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Effect of Uv Radiation on Dielectric Constant And Thermal Conductivity In Epoxy Phenol Blends

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Abstract

Epoxy-phenol system were prepared and studied before and after reinforcing with glass fibers (woven roven 0^o-90^o direction) with volume fraction (γ = 48%). The samples irradiated with uv radiation with wave length (λ= 320 nm), irradiation energy (1.5 watt/ cm^2) for 50 hours. The dielectric constant and thermal conductivity measured for all samples before and after irradiation with uv radiation. The results showed that the increasing percentage of phenolic resin in the blends decreasing the dielectric constant and thermal conductivity of all samples before and after irradiation with uv radiation. While the results before irradiation showed the effect of glass fibers in increasing the dielectric constant and thermal conductivity. Finally the results showed that the dielectric constant decreased, thermal conductivity increased for all samples after irradiation with uv radiation.

تأثير الاشعة فوق البنفسجية على ثابت العزل والتوصيلية الحرارية لخلائط بوليمريه من الايبوكسي والفينول

الخلاصة

تم في هذا البحث تحضير خلائط بوليمرية من الايبوكسي والفينول بدون تدعيم ومدعمة بالالياف الزجاجية المتعامدة الاتجاه (0^o-90^o) بكسر حجمي مقداره .(v_f = 48%) . تم تشعيع العينات كافة بالاشعة فوق البنفسجية بطول موجي مقداره (320 nm) وطاقة اشعاع 1.5 watt/ cm^2 لمدة 50 ساعة. تم قياس ثابت العزل والتوصيلية الحرارية للعينات قبل وبعد التشعيع بالاشعة فوق البنفسجية. أظهرت النتائج ان زيادة نسبة الفينول في الخليط البوليمري يقلل من ثابت العزل والتوصيلية الحرارية للعينات كافة قبل وبعد التشعيع. كما أظهرت النتائج تاثير الالياف الزجاجية في زيادة ثابت العزل والتوصيلية الحرارية للنماذج قيل التشعيع أخيرا أظهرت النتائج بعد التشعيع انخفاض ثابت العزل و ازدياد التوصيلية الحرارية للعينات.

Introduction

Polymer blends become very important subject for scientific investigation in recent years, because of their growing commercial acceptance blending polymers have been successfully used in an increasing number of applications, such success encourage more attempts to apply this technique to a wider range of problems in polymer related industries [1].

A high dielectric constant is associated with the polarization and polarizability of the electrons that form individual bonds in polymer matrix, this in turn depends on the orientation

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of polar groups in the matrix, hence the ability of a polymer groups to switch orientations in phase with an alternating current may be limited [2].

The dissipation of heat by polymer materials is a further subject of same importance, but the shortage of experimental thermal conductivity data has so far prevented a comprehensive appraised of their heat transmission characteristics. The corollary is that heat flow circuits are difficult to make as the thermal conductivity of surrounding insulators may be only an order of magnitude less than the materials they insulate and hence heat flow (leaks) away. An additional problem is that heat can also leak by radiation, as a result an error of typically (5%) will arise [3].

polymers that are used for aircraft or space applications are often tested by irradiation with mercury vapor lamps that simulate the high ultraviolet – light content of unfiltered sunlight, weathering of a polymer usually leads to brittleness, yallowing in color, clearly the utility of a polymer for a particular application may depend on its resistance to weathering [4].

The aim of this work is to study the effect of uv radiation on dielectric constant and thermal conductivity for binary blend epoxy – phenol, with and without reinforcing with glass fibers.

Experimental work

Hand lay – up molding is used for preparing blend materials with the following steps:-

1. Prepare the mold.
2. Mixing the epoxy resin (conbextra Ep 10: Jordan industry) with its hardener (Ep 10) in ratio 3:1.
3. phenolic resin was dissolved in alcohol and adding hexamathyle tetra amin (HMTA) as a hardener in ratio 14 % of the resin, the mixture was placed in an oven at(50 ^{o}C) to evaporate alcohol.
4. Binary blend is obtained by adding epoxy matrix which is still in a liquid state to phenolic matrix by using mechanical mixer to form identical binary blend in different ratio.
5. The blends are left for (96 hours) at room temperature then dried for (5 hours) at (50 ^{o}C) to ensure completion of the process.
6. Glass fibers (E- glass) type woven roven (0^{o}-90^{o}) direction with (V_f = 48 %) were added to the mixture in a complete way till obtaining a composite matching material cast in the mold and left for (96 hours) to solidify and then placed in the oven at (50 ^{o}C).
7. The samples were cut with standard dimension (ASTM-D 150) for dielectric constant and thermal conductivity test with diameter 40 mm.
8. The dielectric constant measured for all samples with dielectric test instrument [Leybold Harris / Germany], this instrument represent an electric circuit (in series connection) which consists of capacitor, coil resistor, ammeter and frequency generator.

After locating the samples between the capacitors plates, the frequency of the power supplier is alternated till maximum current value is gate, the frequency is recorded which represent the resonance frequency value (Fr̈), after that the (Fr) 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:-

$$C = 1/4\pi^2 Fr^{-2} L \quad \ldots\ldots \quad (1)$$

$$C_o = 1/ 4\pi^2 Fr^2 L \quad \ldots\ldots. \ (2)$$

Where:

C: capacity of the capacitor with presence of the sample.

C_o: capacity of the capacitor with presence of the air only.

L: 20 m Henry (the inductance of the coil).

The dielectric constant (ε_r) can be calculated from the equation:

$$\varepsilon_r = C/ C_o \quad \ldots\ldots\ldots(3)$$

$$\varepsilon r = (Fr/ Fr\text{-})^2 \quad \ldots\ldots\ldots\ldots(4)$$

9. The thermal conductivity measured for all samples with (lee's disk) manufactured by (Griffen and George company/England), this instrument consists of three disks of brass and heater.

The heat transfers from the heater to the next two disks then the third disk across the samples.

The thermal conductivity calculated from the equation:

$$I\, v = \pi r^2 e\, (T_A+T_B) + 2\pi re\, [d_A T_A + 1/2\, d_s (T_A+T_B) + d_B T_B + Tc] \quad \ldots\ldots.. (5)$$

$$K\, (T_B-T_A/d_s) = e\, [T_A+2/r\, \{da+ (1/4) ds\}\, T_A+ (1/2r)\, dsT_B] \quad \ldots\ldots\ldots. (6)$$

Where:

I: current value (Ampere).

V: applied voltage (Volt).

r: radius of the disks (mm).

e: heat flow per unit area per second.

T_A, T_B, T_C: temperature of the disk A, B, C.

d_A, d_B, d_C : thickness of the disk A,B,C.

ds: thickness of the sample (mm).

K: thermal conductivity (watt/m.^{o}C).

10. The samples exposed to UV radiation with (Xenotest 150).instrument type- zenotest from [Hanau company/ Germany] with radiation energy (1.5 watt/cm^2) , wave length (320 nm)for (50 hours).
11. The dielectric constant and thermal conductivity measured for all samples before and after irradiation with UV radiation.

Results and Discussion

From the results in table (1) before weathering, addition phenolic resin to epoxy resin to epoxy resin sample (2) decreased the (εr) due to the holes or voids which are collectively called (free volume) in polymers, one of the reasons for the reduced dielectric constant in the blends may be enhanced free volume, the morphology of blends characterized them to be of immiscible category, it seems that more voids have been created at the phase boundaries, enhancing free volume, enhanced free volume lowers polarization by decreasing the number of polarization groups per unit volume [5]. While reinforcing the blend with

E-glass fibers sample(3) increasing the dielectric constant because of (εr) of the E- glass is higher than the (εr) of both (epoxy & phenol) resin[6].
In sample (4) increasing the percentage of phenolic resin in the blend decreased the (εr) which means more voids created during preparation of samples decreasing polarization groups per unit [7].while in sample (5) the (εr) increased after reinforcing with E-glass fibers due to the same reason of sample (3). The weathering behavior of a polymer blend is one of the most important limiting factors in assessing and selecting a plastic for outdoor applications.
From the results in table (1) after weathering the dielectric constant decreased for all samples as a result of UV radiation. The bonds between the atoms in many polymers have dissociation energies that are very similar to the quantum energy present in UV radiation, therefore this quantum energy capable of breaking the bonds in the polymer chains to generate a cascade of reaction, oxygen radicals, hydroperoxide units, carbonyl group formation, chain cleavage, and even phenyl group ring cleave reactions occur, as aresult the polarization groups reduced and (εr) decreased [8].
From the results in table (2) before weathering thermal conductivity of epoxy resin decreased after mixing with phenolic resin sample (2) this decreasing attributed to:-

1. Air voids created during preparation of blend.
2. The thermal conductivity of phenolic resin is less than thermal conductivity of epoxy resin as a result of blending the thermal conductivity decreased [9].

While reinforcing of epoxy-phenol blend with glass fibers sample (3) increased the thermal conductivity of the blend due to:

1. Thermal conductivity of glass fibers is larger than both epoxy and phenolic resin.
2. The direction and length of (0^o-90^o) glass fibers making a continuous path for phonons to transfer heat [10].

From the results in table (2) increasing the percentage of phenolic resin in the blend sample (4) decreased the thermal conductivity of the blend because of:

1. More air voids created during preparation of the blend.
2. The thermal conductivity of phenolic resin is less than epoxy therefore increasing the percentage of phenolic resin decreasing the thermal conductivity [11].

While in sample (5) reinforcing the blend with E- glass fibers increasing thermal conductivity of the blend for the same reason in sample (3).
After weathering with UV radiation the results of thermal conductivity was completely unexpected as shown in table (2).
The thermal conductivity of all samples increased in comparison with the thermal conductivity

before weathering, this result may be attributed to that:

1. Many highly cross-linked polymeric resins, such as epoxy and phenolic resin with stand high doses of radiation without losing their valuable properties; the aromatic structure further protects these materials which can resist extremely high doses up to 1000KGy or even more [12].
2. UV radiation increasing cross-linking of the polymer chains as a result the molecular weight of the polymer chains increased increasing the path to transfer phonons [13].
3. The molecular weight of the polymer chains did not decreased with UV radiation in spite of that the molecular weight increased making the thermal conductivity of the blend increased, this attributed to; solid polymers are formed of entangled linear macromolecules which interact with their neighbors by hydrogen bonds, and are more or less free to move, the mobility of polymer "segments"(chain fragments) very much depends on the physical state of the polymer, the macromolecules are almost frozen in their positions and segmental motion is strongly limited, therefore free species formed by radiation remain trapped if their mobility is hindered in the medium [14].
4. The time of weathering (50 hours) with not existing exposure factor with UV radiation is not enough to make photo degradation and reducing molecular weight in polymer chains, because till (100 hours) the molecular weight of polymer chains increased when the polymer blend exposed to UV radiation, after (100 hours) the molecular weight decreased gradually [15].

Conclusions

1. Blending the epoxy with phenolic resin decreasing the dielectric constant before and after weathering with UV radiation.
2. Reinforcing the (epoxy & phenol) blend with E- glass fibers increasing the dielectric constant before and after weathering with UV radiation.
3. Blending the epoxy with phenolic resin decreasing the thermal conductivity while reinforcing the epoxy & phenol blend with E-glass fibers increasing the thermal conductivity before weathering.
4. After weathering the thermal conductivity of all samples increased.

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Table (1) dielectric constant of the samples before and after weathering with UV radiation

No.	sample	Before weathering			After weathering		
		Fr (KHz)	Fr' (KHz)	εr	Fr (KHz)	Fr' (KHz)	εr
1	Ep(only)	94	91	1.0669	80	80.5	0.9875
2	Ep80%+Re 20%	92	91	1.022	86	93	0.855
3	Ep80% +Re 20% + G.F	92	90	1.0449	79	92	0.73372
4	Ep70%+Re 30%	92	91.5	1.0109	80	84	0.9069
5	Ep70% +Re 30% + G.F	94	91	1.067	78	80	0.9506

Ep: epoxy resin, Re: phenolic resin, G.F: glass fibers

Table (2) Thermal conductivity of the samples calculated from eq.(5, 6) before and after weathering with UV radiation

No.	sample	ds (m)	Before weathering				After weathering			
			T_A °C	T_B °C	T_C °C	K Watt/m. °C	T_A °C	T_B °C	T_C °C	K Watt/m. °C
1	Ep(only)	0.0036	32	40	42	0.1995	41	45	45	0.4378
2	Ep80%+Re 20%	0.0032	33	41	41	0.1796	42	46	47	0.3826
3	Ep80% +Re 20% + G.F	0.002	41	45	46	0.2316	44	46	46	0.4806
4	Ep70%+Re 30%	0.0043	23	33	34	0.1810	40	45	45	0.4196
5	Ep70% +Re 30% + G.F	0.0023	29	33	34	0.2621	45	47.5	48	0.4413

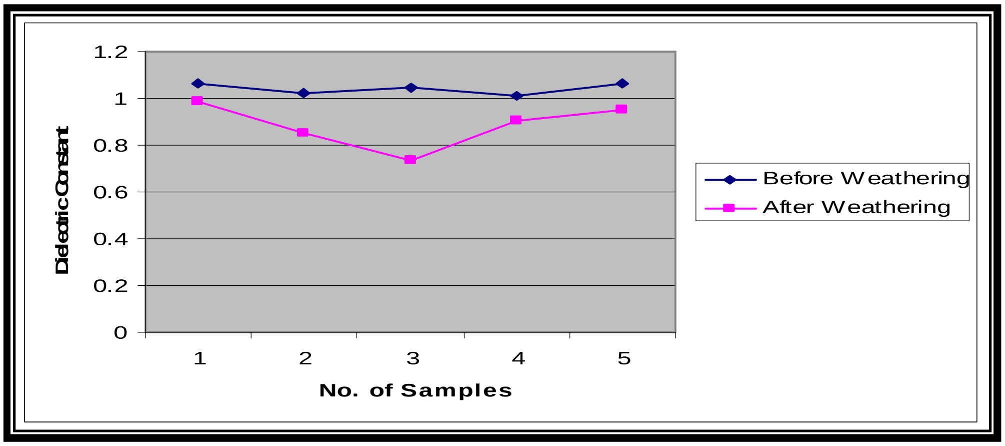

Figure (1) Dielectric constant of the samples before and after weathering with UV radiation.

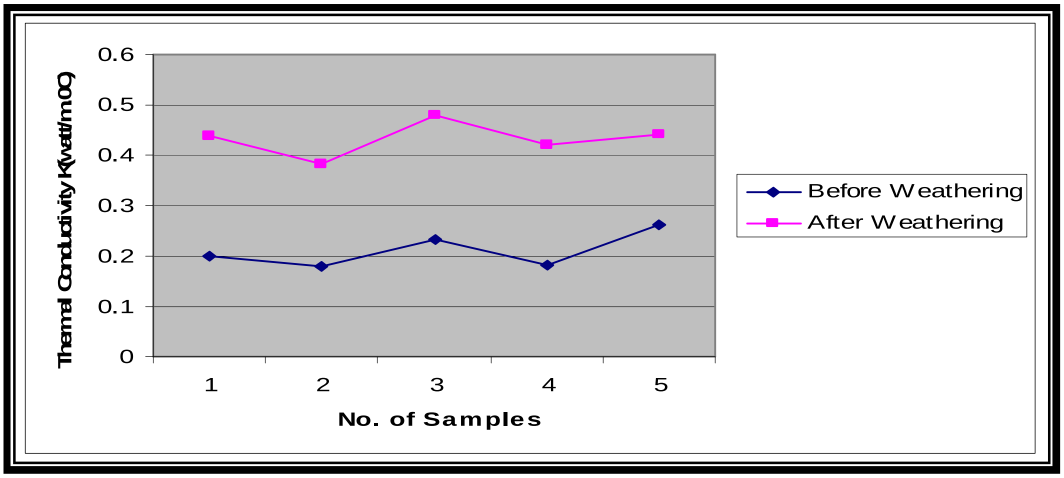

Figure (2) Thermal conductivity of the samples before and after weathering with UV radiation.