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Effect of Chemical Treatment on The Some Electrical And Thermal Properties For Unsaturated Polyester Composites Using Banana Fibers

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Abstract

This study was carried out to investigate the effect of the chemical treatment of banana fibers on the physical properties of composites. Banana fibers were treated with 10% sodium hydroxide and some physical tests were carried out like: dielectric strength, dielectric constant, and thermal conductivity. The results were compared with untreated fibers composites and virgin unsaturated polyester. The results showed that the chemical treatment improved the dielectric strength and thermal conductivity by about 29.37% and 139% respectively compared with untreated fiber composites. Finally, the dielectric constant value of the treated fiber composite was found to be lower than the untreated fiber composite and virgin unsaturated polyester.

Keywords: Banana fiber, Chemical treatment, Electrical and thermal properties, Composites.

تاثير المعاملة الكيميائية على بعض الخصائص الكهربائية والحرارية للبولي استر غير المشبع المدعم بالياف الموز

الخلاصة

تم إجراء هذه الدراسة لبحث تاثير المعاملة الكيميائية لالياف الموز على بعض الخصائص الفيزيائية للمادة المتراكبة حيث تم معاملة الياف الموز بهيدروكسيد الصوديوم بتركيز 10% ثم اجريت بعض الاختبارات الفيزيائية مثل متانة العزل الكهربائي وثابت العزل الكهربائي والموصلية الحرارية وتمت مقارنة النتائج مع المادة المتراكبة المدعمة بالياف الموز غير المعاملة وراتنج البولي استر النقي. اوضحت النتائج ان المعاملة الكيميائية حسنت متانة العزل والموصلية الحرارية بحدود 29.37% و 139% على التوالي مقارنة مع المادة المتراكبة غير المعاملة واخيرا وجد ان قيمة ثابت العزل الكهربائي للمادة المتراكبة ذات الالياف المعاملة اقل من المادة المتراكبة ذات الألياف غير المعاملة وراتنج البولي استر النقي.

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Introduction

Composites are widely used our day to day life. Due to their low weight and ability to be tailored for specific end use they have gained a considerable ground in the high performance applications, such as aerospace and automobile industry[1] .The overhead for using natural fibers is their cleaning and processing needs. The application of natural fiber reinforced composites has been extended to almost all fields [2].

During the last couple of years natural fiber composites have received considerable attention in the automotive, packaging, and construction industries. The uses of natural fiber composites are expanding day by day opening the new application windows. In recent years, low cost natural fiber composites proved of interest for dielectric applications, showing also some potential for future application as dielectric materials in microchips, part of transformers, and circuit boards. These materials can also be easily employed for multi-function applications, as the hollow cellular structure of plant fibers proved effective in providing insulation against heat and noise [3].

The reinforcing efficiency of natural fiber is related to the nature of cellulose and its crystallinity. The main components of natural fibers are cellulose (α-cellulose), hemicelluloses, lignin, pectins and waxes. Cellulose in a nature polymer consisting of D-anhydroglucose ($C_6H_{11}O_5$) repeating units joined by β-1, 4-glycosidic linkages at C_1 and C_4 position. Each repeating unit contains three hydroxyl groups. These hydroxyl groups and their ability to hydrogen bond play a major role in directing the crystalline packing and also govern the physical properties of cellulose [4].Table 1. Presents the chemical composition of banana fiber [5].

The study of electrical properties of natural fiber reinforced polymer also indicates their suitability as insulating materials for special applications such as suspension insulators, bushing, studs, sleeves, gaskets, spacer panels and switch boards. However, very little work has been reported on the electrical properties of natural fibers [6]. Properties such as density, electrical resistivity, ultimate tensile strength and initial modulus are related to the internal structure and chemical composition of fibers [1].

Natural fibers are amenable to modification as they bear hydroxyl groups from cellulose and lignin. The hydroxyl groups may be involved in the hydrogen bonding within the cellulose molecules thereby reducing the activity towards the matrix. Chemical modifications may activate these groups or can introduced new moieties that can effectively with the matrix [1][7].

The following reaction takes place as a result of alkali treatment [1]:

$$\text{Fiber-OH} + \text{NaOH} \longrightarrow \text{Fiber–O}^- \, Na^+ + H_2O$$

The electrical properties of banana fiber-reinforced phenol formaldehyde composites were analyzed by Seena and Sabu [8]. Naik and Mishra investigated the electrical properties of wood polymer composites based on Argo-waste and novolac [9]. Pothan, et al reported mechanical and electrical properties of modified banana fiber/polyester composites. The dielectric constant values of the treated fiber composites were found to be lower than the untreated fiber composites [10].

In this present work the effect of alkali treatment on thermal and electrical properties of banana fiber reinforced unsaturated polyester was studied.

Experimental:

1-1 Preparation of banana fiber and matrix material:

The pseudo stem banana woven fabric reinforced unsaturated polyester composite was prepared by the lay-hand method. The fibers were extracted from banana stems by hand and dried in sunlight for 12 hours. The dried fibers were made in the configuration of woven fabric.

The matrix material was unsaturated polyester (up) resin, the curing of (up) was done at room temperature by the incorporation of 2 volume percent methyl ethyl ketone peroxide (MEKP).A 1% (volume percent) cobalt naphenate was added as a catalyst.

1-2 Mercerization Process (Alkali Treatment):

Banana fiber woven fabric was soaked in 10% NaOH for about 3 hours in order to activate the OH groups of the cellulose and lignin in the fiber. Sherely and Abderrahim (2008) indicated that a 10-30% sodium hydroxide solution produced the best effects on natural fiber properties [11]. The fibers were then washed many times in distilled water and finally dried for a certain time before testing.

1-3 Preparation of Composites:

Unsaturated polyester, its hardener and catalyst were thoroughly mixed and stirred at low speed until it become uniform. The matrix was poured into mold slowly in order to avoid air trapping. The mixture was left for some time so that it becomes a little tacky. After that, the treated banana fiber woven fabric with 10% NaOH was laid on the matrix layer, which was covered by another layer of matrix by pouring the matrix slowly onto the surface of the fiber woven fabric. The three layered composite was cured at room temperature until it was dry. The same steps were used to make untreated banana fiber woven fabric reinforced unsaturated polyester.

The measurements dimensions of all tests were: diameter 40mm and thickness 6.73mm.

Physical Test

Dielectric Constant

The instrument which is utilized to measure the dielectric constant values of the composites represents an electrical circuit (in series connection) which consists of capacitor, coil, resistor, ammeter and frequency generator. After was placed the sample between the capacitors plates, the frequency of the power supplier was alternated till get maximum current value. At this maximum value, the frequency was recorded which represents the resonance frequency value (fr). After that, the (fr) value was 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:-

$$C = \frac{1}{4\pi^2 fr^2 L} \quad \ldots\ldots (1)$$

Where (L) is the inductance of the coil

Dielectric constant (ε_r) can be calculated from the equation:-

$$\varepsilon_r = C/C_o \quad \ldots. (2)$$

Where C_o is the capacity of the capacitor with existence of the air while C is the capacity of the capacitor with the presence the sample [12].

Dielectric Strength

The dielectric strength was carried out using (HV-50Hz 300KV) testing machine. The dielectric strength can be obtained from the following equation:-

$$D = \frac{V}{b} \qquad \text{....... (3)}$$

Where

V= breakdown voltage (KV)

b= thickness of the sample [13]

Thermal conductivity

Lee's disc instrument is used to calculate thermal conductivity of the samples under test. It consists of three discs of brass and heater. The heat transfers from the heater to the next two discs then to the third disc across the sample. The temperatures of the discs (T_A, T_B, T_C) can be measured with the thermometers which are located in them. After from (6 Volt) the power supply was supplied to the heater, the current value through the electrical circuit was about (0.25A), and then the temperatures of the discs were recorded after reaching the thermal equilibrium (nearly after 45min).

The values of thermal conductivity are calculated by applying the equations:-

$$IV = \pi r^2 e(T_A + T_B) \quad + 2\pi r\left[d_A + d_S\left(\tfrac{1}{2}\right)(T_A + T_B) + d_B T_B\right] \qquad \text{.... (4)}$$

Where

I is the current value through the electrical circuit.

V is the supplied voltage.

r is the radius of disc.

T_A, T_B and T_C are the temperature of the brass discs A, B and C respectively.

d_A, d_B and d_C are the thickness of the brass discs A, B and C respectively.

d_S is the thickness of the sample.

From the equation (4), the value of (e) is calculated which represents the quantity of heat that flows through the cross sectional area of the sample per unit time (W/ m^2.C°). K values can be calculated from the following equation:-

$$K = \left(\frac{T_B - T_A}{d_S}\right) = e\left[T_A + \frac{2}{r}\left(d_A + \left(\tfrac{1}{4}d_S\right)\right)T_A + \frac{1}{2r}d_S T_B\right] \qquad \text{...... (5)}$$

Where K is the thermal conductivity coefficient (W/m.C°) [14, 15]

Results and Discussion:-

Dielectric Strength

Table 2. shows the influence of mercerization (alkali treatment) of banana fibers on the dielectric strength values of banana- reinforced (up) composite. From the table it can be seen that the dielectric strength of the untreated fiber composite is lower than that of the virgin (up). This implies that the conductivity is increased upon addition of lignocellulosic fibers. This is due to the presence of polar groups, which facilitate the flow of current [10]. Also, it can be seen that the treated fiber composite improved the dielectric strength of the virgin (up) and untreated fiber composite by approximately 2.49% and 29.37% respectively. As described earlier, chemical modification of fibers resulted in lowering of moisture content and increased interfacial adhesion, leading to increase dielectric strength value [3].

Dielectric Constant

Dielectric constant values of treated and untreated banana fiber composites are presented in table 2. It can be seen that the dielectric constant of untreated banana composite was lower than that of the virgin (up). The presence of natural fiber in composite materials increases the air content of a composite due to the hollow space in the middle of each fiber, termed the lumen. The air trapped in the lumen results in a lower dielectric constant value [16]. The mercerization modification of banana fibers composite resulted in lowering of dielectric constant. This is due to the decrease of orientation polarization of composite containing treated fibers. Mercerization treatment results in reduction of moisture absorption capacity of fibers due to the reduction in interaction between polar- OH groups of banana fibers and water molecules. The resultant decrease of hydrophilocity of the fibers leads to lowering of orientation polarization and subsequently dielectric constant [3] [17].

Thermal conductivity

From table 2. It can be seen that the thermal conductivity of the untreated fiber composite was lower than that of the virgin (up). It can be said that banana fiber is a good thermal insulator. In comparison to untreated banana fiber composite the thermal conductivity of treated banana fiber composite was found to increase by approximately 193%. Chemical treatment of fibers result in increased interfacial adhesion, leading to decrease in voids subsequently easy heat transferences [18][5].

Conclusions

The following conclusions could be drown:-

1- Dielectric strength of composite improved by about 29.37% due to mercerization. The high dielectric strength makes these composites quite suitable for use as insulator. Whereas untreated fiber composite had lower dielectric strength than that of virgin (up).

2- Dielectric constant of treated fiber composite was lower than that of untreated fiber composite. But maximum dielectric constant was observed for Virgin (up).

3- The results of thermal conductivity test showed that the mercerization of banana fibers improved the thermal property by approximately 193% compared with untreated fiber composite.

4- Virgin (up) showed highest dielectric constant and thermal conductivity compared with treated and untreated fiber composites.

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Table (1) Composition of banana fiber [5].

Cellulose %	63-64
Hemicellulose %	19
Lignin %	5
Moisture content %	10-11

Table (2) Results of electrical and thermal tests

Samples	Dielectric strength(KV/mm)	Dielectric constant	Thermal conductivity(W/m.k)
Treated fibers composite	9.213	1.02	0.337
Untreated fibers composites	7.121	1.13	1.115
Virgin (UP)	8.989	1.19	0.4

Figure (1) pseudo-stem banana fibers in the woven fabric configuration