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A Systematic Study for Electrical Properties of Chemically Treated Coir Fiber Reinforced Epoxy Composites with ANN Model

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Abstract: ***An attempt has been made for the study of some electrical properties of chemically treated coir fiber-reinforced epoxy composites in a systematic way. The hand molding method with chemically treated coir fiber has been adopted to make the epoxy composites reinforced. The electrical properties, such as dielectric constant (e_0),dissipation factor and AC conductivity (σ_{ac}), at room temperature and different frequencies have been reported here and the findings of such properties have been also compared with the predictions of artificial neural networking (ANN) model. We have found from the present study that the obtained results are in good agreement with the simulation of ANN model. Finally, the XRD analysis suggested the crystalline nature of coir fiber-reinforced epoxy composites.***

Keywords: coir, fibre, SEM and XRD analysis, dielectric constant, ANN model and AC conductivity.

1. Introduction

Since last few decades, the natural fibers have been used as the main reinforcement for composite materials. Nowadays investigation on properties of natural fibre reinforced polymer composite is the most attractive area for researchers. Study of the properties and applications of fibre-reinforced polymer composite materials is a very fast growing area of research nowadays. The attention arises in natural fibre owing to their excellent performance in mechanical and electrical properties, low cost and considerable advantages of the composite material [1-3]. As a natural fiber is renewable, are of no cost or of very low cost, light in weight due to which they find applications in different areas like in aerospace, electrostatic shielding, electromagnetic shielding etc.

Compared to other natural fibres coir fibre is of particular interest due to its remarkable mechanical and electrical properties. Coir fibre is one of the most widespread natural fibres found abundant in nature, mostly grown in tropical countries. Coir is one of the cheapest fibre among all natural fiber even cheaper than jute and sisal fibre [4, 5]. The use of coir fibre as reinforcement or filler in polymer composites is important as it is inexpensive material when compared to artificial material like glass, aramid etc. The use of coir fibre as reinforcement in many polymers composites has been studied [6, 7].

Research work has been done on the electrical properties of natural fibre reinforced epoxy composite but they never studied the effect of chemical treatment of coir fibre done by annealing method at room temperature. The main motive of this work is to analyze the electrical properties of chemically treated coir fibre reinforced epoxy composite at room temperature and different frequencies.

2. Experiment Methodology

2.1. Chemical Treatment of coir fibre

The treatment of processed coir fiber was done with Nitro / (HNO_3) compounds. For this purpose, the Ferric Nitrate (Nanohydrate Extra pure, Fe $(NO_3)_3$. $9H_2O$) and ammonium chloride (NH_4Cl) was taken in the ratio 10: 4 in 500 ml distilled water. Stir the mixture till homogeneous solution obtained. Submerged 100 gm of processed coir fiber to it and pour 100 drops of liquid ammonia to it and left the solution for one hour. Again the mixed is dried and then fired it in a muffle furnace at 1000 $^{\circ}$C and kept it at that temperature for 15 min. Finally, the fired sample was then powdered for their further study, so called chemically treated samples.

2.2. Fabrication of Composite

The weighted amount of the treated fiber was mechanically mixed with an epoxy polymer in the ratio of 10: 8: 1 (resin: hardener: treated fiber) until a homogenous solution was obtained. Pallets of 10.0 mm diameter were prepared by pouring the homogenous mixture into the mold cavity of the desired diameter. The curing was done at room temperature for one day. The cylindrical rod of diameter 10mm was obtained. The rod was cut in pallets of 2.0 mm thickness.

3. Characterization of Samples

3.1 Scanning Electron Microscope (SEM) analysis

The scanning electron microscope (SEM) images have been taken out from Japan made, JSM 6390A (JEOL Japan) at dissimilar magnification of the above prepared samples. Before SEM examine the prepared samples were layered with gold in a vacuum coating unit. The cross section areas ranging of samples were approximately 1 cm to 5 microns in width and the magnification ranging of SEM was the order of 20X to approximately 30,000X, with spatial resolution of 50 to 100 nm.

3.2 XRD analysis

The XRD measurements were carried out using Bruker D8, X-ray diffractometer. The X-rays were produced using a sealed tube and the wavelength of x-ray was 0.154 nm, and also operated at 40 kV and 100 mA with radiation source (Cu K-alpha). The angle (2θ) was scanned in the range of 5 to 80 at speed of 1.2 min^{-1}.

3.3 Electrical measurements

Capacitance (C) and tan d values were measured using a LCR meter at room temperature range at frequencies 1 kHz, 2 kHz, 4 kHz and 10 kHz. Dielectric constant (e_0) of the sample has been calculated using the following relation:

$$\varepsilon' = \frac{C}{C_o} \quad (1)$$

where C and C_0 are the capacitance with and without dielectric, respectively.

The value of C_o in pF is given by the following relation:

$$C_0 = \frac{(0.08854)A}{d} pF \quad (2)$$

where A (cm^2) is the cross section area of the electrodes and d (cm) the thickness of the sample.

The AC conductivity of the material is given by the following relation:

$$\sigma_{ac} = \varepsilon_o \omega \varepsilon' \tan\delta \quad (3)$$

where ε_o is the permittivity of free space, tan δ the dielectric dissipation factor and ω the angular frequency of the applied electric field.

4. Modeling by Artificial Neural Networking (ANN) model

The ANN technique is described in detail in [8, 9 and references therein]. The main ideas are summarized here.

4.1 Basic principle

An artificial neural network (ANN) consists of a number of very simple and highly interconnected computational elements, also called neurons or nodes and depicted in Figure 1.

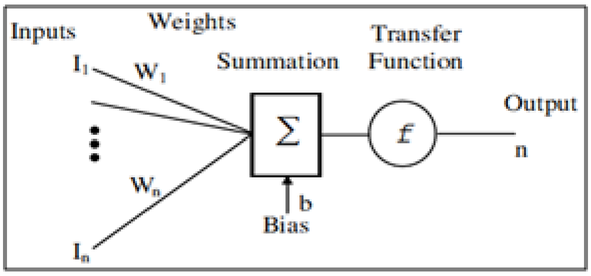

Figure 1: A Schematic diagram of Neuron structure

These nodes are distributed on many different layers: (a) one input layer, (b) one or many hidden layers and (c) one output layer. The processing element calculates the neuron transfer function (f) of the summation of weighted inputs. The neuron transfer function, f, is typically step or sigmoid function that produces a scalar output as in equation (4):

$$n = f(\textstyle\sum_i W_i I_i + b)) \quad (4)$$

where I_i, W_i, b are the i th input, the i th weight and b the bias respectively.

A particular transfer function (f) is chosen to satisfy some specification of the problem that the neuron is attempting to solve. The most commonly used functions is the tansigmoid and logsigmoid transfer function.

For training the neural network, a vector in the data matrix is a pattern. Each pattern is given to the network and the output is compared with the response. The data set is randomly divided into training and test sets. The error function is calculated after all the patterns are presented. Hence, it is a supervised learning. The best architecture (Figure 2) is chosen by changing the number of hidden layers, hidden neurons in each layer, transfer function and learning algorithm.

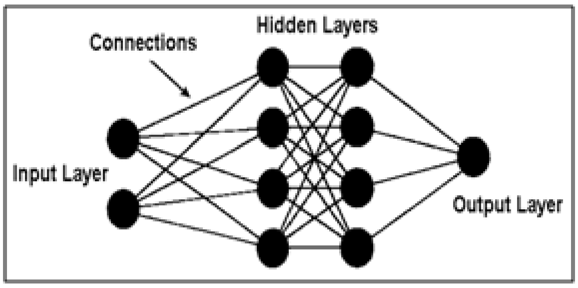

Figure 2: Multilayer perception neural network architecture.

The widely employed optimization procedure (learning algorithm) in 1980, was back propagation (BP), which is a variation of steepest descent algorithm. Recently Marquardt, Conjugate Gradient, simulation annealing algorithm, Genetic algorithm, etc. have been in corporated in ANN software.

5. Results and Discussions

The development of high performance composites from a cheap natural fiber, coconut coir fibre, as reinforcement is particularly significant from an economic point of view. Therefore, during the SEM analysis / prediction the standard criteria have been taken in account to perform the best results as it is mentioned in the Lab manual, Egerton, R. F. (2005) Physical principles of electron microscopy : an introduction to TEM, SEM, and AEM. Springer, 202 [10].

The results from SEM analysis have been depicted in Figures 3 (a and b). The descriptions of these figures are such as: Figure 3(a) is a pictorial view of pure epoxy composite and Figure 3(b) is for the chemically treated coir fibre reinforced epoxy composite. From the said figures, it has been found that chemically treated fibre is not fully bonded but is in poor contact with the matrix. Chemically treated fibre could not adhere with the epoxy matrix and therefore interfacial bonding is poor. In addition to this, the homogeneity of the sample is found to be lost, as the composite appears segregate into dissimilar phases. However, the hardness appears on physical observation. The surface of the composite is not smooth, representing that the compatibility between fibers and epoxy matrices is poor.

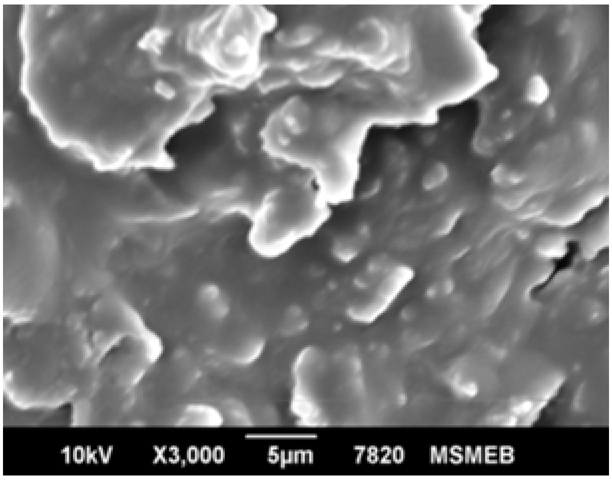

Figure 3(a): SEM analysis for the pure epoxy composite.

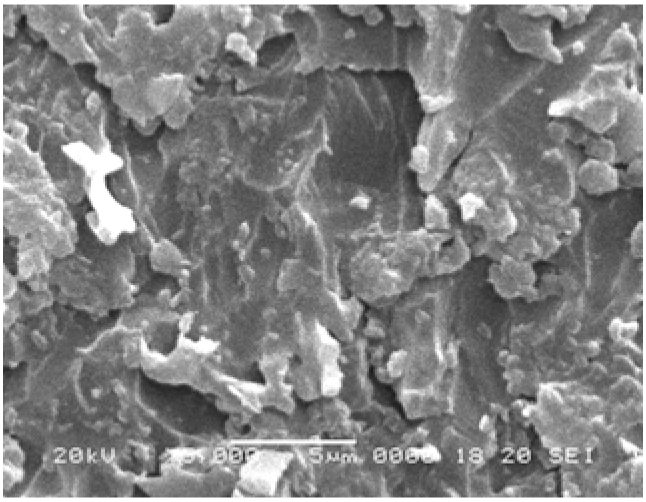

Figure 3(b): SEM analysis for the chemically treated coir fibre reinforced epoxy composite.

Later on the XRD pattern has been studied for the chosen two samples, pure epoxy composite and chemically treated coir fibre reinforced epoxy composite.

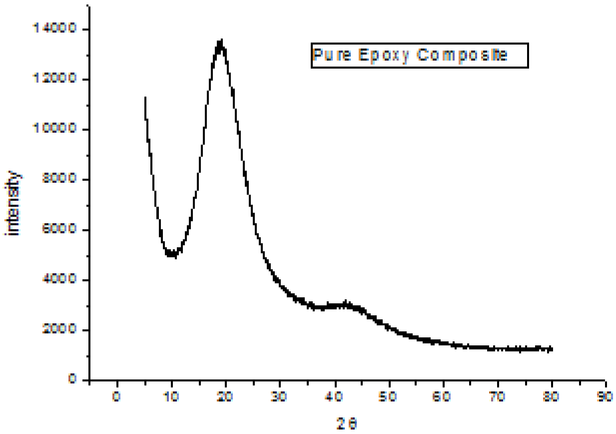

Figure 4(a): XRD plot for the pure epoxy composite

The behavior of XRD analysis have been shown in Figure (4 a & b), in which Figure 4 (a) is for the pure epoxy composite and Figure 4 (b) is for the chemically treated coir fibre reinforced epoxy composite. This analysis has been considered between the intensity and angle (2θ) as per the standard criteria of XRD pattern. In general the results from XRD are in accordance with the SEM pattern.

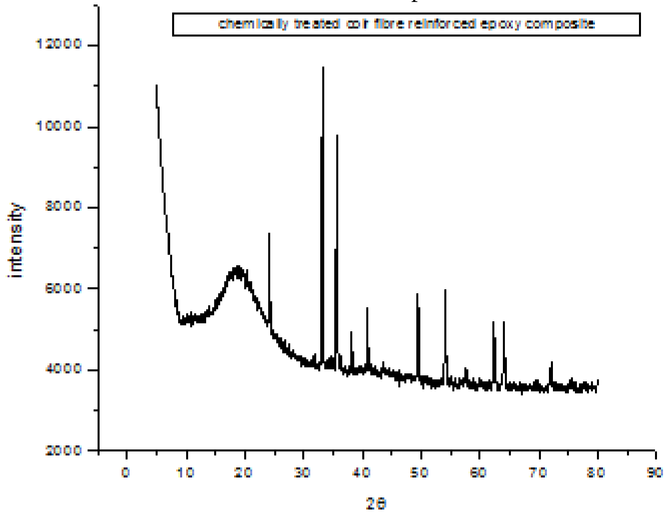

Figure 4(b): XRD plot for the chemically treated coir fibre reinforced epoxy composite

From Figure 4(b), it is observed that the peaks were found at 5.81°, 22.69°, 32.76°, 34.45°, 40.39°, 42.36°, 45.79°, 50.39°, 57.63°, 62.39°, 68.43° and 72.36°. Hence this XRD examine is in good agreement with the crystalline nature of reinforced epoxy composite. At some point the XRD pattern also exhibits sharp diffraction peaks, which indicate that the synthesis of chemically treated coir fibre reinforced epoxy composites were presence in high crystal quality.

Further, the electrical properties have been studied and were compared the prediction of artificial neural networking (ANN) model.

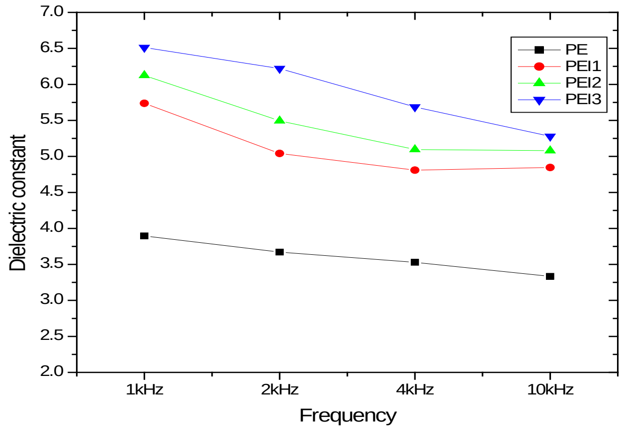

Figure 5 (a): The variation of dielectric constant (ε_o) for pure epoxy and chemically treated coir fibre reinforced epoxy composite measured at 1kHz, 2kHz, 4kHz and 10kHz

From Figure 5(a) it is found that there is decrease in dielectric constant on increasing the frequency while dielectric constant increases on increasing the concentration of filler. It is clear that dielectric constant of pure epoxy composite is found to be lower in comparison to the chemically treated coir fibre reinforced epoxy composite. The value of dielectric constant is highest at .3wt% of chemically treated coir fibre reinforced epoxy composite.

Therefore insulation property of the epoxy has been improved by the addition of filler. Similar work has been done by other researcher in which dielectric constant is found to be increase on the addition of filler [11]

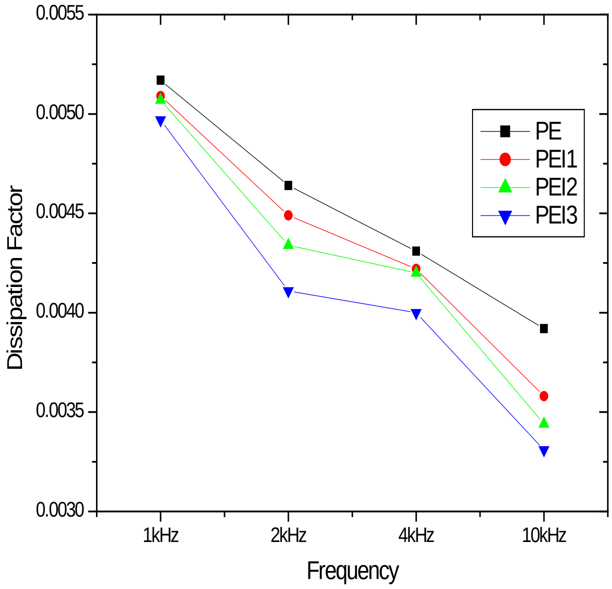

Figure 5 (b): Variation of dissipation factor for pure epoxy and chemically treated coir fibre reinforced epoxy composites measured at 1kHz,2kHz,4kHz and10 KHz.

From Figure 5(b) it is clear that dissipation factor decreases on increasing the frequency as well as on increasing the concentration of filler. The decrease in dissipation factor in chemically treated coir fibre reinforced epoxy composite probably due to low electrical conductivity in the filler. Comparable similarity has been shown by other scholars [12, 13].

Further, the Figure 6 shows the variation of Ac Conductivity values at room temperature for different frequencies (1 KHz, 2 KHz, 4 KHz and 10 KHz) of all prepared samples. It is found that Ac conductivity of pure epoxy is lower than that of chemically treated coir fibre reinforced epoxy composites. On the other hand there is an increase in ac conductivity in increasing the frequency. The conductivity, permittivity and dielectric loss values depend upon the thickness, composition and concentration of filler. Hopping of charge carrier above electronic polarization is the major factor responsible for the increase in Ac conductivity with an increase in frequency and increase in filler concentration [14].

It has been found from Figure 6, that the AC conductivity of chemically treated coir fibre reinforced epoxy composite is more than the pure epoxy composite at all frequencies due to the presence of chemically treated coir fibre in the pure epoxy composite.

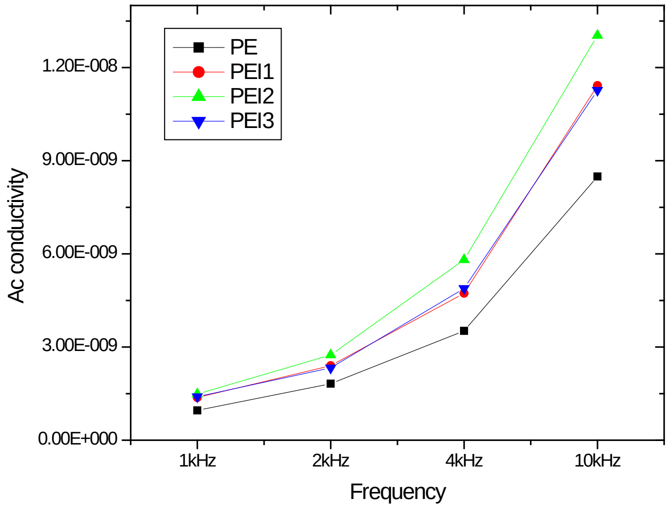

Figure 6: Variation of AC conductivity (σ_{ac}) for pure epoxy and chemically treated coir fibre reinforced reinforced measured at 1kHz,2kHz,4kHz and 10 KHz.

Finally, all the measured electrical properties i.e. the dielectric constant (e_0), dissipation factor and AC conductivity (σ_{ac}) by using the artificial neural networking (ANN) model simulation were observed in the same pattern as it has been shown in Figure 5-6. Therefore, the simulated data by ANN model for such electrical properties are in good agreement with the present experimental data / samples and also confirm the considerable advantages of the composite material / coconut coir fibre.

6. Conclusions

As the result, the paper studies important key points relating to the electrical properties of coir fiber reinforced epoxy composites based on the chemical treatment. This study deals with the preparation of chemically treated coir fibre reinforced epoxy composites with some new modification methods. Finally based upon the present study one can conclude the following:

The increase of coir fibres will make the composite tend to have low stiffness and ductility. On mixing in epoxy resin and treated produce inhomogeniety but possess hardness.

It has been found that the dielectric constant decreases depending on the reinforcement substance and the type of reinforcement.

The AC conductivity found to increase on increasing the concentration of filler

The dielectric loss (tanδ) were found to be decreased with the amalgamation of the treated coir fibre.

7. Acknowledgement

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