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Study of the electrical and thermal Properties of Polyester-foliated Bentonite Composite

دراسة الخواص الكهربائية والحرارية لمتراكب بولي استر- بنتونايت

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Abstract:

In this research , effect of addition the filler material(bentonite) on electrical and thermal conductivity of matrix material(polyester resin) has been studied , the powder was prepared with a granular size less than (75µm) and was calcinated to three degrees of heat (200,400,600 ^oC) and was added to the matrix material after it was formed , Polyvinyl alcohol (PVA) was used as a binder material to study the properties of this material and study the effect of the percentage of filler, temperature and frequency in the value of electrical insulation , the results show increased the electrical conductivity of the composite by increasing the percentage of the filler and frequency of the electric field , also thermal conductivity was increased the temperature and decrease with increasing of weight fraction for the filler .

الخلاصة :

تم في هذا البحث دراسة تأثير اضافة المادة المالئة (البنتونايت) على التوصيلية الكهربائية والحرارية للمادة الاساس (راتنج البولي استر) ، حيث تم تهيئة مسحوق المادة المالئة بحجم حبيبي اقل من(75 µm) وحمصت الى ثلاث درجات حرارية (200,400,600°C) وأضيفت للمادة الاساس بعد تهيئتها واستخدمت مادة كحول البولي فاينيل (PVA) كماده رابطه لدراسة الخصائص لهذه المادة ودراسة تأثير كل من نسبة المالئ ودرجة الحرارة والتردد في قيمة ثابت العزل الكهربائي ، حيث ازدادت التوصيلية الكهربائية للمتراكب بزيادة نسبة المالىء وتردد المجال الكهربائي كذلك ازدادت التوصيلية الحرارية بزيادة درجة الحرارة وانخفضت مع زيادة النسبة الوزنية للمالىء.

Introduction :

Due to the fact that the composite materials have certain characteristics that are suitable for many industrial applications, they have a distinguished place between the various engineering materials. The composite materials combine the properties of two or more substances that exceed the disadvantages of each material. In addition, they have the possibility of controlling their properties, Its constituent materials or through its design and manufacturing methods

Polymeric composite materials are of the oldest materials, and reinforced polymeric materials are characterized by different types of ceramic and metal granules with their extensive uses, which took the bulk of previous research .

The use of polymer in any technological field requires the study of its properties related to these uses. Knowing and understanding physical properties with the chemical composition of polymers can make many improvements to polymers by chemical or technological methods and thus reflect the elimination of inhibitors in polymers[1].

As a result of scientific advances in all areas, the need to use polymeric materials with specific properties that can not be obtained from a single polymer has emerged, so attempts have been made to mix two or more polymers and obtain a polymer mixture with the desired industrial specifications .Polymer blends are defined as a mixture of two or more polymers that are physically synthesized. The resulting mixture has common properties among the basic compounds of the mixture. This depends on the quality of the polymers and the mixing method

Polymers have been used in many electrical and mechanical applications and have often been used as insulating materials for having good electrical properties such as volume resistivity, volume conductivity, impedance and dielectric loss. These properties have been subject to many studies for their importance in various industrial fields. The electrical properties of insulation materials used in many devices and in different sizes depend on the type of use and these characteristics are affected by many factors including frequency, temperature, time, voltages used, additives and others .

The wide use of polymers in the technological fields made it particularly important as this importance emerged from the fact that polymers generally show different changes in their electrical behavior and inertia when they are vaccinated or mixed, although there are still some problems of engineering applications of polymers such as lack of stiffness and lack of strength compared with the metals and used there are several ways to improve these defects, including fiber reinforcement. These fibers are either continuous or random, and can be reinforced by particle or flakes, or as laminates so as to improve polymer properties [2].

The current research aims to use PVA-treated bentonite clay to strengthen the unsaturated polyester resin to study the change in the ratio of additives from the treated coatings to its electrical properties (electrical conductivity, loss factor, insulation constant , thermal conductivity) .

Theoretical part :

The insulation materials are different from conductive and semi-conductive materials where the conduction package is almost free of pure electrons and may also contain free electrons but these electrons may be located within conductive islands separated from each other by dielectric zones that are almost free of electrons. This is why an electric current can not be applied when an electric field is placed because the movement of electrons can not exceed a few particles of matter. Despite the limited movement of electrons and the non-flow of the material of this material, this movement is very important in determining the properties of insulation in the material .

When the voltage applied to a dielectric material changes over time, a variable current will be created. So this insulating material can be represented by an electrical circuit called a resistor. The resistance is a result of resistance and expansion, which are linked in parallel to the nature of that substance [3].

The molecules of the insulator consist of positive and negative charges, the center of negative charges is often applied to the center of the positive charge of these molecules. However, when these particles fall under the influence of an external electric field, the positive charges will drift toward the field, while the negative charges of these molecules are displaced in the opposite direction,the positive charge center is no longer applicable to the center of the negative charge, but is separated by a small distance, causing created of electrical dipoles, the molecule is then polarized and acquired a dipole moment[4] .

The molecules of the insulating material that are characterized as such are called non-polar molecules. However, there are molecules of other insulating materials in which the center of the negative charge is permanently separated from the positive charge center as these molecules have a permanent dipole moment, these particles are called polarized and have constant momentum, but the directions of these atoms are random and if placed under the influence of an alternating external electric field, they rotate these diodes in the direction of the field.

The impedance can be represented by the following equation .

$$Z = \frac{R}{\sqrt{1 + R^2W^2C^2}} \dots\dots\dots (1)$$

Z: is the impedance of the circuit (RC) in parallel .

When attaching a resistor with a capacity in parallel, the value of the total current can be represented by the following equation [4]

$I = I_P + J I_q$ .... (2)
Where: I_P current in the resistance
I_q current in the capacity
The alternating current (I) generated by the diffusion of alternating voltage (V) across capacitance (C) precedes the voltages at an angle of (90 °) and the equation shows that [4]
$Iq = JWCV$ .... (3)
Suppose that the capacity range consists of two panels with area A separated by a distance d and between the two panels thick insulator (ε) so the value of the capacity [4]

$$C = \frac{\varepsilon_o \varepsilon_r A}{d} \quad \ldots\ldots\ldots\ldots (4)$$

Where($\varepsilon_r = \varepsilon / \varepsilon_o$) is the relative square and represents the medium / vacuum tolerance
The relationship between the insulation constant ε, Dielectric loss ε and the impedance can be represented by the relationship

$$\varepsilon = \frac{Z_C}{2\pi f C_o (Z_R^2 + Z_C^2)} \ldots\ldots\ldots\ldots\ldots(5)$$

$$\varepsilon'' = \frac{Z_R}{2\pi f C_o (Z_R^2 + Z_C^2)} \ldots\ldots\ldots\ldots\ldots(6)$$

Where: Z_R is the true axis of the impedance
Z_{im} is the imaginary axis for impedance
It can be written as follows :

$Z_R = Z \cos \varphi$
$Z_{im} = Z \sin \varphi$

The alternating conductivity in the dielectric constant is a measure of the heat generated by the rotation of the dipoles in their positions and depends on the frequency value
$\sigma = w\, \varepsilon_o\, \varepsilon$................. (7)
Low frequencies consist of two vehicles [5]
$\sigma = \sigma_{a.c} + \sigma_{d.c}$ .... (8)
Where: $\sigma_{d.c}$ DC connection does not change with frequency.
. $\sigma_{a.c}$ AC connection which expresses the loss in the insulator
The friction and thermal irritation affect the impedance and obstruction of the dipoles and the rotation with the effect of field and the energy needed to maintain this rotation ,the loss of power is dependent on the frequency of the electric field, but the loss may be smaller at high frequency because the field is reflected very quickly, completely with the domain electrical dipole with the field ,produce of the loss of the insulating material from the absorption of electrical energy (internal friction of the dipole) and the leakage currents during the material, leakage occurs through the electrical conduction which is usually neglected except at high temperature .

The loss of absorption under the influence of the electric field alternates to the dissipation of electrical energy as the heat of the material heated, and the real insulating material always cause some of the loss of electrical energy, but it is often small, and this loss is measured by phase difference between the angle of phase and angle (90) for capacity .

The loss factor is affected by the frequency of the electric field. At low frequencies, the dipoles have sufficient time to fully orient themselves in parallel to the instantaneous direction of the electric field, the dipole rotation is met with resistance, namely the internal friction of the material and the thermal irritation of the particles. As the frequencies increase, the rotation becomes faster and increases the lost energy, at high frequency the electric field is reflected very quickly, the diodes can not be fully aligned with the field, and as a result, the dipole oscillations are reduced and the dielectric constant value decreases [5]

Experimental part :

The materials used in this study are :

1) Matrix Material :

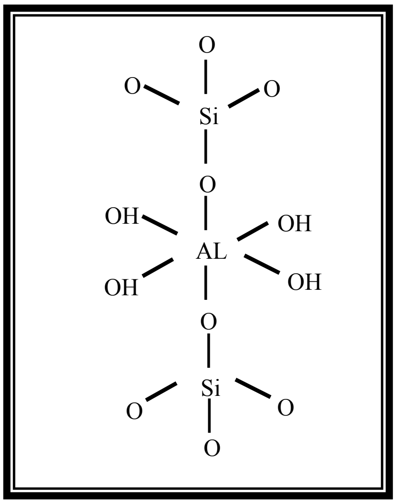
The matrix material used is polyester resin, which is a type of heat-hardener resin and has good thermal properties. It can withstand high temperature up to (260 °C), but it suffers from automatic disintegration at a temperature of (300 °C), Even without oxygen, it also has an electrical resistivity Excellent and chemical resistance to solvents, acids, salts, anti-wear and environmental effects in addition to being low cost and adding polyester to glass fiber for the manufacture of mold structures and components of aircraft bodies, automobiles and other industries [6]

Filler Material : 2)

Local Iraqi materials (bentonite Al-sufrra) were selected as a filler to form the composite and table (1). The chemical analysis of this material is illustrated with the diagram [7]:-

Table (1) The chemical Analysis of the Iraqi bentonite

SiO_2	56.77	K_2O	0.6
Al_2O_3	15.67	P_2O_5	0.65
Fe_2O_3	5.12	SO_3	0.59
CaO	4.48	CL	0.57
MgO	3.42	L.O.I	0.49
Na_2O	1.11	C	0.56



Figure(1) Diagram for bentonite structure (7)

$$A = \frac{V_2}{V_1} = \frac{-R_f}{Z} \quad \text{.........(9)}$$

$$\frac{Log\, Z}{R_f} = Log(\frac{V_2}{V_1}) \quad \text{..........(10)}$$

$$Log\left(\frac{V_2}{V_1}\right) = \frac{(B/A)dB}{20} \quad \text{...........(11)}$$

Where (B / A) dB is the ratio between the output signal to the input in decibels and measured by the phase gain device. Thus, equation (10) can be written as follows :

$Z = R_f\, 10^{(B/A)/20}$ .... (12)

The second operational amplifier is connected as a non-converting resistor with R2 and R1, which are tied in parallel. Thus, the gain for this amplifier (A)

$$A = \frac{V_2}{V_1} = \frac{(R_1 + R_2)}{R_1} \quad \text{..........(13)}$$

This amplifier is linked to a special case such that R1 >> R2. Therefore, equation (12) can be expressed as follows [10]:

V2 /V1 = 1

Therefore :

V2 = V1

Electrical conductivity measurement :

The following equation is used to calculate electrical conductivity:-

$$\sigma = \frac{1}{\rho} = \frac{L}{RA} \quad \text{............(14)}$$

Where :

σ = Electrical conductivity(ohm.cm)$^{-1}$

ρ = resistivity

R = Volumetric resistance (ohm)

A = area affecting

L = average thickness of the sample(cm)

Measurement of thermal conductivity :

Fourier Law can be used to calculate thermal conductivity. This law states that

$$-K = \frac{Q}{A(\Delta T/\Delta X)} \quad \text{............(15)}$$

Where :

K = thermal conductivity coefficient (W/m.°C)

Q = amount of heat passing by the unit of time(W)

A = space flow rate of heat(m^2)

$\Delta T / \Delta X$ = Thermal gradient relative to the distance(°C/m)

Results and discussion :

Fig. (2) shows the electrical conductivity of a poly unsaturated polystyrene-bentonite composite with several degrees of heat as a function of frequency. The electrical conductivity is the result of the difference between the conductivity at the liquid surface and the conductivity of the internal particles of the fluid. The largest distributor of electrical connections increases at the surface of the mixture. On the other hand, the difference between the conductivity in the range of the double layers of the total composite is equal to the electrical conductivity of the surface

As for the temperature of incineration within the thermal range (200-600 °C) increased the electrical conductivity of the formed sample, This is due to the fact that increasing the temperature of roasting has reduced the value of the electrical resistivity of the composite, that is, there is a close relationship between the variables of the composite and the temperature. This increases to the increase in the value of the conduction current passing through the composite and the absorbed current from the composite , leading to an increase in the conductivity which arises from the increase of the conductivity electrons in the composite material rather than the increase in the vibration of the atoms[11] .

The values of the insulation constant (ε_r) for all models prepared for this purpose were calculated at different temperatures for roasting of the filling material, As shown in Fig. (3) , the increase in the frequency of the electrolytic field has resulted in decreasing the constant isolation at high frequencies due to the fact that the molecules of the material Under the influence of an alternating external electric field will make the polarized matter particles polarized as bipolar In addition, the charge carriers accumulate and block the negative pole, and the charge of the vacuum leads to a decrease in capacitance, which in turn leads to a decrease in the constant insulation. [12]

The degree of alignment of the dipoles in the insulation materials depends on the temperature where these diodes find it difficult to rotate itself at very low temperature and when increasing the temperature, the rotation of these diodes becomes easy and this increases the value of the insulation constant for that material,as shown in fig. (4) The insulation constant increases with the temperature rise of the roasted samples by three temperature degrees (200,400,600 °C) [13]

Fig. (5) represents the thermal conductivity of the poly unsaturated polyester-bentonite composite where the conductivity begins with an increase with an increase in temperature due to the vibrations in the internal structure of the composite which increases with high temperature and decrease with increase of weight fraction for the filler material .

The reliability of the electrical conductivity of the bentonite -polyester complexes with the weighted fraction of the fill material is shown in Fig. (6) where the results indicated the increase of the conductivity with the increase of the weight fracture of the filler material for the weights (2.5-12.5%) .Where the material is placed in an electric field as a result of the electrical resistance decreases with increasing the percentage of fill (concentration of filler) because when moving an electric current during a material will be a packet connection to the material, this will

lead to the movement of the charge carriers of the particles during the base material, this concentration will increase the number of ions connected to the material. And the distance between them becomes smaller, this resistance in the composite is decrease dependent on the equation (13) and the electrical conductivity of the material increases with decreasing the resistance of the substance by increasing the concentration of the filler substance[14].

Fig. (7) shows the relationship between the insulation constant as a function of the concentration of filler to the weight ratios ranging between (2.5-12.5%) at frequency (1KHz) and density of material increase with increasing the filler material and increase for the value of insulation constant , in addition to increasing the value of the insulation increases the loss of insulation due to the increase of the losses of polarization and electrical conductivity[15] .

Thus, the material gave the properties of good electrical insulation used widely in the electronic diagram and in the molding of electric machines (pour) and many kinds of other electrical requirements.

Conclusions:

1-This study has shown that electrical conductivity varies according to the frequency of the electric field, the percentage of filling as follows :

a) The electrical conductivity of the composite increased by increasing the frequency of the electric field

b) Increasing the electrical conductivity of the composite by increasing the percentage of the filler

2-This study has shown that the insulation constant varies according to the frequency of the electric field, temperature, and fill ratio as follows :

a) The insulation constant of the composite decreases by increasing the frequency of the electric field

b) The insulation constant increases with the temperature rise due to the fact that at low temperature polar diodes are in a state of dormancy and therefore a degree of freedom of rotation when the temperature rises but with the continuation of the increase in temperature, the degree of temperature in order of dipoles decrease because thermal vibration resulting in a decrease in the amount of constant insulation

c) It was noted that the value of the electric insulation constant increases with the increase of the percentage of the filler

3-Increasing the thermal conductivity of the unsaturated polyester-bentonite composite by increasing the temperature and decrease with increasing of weight fraction for the filler .

4- increase in loss factor with increasing of frequency for unsaturated polyester-bentonite composite.

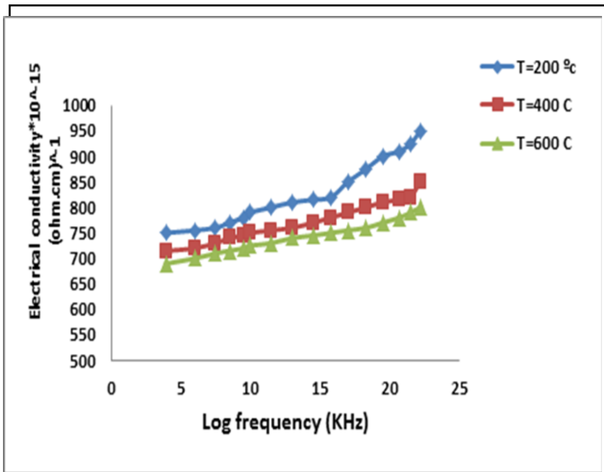


Fig (2) Electrical conductivity as a function of frequency

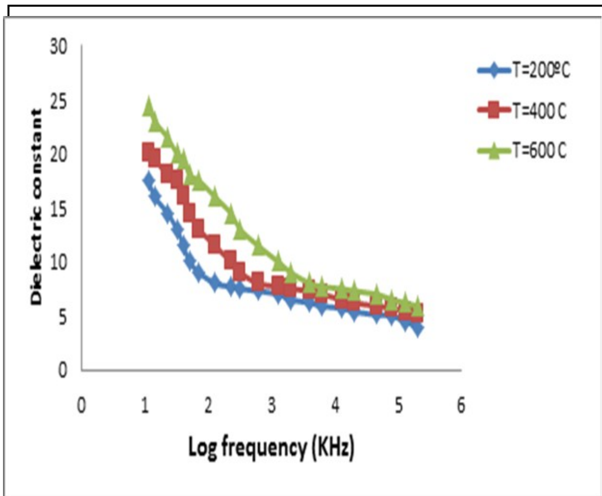
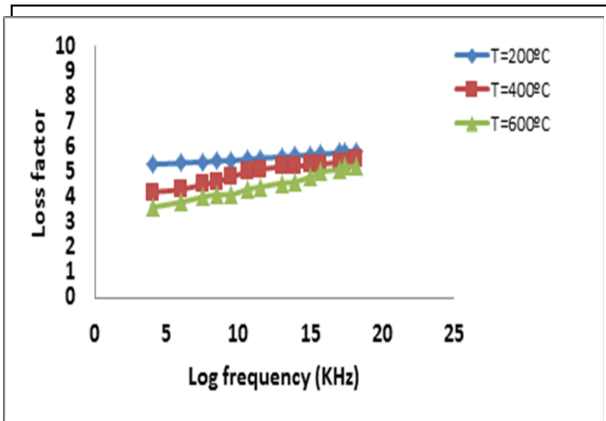


Fig (3) Dielectric constant as a function of frequency



Fig(4) Loss factor as a function of frequency

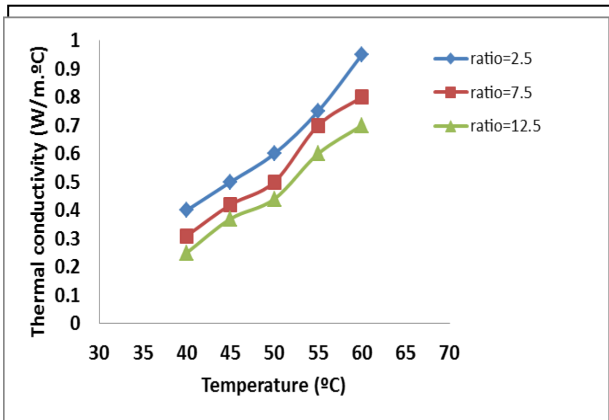


Fig (5) Thermal conductivity as a function of

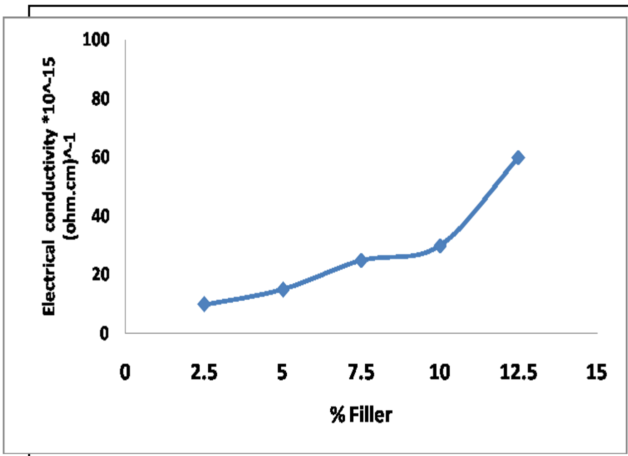


Fig (6) Electrical conductivity as a function of weight fraction

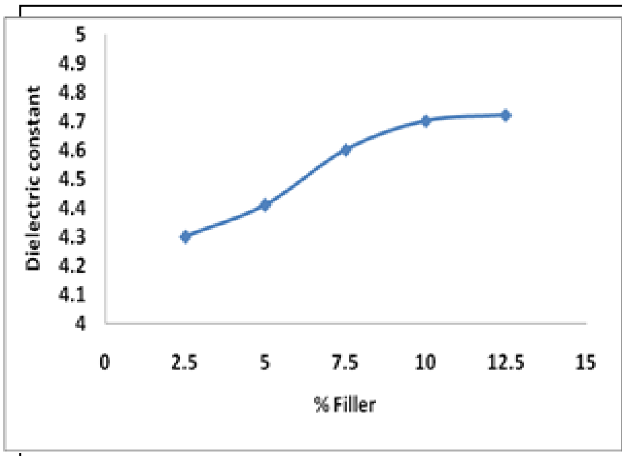


Fig (7) Dielectric constant as a function of weight fraction

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