

## **The effect of temperature and chemical solutions on the electrical properties of hybrid composites**

### **دراسة تأثير درجات الحرارة والمحاليل الكيميائية على الخصائص الكهربائية لمواد متراكبة هجينة**

Dr. Ali Hassan.R.H Al-Azzawi

University of Kufa /College of Science / Physics Department  
Materials Science

#### **Abstract**

In this work a hybrid composite materials were prepared containing matrix of polymer (Epoxy) reinforced by different reinforcing materials (Alumina powder + Carbon black powder + asbestos fiber) with two values of volume fraction (30, 40) %.

The hybrid composite materials prepared are:

- $H_1 = EP + Al_2O_3 + As$  (30) %
- $H_2 = EP + CB + As$  (30) %
- $H_3 = EP + Al_2O_3 + CB + As$  (30) %
- $H_4 = EP + Al_2O_3 + As$  (40) %
- $H_5 = EP + CB + As$  (40) %
- $H_6 = EP + Al_2O_3 + CB + As$  (40) %

All samples related to electrical tests were prepared by hand lay up process.

Electrical tests were carried out in order to determine the dielectric constant at different temperatures and different chemical solutions at different immersion times.

Dielectric constant values decrease with an increase of temperature and the immersion times for all the samples.

#### **الخلاصة**

تم في هذا البحث تحضير مواد متراكبة هجينة مكونة من مادة أساس بوليميرية هي عبارة عن راتنجات الايبوكسي ومقواة بأنواع مختلفة من مواد التقوية الليفية ( الالومينا + اسود الكربون ) بالإضافة إلى ألياف الاسبستوس العشوائية وبنسب ( 30% , 40% )

المواد المتراكبة الهجينة التي تم تحضيرها هي :

- عينات مدعمة بالالومينا والاسبستوس وبكسر حجمي 30% ورمزت ( $H_1$ ) .
- عينات مدعمة باسود الكربون والاسبستوس وبكسر حجمي 30% ورمزت ( $H_2$ ) .
- عينات مدعمة بالالومينا، اسود الكربون والاسبستوس وبكسر حجمي 30% ورمزت ( $H_3$ ) .
- عينات مدعمة بالالومينا والاسبستوس وبكسر حجمي 40% ورمزت ( $H_4$ ) .
- عينات مدعمة باسود الكربون والاسبستوس وبكسر حجمي 40% ورمزت ( $H_5$ ) .
- عينات مدعمة بالالومينا، اسود الكربون والاسبستوس وبكسر حجمي 40% ورمزت ( $H_6$ ) .

تم استخدام طريقة القولية اليدوية في تحضير العينات المستخدمة في الاختبار.

الاختبارات الكهربائية والتي تضمنت حساب قيمة ثابت العزل الكهربائي في درجات حرارية مختلفة في محاليل كيميائية مختلفة وفق أزمان غمر مختلفة.

وأثبتت النتائج ان قيم ثابت العزل قلت مع ارتفاع درجة الحرارة وكذلك مع الزيادة في فترة الغمر في المحاليل الكيميائية المختلفة.

**Introduction**

**Dielectric Constant:**

When the dielectric material is placed in electric field, it can be polarized and the capacitance is increased as the dielectric materials placed between the capacitor plates. When electric field is applied across the two parallel plates of the capacitor, the charge accumulated on the each plate is Q, which is directly proportional to the applied voltage across the two plates. It's expressed as [1]:

$$Q = CV \dots\dots\dots (1)$$

where ,C is the capacitance of the capacitor, V is the applied voltage, when the area of the plates A and the distance of the separation between plates is d,and the capacitance is given by:

$$C = \epsilon_0 (A / d) \dots\dots\dots (2)$$

Where:  $\epsilon_0$  is the permittivity of the vacuum ( $8.85 \times 10^{-12}$  F/m). When dielectric materials of permittivity  $\epsilon_m$  are placed in between the two plates, the capacitance becomes:

$$c = \epsilon_m (A / d) = \epsilon \epsilon_0 (A / d) \dots\dots\dots (3)$$

Where:  $\epsilon = \epsilon_m / \epsilon_0$  are the relative permittivity of the medium, it is also called the dielectric constant of the medium.

Most plastics are dielectrics or insulators (poor conductors of electricity) and resist the flow of a current. This is one of the most useful properties of plastics, used as wire coatings, switches and other electrical and electronic products. Despite this, dielectric breakdown can occur at sufficiently high voltages.

Plastics can be classified as 'polar' or 'non-polar' to describe their variations in behavior. The polar plastics do not have a fully covalent bond and there is a slight imbalance in the electronic charge of the molecule. In polar plastics, dipoles are created by an imbalance in the distribution of electrons and in the presence of an electric field the dipoles will attempt to move to align with the field. This will create 'dipole polarization' of the material and because movement of the dipoles is involved there is a time element to the movement. Examples of polar plastics are PMMA, PVC; these materials tend to be only moderately good as insulators.

The non-polar plastics are truly covalent and generally have symmetrical molecules. In these materials there are no polar dipoles present and the application of an electric field does not try to align any dipoles. The electric field does, however, move the electrons slightly in the direction of the electric field to create 'electron polarization', in this case the only movement is that of electrons and this is effectively instantaneous. Examples of non-polar plastics are PTFE (and many other Fluor polymers), PE, PP and PS and these materials tend to have high sensitivities and low dielectric constants.

The dielectric constant is a measure of the influence of a particular dielectric on the capacitance of a condenser. It measures how well a material separates the plates in a capacitor and is defined as the ratio of the capacitance of a set of electrodes with the dielectric material between them to the capacitance of the same electrodes with a vacuum between them. The dielectric constant for a polar plastics the alternating current frequency is an important factor because of the time taken to align the polar dipoles. At very low frequencies the dipoles have sufficient time to align with the field before it changes direction and the dielectric constant is high. At very high frequencies the dipoles do not have time to align before the field changes direction and the dielectric constant is lower. At intermediate frequencies the dipoles move but have not completed their movement before the field changes direction and they must realign with the changed field [2].

Polar plastics at low frequencies (60 Hz) generally have dielectric constants of between 3 and 9 and at high frequencies ( $10^6$  Hz) generally have dielectric constants of between 3 and 5 .

For non-polar plastics the dielectric constant is independent of the alternating current frequency because the electron polarization is effectively instantaneous. Non-polar plastics always have dielectric constants of less than 3 [3].

## **Experimental part**

### **Epoxy Resin (EP):**

Epoxy resin (type Conbextra EP10) was used in this research; it is a liquid with moderate viscosity and capable to be converted to solid state by adding the solution (Metaphenylene Diamine, MPDA) as hardener. This hardener is a light liquid with yellowish color, the ratio of this hardener to the epoxy is about (1:3). This resin also has applicable technical specification such as, high adhesion to fibers and low shrinkage during solidification.

### **Asbestos :**

Chrysotile known as white asbestos was used, Chrysotile is hydrated silicates are found in certain types of rocks, known for its snake-like, curly appearance, soft, flexible, strong, durable, and resistant to heat and fire, its density is  $2.4 \text{ g/cm}^3$  [4] .

### **Alumina powder:**

A white powder  $\text{Al}_2\text{O}_3$  of density  $(3.89) \text{ g/cm}^3$  and of particle size less than  $250 \mu$  was used .It is useful at high temperature and has a high dielectric strength, excellent electrical resistance [5].

### **Preparation methods for hybrids composites materials:**

1 - Epoxy resin mixed with (33) % hardener.

2 – The epoxy in the step (1) reinforced by different types of particles ( $\text{Al}_2\text{O}_3$ , Carbon black CB) and asbestos fibers with two values of volume fraction (30, 40) %.

3 – Six hybrids composites materials prepared:

**H<sub>1</sub> = EP + Al<sub>2</sub>O<sub>3</sub> + As (30) %**

**H<sub>2</sub> = EP + CB + As (30) %**

**H<sub>3</sub> = EP + Al<sub>2</sub>O<sub>3</sub> + CB + As (30) %**

**H<sub>4</sub> = EP + Al<sub>2</sub>O<sub>3</sub> + As (40) %**

**H<sub>5</sub> = EP + CB + As (40) %**

**H<sub>6</sub> = EP + Al<sub>2</sub>O<sub>3</sub> + CB + As (40) %**

4 – For all cases, this was calculated by applying the relation ship:

$$\Phi = \frac{1}{1 + ((1 - \psi) / \psi) \times (\rho_f / \rho_m)} \dots (4)$$

Where  $\Phi$ ,  $\psi$  are the volume and weight fractions of the reinforcements respectively.

$\rho_f$ ,  $\rho_m$  are the density of reinforcements and matrix respectively.

The density of the prepared hybrids was determined from the equation:

$$\rho_m = x_1\rho_1 + x_2\rho_2 \dots \dots \dots (\text{rule of mixtures})$$

Where  $\rho_m$  : the density of the matrix (polymer blend).

$\rho_1$ ,  $\rho_2$  : the density of the first polymer and the second respectively.

$x_1$ ,  $x_2$  : the percentages of the first polymer and the second respectively.

5 – The metal mould was cleaned with dimensions  $(25 \times 25 \times 3)$  cm used for casting the sheet of hybrids composite material.

6 – The fablon was fixed on the inner mould faces before casting to facilitate the releasing of casting hybrids and having smooth faces.

7 – Cover plate, with identical dimension of the mould face, was used to apply appropriate load on the casting sheet for releasing voids, bubbles, to have a specified thickness and smooth face.

8 – Casting sheet was left inside the mould at room temperature about (24h).

9 – After solidification, the casting sheets were released from the mould and placed in an oven with  $(50^\circ\text{C}$  setting temperature) for (3h) to post cure the considered sheets.

10 –The testing samples were obtained by cutting the casting sheets according to the related ASTM. All properties were measured at different temperatures and different solutions.

## Dielectric Constant Test Instrument:

LRC circuit manufactured by (LEYBOLDHARRIS/Germany). Dielectric constant instrument is utilized to measure the dielectric constant values of polymer blends and their composites. This instrument represents an electric circuit (in series connection) which consists of capacitor, coil, resistor, and ammeter and frequency generator. After locating the sample between the capacitor's plates, the frequency of the power supplier is alternated till maximum current value is gained. At this maximum value, the frequency is recorded which represents the resonance frequency value ( $F_r$ ). After that, the ( $F_r$ ) value is determined without the presence of the sample (i.e. with existence of the air only). The capacity of the capacitor can be calculated from the relationship:-frequency used (100 MHZ).

$$C = (4 \pi^2 F_r^2 r L)^{-1} \quad \dots (5)$$

where: L is the inductance of the coil; Dielectric constant ( $\epsilon_r$ ) can be calculated from the equation:

$$\epsilon_r = C/C_0 \quad \dots (6)$$

Where:

$C_0$ : the capacity of the capacitor with the existence of air while, C: the capacity of the capacitor with the presence of the sample.

## Result and discussion

### Temperature effect

Table (1) represents the changes in (Dielectric Constant) and temperature for hybrids composites materials. The following results can be concluded:

1 - The values of (Dielectric Constant) decrease with increasing temperature.

2 - Specimens that contain both (  $Al_2O_3 + CB$  ) give (Dielectric Constant) higher than the Specimens that contain only (  $Al_2O_3$  ) or Specimens that contain only (CB) .

$H_3 > H_1$  ,  $H_3 > H_2$  ,  $H_6 > H_4$  ,  $H_6 > H_5$  .

3 - The values of (Dielectric Constant) decrease with increasing the volume fraction.

$H_3 > H_6$  ,  $H_2 > H_5$  ,  $H_1 > H_4$  .

4- Specimens that contains only (CB) give (Dielectric Constant) higher than the Dielectric Constant of the Specimens that contain only (  $Al_2O_3$  ).

$H_2 > H_1$  ,  $H_5 > H_4$  .

From table (1) one can find the hybrid ( $H_3$ ) which gives high values of ( $\epsilon_r$ ), ( $H_4$ ) gives low values of ( $\epsilon_r$ ). It is concluded that increasing ( $V_f$ ) leads to an increase in ( $\epsilon_r$ ) due to the porosity composition of the ceramic particles which tend to give high thermal insulation and low electrical resistance.

The dispersion of the particles leads to the formation of gaps between the coarse grain sizes leading to high electrical resistance. But when the electrical conductivity increases due to the agglomeration of particles, this will reduce the gaps between the particles and increase the values of ( $\epsilon_r$ ) [6].

### Chemical Solutions effect:

Tables (2) to (7) represent the changes in (Dielectric Constant) and the immersion times in different Chemical Solutions for hybrids composites materials. From these figures one can conclude the following results:

1 - The values of Dielectric Constant decrease with increasing the immersion times in different Chemical Solutions.

2 -  $H_1(KOH) > H_1(K_2CO_3) > H_1(H_2CO_3)$

3 -  $H_2(KOH) > H_2(H_2CO_3) > H_2(K_2CO_3)$

4 -  $H_3(H_2CO_3) > H_3(KOH) > H_3(K_2CO_3)$

5 -  $H_4(H_2CO_3) > H_4(KOH) > H_4(K_2CO_3)$

6 -  $H_5(KOH) > H_5(H_2CO_3) > H_5(K_2CO_3)$

7 -  $H_6(Na_2CO_3) > H_6(KOH) > H_6(H_2CO_3)$

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The change in the values of dielectric constant in the different chemical solutions depends on the volume fraction and the type of reinforced materials because the chemical solutions will deploy in the interface region which will lead to a weakness in cross linking in the matrix and then will lead to breaking down these bonds and the occurrence of chemical interactions between the matrix and the solutions. This will lead to degradation of the composite; these factors will lead to a shortage in the dielectric constant, in addition to the fact that the chemical solutions represent conductor materials. Then it will increase the values of the electrical conductivity faced by shortage in the dielectric constant [7].

### Conclusions:

- 1 –The values of (Dielectric Constant) decrease with increasing temperature.
- 2 – Specimens that contain both (  $Al_2O_3$  + CB ) give (Dielectric Constant) higher than the Specimens that contain only (  $Al_2O_3$  ) or Specimens that contain only (CB) .
- 3 –The values of (Dielectric Constant) decrease with increasing the volume fraction.
- 4 – Specimens that contains only (CB) give (Dielectric Constant) higher than the Dielectric Constant of the Specimens that contain only (  $Al_2O_3$  ).
- 5 – The values of Dielectric Constant decrease with increasing the immersion times in different Chemical Solutions.

Table (1) gives the values of Dielectric Constant of different types of hybrids composites materials at different temperature.

Hybrid Composite Material	Dielectric Constant		
	Temperature (°C)		
	30	60	90
H <sub>1</sub>	3.68	3.569	3.399415
H <sub>2</sub>	4.44917	4.27526	4.03705
H <sub>3</sub>	7.256312	6.84903	6.30715
H <sub>4</sub>	3.62936	3.45416	3.245115
H <sub>5</sub>	4.06734	3.850092	3.7301
H <sub>6</sub>	6.7156	6.02429	5.44809

Table (2) gives the values of Dielectric Constant of hybrids composites materials (H<sub>1</sub>) immersed in different chemical solutions with different immersion times.

Solutions	Dielectric Constant		
	Exposure Time (Day)		
	50	100	150
H <sub>2</sub> CO <sub>3</sub>	2.82985659	2.68146	2.5865
KOH	3.29496	3.19677	3.10435
K <sub>2</sub> CO <sub>3</sub>	2.9756	2.8599	2.78417

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Table (3) gives the values of Dielectric Constant of hybrids composites materials (H<sub>2</sub>) immersed in different chemical solutions with different immersion times.

Solutions	Dielectric Constant		
	Exposure Time (Day)		
	50	100	150
H <sub>2</sub> CO <sub>3</sub>	3.42657	3.26984	3.03857
KOH	3.927136	3.756137	3.5396
K <sub>2</sub> CO <sub>3</sub>	2.91531	2.802133	2.724919

Table (4) gives the values of Dielectric Constant of hybrids composites materials (H<sub>3</sub>) immersed in different chemical solutions with different immersion times.

Solutions	Dielectric Constant		
	Exposure Time (Day)		
	50	100	150
H <sub>2</sub> CO <sub>3</sub>	5.76273	5.554025	5.11576
KOH	4.73588	4.4044807	4.137137
K <sub>2</sub> CO <sub>3</sub>	4.27526	3.9271364	3.73010085

Table (5) gives the values of Dielectric Constant of hybrids composites materials (H<sub>4</sub>) immersed in different chemical solutions with different immersion times.

Solutions	Dielectric Constant		
	Exposure Time (Day)		
	50	100	150
H <sub>2</sub> CO <sub>3</sub>	3.62936	3.4541609	3.2451121
KOH	2.82034	2.7147444	2.571506
K <sub>2</sub> CO <sub>3</sub>	2.52739	2.457529	2.41764

Table (6) gives the values of Dielectric Constant of hybrids composites materials (H<sub>5</sub>) immersed in different chemical solutions with different immersion times.

Solutions	Dielectric Constant		
	Exposure Time (Day)		
	50	100	150
H <sub>2</sub> CO <sub>3</sub>	3.1133534	2.9797	2.8425
KOH	3.660271	3.4653	3.2798
K <sub>2</sub> CO <sub>3</sub>	2.7351774	2.5955	2.45218

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Table (7) gives the values of Dielectric Constant of hybrids composites materials (H<sub>6</sub>) immersed in different chemical solutions with different immersion times.

Solutions	Dielectric Constant		
	Exposure Time (Day)		
	50	100	150
H <sub>2</sub> CO <sub>3</sub>	3.469804	3.250031	3.034286
KOH	4.160901	3.85422	3.4698
K <sub>2</sub> CO <sub>3</sub>	5.252766	4.5637	4.314134

### References

- 1- Definitions of Terms Related to Polymer Blends, Composites, and Multiphase Polymeric Materials. W. J. Work et al. Pure Applied Chemistry, Vol. 76, No. 11, PP. 1985-2007.
- 2- Q.Q.Yong & J.Z.Liang , “ Journal of Reinforced Plastic and Composites”, vol.28,No.3,PP.295-304,(2009).
- 3- Ghosh, Premamoy "Polymer Science and Technology; Plastics, Rubbers, Blends and Composites", 2nd.Edition, Tata McGraw Hill publishing Company Ltd., New Delhi.2008
- 4- Titanium oxide, internet article, Wikipedia, 2009.
- 5- Mechanical Bonding Article Published in the WEB [http:// en. Wikipedia. Org/wiki/ Mechanical Bonding](http://en.wikipedia.org/wiki/Mechanical_Bonding) (Last visit 11-6-2008)
- 6- A.H.AL-Azzawi,"The effect of some solutions on the physical properties of particulated composites" PhD thesis, Applied science department, University of Technology, 2008.
- 7- Hafadh S. " Study of Some Physical and Mechanical Properties of Binary Polymeric Blends and Its Composites Under Different Medias" PhD thesis, Applied science department, University of Technology, 2007.