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Determination of the Dielectric Constants of Carbonated Polypropylene

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ABSTRACT

In this study, we investigated the dielectric constant of carbonated polymer using inductive capacitance resonance circuit. We considered Polypropylene. The result revealed that the dielectric constant of the polymer decreased at the increase in carbon weight. The dielectric constant for polypropylene was 0.1483-0.0700 as the percentage carbon increased from 0% to 75%. This showed that charcoal as a dielectric material can affect the storage properties of polymer materials..

INTRODUCTION

In this work, we studied the dielectric constant of carbonated polymers. Polymers implies large molecule or macromolecule composed of many repeated subunits [1]. We have natural and synthetic polymer. They play essential and ubiquitous role in everyday life [2]. Polymer ranged from synthetic plastics such as polystyrene to natural biopolymer such as DNA and proteins [3]. Polymers both natural and synthetic are created through polymerization of many small molecules known as monomers [4].

DIELECTRICS AND DIELECTRIC CONSTANTS K

A dielectric material is an electrical insulator that can be polarized by an applied electrical field [5]. 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 in 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. They increase the effective capacitance by reducing the electric field strength [6]. Most dielectric material are solids examples include mica, glass, plastics, oxides of various 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 [7].

CARBONATION OF POLYMER

Carbonation of polymer means addition of extra carbon substance to polymer. There are different isotopes of carbon; graphite, diamond and amorphous carbon. They come in different forms like lamp black and charcoal [8]. Lamb black is a form of carbon also known as carbon black or furnace black. It is fine soot collected from incompletely burned carbonaceous material. It is used in matches, lubricants, fertilizers and as pigments. Charcoal is a light black residue consisting of carbon and residual ash obtained by removing water and other constituents from animal and vegetation substances. Charcoal is produced by pyrolysis through the heating of wood and other substances in the absence of oxygen [8]. It is an impure form of carbon because it contains ash.

CAPACITORS AND CAPACITANCE

A capacitor is a passive two terminal electrical component used to store energy in an electrical filed [9]. Capacitors are widely used as part of electrical circuits in many common electrical devices. The different types of capacitors 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 [10].

METHODOLOGY/SAMPLE PREPARATION

Here, many samples of Polypropylene were purified by washing them in cold distilled water and allowed to dry under the sun. Each sample was measured with digital weighing balance to obtain four specimens of different weights. Charcoal which is a form of carbon obtained from the burning of star apple wood was crushed into powdered form and sieved to remove rough and ungrounded ones. The grounded charcoal was measured to get different weighed samples for the polymer used. 20g of Polypropylene was measured for four different times and were poured in four beakers (100ml) labeled samples D1, D2, D3 and D4, respectively. D1 was uncarbonated and it melted in the temperature range of 165^oC-180^oC. The other samples were carbonated with 5g, 10g and 15g of carbon (charcoal) respectively. They were heated, melted and allowed to solidify. The result of the experiment is as shown on table 1.1 below.

Table 1.1: Polypropylene

Sample	Weight of Polymer (g)	Weight of Carbon (g)	% Weight of Carbon	Ratio of Polymer to Carbon
D1	20	0	0	20:0
D2	20	5	25	4:1
D3	20	10	50	2:1
D4	20	15	75	4:3

EXPERIMENTAL CONSTRUCTION OF A CAPACITOR PLATE

Two circular plates of diameter 118mm (0.118m) were cut out from a thin copper plate bought from bridge head market Onitsha. The edges of the cut out circular plates were smoothened with a filing machine (bench grinder). The surface of the plates were also washed with sandpaper and clean water to remove trapped dirt and oxide, they were allowed to dry. Two thin wires were soldered at the back of the plate respectively. A wooden guard ring was constructed to support the two circular plates when they were placed parallel to each other. The plates were also glued on the ring to enable a firm grip, a rectangular base was provided for the guard rings. The wooden guard rings reduced and eliminated edge effect (they protect the two copper plates from being touched with hand).

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

The dielectric constant of a material can be measured with any of these 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. In this work we used resonance method which involves the application of voltage or current into an LC resonance circuit. It is a useful method used especially when the frequencies are greater than 1MHz. Measurement over a range of frequencies may be made by using coils with different inductive values but ultimately the inductance required becomes impracticably small in the range of 10^8-10^9 H, reentrant cavity are often used. These are hybrid devices in which the plate holding the specimen still forms a lumped capacitor but the inductance and capacitance are distributed along a coaxial line. In this method, the resonance frequency f_o and the amplitude where the resonance frequency occurred are noted.

Figure 1.1: Experimental Set up for the Measurement of Diaelectric Constant of Polymers by Resonance Frequency Method

The cathode ray oscilloscope used is a single beam type (instek oscilloscope Gos 620 20MHZ). It provided accurate time and amplitude measurement of voltage signals over a wide range of frequencies. The oscilloscope was plugged to the main supply and the power was switched on, a green light was shown indicating the presence of power supply. The oscilloscope warmed up within a short period of one minute after which a trace of beam appeared. The vertical and the horizontal controls were used to place the line on the center of the graticule. The signal generator was connected between red inputs. An A⁄C knob was pressed since an A⁄C main was used. Volt ⁄cm knob was adjusted to obtain a display of convenient amplitude. The time⁄cm switch was adjusted to display as much details as required.

The different samples of both carbonated and noncarbonated polymer with different thicknesses ranging from 0.5cm-2.0cm were inserted one at a time between the capacitor plates, the plates were made to fit closely on both sides of the dielectric material. Firstly, the two plates of capacitors are placed at a very small distance of about (2cm), the resonance frequencies f_o and amplitudes A were obtained with air as the dielectric. The spacing between the two copper plates should be small for a good result to be obtained. The electric materials were introduced between the plates which raised the capacitance of the capacitor. The resonance frequency when air was the dielectric is denoted by f_o and that of the polymer material was f_p, the peak to peak values of the wave form were recorded.

THEORY

At resonance, the tuned signal generator frequency is in phase with the natural oscillation of the LC system. The energy (amplitude) superimposition was observed on the CRO under this condition

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

Were L=inductance of the inductors, C=capacitance of the capacitor, F= frequency.

$$2\pi f=\sqrt{LC} \quad (2)$$

$$4\pi^2 f^2=LC \quad (3)$$

$$C=4\pi^2 f^2 /L$$

Then with air and polymer material as dielectric we have

$$_O=4\pi^2 f_o{}^2 /L \text{ or } Cp=4\pi^2 fp^2 /L \quad (4)$$

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

$$C_p/C_O = Cp = 4\pi^2 fp^2 / LxL/4\pi^2 f_o^2 \quad (5)$$

$$C_p/C_O = F_p^{\ 2} / F_o^{\ 2} = k \quad (6)$$

Where C_O and C_P, are capacitances of the capacitor with air and polymer as dielectric materials. Equation 6 was used in calculating the dielectric constant of both carbonated and pure polymer samples. The tabulated result is as shown below;

Table 1.2: 20g Polypropylene with 0% Carbon and Thickness of 1.3cm

With Air		With Polymer	
Frequency (Hz)x10^4	Amplitude (Cm)	Frequency (Hz)x10^4	Amplitude (Cm)
1.0	0.6	1.0	0.4
2.0	0.7	1.5	0.8
3.0	1.0	1.7	1.7
3.3	2.2	2.3	3.5
3.7	3.8	3.0	2.7
4.0	1.8	4.0	1.5
5.0	0.5	5.0	0.9

Table 1.3: 20g of Polypropylene with 5% Carbon (25g carbon) with Thickness 0.3cm

With Air		With Polymer	
Frequency (Hz)x10^4	Amplitude (Cm)	Frequency (Hz)x10^4	Amplitude (Cm)
1.0	0.6	1.0	0.4
2.0	0.7	1.4	0.5
3.0	1.1	1.6	1.7
3.3	2.4	2.0	2.9
3.6	3.9	3.0	1.1
4.0	1.9	4.0	0.9
4.5	0.7	4.5	0.4

Table 1.4: 20g of Polypropylene with 5% (25g Carbon) and Thickness of 0.3cm

With Air		With Polymer	
Frequency (Hz)x10^4	Amplitude (Cm)	Frequency (Hz)x10^4	Amplitude (Cm)
1.0	0.6	1.0	0.4
2.0	0.7	1.4	0.5
3.0	1.1	1.6	1.7
3.3	2.4	2.0	1.1
3.6	3.9	3.0	1.1
4.0	1.9	4.0	0.9
4.5	0.7	4.5	0.4

Table 1.5: 20g of Polypropylene with 10% Carbon (50g of Carbon) and Thickness of 1.5cm

With Air		With Polymer	
Frequency (Hz)x10^4	Amplitude (Cm)	Frequency (Hz)x10^4	Amplitude (Cm)
1.0	0.7	1.0	0.5
2.0	0.8	1.2	0.7
3.0	1.2	1.5	2.1
3.3	2.7	2.0	2.7
3.6	3.7	3.0	1.7
4.0	1.8	4.0	1.0
4.5	0.9	4.5	0.8

Table 1.6: 20g of Polypropylene with 75% Carbon (75g of Carbon) with Thickness of 1.8cm

With Air		With Polymer	
Frequency (Hz)x10^4	Amplitude (Cm)	Frequency (Hz)x10^4	Amplitude (Cm)
1.0	0.5	1.0	0.7
2.0	0.7	1.2	0.9
3.0	1.9	1.3	1.8
3.5	3.2	1.8	2.6
4.0	2.2	3.0	1.3
4.5	0.8	4.0	0.7

Table 1.7: 20g of Polypropylene with 100% Carbon (20g of Carbon) and Thickness of 1.9cm

With Air		With Polymer	
Frequency (Hz)x10^4	Amplitude (Cm)	Frequency (Hz)x10^4	Amplitude (Cm)
1.0	0.6	0.7	0.4
2.0	1.0	1.0	0.5
3.0	2.1	1.1	1.9
3.5	3.0	1.2	2.8
4.0	1.8	3.0	1.1
4.5	0.5	4.0	0.7

Tables 1.2-1.7 show that there is increase in frequency when air and polymer were used as dielectrics. The amplitude also increased until it gets to a maximum value after which it started decreasing. The frequency that gave the maximum value of amplitude is known as resonance frequency. This occurred in both pure and carbonated polymer samples.

Calculation of Dielectric Constant

The table below shows the resonance frequencies for different carbon composition of polypropylene with their dielectric constants.

Table 1.7: Calculated Dielectric Constants of Polypropylene (PP)

Weight of Carbon (%)	Resonance frequency with air F_o (Hz)	Resonance frequency with polymer F_p	F_o^2 (Hz)	F_p^2	$K=F_o^2/F_p^2$
0	3.7x10^4	2.3x10^4	1.369x10^9	5.29x10^8	0.1493
25	3.6x10^4	2.0x10^4	1.296x10^9	4.01x10^8	0.0957
50	3.6x10^4	1.8x10^4	1.296x10^9	4.00x10^8	0.0953
75	3.5x10^4	1.5x10^4	1.225x10^9	3.24x10^8	0.0700

CONCLUSION

The dielectric constant of carbonated Polypropylene was studied. The dielectric constants of polymers decreased with increase in the weight of carbon (charcoal). For the pure samples, the dielectric constant of Polypropylene was found to be 0.1493. As different weights of carbon were added, the dielectric constants of the samples decreased with the increase in the carbon weight. The introduced carbon black acted as filler and improved the physical properties of the polymer. This filler to a great extent controls the mechanical properties (dielectric constant) and strength of polymer; it has lesser effect on the electrical properties. When there is excessive potential difference across the dielectric separating a pair of charged conductor, the dielectric will break down and become conductor.

This effect is taken care of in the resonance frequency method used as the current is passed through the generator through the inductors to the plates. To obtain maximum value of capacitance, the thickness of the plates must be so very small and also the surfaces of the heated polymer samples must be very flat so that the capacitor plate will fit closely and tightly and capacitance improved.

REFERENCES

[1] Roiter, Y.; Minko, S. **(2005)**. "AFM Single Molecule Experiments at the Solid-Liquid Interface: In Situ Conformation of Adsorbed Flexible Polyelectrolyte Chains". Journal of the American Chemical Society **127** (45): 15688–15689.

[2] Painter, Paul C.; Coleman, Michael M. **(1997)**, Fundamentals of Polymer Science: an introductory text, *(*Pa.: Technomic Pub. Co: Lancaster*)*, p1.
[3] McCrum, N. G.; Buckley, C. P.; Bucknall, C. B. **(1997)**, Principles of Polymer Engineering, (Oxford University Press: New York :) p1.
[4] Define Polymer **(2013)**, Dictionary Reference.
[5] Dielectric Physics, Britannica **(2009)**, p1.
[6] Piringer and Baner **(2008)**: Polymer Science Hand Book, Wiley- Intersciene Publication.
[7] Arthur R Von Hippel, **(1954)** Dielectric Materials and Applications, (Technology Press of MIT and John Willey: New York).
[9] Dorf, Svoboda and Jame A **(2001)** Introduction to Electric Circuits, John Wiley & Sons, pp.35.
[10] Alan I., **(2003)**, Dictionary of Physics, (Oxford University Press Inc: New York) p56.