Novelty Journals

ISSN 2394-9651

International Journal of Novel Research in Physics Chemistry & Mathematics
Vol. 5, Issue 1, pp: (45-49), Month: January - April 2018, Available at: www.noveltyjournals.com

Determination of the Dielectric Constants of Raffia Carbonated Low Density Polyethylene

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Abstract: **The dielectric constant of raffia carbonated low density polyethylene using inductive capacitive resonance circuit was studied in this work. Bulk raffia frond materials were whittled done using top down approach through burning to produce charcoal and other isotopes of carbon. The charcoal was crushed into powder form and was sieved to remove rough and ungrounded ones and was used as filler. Samples of carbonated and un-carbonated polyethylene with thicknesses ranging from 0.3cm-0.7cm were inserted between the capacitor plates separated by very small distance of 1.5cm. The resonance frequencies f_o and f_p and corresponding amplitudes were obtained with air and polymer as the dielectrics, respectively. The spacing between the two copper plates was made very small to obtain a good result/capacitance. The peak to peak values of the wave form and their corresponding frequencies were recorded. The results showed that the dielectric constant of the polymer increased with increase in raffia carbon weight. The dielectric constant for the polyethylene was calculated to be 0.282 for pure samples and ranged from 0.524-0.790 when carbon black was introduced as filler. This showed that raffia charcoal can be a good material for carbonation of polymer and such polymer can be employed in solid state/solar energy industries.**

Keywords: **Capacitance, Dielectric Constants, Low Density Polyethylene and Raffia Charcoal.**

1. INTRODUCTION

In this research work, the dielectric constants of raffia carbonated low density polyethylene is studied using resonance method which involves the application of voltage or current into an LC resonance circuit. . The dielectric constant of a material can be measured with different methods; alternating current bridge method, time domain method, transmission method, direct current (D/C) method, sub millimeter method, ballistic method, impedance method and resonance method. A dielectric material is an electrical insulator that can be polarized by an applied electrical field, Britannica (2009).

A polymer can be seen as a large molecule or macromolecule composed of many repeated subunits. Both synthetic and natural polymer plays an essential and ubiquitous role in everyday life. Polyethylene is a light, versatile synthetic resin made from the polymerization of ethylene. It is the simplest polymer, composed of chain of repeating -CH_2- units, Piringer & Baner 2008. It is produced by addition polymerization of ethylene $CH_2 = CH_2$ (ethene). The properties of polyethylene depend on the manner in which ethylene is polymerized, Kenneth (2005). When it is catalyzed by organo metallic compounds at moderate pressure (15atm), the product is low density polyethylene LDPE. LDPE is hard, tough resilient and are mostly used in manufacturing of containers like milk bottles and laundry detergent jugs. The annual production is around 80 million tonnes, Piringer & Baner (2008).

Molecular arrangement of Polymers can be either Crystalline or amorphous. A dielectric material is an electrical insulator that can be polarized by an applied electrical field, Britannica (2009). Dielectrics are placed across the plate of a compaction like a little non – conducting bridge and are also used in reference to non-conducting layer of a compactor. When a dielectric field, electric charge do not flow through the material as they do in a conductor. They serve three purposes in compactor these are to keep the conducting plates from coming in contact, allowing for small plate separation and higher capacitance. Most dielectric material are solids examples include mica, glass, plastics, oxides of various

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metals, dry air and are used in variable capacitors. Dielectric constant K is the relative permittivity of a dielectric material. It is the measure of the ability of a material to be polarized by an electric field or store electric energy in the presence of an electric field. The study of dielectric properties concerns storage and dissipation of electric and magnetic energy in materials, Arthur (1954). It also determine how rapidly a material will heat in radio wave frequency or microwave dielectric applications, Stuat (2010).

Capacitors:

A capacitor is a passive two terminal electrical component used to store energy in an electrical filed, Dorf and James (2001). Capacitors are widely used as part of electrical circuits in many common electrical devices. The different types of capacitor are electrolytic capacitors, solid dielectric capacitors and air dielectric capacitor. Electrolytic capacitors are devices in which a thin layer of an oxide is deposited on one of the electrodes to function as the dielectric as used in an aluminum or tantalum plate with an oxide dielectric layer, Alan (2003).

Raffia:

Raffia has been used to fabricate many ethnographical items. The epidemis of the leaflet is the fiber, Elenga et-al., (2008). When exposed to scanning electron microscopy, it revealed a layered structure that has a top layer with a tie-like structure and a bottom layer with a honey comb-like structure. The presence of cellulose I_B with crystallinity index of 64% was revealed through XRD. It has the highest known specific mechanical properties among all vegetable fibers due to its fiber density is 0.75+0.07, Elenga et-al. (2009). It is employed in this work to know how it would affect the dielectric property of the polymer material (low density polyethylene).

2. METHODOLOGY/SAMPLE PREPARATION

In this work, many samples of low density polyethylene were purified by washing them in cold distilled water and dried in a drier. Bulk raffia frond materials were whittled done using top down approach through burning to produce charcoal and other isotopes of carbon. The charcoal was crushed into powder form and was sieved to remove rough and ungrounded particles. The grounded charcoal was measured to get different weighed samples for the polyethylene samples used. 40g of low density polyethylene was measured in five different beakers of equal volume (100ml) labeled as samples A_1, A_2, A_3, A_4 and A_5, respectively. It was observed that this low density polyethylene has bright white colour, very strong and tough when felt with both hand and teeth. Sample A_1 was left pure, un-carbonated and was heated with a heating mantle; a type of electric heater for 5 minutes and it melted at a temperature range of 185-205^oC. A choking smell was perceived caused by the grayish smoke coming out of the melting sample. The cooled finished sample appeared light brown in colour. The four other remaining samples; A_2, A_3, A_4 and A_5 were measured 40g each and heated differently. Four different weighed samples of carbon 10g, 15g, 20g and 25g were added to the above samples respectively and stirred vigorously to ensure homogeneity of mixture of the sample. All the samples were allowed to solidify and cool in the beakers. They gave darkish cylindrical finished samples. The result of the experiment is as shown on table 1.1 below.

Table 1.1: Low Density Polyethylene (LDPE)

Sample	Weight of Polymer (g)	Weight of Carbon (g)	% Weight of Carbon	Ratio of Polymer to Carbon
A1	40	0	0	40:0
A2	40	10	25	4:1
A3	40	15	37.5	4:3
A4	40	20	50	2:1
A5	40	25	62.5	8:5

EXPERIMENTAL CONSTRUCTION OF A CAPACITOR PLATE:

In this experiment, two circular plates of diameter 113mm (0.113m) were cut out from a thin copper plate. Filing machine was used to smoothen the edges of cut out circular plates. The surface of the plates were sandpapered and washed with clean water to remove trapped dirt and oxide. They were allowed to dry. At the back of the plates, two thin wires were soldered and a wooden guard ring was constructed to support the two circular plates when they were placed parallel to each other. To enable a firm grip, the plates were glued on the ring and a rectangular base was provided for the guard rings. The essence of the wooden guard rings was to reduce and eliminated edge effect.

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3. EXPERIMENTAL MEASUREMENT OF THE DIELECTRIC CONSTANT OF BOTH CARBONATED AND UNCARBONATED POLYMER SAMPLES

Here, resonance method which involves the application of voltage or current into an LC resonance circuit was used. It is always employed when the frequencies are greater than 1MHz. Measurement over a range of frequencies can be made by using coils with different inductive values but ultimately the inductance required became impracticably small in the range 10^8-10^9 H. In this method the resonance frequency f_o, was noted alongside with the amplitude where the resonance frequency occurred. Oscilloscope was used to provide accurate time and amplitude measurement of voltage signals over a wide range of frequencies. Different samples of both carbonated and un-carbonated polyethylene with different thicknesses ranging from 0.3cm-0.7cm were inserted one at a time between the capacitor plates. The plates were made to fit closely on both sides of the dielectric material. Two plates of capacitors were placed at a very small distance of 1.5cm and the resonance frequencies f_o (with air), f_p (with dielectric material) and corresponding amplitudes A were obtained. The spacing between the two copper plates was made small to obtain a good result/capacitance. The dielectric materials were also introduced between the plates to raise the capacitance of the capacitor. The tuned signal generator frequency was in phase with the natural oscillation of the LC system, at resonance. The energy superimposition was observed on the oscilloscope under this condition.

$F=1/2\pi\sqrt{LC}$ (1)

Were L=inductance of the inductors, C=capacitance of the capacitor, f= frequency. Making C the subject we have;

$C= 4\pi^2 f^2 \backslash L$ (2)

$C_O=4\pi^2 f_0^2/L$ (3)

$C_P=4\pi^2 f_P^2/L$ (4)

Where f_o is the resonance frequency with air as the dielectric,

f_p= the resonance frequency with polymer as the dielectric, L= the inductor of the circuit then

$C_p/C_O= 4\pi^2 f_P^2/L|4\pi^2 f_0^2/L$ (5)

$C_p/C_O= f_p^2 / f_o^2=k$ (6)

Where C_O and $C_{P,}$ are capacitances of the capacitor with air and polyethylene as dielectric materials. Here, equation 6 was used in calculating the dielectric constant of both carbonated and pure polyethylene samples. The tabulated results are as shown below 1.2-1.6;

Table 1.2: 40g Low Density Polyethylene with 0% Carbon 0.3cm

With Air		With Polymer	
Frequency (Hz)x10^4	Amplitude (Cm)	Frequency (Hz)x10^4	Amplitude (Cm)
2.0	1.0	1.0	0.6
3.0	1.3	1.2	1.1
3.2	1.9	1.4	1.3
3.1	1.6.	1.7	1.5
2.9	1.3	1.6	1.1

Table 1.3: 40g Low Density Polyethylene with 25% Carbon (10g carbon) with thickness 0.4cm

With Air		With Polyethylene	
Frequency (Hz)x10^4	Amplitude (cm)	Frequency (Hz)x10^4	Amplitude (Cm)
1.0	0.5	1.0	0.4
2.0	0.6	1.2	0.5
2.1	1.7	2.1	1.6
2.2	2.3	2.0	0.9
2.9	2.5	1.9	0.7
2.3	2.1	1.7	0.5

Table 1.4: 40g Low Density Polyethylene with 15g Carbon 37.5% carbon (15g of Carbon) with thickness of 0.5cm

With Air		With Polymer	
Frequency (Hz)x10^4	Amplitude (Cm)	Frequency (Hz)x10^4	Amplitude (Cm)
1.0	0.5	1.0	0.4
2.0	0.6	1.2	1.3
2.8	1.8	1.7	1.4
2.4	1.5	2.0	1.5
2.5	1.3	2.2	1.7
2.6	0.9	1.8	1.3

Table 1.5: 40g Low Density Polyethylene with 20g Carbon (50%) thickness 0.6cm

With Air		With Polymer	
Frequency (Hz)x10^4	Amplitude (Cm)	Frequency (Hz)x10^4	Amplitude (Cm)
1.0	0.5	1.0	0.7
1.5	0.6	1.1	0.8
2.3	1.1	1.2	1.0
2.5	1.5	2.1	1.6
2.6	1.7	2.0	1.4
2.1	0.9	1.8	1.2

Table 1.6: 40g Low Density Polyethylene with 25g Carbon (62.5% carbon) with thickness 0.7cm

With Air		With Polymer	
Frequency (Hz)x10^4	Amplitude (Cm)	Frequency (Hz)x10^4	Amplitude (Cm)
1.0	0.5	1.0	0.3
1.5	0.7	1.5	0.7
2.0	0.8	2.0	1.3
2.2	2.0	2.4	1.7
2.7	2.4	2.3	1.4
2.5	2.1	2.1	1.1
2.4	0.9	1.9	0.7

Tables 1.1-1.6, shows that there were increase in frequency when air and polymer were used as dielectrics. The amplitude also increased until it got to a maximum value after which it started decreasing. The frequency that gave the maximum value of amplitude was known as resonance frequency. This occurred in both pure and carbonated polymer samples.

Calculation of Dielectric Constant:

The table below shows the resonance frequencies of different carbon composition of low density polyethylene including their dielectric constants.

Table 1.7: Calculated Dielectric Constants of Low Density Polyethylene

Weight of Carbon (%)	Resonance frequency with air f_o (Hz)	Resonance frequency with polymer f_p	f_o^2 (Hz)	f_p^2	$K=f_p^2/f_o^2$
0	3.20x10^4	1.70x10^4	10.24x10^8	2.89x10^8	0.282
25	2.90x10^4	2.10x10^4	8.41x10^8	4.41x10^8	0.524
37.5	2.80x10^4	2.20x10^4	7.84x10^8	4.84x10^8	0.617
50.0	2.60x10^4	2.10x10^4	6.78x10^8	4.41x10^8	0.650
62.5	2.70x10^4	2.40x10^4	7.29x10^8	5.76x10^8	0.790

4. CONCLUSIONS

The dielectric constant of pure and carbonated samples of low density polyethylene and their thicknesses were studied. The dielectric constants of polymers increased with increase in the weight of carbon. For the pure samples, the dielectric constant was found to be 0.282. The introduced carbon black acted as filler and affected the physical properties of the polymer. This filler to a great extent controlled the mechanical properties (dielectric constant) and strength of polymer. The dielectric constant obtained for various carbon compositions ranged from 0.524-0.790. In order to obtain maximum value of capacitance, the thickness of the plates was made very small and the surfaces of the heated polymer sample made very flat for the capacitor plate to fit closely and tightly, Anyeji and Okpala (2015). The dielectric materials produced in this work can be used in solid state and solar energy applications.

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