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Dielectric and Electrical Characterization Study of Synthesized Alumina Fibre Reinforced Epoxy Composites

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ABSTRACT

Fillers added to the matrix material help to enhance the properties of a composite. The present research investigation has aimed to the electrical study on synthesized alumina fibre reinforced epoxy composites at room temperature with different concentration of alumina fibre along with different frequencies. Decrease in dielectric constant and dielectric loss is found on increasing the frequency. Increase in ac conductivity has been found on increasing the frequency as well as concentration of filler. The resultant samples were prepared by hand lay technique. Cluster of alumina fibre is found on the surface of epoxy composite when examined by Scanning electron microscopy.

Introduction

Natural fibres such as coir, sisal, jute etc. are of interest to most of the researchers in the field of composite materials. Since these fibres are found plenty in nature and are economical as compared to synthetic fibres like glass, aramid, asbestos etc. [1]. Natural fibres may possibly replace synthetic fibres in many dedicate purposes, like where high strength and rigidity are not expected. It is thus important to illustrate and modify overall properties of these fibres and to explore some other alternate sources to natural fibres [2]. Natural fibres exhibit many exceptional properties such as impact resistance [3], flexibility [4], stiffness [5], positive ecological impact as they are mostly renewable and biodegradable in nature [6] etc. which on treatment are likely to make their composites striking replacement to simple synthetic fibres.

Coir is a lingo-cellulosic fibre which is obtained from coconut trees. Coir fibre is a seed fibre mostly grown in tropical regions of India [7]. Coir fibre is the cheap fibre among all natural fibres, even cheaper than sisal fibre [8]. In contrast to synthetic fibres, coir fibre is not brittle in nature and is also amenable to chemical modulation, beside this it is non-toxic and holds no waste disposal problems.

Further, these have low cellulose but higher lignin content, variable diameter. Yet, till date the performance of coir fibre as a replacement in polymer composites has not proved satisfactory and comparable to other natural fibres [7]. A variety of treatments have been tried to modify the properties of natural fibres [9, 10]. It is known that those and other investigators have done chemical modification of natural fibres in order to improve them with a polymer composite [11, 12, 13, 14, and 15].

The dielectric constant of lingo-cellulosic fibres provides a sign of their stableness, moisture content and constancy under electric fields. The electrical study of these natural fibres also endowed with their appropriateness as insulating materials for some applications like bushings, studs, gaskets, switch boards and spacer panels etc. therefore, due to these reasons natural fibres gained noteworthy importance both in automotive and electronics industry. The electrical properties of composite materials have been investigated with respect to the effect of fibre treatment, fibre length and fibre concentration. It has been illustrated that there are many factors that can change the properties of natural fibre reinforced polymer composites [16, 17, 18, 19, 20, 21, and 22].

One of the significant thermosetting polymers is epoxy resin found different industrial applications their outstanding properties. It has desired quality mechanical properties that make it find application in surrounding such as coil insulators in rotating machines [23], as spacers in gas insulating switchgear [24], as an insulator in integrated circuits [25]. Due to their manifold usage researchers have performed several investigations on different fillers for enhancing the properties of epoxy [26].

Many researchers have studied the electrical properties of natural fibre reinforced polymer composites, but no work has been done on synthesized alumina fibre reinforced epoxy composites at room temperature. The present study has an attempt to use synthesized alumina fibre by using coir fibre, a waste product just to enhance the properties of epoxy polymer.

Materials and Method

The epoxy matrix used in this study was provided by Sumeet Enterprises, Malviya Nagar, Bhopal. The density of the resin at room temperature was 1.15g/cm^3. The coir fibre used for the present study was collected from the temples of Bhopal, India.

Treatment of coir fibre was done with Aluminum Nitrate and Ammonium Chloride. After the treatment of coir fibre we have found alumina fibre (Al_2O_3: fibre) as the resultant product and it was confirmed by X-Ray Diffraction technique [27].

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Composite preparation

Composite was prepared using a resin / hardener / + (synthesized alumina fibre in powder form) in the ratio of 10:8:(0.1g). First of all the resin and hardener are mixed together by magnetic stirrer and then treated powder was mixed in the desired ratio so that a uniform paste is obtained. The resultant paste was poured in a glass bottle of diameter 10 mm and allowed to set for 24 hours. Tests samples were cut from the cylindrical bottle in the form of circular discs of 2 mm thickness and 10 mm diameter. Uniformity of the surface of test samples was obtained by polishing the sample using polishing cloth. The test samples were then kept in between the electrodes of the impedance analyzer for various measurements.

Table 1 gives the composition of the samples.

Table 1. Composition of the sample and their nomenclature

S.No.	Name	Composition	Appearance	Fibre
1	PE	Pure epoxy polymer (100%)	Pale white pallet having opaque surface, hard in nature	Nil
2	PEA1	(0.1%) Alumina fibre reinforced epoxy (99.9%) composite	Pale white pallet having spotted dots found rarely on the surface of the pallet due to the reinforcement Synthesized alumina fibre of alumina fibre	Synthesized alumina fibre as a reinforcing agent (0.1%)
3	PEA2	(0.2%) Alumina fibre reinforced epoxy (99.8) composite	Pale white pallet having spotted dots found on the surface of the pallet due to the reinforcement of alumina fibre	Synthesized alumina fibre as a reinforcing agent (0.2%)
4	PEA3	(0.3%) Alumina fibre reinforced epoxy (99.7%) composite	Pale white pallet having spotted dots found on the surface of the pallet due to the reinforcement of alumina fibre	Synthesized alumina fibre as a reinforcing agent (0.3%)

Results and Discussion

In dielectric properties investigations, the test sample is put securely in between two parallel electrodes. A sinusoidal voltage is applied in between the electrodes to produce an alternating electric field and owing to this field polarization is produced in the test sample [28].

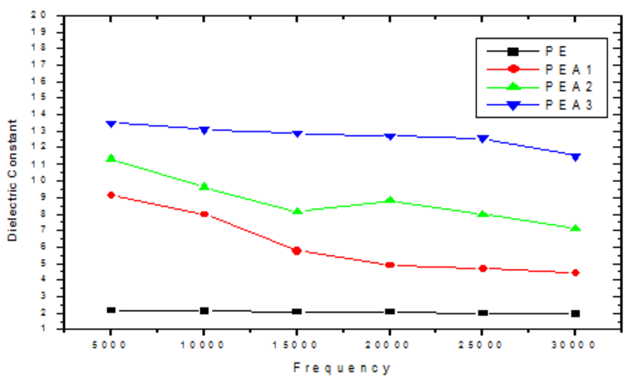

Fig 1 (a). Variation of dielectric constant of pure epoxy and chemically treated coir fibre (Alumina Fibre) reinforced epoxy composites

Fig.1. (a), shows the variation of dielectric constant with respect to frequency at room temperature for pure epoxy, 0.1gm synthesized alumina fibre reinforced epoxy composite, 0.2gm synthesized alumina fibre reinforced epoxy composite, 0.3gm synthesized alumina fibre reinforced epoxy composite measured at 5, 10, 15,20,25 and 30 kHz respectively. From Fig.1. (a) It is clear that the value of dielectric constant decreases on increasing the frequencies in the composites.

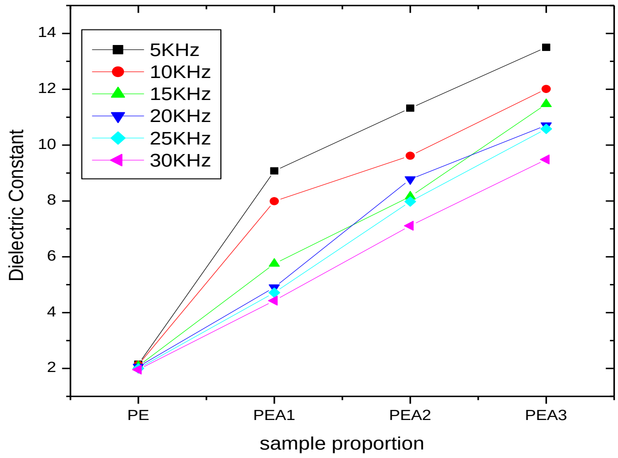

Fig 1(b). Variation of dielectric constant of pure epoxy and chemically treated coir fibre (Alumina Fibre) reinforced epoxy composites at different frequencies.

But the dielectric constant increases with the increase in content of alumina fibre as is evident from Fig.1 (b). As a result the insulating property of the composites improved on the addition of alumina fibre. Similar studies are reported by Janu Sharma et.al [29]. For alumina fibre reinforced epoxy composites, there is very small decrease in dielectric constant on increasing the frequency in the studied frequency range. It might be due to the presence of interfacial or space charge polarizations owing to the accretion of space charged at interface boundaries. When an electric field is applied, at higher frequencies, applied to the prepared composite, the chances of these space charges to drift and accrete at the interface of the prepared composite become extremely negligible [30]. In one more study it has been found that there is an increase in dielectric constant on increasing the concentration of coir dust. In the coir dust reinforced epoxy composites on increasing the frequency as well as of the concentration [31].

As a result, it can be seen from Fig.1 (b) that there is an increase in the dielectric constant on increasing the alumina concentration in epoxy composite. The dielectric constant of synthesized alumina fibre reinforced epoxy composites depend on the dielectric constant of epoxy, dielectric constant of alumina and the concentration of alumina fibre (Alumina: coir fibre) in the prepared composites. The higher dielectric constant in the prepared composites on addition of alumina fibre is observed at higher concentration of alumina fibre which is 0.3g in this case. It has been found that with the increase in alumina fibre concentration in epoxy composites marks in an increase in the number of particles along with the dielectric constant of each individual particles resulting in the increase of dielectric constant. As the concentration of fillers increases, there are more probabilities of polymer chain immobilization. Mostly it is found that immobilization of chain is one of the factor responsible for higher dielectric constant [32]. Therefore rate of increase in dielectric constant with respect to alumina fibre concentration decides the mode of change in dielectric constant [33].

Fig.1 (b) shows the variation of dielectric constant with weight ratio of filler (Al_2O_3: fibre) at various frequencies. It is found that there is decrease in dielectric constant on increasing the frequency. Similar study has been done in the case of banana fibre reinforced phenol formaldehyde composites. But it has been found that dielectric constant decreased with frequency [34]. In another study it reported that dielectric constant decreases on increasing the frequency in graphite filled modified epoxy resin at various frequencies [35].

Fig. (2). (a) shows the variation of dielectric loss (tan δ) values at room temperature for different frequencies (5 kHz, 10 kHz, 15 kHz, 20 kHz, 25 kHz, and 30 kHz) of all prepared samples. One can found from figure that there is decrease in loss factor on increasing the frequency as well as on increasing the concentration of filler.

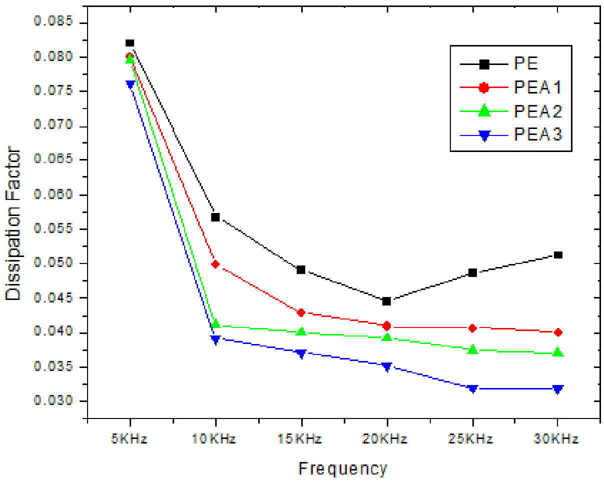

Fig 2(a). Variaion of dielectric loss (tan δ) of pure epoxy and Alumina fibre reinforced epoxy composites at different frequencies (5kHz, 10kHz, 15kHz, 20kHz, 25kHz, 30kHz)

Fig 2(b) shows the variation of dielectric constant of pure epoxy and synthesized alumina fibre reinforced epoxy composite with respect to sample proportion of the filler. From fig 2(b) it is clear that there is decrease in dielectric loss on increasing the frequency. At the same time there is decrease in dielectric loss on increasing the concentration of filler. The occurrence in the lower value of dielectric loss in chemically treated coir fibre reinforced epoxy composite may be due to a lower rate electrical conductivity in the filler. Similar trend has been observed by some other researchers [31, 35, 36, and 37].

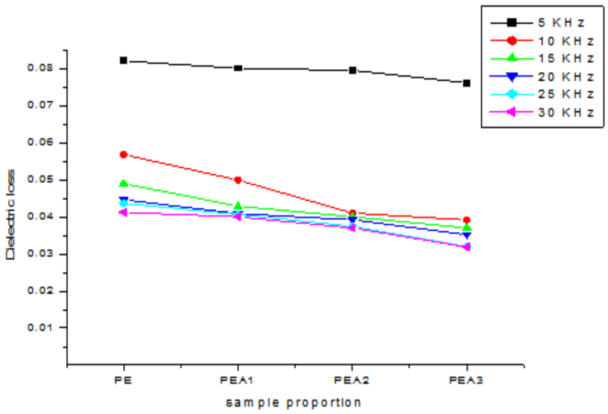

Fig 2 (b). Variaion of dielectric loss (tan δ) of pure epoxy and chemically treated coir fibre (Alumina fibre) reinforced epoxy composites with respect to sample proportion

Here, ac conductivity of synthesized alumina fibre reinforced epoxy composites are studied as a function of frequency and filler concentration at room temperature .Fig. 3(a) shows the variation of ac conductivity values at room temperature for different frequencies (5 kHz, 10 kHz, 15 kHz, 20 kHz, 25 kHz, and 30 kHz) of all prepared samples. From above Fig.3 (a) it is found that there is an increase in ac conductivity of the composites on increasing the frequencies as well as on increasing the concentration of alumina fibre. The ac conductivity was highest at 0.3% alumina fibre reinforced epoxy composite. Similar results have been observed by some other researchers too [38, 39].

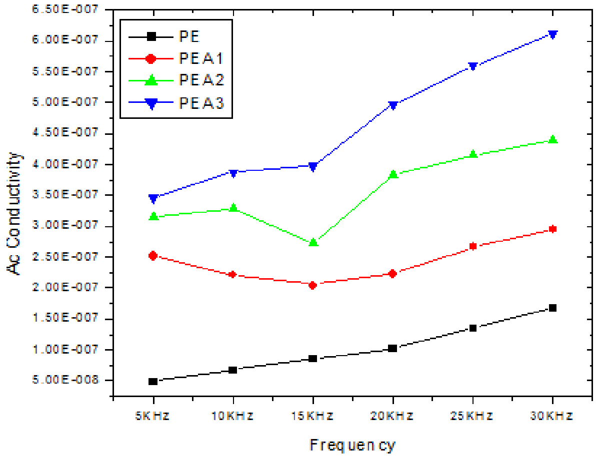

Fig 3(a). Variation of ac conductivity of pure epoxy and chemically treated coir fibre (Alumina fibre) reinforced epoxy composites with respect to different frequencies (5kHz, 10kHz, 15kHz, 20kHz, 25kHz, 30kHz)

The increase in ac conductivity with an increase in frequency as well as an increase in filler concentration can be due to a larger probability of hopping of charged carrier above electronic polarization, small barrier height and electronic polarization [38]. It may be assigned to the fact that on increasing the concentration of alumina fibre, conductivity increases due to the increase in charge carriers which increased on increasing the filler contact, when the concentration of alumina fibre increases and the network is connected to each other having the overlapping paths to allocate the charge carriers to pass through them [39, 40, 41].

On scrutiny of Fig.3 (b), presented below it is found that there is an increase in ac conductivity of the composites on increasing the frequencies as well as on increasing the concentration of alumina fibre. The ac conductivity is found highest at 0.3% alumina fibre reinforced epoxy composite. Similar results have been observed by some other researchers too [38, 39].

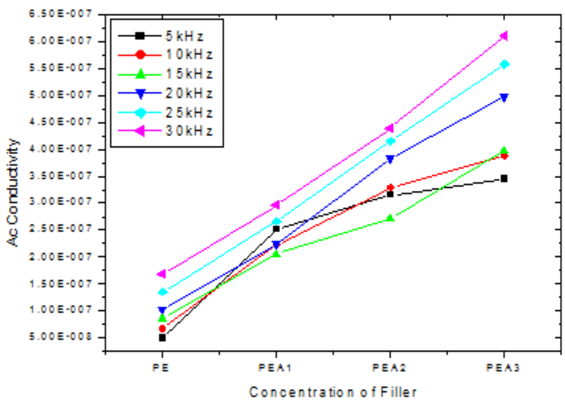

Fig 3(b). Variation of ac conductivity of pure epoxy and synthesized Alumina fibre reinforced epoxy composites with respect to sample proportion

Scanning Electron Microscopy Analysis

The scanning electron microscopy of the test samples were done by JSM 6390A (JEOL Japan) at various magnifications. Samples were first coated with gold in vacuum coating unit before the investigation. Images of the prepared samples were taken at the plane polished surface. Fig. 4 (a) shows the scanning electron microscopy image of synthesized alumina fibre. Fig4 (b) shows the scanning electron microscopy of pure epoxy composite while Fig3 (c) shows the scanning electron microscopy of alumina fibre reinforced epoxy composite.

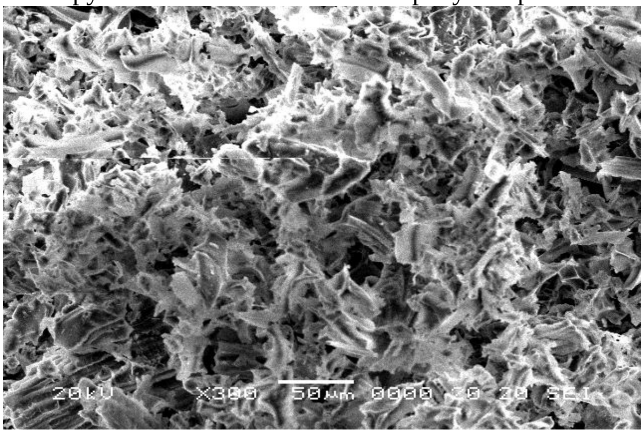

Fig 4 (a). Scanning electron microscopy image of Alumina Fibre

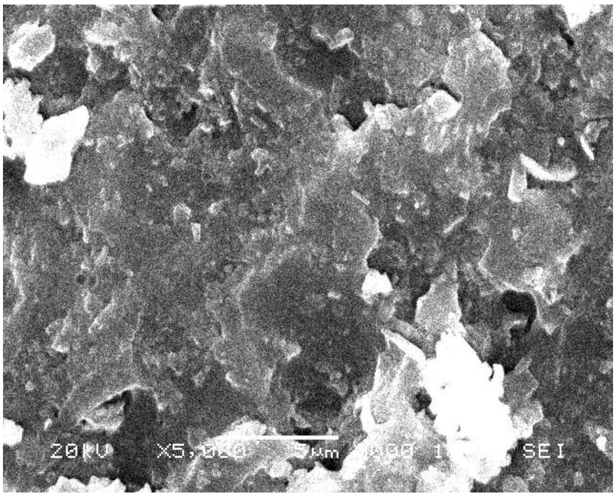

Fig 4 (b). Scanning electron microscopy image of Pure epoxy composite

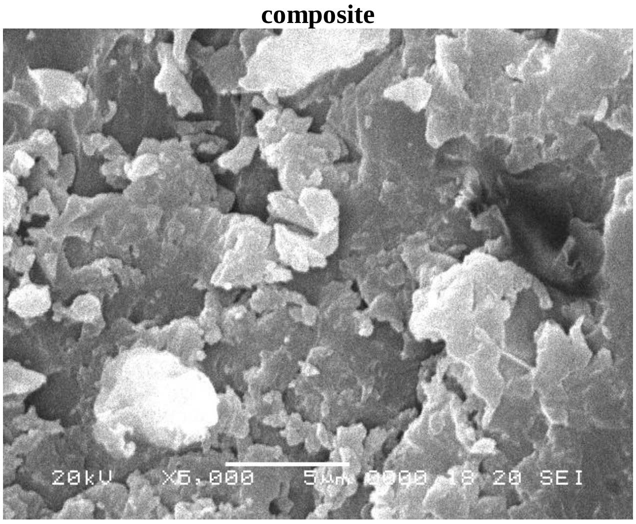

Fig 4(A).4 (c). Scanning electron microscopy of Alumina fibre reinforced epoxy composite

To make certain proper dispersion of alumina particles in the epoxy matrix SEM images were taken at different magnifications and it is clear from these images that cluster of alumina fibre is seen on the surface of the epoxy and the surface of the epoxy composite is found to be inhomogeneous and deformed at microscopic level and therefore can be the reason for resistive ac conduction [33]. Uneven surface of the composite shows the improper contact with the matrix. Comparable behavior has been shown by some other researchers [42, 33].

Conclusions and Final Remarks

Following conclusions have been drawn based on the present study:

There is a decrease in dielectric constant with different frequencies in the alumina fibre reinforced epoxy composites while dielectric constant increases with the increase in content of alumina fibre in the composite. As a result the insulation property of the composites was found to improve by the addition of alumina fibre.

There is a decrease in loss factor on increasing the frequency as well as on increasing the concentration of filler in alumina fibre reinforced epoxy composites. The occurrence in the lower value of dielectric loss in alumina fibre reinforced epoxy composite may be due to a lower rate of electrical conductivity in the filler.

It was observed that ac conductivity increases with increasing frequencies. On the other hand, on increasing the concentration of alumina fibre there is an increase in the ac conductivity of the composites which ensure that conduction, permittivity and dielectric loss values depend upon the thickness, composition and concentration of filler.

Scanning electron microscopy images shows that cluster of alumina fibre was seen on the surface of the epoxy and the surface of the epoxy composite is found to be inhomogeneous and deformed at microscopic level and therefore can be the reason for resistive ac conduction.

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