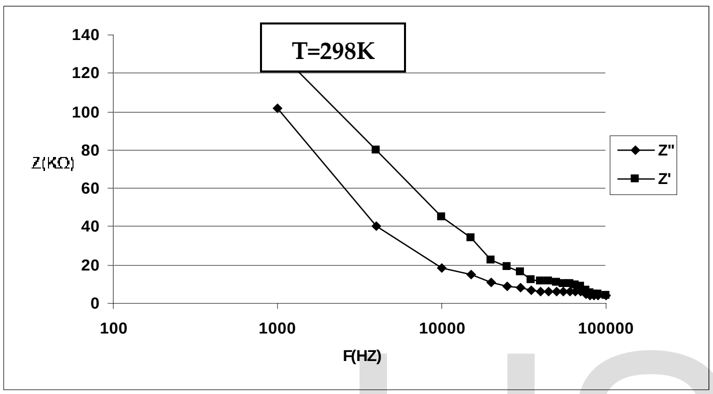

Fig.(2):The relation between the frequency and the impedance.

From figure (2) it is shown that the impedance two components (real and imaginary parts) decrease as the frequency increases.

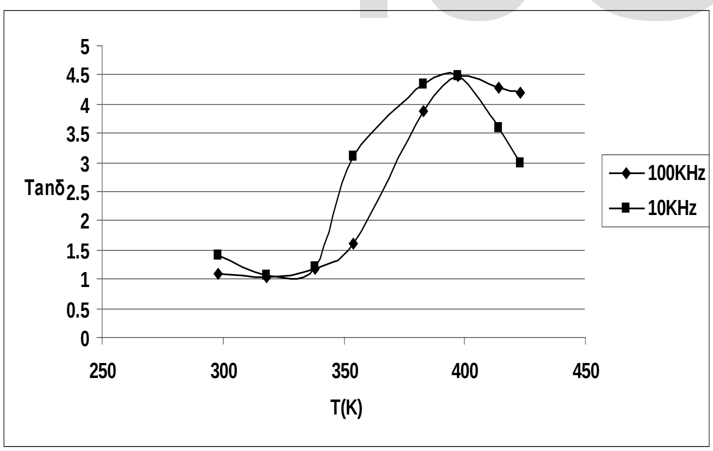

Fig.(3): The relation between dielectric tangent loss and temperature at frequencies 10KHZ and 100KHZ .

From figure (3) it is noticed that as the temperature increases the dielectric loss (Tanδ) gradually increases and reaches a maximum value at the glass transition point (Tg) , optimum frequency ,at temperature 397K where Tanδ =4.47 for all frequencies (e.g.10 and 100 KHz).

5.2 Sample-2 measured parameters

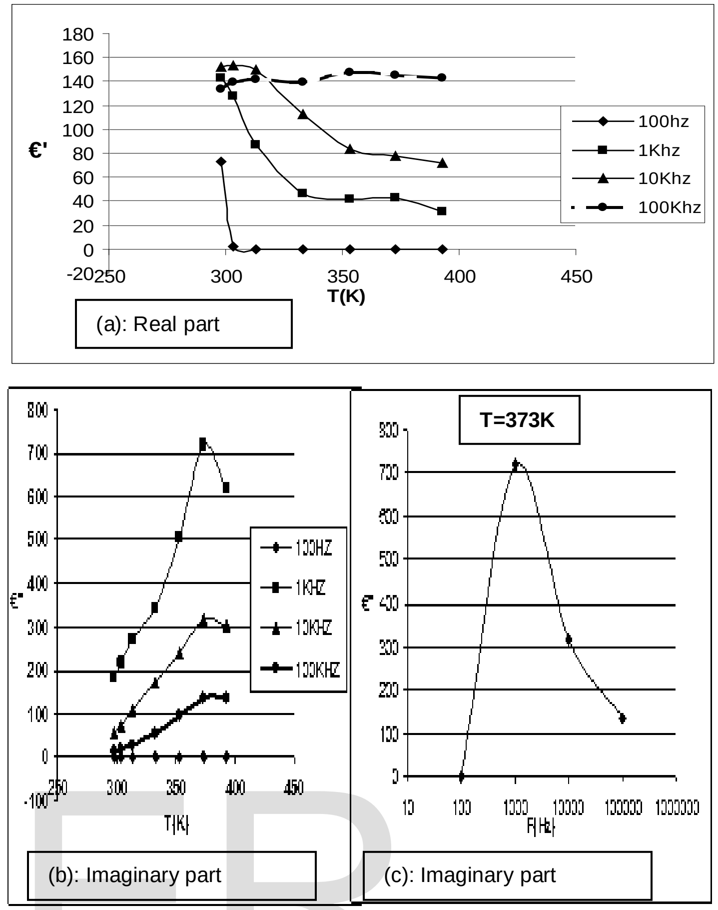

Fig. (4): The relation between temperature and dielectric for sample-2.

Figure (4-a) shows the relation between the dielectric and temperature at different frequencies. From figure (4-a) it is shown that the real part of the dielectric (€′) decreases as the temperature increases and as frequency increases €′ increases. This means that after adding carbon the material can polarize and store energy .It is worth to note that when comparing figure (1-a)(pure pellet) with figure (4-a)(with carbon dissolved) the dielectric €′ frequency dependence is inversed , i.e as the frequency increases the dielectric increases.

Figure (4-b) shows the relation between the imaginary part (€″) of the dielectric and temperature at different frequencies. From this figure it is shown that €'' increases as the temperature increases and it is evident its dependence on frequency. Also it is worth to note that the imaginary component of the sample-2 with carbon addition initially increases as both temperature and frequency increases to a maximum value after which the dielectric value decreases .The maximum dielectric value attends at temperature (T_{opt}=373 and f_{opt}=4KHz) as shown in figure (4-c).

In conclusion, it is evident that this polymer has optimum dielectric constant values (real and imaginary) depending on additive material type, optimum temperature and optimum frequency.

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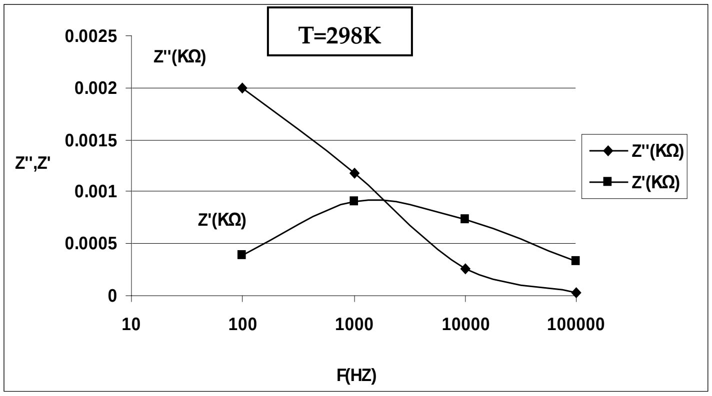

Fig. (5): The relation between the frequency and the impedance.

Figure (5) Shows the relation between real and imaginary parts of the impedance (Z′ and Z′′) at different frequencies. From this figure it is shown that the imaginary part of the impedance Z″ decreases as the frequency increases and the real part of the impedance Z′ has a maximum that takes place at frequency $f=f_{opt}$=4 KHz.

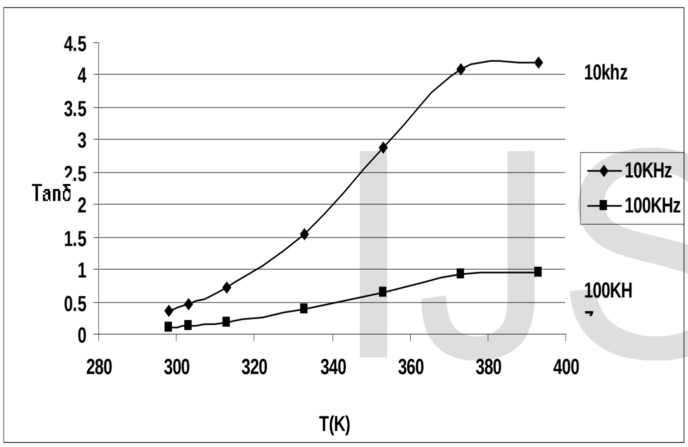

Fig.(6): The relation between the dielectric tangent loss and temperature in K at frequency 10KHz and 100KHz.

From figure (6) it is shown that the dielectric loss Tanδ increases as the temperature increases and as frequency increases the dielectric loss Tanδ decreases. Also it is noticed that Tanδ has a peak at temperature 393K which corresponds to a glass transition point (Tg).

In conclusion it is clear that the addition of carbon has largely affected the dielectric loss Tanδ, since at f=10 KHz, Tanδ =4.2 and at frequency =100 KHz, Tanδ=0.93.

6 CONCLUSION

From the previous measurements it is clear that the Poly (1, 2, 3 trihydroxy 4,5 phenylene) polymer is sensitive to additives and frequency. It has maximum parameter values that depends on optimum frequency (f_{opt}) and temperature (T_{opt}) .Also , the glass transition point is drastically affected by those parameters.

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