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DIELECTRIC STRENGTH ANALYSIS OF *ACACIA NILOTICA* WITH CHEMICALLY TREATED SISAL FIBER REINFORCED POLYESTER COMPOSITE

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This work focuses on utilizing the chemically treated and untreated sisal fiber along with *Acacia Nilotica* as a secondary reinforcement in the polyester matrix. Composite specimens were prepared by using different volume percentage of the reinforcements. Dielectric properties of untreated and NaOH, $KMnO_4$, $C_{18}H_{36}O_2$ and $C_4H_6O_5$ treated sisal fiber reinforced polyester composites were studied initially. Test results have shown that the composite material incorporated with 20% v/v treated sisal fiber has higher dielectric strength. Further investigations were carried out on the effect of the *Acacia Nilotica* natural filler in the Dielectric and water absorption properties of the sisal fiber/ polyester composite. The Composites were fabricated by incorporating the *Acacia Nilotica* filler in 5, 10, 15 and 20 volume percentages with the NaOH treated sisal fiber reinforced polyester composite. It is found that the addition of natural filler and surface treatment enhanced the dielectric properties of the composites.

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Keywords: Bio filler, Sisal fiber, Dielectric analysis

1. Introduction

Fiber-reinforced plastic (FRP) composites have been used extensively for the past few decades due to their high strength to weight ratio, low density, high corrosion resistance, and low cost. These FRP composites are best suited for low-and medium-load engineering applications. Increasing demands for recyclable and sustainable materials due to environmental concerns and government policies have necessitated the research in the composites made from agricultural and bio waste materials. Yang *et al.* [1] conducted experiments by using lignocellulosic material (rice-husk flour) as reinforcement in polypropylene matrix. Test results revealed that the mechanical strength of the composite have decreased with increase in the filler loading whereas the tensile modulus had shown improved with filler loading**.** Li *et al.* [2] studied the effect of surface modification of different bio fibers using various chemical treatments and concluded that chemical treatment of the fiber resulted in better surface adhesion and also improved the tensile strength of the fiber. Uma Devi *et al.* [3] made experimental studies of viscoelastic properties on the palm leaf and glass fiber reinforced polyester hybrid composite and found that the addition of bio fiber resulted in the enhancement of the viscoelastic properties. Tran *et al.* [4] studied the effect of the fiber loading and alkali treatment on the tensile and flexural properties of short coir/poly butylene succinate (PBS) biodegradable composites and found that the chemical treatment of coir fibers increased the interfacial adhesion between the fiber and the matrix. Better tensile and flexural properties were obtained for the alkali treated bio fiber loading of 20%. Prithivirajan *et al.* [5] made experimental investigation on the mechanical properties of the

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hybrid bio composites made using the bio wastes. Rice husk, coir pitch and groundnut shell powder were used as particulate bio fillers in the epoxy matrix. The results have shown that the hybridization of the bio fillers resulted in enhanced mechanical properties and reduced swelling behavior of the composite material. Ray *et al.* [6] have conducted experiments to determine the effect of soaking time of 5% NaOH on the jute fibers. It was shown that the elastic moduli of the treated jute fibers were improved due to alkali treatment. It was also reported that the maximum flexural strength and laminar shear strength was obtained for the jute/vinyl ester composite with 35% jute fibers with a soaking time of 4hrs. Mishra *et al.* [7] investigated the effect of maleic anhydride (MA) on the properties of banana, hemp and sisal fibers. Composites were fabricated by using MA treated bio fibers as reinforcement in novolac resin. Test results had shown that, the better mechanical properties were obtained for the composites with MA treated fibers. Higher absorption of steam and water was also observed for the composites with untreated fibers. Rong *et al.* [8] carried out different types of surface treatments such as heating, silane, alkalization, acetylation, and cyanoethylation on the sisal fiber. The investigations revealed that the fiber treatment resulted in partial removal of lignin and hemicellulose of the bio reinforcement. Composites were fabricated by incorporating treated sisal fiber in the epoxy matrix and it was shown that the mechanical strength had been increased due to changes in the surface and internal structure of the fiber. Dynamic mechanical properties and thermal behavior of the short sisal/polystyrene composites were investigated by Nair *et al*. [9]. The thermal stability of the composites was found to be better than the sisal fiber and polystyrene matrix. The effects of fiber loading, fiber orientation and fiber surface treatment on the thermal and viscoelastic properties of the composites were studied. Sreekumar *et al.* [10] have conducted experiments to determine the effect of different chemical and physical modifications on the sisal fibers in its mechanical properties. Composites were prepared using resin transfer moulding technique and tests results revealed that an increase of 36% in the tensile strength and 53% increase in Young's modulus were obtained due to surface treatments. Arun prakash *et al.* [11] prepared composites using iron oxide particle dispersed E-glass fiber and epoxy resin. Dielectric properties of the composites were studied and the results revealed a significant improvement in the thermal and dielectric properties of the composites. Due to the growing significance of the bio materials, in this work *Acacia Nilotica* was used as bio filler and sisal was used as fiber reinforcement in the polyester matrix. Dielectric and water absorption characteristics of the untreated and chemically treated sisal fiber reinforced polyester composites were studied. Also the effect of bio filler on the dielectric properties was studied in this work.

2. Materials and methods

Unsaturated Polyester resin was used as matrix and *Acacia Nilotica* bio filler was used as natural filler with sisal fiber as reinforcement in the composites. The surface property of the Sisal fiber was modified using various chemical treatments such as Sodium hydroxide (NaOH), Potassium permanganate ($KMnO_4$), Stearic acid ($C_{18}H_{36}O_2$) and Malic acid ($C_4H_6O_5$). Composite specimens were prepared by using different volume fractions of *Acacia Nilotica* bio filler and the effect of filler loading and chemical treatment of the reinforcement fiber on the dielectric and water absorption properties of the composite was studied. Composite specimens were prepared by using short random oriented sisal fibers, the fiber length was maintained at 10mm for all the specimens. Figure 1 shows the composite preparation using hand layup method.

The ability of a material to get polarized and store electric charge when an external electric field is applied to it through two parallel plates acting as capacitor, gives the value of dielectric constant of that material. Dielectric constant helps in selection of capacitor material for the design and manufacturing of capacitor which will be used in capacitor banks for electrical power factor improvement. Polarizability of the material determines the degree of dielectric constant. Dielectric constant is directly proportional to the polarizability of the molecules. Dielectric constant depends on factors such as atomic polarization, dipole, and electronic polarization. Polar groups present in the materials results in the dipole or orientation polarization, it is also called relative permittivity and is denoted by symbol ε. When a voltage is applied to a material certain amount of energy is wasted by the insulating material, this is represented by dissipation factor (tan δ). It is the ratio of electrical energy dissipated to the total energy circulated in the circuit. The test setup and the specimens are shown in figure 2.

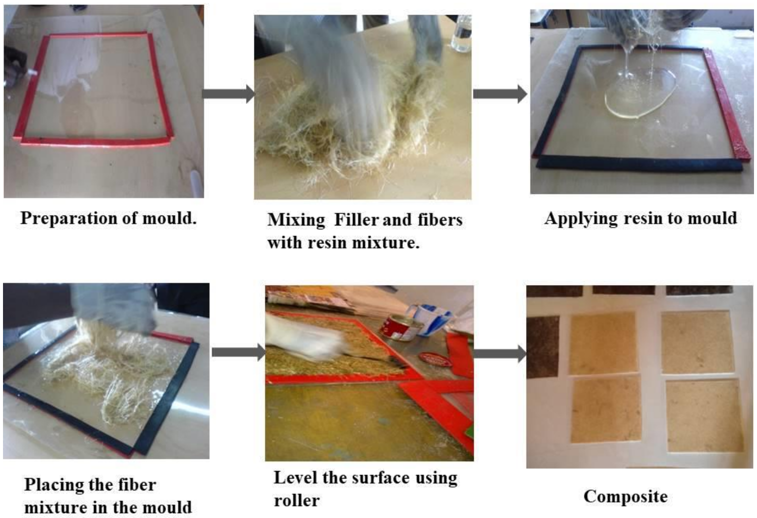


Fig. 1 Fabrication of composite using hand layup process.

a) *b)*

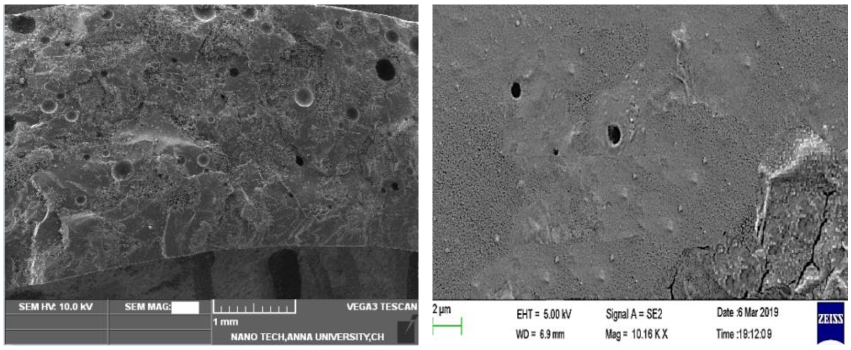
Fig. 2. Dielectric strength a) tester machine. b) Composite samples.

3. Results and Discussion

3.1. Dielectric strength:

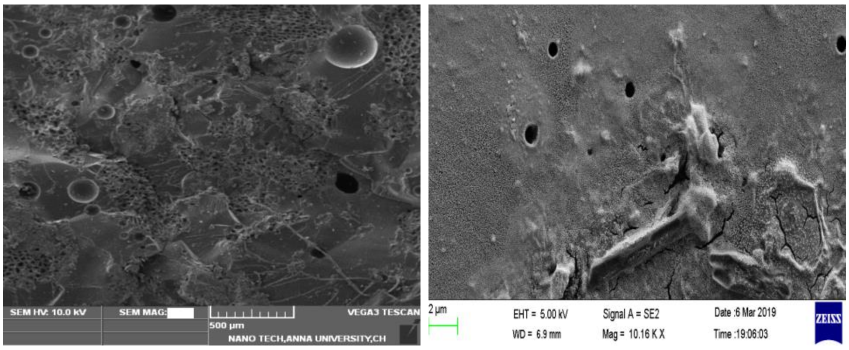
The value of dielectric strength of the composites is given in table 1. It was observed from the table that the polyester composite reinforced with untreated sisal fibers had shown higher value of dielectric strength. In general, the dielectric strength of the fiber reinforced plastic composite materials depends on the interfacial polarization and orientation polarization of the matrix and the sisal fibers/bio filler. The difference in conductivities of both the reinforcement and matrix resulted in interfacial polarization. It is noted from the table 1 that the dielectric constant of the treated fiber reinforced polyester composite is low compared to that of the untreated fiber reinforced composite. This is because of the reduction in the orientation polarization of the composite material because of the hydrophobic nature of the chemically treated sisal fibers. The higher value of dielectric constant for the untreated sisal fiber composite is also due to the presence of the moisture content and impurities in the fiber. NaOH treated fiber reinforced composite showed lower value of dielectric constant representing the removal of moisture absorption capability by limiting the interaction between the polar –OH groups in the material. It is also observed from the results that the surface modification by various chemical treatments have reduced the dielectric voltage of the composite material in similar fashion to that of NaOH treatment.

SEM images of different surface treated sisal fiber based composites before and after the dielectric strength testing are shown in Fig 3 - 6. The burnout of the composite specimens due to the application of the breakdown voltage during the dielectric testing is seen from the SEM images. The addition of bio filler, *Acacia Nilotica* showed an improvement in the value of dielectric constant upto 10% v/v and a slight reduction in the value of dielectric constant is noted at higher volume fraction of *Acacia Nilotica* in the sisal fiber/polyester composite. The reason for increase in the value of dielectric constant could be because of the formation of heterogeneous mixture due to the addition of bio filler in the matrix. The charges are accumulated and trapped in between the interfaces of the reinforcement/matrix, leading to the interfacial polarization while applying the external electric field. A slight decrease in the value of dielectric constant was observed at 15% v/v and 20% v/v bio filler content in the polyester matrix; this may be due to the agglomeration of the bio filler in the composite material at higher volume fractions.



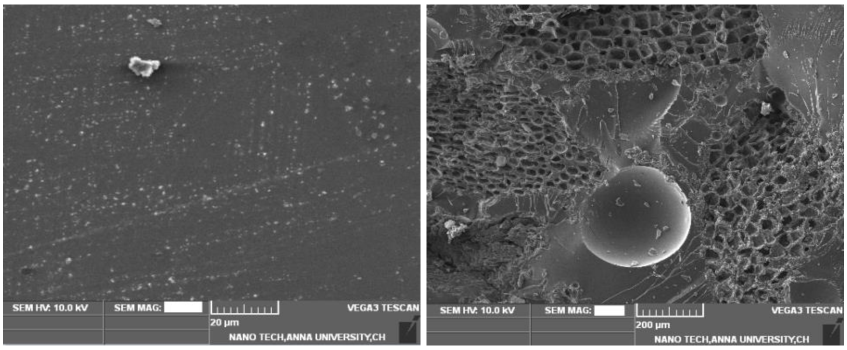
a) *b)*

Fig. 3. SEM images of Malic acid treated fiber composite specimen: a)before dielectric testing and b) after dielectric testing



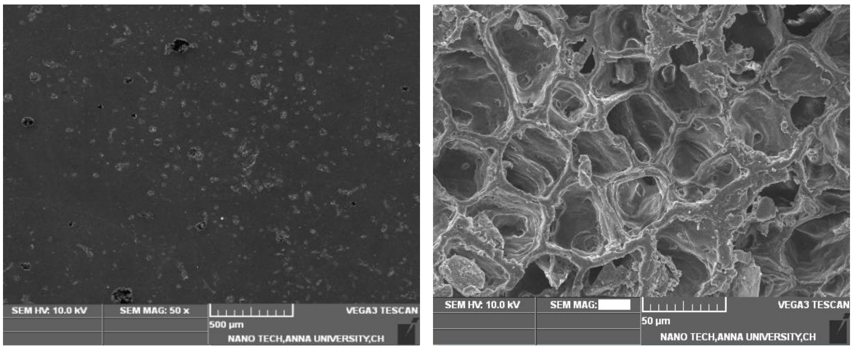
a) *b)*

Fig. 4. SEM images of NaOH treated fiber composite specimen: a)before dielectric testing and b) after dielectric testing



a) *b)*

Fig. 5. SEM images of $KMnO_4$ treated fiber composite specimen:
a)before dielectric testing and b) after dielectric testing



a) *b)*

Fig. 6. SEM images of Stearic acid treated fiber composite specimen:
a)before dielectric testing and b) after dielectric testing

Table 1. Dielectric strength of different surface treated sisal fiber and natural filler based composite.

S.No.	Different Surface Treatments	Dielectric Strength (V)
1	Untreated Sisal fiber (20% v/v) reinforced Composite	93.87512
2	NaOH treated sisal fiber (20% v/v) reinforced Composite	64.96681
3	$KMnO_4$ treated sisal fiber (20% v/v) reinforced Composite	71.200152
4	Stearic acid ($C_{18}H_{36}O_2$) treated sisal fiber (20% v/v) reinforced Composite	74.433494
5	Malic acid ($C_4H_6O_5$) treated sisal fiber (20% v/v) reinforced Composite	72.133519
6	NaOH treated sisal fiber with 5 % filler (20% v/v) reinforced Composite	67.142371
7	NaOH treated sisal fiber with 10 % filler (20% v/v) reinforced Composite	75.561413
8	NaOH treated sisal fiber with 15 % filler (20% v/v) reinforced Composite	74.874691
9	NaOH treated sisal fiber with 20 % filler (20% v/v) reinforced Composite	73.441567

3.2. Water Absorption Test:

The water absorption test was carried out as described by ASTM D570 standard. The experimental results were shown in figure 7. The percent weight gain which is an indicator of amount of water absorbed is calculated by using the expression given in equation 1.

$$w_g = \frac{W_t - W_i}{W_i} \text{ x } 100 \qquad (1)$$

w_g - Percent weight gain
w_i –Initial weight of the specimen (g)
w_t – Weight of the specimen after time ‘t’ (g)

The influence of chemical treatment of the treated and untreated sisal fiber reinforced polyester composites on the water absorption characteristics had been studied. The percent weight gain is calculated by weighing the composite specimen after immersing in the water for a specific period of time and then measuring the weight at regular intervals to observe for any changes in its weight. It was observed from the plot that the weight gain of the composites exhibited an increasing trend with increasing time of immersion. But the water absorption of the composites have saturated after an immersion time of 8 days. It was observed from the plots that the untreated sisal fiber reinforced polyester composite exhibited higher water absorption which is due to the hydrophilic nature of the untreated sisal fibers. The water absorption of chemically treated fiber reinforced composites had shown a reduction in the water absorption when immersed in water. NaOH treated sisal fiber reinforced composite exhibited lower value of water absorption when compared with other surface treatments, showing higher value of hydrophobic nature.

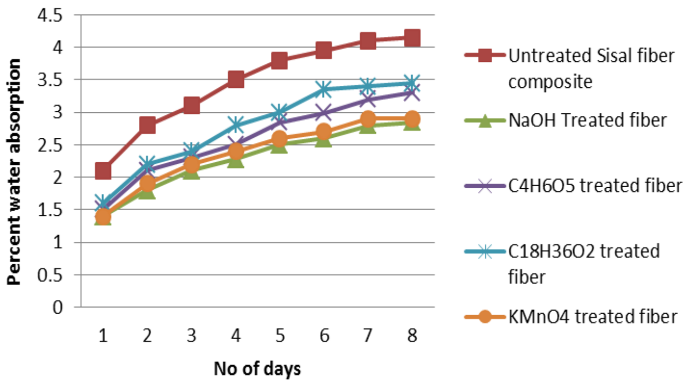


Fig. 7. Water absorbtion properties of treated and untreated sisal fiber composites.

4. Conclusions

FRP Composites based on untreated and chemically treated sisal fiber and *Acacia Nilotica* bio filler were developed, the composite specimens were prepared by keeping the sisal fiber loading at 20% v/v in polyester matrix. Dielectric property was evaluated for the composites and it was found that the composite with untreated sisal fiber resulted in higher dielectric constant. NaOH treated sisal fiber reinforced polyester composite had shown low dielectric constant value indicating hydrophobic nature of the composite material.

The addition of bio filler resulted in marginal increase in the dielectric constant value up to 10% v/v filler loading. Further composite specimens were tested to assess the influence of chemical treatments on the water absorption characteristics of the composite materials. It was observed that the composites incorporated with the untreated sisal fiber exhibited higher water absorption; whereas composite specimen with NaOH treated sisal fiber had shown lesser water absorption. SEM images were taken to study the fiber matrix interaction.

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