Processing and Dielectric Properties of Bio-fiber Reinforced Polymer Composite Using Brown Grass Flower Broom

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Abstract
A novel low-cost polymer composite using brown grass flower broom reinforcement is prepared. From the physico-mechanical characterization, it is found that the prepared composite is lightweight and of high strength. Investigation of dielectric behavior of this polymer composite proves its efficiency as a high-value marketable product. As the composite is made using bio-materials from local resources, its cost is less as compared to other polymer composites available today.

Keywords: *polymer composite, dielectric loss, dielectric relaxation, grass flower broom, orientation polarization, epoxy resin*

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INTRODUCTION

Natural fibers such as jute, coir, sisal, pineapple, ramie, bamboo, banana, etc., as reinforcement in composites have recently attracted the attention of researchers because they are fully biodegradable, have high specific strength and are modulus materials, abundantly available, renewable and economical. Such natural fiber-reinforced composites have raised great attention and interest among materials scientists and engineers in recent years due to the considerations of developing an environmental friendly material and partly replacing currently used glass or carbon fibers in fiber-reinforced composites. These fiber composites are well suited as wood substitutes in the housing and construction sector [1–7]. The surface adhesion between the fiber and the polymer plays an important role in the transmission of stress from matrix to the fiber and thus contributes toward the performance of the composite [8, 9]. The potential of fiber-reinforced polymer composites was recognized more than 50 years ago; now they can find their applications in almost every industry including construction, aerospace, automotive and electronics. Composite materials are increasingly used for dielectric applications, i.e., applications that make use of electrically insulating or nearly insulating behavior. This is because of the need of the electronic industry for dielectric materials in electrical insulation, encapsulation, multilayer ceramic chip and capacitors and for piezoelectric, ferroelectric, and pyroelectric devices that provide sensing, actuation, etc. Development of dielectric material with low dielectric constant k and low dielectric loss is considered to be one of the main issues in high-speed microelectronics. The dielectric constant of any material depends upon the polarizability of its molecules and is determined by different contributions: interfacial, dipole, atomic and electronic polarizations. Interfacial polarization in the composite influences the dielectric properties at very low frequencies and usually decreases with increasing frequency [10–12].

Developing an efficient and light-weight dielectric material from sustainable resources, such as brown grass broom fiber, is quite attractive from both application and environmental point of view. This research work aims at development of a bio-fiber-reinforced polymer composite using natural fiber, i.e., brown grass flower broom which is lightweight, commonly available, biodegradable and low cost. The raw material is commonly available in agricultural sector.

MATERIALS AND METHODS

Materials Used

Epoxy LY 556 (common name: Bisphenol A diglycidyl ether) is used as matrix material in the composite fabrication. The hardener used here is HY-951 (IUPAC Name: NN′-bis (2-aminoethylethane-1, 2-diamine). Epoxy Resin and hardeners are mixed in a ratio of 10:1 by weight. Brown grass flower broom is commonly used in houses (Figure 1). Short fiber of the broom, i.e., nearly 10 mm in length was prepared and used as the reinforcing agent in the composite preparation.

Fig. 1: *Brown Grass Flower Broom.*

Preparation of Test Samples

The bio-fiber (brown grass fiber) was mixed with epoxy by stirring at room temperature, in a glass beaker with the help of a suitable glass rod. The hardener was added into the beaker containing mixture at the time of stirring. With proper stirring for 10 min, uniform mixing of the reinforcing agent and the polymer matrix was possible. Proper stirring was required for uniform mixing of the reinforcing agent and the polymer matrix and they were poured into suitable moulds to obtain disc-shaped samples of 12 mm diameter and 2.5 mm thickness. Three different broom fiber reinforced epoxy composites (Figure 2) were fabricated varying the amount of reinforcement. Test specimens of suitable dimensions were cut from the composite. The composites prepared are described in Table 1.

Table 1: *Test Samples Prepared.*

Samples	Composition
Sample A	Pure epoxy
Sample B	Epoxy + 10% brown grass flower broom
Sample C	Epoxy + 20% brown grass flower broom

Fig. 2: *Polymer Composites of Brown Grass Flower Broom and Epoxy.*

Characterization and Dielectric Measurement

Hardness test was conducted in a Vickers hardness tester, Leitz make. The Vickers Hardness Number (VHN) of the hybrid composite was measured under a load of F = 0.3 kgf and Vickers hardness number was calculated by using the formula:

$$HV = 0.1889\ F/L^2$$

and

$$L = (X + Y)/2 \quad (1)$$

where F is the applied load, L is the diagonal of square impression (mm), X is the horizontal length (mm), and Y is the vertical length (mm). The density of neat epoxy and the composite was measured by measuring its mass and volume. The surface morphology of the samples was examined with JEOL T-330 Scanning Electron Microscope. Samples were coated with 60 A° thick platinum in JEOL sputter ion coater for surface conductivity and then observed under SEM, operated at an acceleration voltage of 20.0 kV. Dielectric measurements were carried out with the help of a Solartron 1296 Impedance Analyzer. For that, the samples of the composites had to be cut into thin circular shape and their surfaces were polished. Then graphite coating was given on their surfaces to make surface conducting and for allowing measurements over frequency interval from 100 Hz to 1 MHz. The dielectric constant and dielectric loss was determined as follows:

$$\text{Dielectric constant } (k) = C'/C \quad (2)$$

where, C' (pF) is the measured capacitance and C (pF) is calculated using the equation,

$$C = \varepsilon_0(A/d) \quad (3)$$

where, A is area of the electrode (mm^2) and d is the thickness of the sample (mm).

Table 2: *Hardness Value in HV of Different Samples.*

Samples	Hardness
Sample A	20.5 HV
Sample B	26 HV
Sample C	29.5 HV

The dielectric loss is given by,

$$\tan \delta = G(S)/(wC'(F)) \quad (4)$$

where, $w = 2\pi f$, f is the measuring frequency and $G = G_0(R - R_0)$ [13].

RESULTS AND DISCUSSION

Hardness values of the samples are given in Table 2. From the table, it can be seen that the hardness of broom fiber-reinforced polymer composite is more than that of the pure epoxy and also increases with increase in amount of reinforcement. The increase in hardness of the composite may be due to stronger interface bonding of the broom fiber with epoxy resin.

The actual density of the composite is determined experimentally by simple water immersion technique by using Archimedes principle. The densities of the samples are given in Table 3. It is observed that the presence of broom fibers as fillers in epoxy matrix reduces the density of polymer composite and hence makes it lightweight. This may be due to presence of high air content.

Table 3: *Variation of Density with Different wt.% of Fiber Reinforced in Epoxy Matrix.*

Sample	Fiber (%)	Density (gm/cc)
Sample A	Nil	1.92
Sample B	10	1.852
Sample C	20	1.614

The surface morphology of the prepared test sample with 10% broom fiber is shown in Figure 3. The interface bonding of the broom fiber with epoxy resin is clearly visible. This composite has the lowest porosity and homogeneous surface structure.

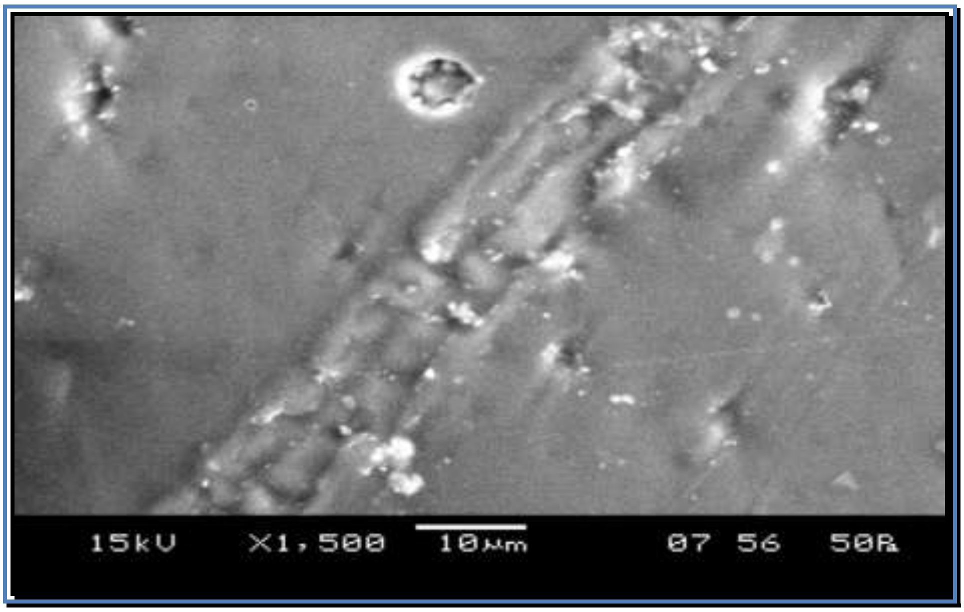

Fig. 3: *Surface Morphology of the Composite with 10% Broom Fiber Reinforcement.*

It is observed from Figure 4 that the dielectric constant (at 100 Hz frequency) increases with reinforcement volume fraction. However, from Figures 5 and 6, it is inferred that the dielectric constant and the dielectric loss initially reduces and attains a steady state with increase in frequency. This may be the fact due to: (i) dielectric behavior is dependent on porosity, (ii) material properties and also (iii) interface bonding in case of composite materials. So in this study, the materials used have many diverse physico-mechanical properties. However, it is found that making a composite with these wastes, using a polymer binder is best suited for providing good mechanical strength without sacrificing its dielectric property. Impregnation of natural fiber helps in the interface bonding and distribution of absorbed moisture in the material which may be one of the reasons for change in dielectric properties. With increase in frequency, the dielectric constant of the composites decreases due to dielectric relaxation. From structural point of view, the dielectric relaxation involves oriental polarization which in turn depends on molecular arrangement of the dielectric material. At high frequency, the rotational motion of polar molecule is not sufficiently rapid for attainment of equilibrium with applied field, hence dielectric constant decreases. As the reinforcement content increases the dielectric constant also increases. Dielectric loss of the composite shows a stabilizing trend with increase in frequency which appears to be beneficial from application point of view.

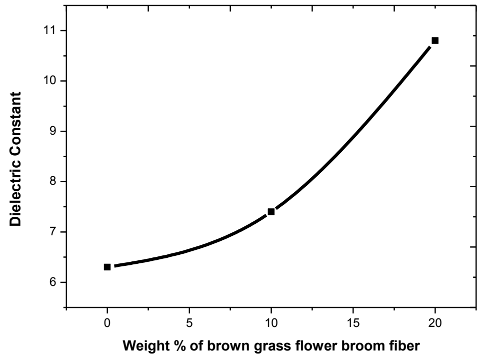

Fig. 4: Variation of Dielectric Constant with Amount of Fiber Reinforcement.

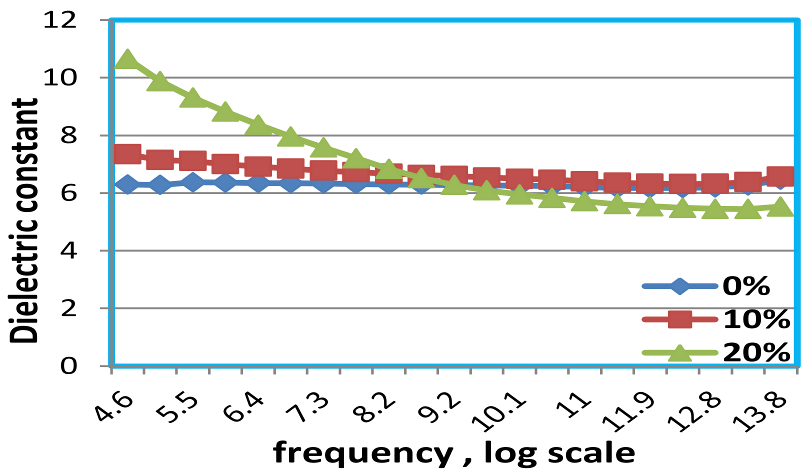

***Fig. 5:** Variation of Dielectric Constant with Frequency.*

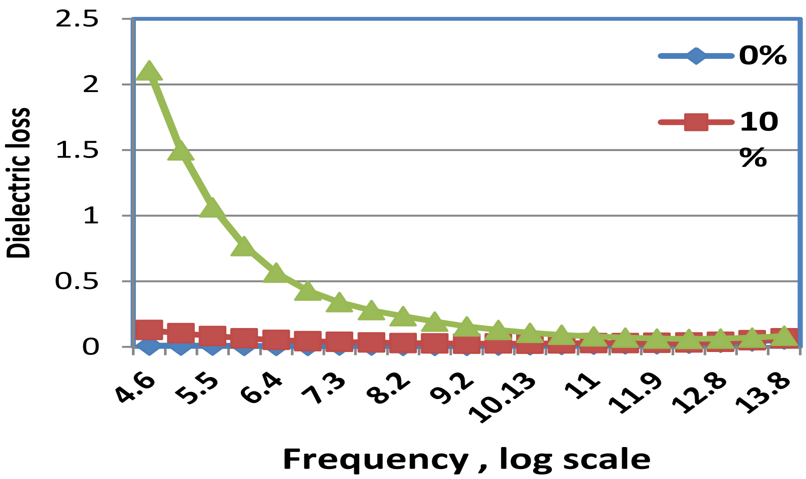

***Fig. 6:** Variation of Dielectric Loss with Frequency.*

CONCLUSIONS

Brown grass flower broom fiber-reinforced epoxy composites can be prepared easily with different weight percentages of reinforcement. With increase in reinforcement content, the density of the composite decreases and the hardness of the composite increases and hence make it lightweight and high strength. Dielectric properties (relative permittivity and loss factor) of pure epoxy resin and composites with different amount of broom fiber-reinforced polymer composite have been studied in the frequency range of 100 Hz to 1 MHz. The experimental results indicate that the dielectric constant and dielectric loss factor decrease with increasing frequency maybe due to the orientation polarization and increases with increasing temperature due to greater movement of polar molecular dipole which appears to be beneficial in electronic industry and which can be processed by village artisans also. As the composite is made using bio-materials from local resources, its cost is less compared to other polymer composites available today. This can further open up a new frontier for industrialization in rural sector.

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