Effect of chemical treatment on electrical properties of coir fibre reinforced epoxy composites

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Abstract: In this paper, the effect of chemical treatment on electrical properties of coir fibre-reinforced epoxy composites has been reported. For this purpose, epoxy composites reinforced with chemically treated coir fibre prepared by hand molding method. Samples were characterized for their electrical properties, such as dielectric constant ($\varepsilon_0$), and AC conductivity ($\sigma_{ac}$), at different temperatures and frequencies. It was observed that dielectric constant increases with increase in temperature and decreases with increase in frequency from 5 KHz to 30 kHz. The peak height at the transition temperature decreases with increasing frequency. Electrical characterization of the samples has been done by impedance analyzer. Morphology of the samples has been done by SEM technique. Crystalline nature of the sample has been done by XRD analysis.

1. Introduction

Over the previous few years, 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 arises owing to their excellent performance in mechanical and electrical properties, low cost and considerable advantages of the composite material [1-3]. As natural fibre are 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]. 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 composite has been studied [5].

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 higher temperatures. The main motive of this work is to analyze the electrical properties of chemically treated coir fibre reinforced epoxy composite at different temperatures and frequencies.
2. Experimental
2.1. Chemical treatment of coir fibre:
The treatment of processed coir fiber was done with nitro compounds. Ferric nitrate (Nanohydrate Extra pure, Fe(NO\textsubscript{3})\textsubscript{3}. 9H\textsubscript{2}O) and ammonium chloride (NH\textsubscript{4}Cl) was taken in the ratio 10:4 in 500 ml distilled water. Stir the mixture till homogeneous solution obtained. Submerged 100gm 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\degree C and kept it at that temperature for 15 min. The fired sample was then powdered for their further study

2.2. Fabrication of composite:
Weighted amount of the treated fiber was mechanically mixed with epoxy polymer in the ratio of 10:8:1(resin: hardener: treated fiber) until a homogenous solution was obtained. Pallets of 10 mm diameter were prepared by pouring the homogenous mixture into the mold cavity of desired diameter. The curing was done at room temperature for one day. Cylindrical rod of diameter 10mm was obtained. The rod was cut in pallets of 2mm thickness

3. Characterization of the sample
3.1. X-ray diffraction (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 (Cu K-alpha).

3.2. Scanning electron microscope (SEM) analysis
SEM images of the prepared samples were taken by JSM 6390A (JEOL Japan) at dissimilar magnification. Before examination the prepared samples were layered with gold in a vacuum coating unit

3.3. Electrical measurements
Capacitance (C) and tan \(\delta\) values were measured using a Wayne Kerr 6500B Impedance Analyzer in the temperature range from 30 to 180 \degree C at frequencies (5 to 30) KHz keeping the heating rate constant at 2 \degree C/min. Dielectric constant (\(\varepsilon_0\)) of the sample has been calculated using the following relation

\[
\varepsilon' = \frac{C}{C_0}
\]

where C and \(C_0\) are the capacitance with and without dielectric, respectively. Value of \(C_0\) in pF is given by the following relation

\[
C_0 = \frac{(0.08854)A}{d} \text{ pF}
\]

where A (cm\textsuperscript{2}) is the area of the electrodes and d (cm) the thickness of the sample. Ac conductivity of the material is given by the following relation

\[
\sigma_{ac} = \varepsilon_0\omega\varepsilon'\tan\delta
\]

where \(\varepsilon_0\) is the permittivity of free space, \(\tan\delta\) the dielectric dissipation factor and \(\omega\) the angular frequency of the applied electric field.

4. Results and discussions
The XRD analysis of the two samples are given below 1 (a) pure epoxy composite 1 (b) chemically treated coir fibre reinforced epoxy composite
Fig. 1(a) and 1(b) show the XRD structure of pure epoxy composite and chemically treated coir fibre reinforced epoxy composite. XRD structure of the composite shows their crystalline nature as it is reported by Khan et al. [6].

Fig. 2(a) and 2(b) show the pictorial view of pure epoxy composite and chemically treated coir fibre reinforced epoxy composite. 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) shows that dielectric constant increases with increase in temperature from 30°C to 180°C and there is a decrease in dielectric constant with increase in frequency from 5 to 30 KHz. the dielectric constant of pure epoxy have merged at lower temperatures. Fig 3(b) shows there is a increase in dielectric constant on increasing the temperature from 30°C to 180°C and there is a decrease in dielectric constant on increasing the frequency from 5 to 30 KHz. The dielectric constant of chemically treated coir fibre reinforced epoxy composite is found to be greater than pure epoxy composite. This increase in dielectric constant is due to the agglomeration of chemically treated coir fibre in the epoxy composite. Same work has been reported by some researchers [7].
Dielectric constant

Temperature °C

Figure 3(a). The variation of dielectric constant ($\varepsilon_0$) with temperature (T) for pure epoxy, measured at 5 to 30 KHz.

Figure 3(b). Variation of dielectric constant ($\varepsilon_0$) with temperature (T) for chemically treated coir fibre reinforced epoxy composites measured at 5 to 30 KHz.

From figures 4(a) and 4(b) it has been found 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 4(a). Variation of AC conductivity ($\sigma_{ac}$) with Temperature (T) for pure epoxy, measured at 5 to 30 KHz.

Figure 4(b). Variation of AC conductivity ($\sigma_{ac}$) with Temperature (T) for chemically treated coir fibre reinforced epoxy composite measured at 5 to 30 KHz.

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