Dielectrical Insulation of Polyvinyl Alcohol, Ethylene Glycol and Crushed Pomegranate Peel (PVA-EG-PP) Composite materials

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الخلاصة

تم تحضير نماذج من مخلوط بولي فاينيل الكحول مع الأثلين كلايكول ومضاف مسحوق قشور الرمان المغربل. تم تشخيص مسحوق قشور الرمان والمخلوط باستخدام مطياف تحويلات فورير للأشعة تحت الحمراء. تم قياس قيم العزل الكهربائي. معاملات العزل الكهربائي مثل ثابت العزل، فقد العزل، سعة الفضاء الحر، المواصلة، التوصيل المتناوب والتوصيل المستمر. وجد ان نقص جدير بالاهتمام في فقد العزل الى 2.639 مع زيادة حجم حبيبات مسحوق قشور الرمان المغربل الى (600) مايكروميتر النموذج (4) ومختلف الدراسات اللاحقة لفاعلية انسجام مسحوق قشور الرمان مع البوليمرات. وجد زيادة في التوصيلية الكهربائية للنماذج (2) و (3) حجم حبيبات قشور الرمان (212) مايكروميتر و(300) مايكروميتر ونقص عند النموذج (4).

الكلمات المفتاحية

مخلوط، مضاف، تشخيص، عزل، السعة، الحث.

Abstract

Samples are prepared from mixture of manufacture foam material polyvinyl alcohol with ethylene glycol (PVA-EG) and additive of crushed and sieved pomegranate peel (PP). Crushed pomegranate peel (PP) and the mixture are diagnosed by Fourier transforms infrared (FTIR) spectrophotometer. The electrical insulation parameters are measured. The dielectric parameters such as dielectric constant (ε′), dielectric loss factor (ε″), free space capacitance (Co), conductance (Gs), dependent conductivity (σac), and independent conductivity (σdc) have been investigation. There is a significant decrease in dielectric loss factor ε″ to 2.39 as the grain sizes of crushed and sieved (PP) increased to (600) µm sample (4), and various recent investigations of functionalization of PP fillers to improve compatibility with polymers. The electrical conductivities of composites are found to increase at sample (2) and (3) PP grain size (212) µm and (300) µm and decrease at sample (4).

Keywords

Mixture, Diagnosis, Insulation, capacitance, Inductance.

1. Introduction:

Applications of polymers have been increasingly used for many technical tasks, such as biopolymers, Copolymers and composites. Biopolymers may occur in natural or synthesis sources as proteins and carbohydrates and synthetically prepared as poly (lactic acid), polyvinyl alcohol (PVA), polyethylene glycol (PEG) etc. most natural biopolymers are degradable soon after treating to be used for industrial purposes [1]. Polymers composites have many lubricants, that can be used in various applications such as dielectric materials, Nano-sized conductor fillings, including grapheme nanoplatelets, can create a filter network inside the polymer matrix in low-weight part, while the presence of conductive nanoinclusions into a polymer matrix could alter the permittivity of the composite systems resulting in enhancement of their energy storing capability [2]. Pomegranate polyphenols are strong antioxidants and chemical protective factors but possess low availability and biological half-life. For example, punicalagin (PU), is the phenol in pomegranates, is not absorbed in its proper form and for those decomposed into ellagic acid (EA). The major polyphenols in pomegranate are decomposed to ellagic acid (EA) moieties and rapidly metabolized into short-lived metabolic product. A pomegranate contains many polyphenolic compounds with high antioxidant and free-radical-scavenging activity including flavonoids, condensed and hydrolyzed tannins, and hydrolyzed tannins (ellabitannins (ETs) and Gallo tannins). Encapsulation of ellagitannins (ETs) into biocompatible and biodegradable nanoparticles (NPs) may overcome their susceptibility to gastrointestinal hydrolysis, poor absorption, low systemic bioavailability and short half-life. The hypothesis that encapsulation of pomegranate polyphenols into biodegradable sustained release nanoparticles (NPs) may circumvent these limitations [3]. Chloroform is a volatile liquid has a molecular weight 119.38 with molecular formula $CHCl_3$ was supplied from Sd Fine chem.-limited, India. Polyvinyl alcohol (PVA) was hot water soluble supplied from HIMEDIA REF Laboratories Put ltd. India. PVA is a hydrophilic linear polymer, has molecular weight 89,000 to 98,000. Chemically and physically modified PVA with molecular formula -[CH_{2}-CHOH]- repeated unit, (C_2H_4O). Polymer systems have been developed due their high ionic conductivity and became main objectives in polymer research. Due to their potential applications as electrolytes in solid-state batteries, fuel cells, electrochemical display devices/smart windows, photochemical cells etc., according to their high conductivity, high energy density, wide electrochemical stability and easy process ability. The main advantages of polymer electrolytes are their mechanical behaviors, ease of fabrication of thin films of desirable sizes and their ability to form proper electrode/electrolyte in contact in electrochemical devices [4].

More over their studies of phase separation in thin films of binary mixtures is effective production and commercially important for different coatings and films, including insulating layers, photographic materials and paint systems. Film of polymer blends exhibit more desirable characteristics than individual homopolymer, many blends polymer components are also highly incompatible with each other, will remix and phase separate. The degree separation in polymer blends will greatly affect the resulting morphology, that can have adverse effects on the resulting film [5]. FTIR technique has attained high precision and accuracy in measurement to be sufficiently reproducible for most industrial; research and development purpose. Spectra from polymeric samples are usually relatively rapid and straightforward. Moreover, FTIR micro-spectroscopy combines the spatial specificity of microscopy with the powerful chemical specific of spectroscopy [6].

Ethylene glycol is a chemical commonly is used in many commercial and industrial applications including antifreeze in winter and coolant to reduce over heating in summer. The molecular formula of ethylene glycol is $HOCH_2OH$ or $C_2H_6O_2$ and its molecular weight is (62.067) g/mol, is a colorless, odorless, viscous dihydroxy alcohol. Bulk dielectric polymer film with an intrinsic ultralow dielectric constant at (10) kHz has been successfully synthesized based on a novel polyimide. More importantly, such outstanding dielectric properties remain stable up to (280) ^{o}C. The excellent ultra-low dielectric is mainly because of the large free volume (subnanoscale), that intrinsically exist in the amorphous region of polymeric materials [7]. The aim of the project is focused on the dielectric own quality of the composites, specifically the measurement of dielectric parameters and the dielectric properties are investigation.

2. Experiment Work

2.1. Manufacture of Foam Material of PVA

(10) gm of polyvinyl alcohol (PVA) powder supplied from HEMEDIA Laboratories, Ltd, India, has been weight by using Sartorius balance, Germany. (10%) concentration of PVA with (100) millimeter of distilled water have been emplaced into a bottom round flask was put into isomental heater and stirrer sort Heidolf, Germany is used to mix the mixture. The system operated with temperature has been raised between (92-98) ^{o}C as in Fig. (1). Each (15) minutes the system is stopped to measure the temperature by thermometer and the vapor steam is let out to avoid solidification of the material, continuation of the operating the system until a complete dissolve of PVA in time period one and half hour. The obtained product of foam material of PVA is collected in clean glass container as in Fig. (2).

Fig. (1): Setup of Manufacture foam material of PVA

Fig. (2): Foam material of PVA and set up of measurements

2.2. Samples Preparation:

Glass substrates were emplaced in flask that is cleaned with distilled water for (10) minutes and was rinsed with acetone then is washed by distilled water. The glass substrates were put in vacuum furnace at (90) °C until they were dried. The furnace is put off and the clean glass substrate is left inside the furnace over night to let the temperature falls to room temperature and the clean glass substrates are taken out for use. Pomegranate peel (PP) was left to be dried in open air for two months. The dried pomegranate peel was crushed by stainless steel mortar and was kept in plastic container. The crushed PP. was sieved for different grains size, (75) μm, (212) μm, (300) μm, (600) μm and remaining from the last sieving is large than (600) μm grain size (2360) μm. Each weight (0.03) gm. of pomegranate peel particle size was dissolved in (0.025) mole of chloroform and mixed by spatula to ensure homogeneous solution; this is added and mixed with (0.092) mole polyvinyl alcohol (PVA). And (0.041) mole of ethylene glycol (EG) mixture, all the mixtures were deposited on the clean glass substrates as samples. Two copper electrodes were fastened at both ends of the films and left over night to be dried and to ensure the chloroform will be evaporated from the mixture. These specimens are subjected to dielectric measurements by using FLUKE PM (6303) RCL meter serial number 781003, Germany. The dimensions of the specimens and the cross sections of the tip vicinity have been measured with Vernier Caliper Certificate made in China. Table (1): indicates the samples preparation

Table (1): Samples preparation

PVA moles	EG moles	PP. grain sizes µm	Length of specimens .mm	Width of specimens .mm	Thickness of specimens .mm	Cross sectional area of the tip .vicinity mm^2
0.091	0.041	75	16.20	20.00	1.31	0.8
0.091	0.041	212	16.54	18.53	1.33	0.915
0.091	0.041	300	15.22	12.35	1.521	0.142
0.091	0.041	600	16.33	12.95	1.51	3.14
0.091	0.041	> 600	16.65	13.42	1.63	0.138

3. Calculations and Results:

3.1. Dielectrical Insulation

Dielectrical parameter measurements were included quality factor (Q), dissipation factor (D), impedance (Z), parallel resistance (Rp), series resistance (Rs), parallel capacitance (Cp), series capacitance (Cs) and phase shift (ϕ). Table (4) indicates the dielectric measurements and calculations. Dielectric constant (έ) and dielectric loss (ἕ) of samples were calculated using the following relations [8]:

$$'\varepsilon = Cs\frac{d}{\varepsilon o A} \qquad (1)$$

Where Cs: the series capacitance in pF

ε_o permittivity of free space $F.m^{-1}$. d: the thickness of sample mm.

A: cross sectional area of effective electrode area mm^2. Dielectric loss factor is given by [9]:

$$''\varepsilon = \frac{\varepsilon}{RpCpw} \qquad (2)$$

$$Rp = \frac{1}{DwCp} \qquad (3)$$

Where w: angular frequency 2πf. And f: frequency Hertz.

The free space capacitance

$$Co = \varepsilon o\frac{A}{d} \qquad (4)$$

Where ε_o: permittivity of free space $8.85*10^{-12}$ F m^{-1}.

A: electrode area mm^2

d: thickness of the electrode mm.

C_o is equal to $4.863*10^{-4}$ pF

Conductance is given by

$Gs = \varepsilon' Co\ \omega$ (5)

ac conductivity σac:

$\sigma ac = \varepsilon o \varepsilon'' w$ (6)

Total conductivity σt is:

$$\sigma t = Gs\frac{d}{A} \qquad (7)$$

3.2. Fourier Transforms Infrared (FTIR) Spectroscopy:

FTIR spectroscopy of crushed PP grain size (75) µm is carried out with kBr disc by using JASCO spectrophotometer (4200), serial No. C08176018, Japan. Spectra are taken in wave number (400-4000) cm^{-1} as in Fig. (3). Band at (3410.98) cm^{-1} is the presence of stretching primary amines, band at (2928.76) cm^{-1} is due to secondary amines with corresponding vibration peak at (1615.57) and band at (1364.86) cm^{-1} corresponding to C-N stretching vibration aromatic group[10] and band at (1049.09) cm^{-1} is corresponding to C-H of alkanes, peak at (1445.39) cm^{-1} stretching vibration C-OH of protein and polyphenols and peak at (1731.760) cm^{-1} corresponding to C=O stretching vibration of flavonoids and amides[11], peak at (639) cm^{-1} alkenes[12]. Table (2) is the comparison of the obtained results with previous studies. FTIR spectroscopy of (PVA-EG-PP), for sample (1) at foam material of PVA (0.092) mole, EG (0.041) mole and crushed PP grain size (75) µm and 0.03 gm. in weight is dissolved in (0.025) mole of chloroform and added to the mixture (PVA-EG). The spectra have been carried out in wave number (400-4000) cm^{-1} as in Fig. (4) by using JASCO spectrophotometer (4200), serial No. (C08176018), Japan. Band at (3385.42) cm^{-1} attributed to OH [13], band at (2927.41) cm^{-1} related to the presence of –CH groups [14] and band at (1078.98) cm^{-1} is not noted and used as an indicator for PVA structure [15]. Peak (1727.42) cm^{-1} and peak (1616.54) cm^{-1} pomegranate peel powder [16] and peak (1364.39) cm^{-1} C-N complex reaction, Yang, et al [11]. Table (3) is the comparison of the obtained results with previous studies.

4. Results and Discussion:

FTIR test of pomegranate peel (PP) grain size (75) µm as shown in Fig. (3), have been investigated. Table (2) indicates the comparison between the obtained results with other studies, band (3410.98) cm^{-1} is primary amines, in comparison with Fig. (4); of PVA-EG-PP, Table (3) band (3385.42) cm^{-1} is determine OH. Peak at (1364.34) cm^{-1} for PVA-EG-PP is complex reaction took place between C-N. Table (4) Maximum calculated dielectric constant is ($2.47*10^3$) for sample (1) PP grain size (75) µm and minimum value is (16.301) for sample (4) PP grain size (600) µm. the dielectric constant decreases with increasing of PP grain size so that the giant dielectric constant is close to (75) µm of PP [17]. The maximum calculated dielectric loss factor is ($2.03*10^3$) for sample (1) and minimum value is (2.639) for sample (4). ε' and ε'' are experimentally observable parameters and used to characterize dielectric dispersion over (1) kHz [18]. Dielectric constant measures the efficiency of an insulating material and is used to determine the ability of an insulator to store electric energy [19]. If a material is to be used for strictly insulating purposes, it would be better to have a lower dielectric loss. However, one of the major reasons for the choice of a particular dielectric material its dielectric constant. Those with high dielectric constant enable high values of capacitance to be achieved, each one having a different permittivity or dielectric constant. Free space capacitance Co value ($4.863*10^{-4}$) pF.

Maximum conductance is ($2.768*10^{-9}$) S for sample (1), and minimum ($4.97*10^{-11}$) S for sample (4), Maximum σac ($1.132*10^{-4}$) S m^{-1} for sample (1) and minimum ($1.46*10^{-7}$) S m^{-1} for sample (4). Maximum σdc is ($1.078*10^{-4}$) S m^{-1} samples (1) and minimum ($12.2*10^{-8}$) S m^{-1} Samples (4). Fig. (5) Indicates the relation between the dielectric constant ε′ and the series capacitance Cs, the decrease in Cs will cause decrease in ε′, consequently the larger relative permittivity is the larger resulting capacitance becomes as in sample (1) and (2), the important of the case is to maintain the conductance Gs. Fig. (6) Indicates the dependence of the ac conductivity on the dielectric loss factor ε″ according to the linear relationship the value of σac increase with increasing ε″. It is important to consider the losses in ac capacitors. The complex dielectric constant is usually defined as ε* = ε^'- jε''. The real part of permittivity ε′. It is a measure of how much energy from an electric field is stored in a material. ε″ is the imaginary part of permittivity. It is a measure of how dissipative or lossy a material is to an external field. The ratio (ε''/ϵ') is tanδ.[20]. Fig. (7), the dependant of the dielectric constant ε′ on PP grain size μm, the value of ε′ is decreased at sample (4) and alternatively cause decrease in values of Gs, σac and σdc. Fig. (8), the dependant of ε″ on PP grain size as the grain size increase ε″ decrease except at sample (4), is nearly the same as in Fig. (8). Fig. (9), indicates variation of the σac S m^{-1} with PP grain size μm, σac decreases as the PP grain size increases. Fig. (10), the variation of σdc S m^{-1} with particle size PP μm the variation gave a peak at sample (3), σdc is equal to ($8.58*10^{-4}$) S m^{-1} and electrical conductivity gradually decreases as the PP grain sizes increases, this is related to the complex dielectric constant, similarly complex AC conductivity consists of real and imaginary part [21]. Fig. (11) the variation of conductance Gs S with PP grain size μm, Gs decrease at sample (4) and (5) ($4.97*10^{-11}$) S and ($1.22*10^{-9}$) S. Fig. (12), the variation of total conductivity σt S m^{-1} with PP grain size μm there is increase at sample (3) (8.71*10-4 S m^{-1}). Capacitive reactance Xcs and inductive reactance X_L have been calculations. Generally, PP filler enhance the electrical conductivity and the polar behavior of PVA [22]. The dielectric behavior relates to the tendency for capacitance build-up, that is commonly involve electric polarization. The associated charge movement can be due to polar bond rotation, functional group movement etc. [23] the measurement of capacitance (as measured at 1 kHz) for the composites of the specimen's inclusion the effect of the two copper wires and the tip vicinity at the points of contact.

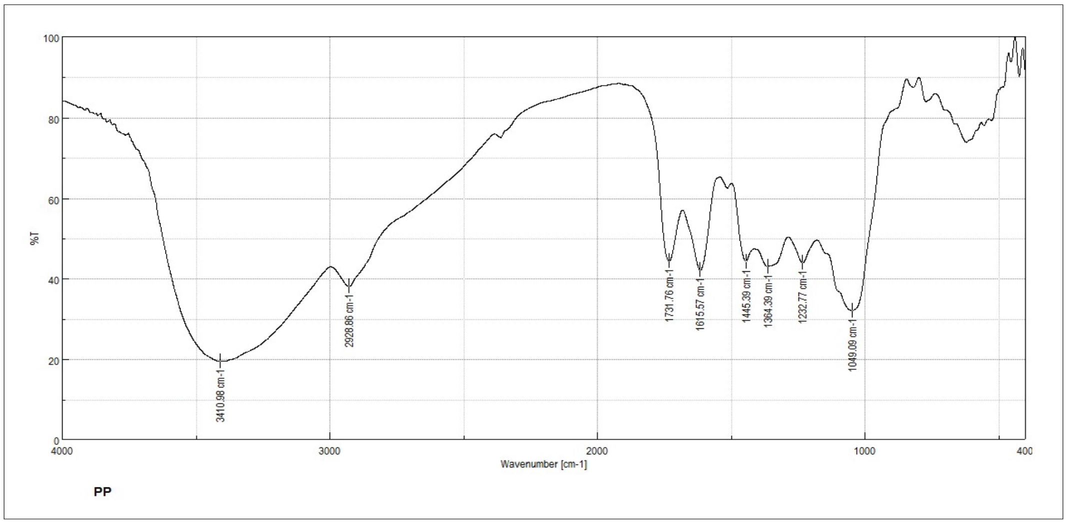

Fig. (3): FTIR spectroscopy of (75) µm Pomegranate Peel (PP)

Table (2): Comparison of the obtained results with previous studies

Functional group obtained results	Wave number cm^{-1}	Functional groups of reference	Wave number cm^{-1}
Primary amines	3410.98	Primary amines	ref.10,3371
Secondary amines	1615.57 ,2928.86	Secondary amines	ref. 10 ,2927
C-N stretching vibration aromatic groups	1364.86	C-N stretching vibration aromatic groups	ref. 10 ,1373
C-OH of alkenes	1049.09	C-OH of alkenes	ref. 11 ,1060
C-C stretching vibration of Aromatics	1445.39	C-OH stretching of protein and polyphenols	ref. 11 ,1616
C=O stretching vibrations of flavonoids	1731.76	C=O stretching vibrations of flavonoids	ref. 11 ,1724.90
Alkenes	639	Alkenes	ref, 12 ,698.23

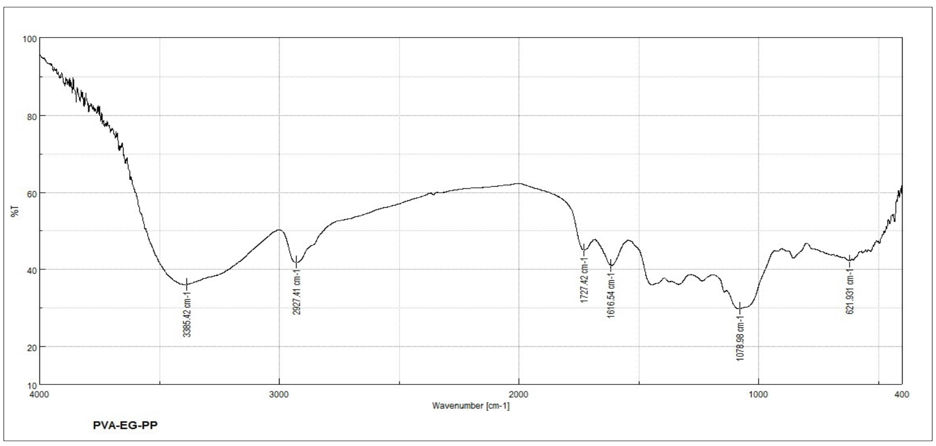

Fig. (4): FTIR of PVA-EG-PP

Table (3): The comparison of the obtained results with previous studies.

Functional groups of obtained results	Wave number cm^{-1}	Functional groups of references	Wave number cm^{-1}
OH	3385.42	OH	3391.21, ref. 13
-CH2 groups	2927.41	-CH2 groups	2940, ref. 14
Indicator for PVA structure	1078.98	Indicator for PVA structure	1150-1050, ref. 15
Pomegranate peel powder	1727.42, 1616.54	Pomegranate peel powder	1614, ref. 16
C-N complex reaction	1364.39	C-N complex reaction	1350.64, ref. 11

Samples	**Q**	**D**	**Rp MΩ**	**Rs MΩ**	**Z MΩ**	**Cp pF**	**Cs pF**	**Lp kH**	**Ls kH**
75µm PP.	1.07	0.847	33.32	36.3	71.95	5.8	4.9	7.4	3.038
212 µm PP.	1.24	0.912	28.8	22.6	73.6	6.9	8.9	7.42	2.382
300 µm PP.	1.07	1.01	788.2	-------	-------	0.2	0.3		
600 µm PP.	2.07	0.162	3278	-------	-------	0.3	0.3		
< 600 µm PP.	3.82	0.298	2673	--------	-------	0.2	0.3		
ε′	**ε″**	**Gs S**	**σac S m^{-1}**	**σdc S m^{-1}**	**σt S m^{-1}**	**Xcs MΩ**	**XL MΩ**	**ϕc**	**ϕL**
$9.06*10^2$	$10^3*2.03$	$10^{-9}*2.768$	$10^{-4}*1.132$	$10^{-4}*1.087$	$10^{-6}*4.532$	32.497	19.078	-69.9	68.0
$1.46*10^2$	$10^3*1.17$	$4.46*10^{-9}$	$6.5*10^{-5}$	$6.00*10^{-5}$	$6.65*10^{-4}$	17.891	14.958	-88.7	82.6
$3.6*10^2$	$10^2*2.44$	$8.81*10^{-9}$	$1.35*10^{-5}$	$10^{-4}*8.58$	$10^{-4}*8.71$	530	----	-84.2	-------
16.301	2.639	$4.97*10^{-11}$	$1.46*10^{-7}$	$12.2*10^{-8}$	$2.39*10^{-8}$	530	----	-80.7	-------
$3.99*10^2$	$10^2*1.18$	$10^{-9}*1.22$	$6.60*10^{-6}$	$0.78*10^{-5}$	$1.43*10^{-5}$	530	----	-76.2	-------

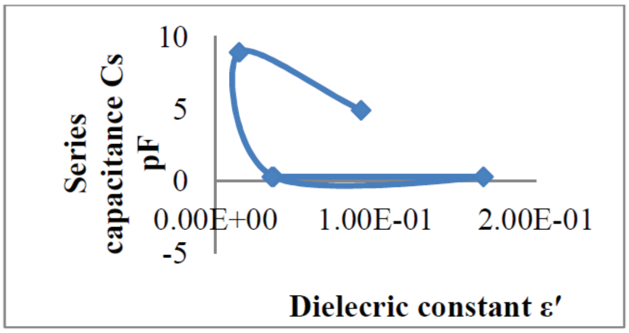

Fig. (5): the relation between the dielectric constant ε′ and Series capacitance Cs

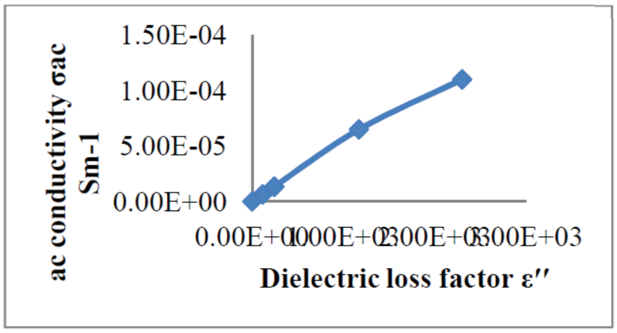

Fig. (6): the dependant of ac conductivity σac on the dielectric loss ε′′ factors ε′′

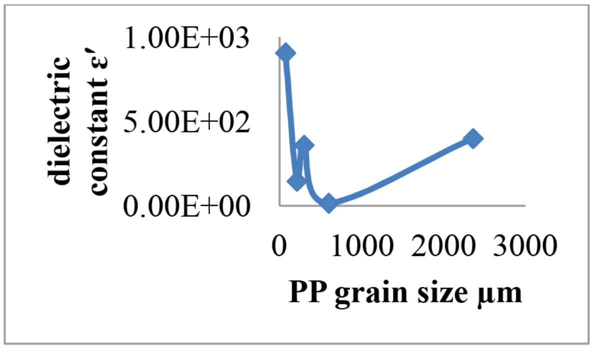

Fig. (7): the dependant of dielectric constant ε′ on PP grain size µm

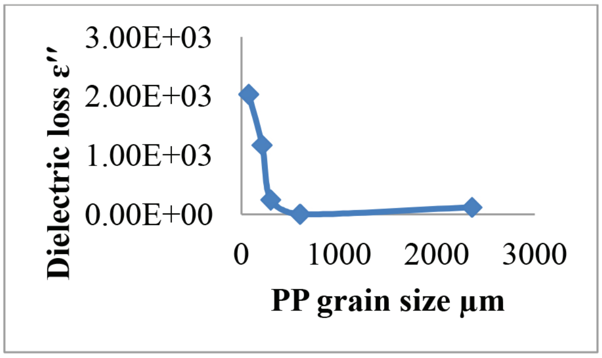

Fig. (8): the dependant of dielectric loss ε′′ on PP grain size µm

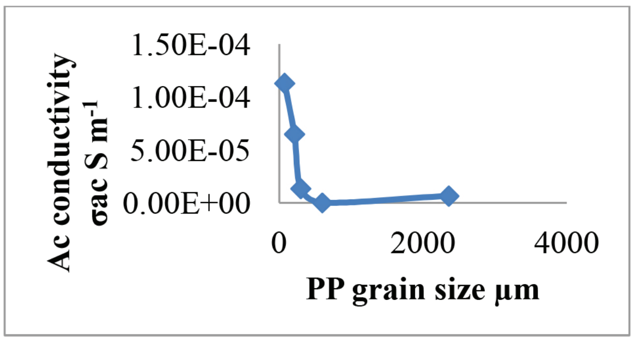

Fig. (9): the variation of AC conductivity σac S m^{-1} with PP grain size µm

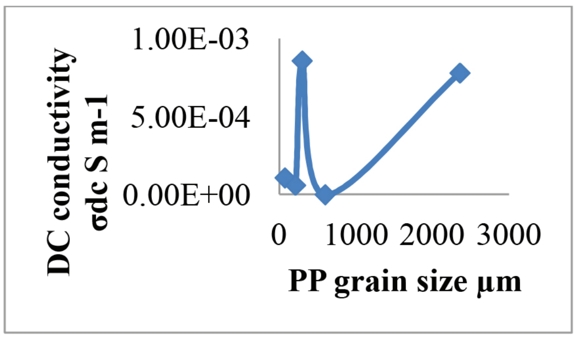

Fig. (10): the variation of Dc conductivity σdc S m^{-1} with PP grain size µm

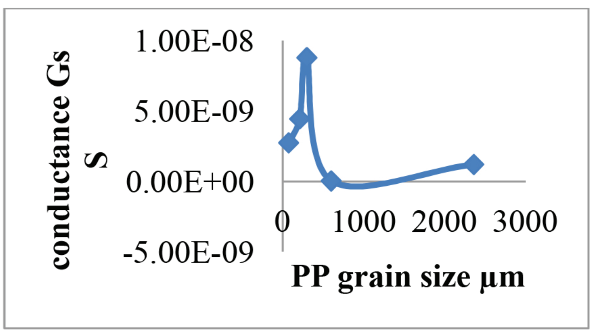

Fig. (11): Variation of conductance Gs S with PP grain size µm

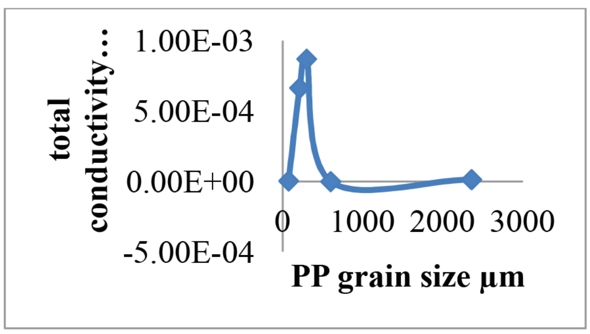

Fig. (12): Dependant of total conductivity σt S m^{-1}on PP grain size µm

5. Conclusions:

1- Decrease in the dielectric loss factor is due to the dielectric material changes polarity and in specimen (4) is due to increase particle size of PP. to 600 µm.

2- The volume of capacitor depends on the dielectric material that was chosen.

3- Capacitors are used for a wide variety of purposes and made of different materials and in different styles. They will consider three board types, that is, capacitors made for ac, dc and pulse applications. ac case is the most general since ac capacitors will work (or at least survive) in dc and pulse applications and the reverse may not be true.

4- Losses in ac capacitor one is due to a conduction loss represent the actual freightage flow in the dielectric and the other is a dielectric loss due to movement or rotation of the atoms or molecules in an alternating electric field.

5- Dielectric loss refers to the energy that is lost to heating of an object that is made of dielectric material if a variable voltage is applied to it. This loss happen because as the material changes polarization 6- Ideal capacitor is a purely reactive device, containing absolutely zero resistive (power dissipation) effects.

7- Dependent frequency ac conductivity can be calculated from the equation and.

8- Composites, the wonder materials are becoming an essential part of today's materials due to the advantages such as low weight, corrosion resistance, high fatigue strength and faster assembly. They are extensively used as materials in making aircraft structure, electronic packaging to medical equipment and space in extensive composite polymers with an appropriate weight, appropriate electric conductivity and/or appropriate impact value for use with practical articles.

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