

Biodegradable *Sansevieria cylindrica* Leaves fiber/ Tamarind fruit fiber based Polymer hybrid composites on characterization

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ABSTRACT

This paper deals with the preparation and characterization of epoxy tamarind fruit (Tf) and *Sansevieria cylindrica* (Sc) hybrid composites containing fiber 0:20, 5:15, 10:10, 15:5 and 20:0 of (Tf:Sc) combinations loading. *Sansevieria cylindrica* leaves were used in this paper for extracting fiber out of it and in the similar manner ripen Tamarind fruit was used to extract fiber. Two different fibers viz. tamarind fruit/ *Sansevieria cylindrica* fibers were loaded into the epoxy system to develop the hybrid composites. The tensile and flexural properties of the resulting 20 wt. % loading of Tf/Sc/epoxy hybrid composites were examined. The resulting hybrid composites of 20 wt. % Tf/Sc with varying combinations exhibit the optimum improvement of mechanical properties and dielectric strength. 2 °C rise in decomposition temperature and 5 °C rise glass transition temperature were observed from the TGA and DSC thermal analysis. The fractured cross sections of flexural samples were assessed their performance as a function of fiber loading of Tf/Sc/epoxy hybrid composites by SEM analysis.

Keywords: hybrid composites; mechanical properties; thermal; SEM

1. INTRODUCTION

In the present scenario, one of the biggest scientific and technological challenges of the day is to create novel materials for innovative applications. New fiber-reinforced materials called hybrid composites were created and are still being developed. First, shrinking a something means that lesser material is required to build it. Material is like an excess baggage.

It costs money, adds weight and takes up space. These considerations weigh heavily on all engineering decisions and are of utmost importance for certain applications-for example, satellite and space craft systems, which must be as small as possible. Moreover, it is expensive and inefficient to take heavy things into space: the cost of launching the space shuttle in 2004 is about \$10,000 per pound of weight. Smaller systems perform quicker because they have less mass and therefore lesser inertia (the tendency of mass to resist acceleration). This improved speed leads to products that perform tasks faster, just as a fly can flap its wings much faster than the bird. Another example cited is an assembly robot in a factory. It might perform ten welds in a second, while an enzyme in our body performs as many as millions chemical operations in the small amount of time. Thermal distortions and vibrations do not perturb smaller devices as much as the larger ones, because the resonant vibration of a system is inversely proportional to its mass. In this context fibers reinforce hybrid composites ruling proved themselves that they are unique way of sinking weight when compared to the other ways. Fiber reinforced hybrid silk/sisal unsaturated polyester based hybrid composites were studied to assess the influence of fiber length viz. 1, 2 and 3 centimeters length on mechanical and chemical resistance properties [1].

Chemical resistance and tensile properties of epoxy/unsaturated polyester-blend coated bamboo fibers are evaluated [2]. Sisal/glass reinforced unsaturated polyester hybrid composites were studied on chemical resistance and tensile properties of sisal fibers [3]. Flexural, compressive, and interlaminar shear resistance properties of kapok/glass polyester composites with and without alkali treatment of fabrics were evaluated and mechanical performance of kapok/glass composites were proved excellent and these properties increase with increasing glass fabric content in composite [4]. Hybridization with glass fabric enhanced the performance properties namely impact strength was increased upto 34% of kapok/ glass and kapok/sisal fabrics reinforced polyester hybrid composites. Similarly, addition of kapok fabric to sisal/polyester composites enhanced the properties. The effect of alkali treatment of fabrics on impact strength of these composites was studied [5]. Composite from hand lay-up technique was proved to be virtually shown significant results as tensile and hardness properties were improved for kapok/glass fiber hybrid fibers [6]. Manufacture of textile composite beams and on the determination of their mechanical properties and the effects of fibre orientation on the mechanical properties of braided and woven textile composites were investigated [7].

Hardness, impact strength, frictional coefficient, and chemical resistance of hybrid composites with and without alkali treatments at different fiber lengths such as 1, 2 and 3 cm [8]. Physical and mechanical performance of hybrid betel nut (*Areca Catechu*) short fibre/*Sansevieria cylindrica* (agavaceae) polypropylene composite filled with betel nut(*Areca catechu*) short fibre (Bn) at different compositions (3, 5, 10, 20 and 30 wt. %), using the extrusion and hot press molding technique were studied [9]. The effect of dispersion, alkali treatment, resistance to chemicals and influence of silica powder on mechanical, thermal properties of hybrid fibre (i.e. jute/glass) composites were investigated as a function of silica loading. NaOH treatment of jute fibres was found to increase the interface between matrix and hybrid fibers [10].

Coir dust reinforced polymer composites were prepared with epoxy resin as the matrix and the experimental results show that ϵ' , ϵ'' , and σ are increased and ρ is decreased with the addition of coir dust in epoxy resin. It is also observed that the dielectrical properties of the composites showed a strong dependence on frequency and temperature [11]. The uniaxial natural fabric *Hildegardia populifolia* was coated with polycarbonate and its tensile strength, modulus and percent elongation at break were determined.

The effect of alkali treatment and a coupling agent on the tensile properties of the fabric was also studied [12]. Ridge gourd/phenolic and ridge gourd/phenolic/glass hybrid composites were prepared using resol resin PF-108 as the matrix, the twin layered vegetable fabric ridge gourd (without and with alkali treatment) as the reinforcement and glass fabric as a co-reinforcement were studied [13]. Initial and final degradation temperatures (using Doyle method), morphology, effect of alkali treatment and tensile parameters of natural uniaxial fabric from the bark of the tree *Polyalthia cerasoide* was extracted were studied [14]. The flexural, compressive properties of bamboo/glass fiber-reinforced epoxy hybrid composites were studied. The effect of alkali treatment of the bamboo fibers on these properties was also studied. It was observed that both flexural and compressive properties of the hybrid composite increase with glass fiber content. These properties were found to be higher when alkali-treated bamboo fibers were used in the hybrid composites [15].

The chemical resistance of the glass/bamboo fibers reinforced polyester composites to acetic acid, sodium hydroxide, ammonium hydroxide, sodium carbonates, benzene, toluene, carbon tetrachloride, and water was studied. The hybrid fiber composites showed better resistance to these chemicals [16]. A microstructural analysis of *Sansevieria cylindrica* leaves showed the presence of structural fibres and arch fibres. Polarised light microscopy and scanning electron microscopy of these fibres revealed a hierarchical cell structure that consisted of a primary wall, a secondary wall, a fibre lumen and middle lamellae [17]. Polyester filled with *Sansevieria cylindrica* fiber composites were studied successfully on mechanical properties, performance increases in increasing fiber content and optimized at 40wt.% fiber ratio were recorded [18].

Tamarind fruit fiber was first time doped into the polyester matrix, effect of with and without alkali treatment was ascertained on tensile properties, thermal properties [19]. Epoxy resin is the most important class of thermosetting material and widely used for fiber reinforced composite material (FRCM) and for structural adhesives. They have high tensile strength, modulus, uncomplicated during processing, good thermal and chemical resistance and dimensional stability as they are amorphous and highly crosslinked but poor toughness and impact resistance. One of the successful method of promoting the above deficient mechanical properties are reinforcing with innovative natural fibers as natural fibers are strong, rigid, light weight, environmentally friendly, renewable and abundant. It is also clear from the perusal of the literature that the novel and innovative with different fibres have been little explored and hence there is a need to explore this aspect. Aim and the objective of this study is to fabricate light weight, high strength composite that suits for today's transportation systems which is windfall in fuel economy.

In the present paper hybrid fibers such as *Sansevieria cylindrica* and tamarind fruit fibers were used to reinforce the epoxy matrix on mechanical and thermal properties. The hybrid fibers *Sansevieria cylindrica* and *tamarind fruit* fibers weight ratios are viz.0:20, 5:15, 10:10, 15:5 and 20:0 respectively.

2. EXPERIMENTAL

2. 1. Materials

The employed epoxy in this study is (Ciba-Geigy, Araldite-LY 556 and Amine Hardener- HY 951). *Sansevieria cylindrica* and *Tamarind fruit* fibers were plant was obtained from the Enumuladoddi forest, near Kalyanadurg, Anantapur (AP) India.

2. 2. Fiber Treatment

Tf and Sc fibers were taken in a glass tray and a 5 % NaOH solution was added in to the tray and the fibers were allowed to soak in the solution for half an hour separately. The fibers were then washed thoroughly with water to remove the excess grease and hemicellulose sticking to the fibers. Final washing was carried out with distilled water and the fibers were then dried in hot air oven at 70 °C for 4 hrs.

2. 3. Preparation

Twosome Tamarind fruit (Tf) and *Sansevieria cylindrica* (Sc) fibers blends were used for the present study is 20 wt. % with a varying combination of (0:20, 5:15, 10:10, 15:5 and 20:0). Epoxy, Tf and Sc were predried at 100 ±5 °C for 5 h prior to compounding. The Tf (20 wt %) was added to epoxy. The composites were prepared by using melt mixing in a counter-rotating, twin-screw extruder (RC 9000 Haake, Germany).

The temperature profiles in the barrel were 200, 250, 320, 340, and 360 °C from feed zone to die. The screw length to diameter ratio (L/D) was 20:1 and the screw speed was 40 rpm. The extrudates were water-cooled at room temperature, and palletized. The palletized granules of epoxy Tf/ Sc composites were predried at 100 ±5 °C for 5 h. Test specimens were prepared from compression molding in a sheet mold of 180 x 180 x 3 mm³ using a machine from M/s. Sterling Hydraulic Co. Ltd., Mumbai, India.

The temperature of the mold plate was 390 ±5 °C with a cycle of time 15 min, breathing was done after 5 min with an interval of 1 min and then kept at 390 ±5 °C temperature and pressure and cooled to 40 °C under continuous hydraulic pressure of 180 kg/cm². Testing samples were prepared according to ASTM standards.

2. 4. Characterization

Tensile properties measured in this study include tensile modulus, tensile strength and elongation to break, were determined in accordance with the ASTM D638 taking specimens of dimensions (165 x 13 x 3) mm³.

The tensile testing was carried out using a Instron Universal Tensile Testing Machine (UTM) series-3369 at a cross-head speed of 50 mm/min. Flexural properties were measured using a three-point bending test method according to ASTM D790 and tests were carried out using the same UTM, with rectangular bars of dimension (80 x 12.7 x 3) mm³.

Tf/Sc epoxy hybrid composites conducted at a jaw speed of 0.8mm/min at room temperature. Charpy impact tests were performed using a 2.7 J pendulum and striking velocity of 3.46m/s on an Avery Denison Impact tester (model 6709), according to ASTM D256. The specimen dimension was (127 x 12.7 x 3) mm³. The dialectic strength was measured as per ASTM D149 using Zaran Instruments Ltd.

India, with a 3mm thick composite disc. The thermal characteristics TGA/DSC was measured on Tf/Sc reinforced epoxy hybrid composites using SDT Q600 TGA/DSC (TA Instruments) at a rate of 10 °C/min under nitrogen flow. Measurements were carried out at 22 °C temperature, 40 % relative humidity.

Scanning electron microscopy (SEM) studies of the fractured surface of the tensile specimen were carried out on a Jeol (6380LA, Japan). The specimen was sputter-coated with gold to increase surface conductivity. The digitized images were recorded.

3. RESULTS AND DISCUSSION

3. 1. Mechanical

Due to low density natural fibres are widely used as reinforcing agent as it is high biodegradability. Natural fibers are largely divided into two categories depending on their origin: plant based and animal based. Therefore, natural fiber can serve as reinforcements by improving the strength and stiffness and also reducing the weight of resulting biocomposite materials, although the properties of natural fibers vary with their source and treatments. **Figure 1** depicts the change in tensile and flexural strengths with varying Tf/Sc composition. As the Tf concentration with Sc increases, the tensile strength increases up to the 10Tf10Sc (10 wt% Tf: 10 wt. % of Sc) at higher Tf concentration, the tensile strength decreases and remains almost constant at higher concentration of Tf. The increase in tensile strength indicates improved dispersion and reduced the number of failures initiating stress concentration. There is adhesion between the polymer matrixes and fiber, if there is no or weak adhesion, and tensile strength decreases as already reported. The flexural strength slightly increases with the varying composition of Tf/Sc up to 10Tf10Sc, then decreases. The increasing flexural strength is due to Tf which forms bridging across the crack initiation point, which is developed by Tf fiber.

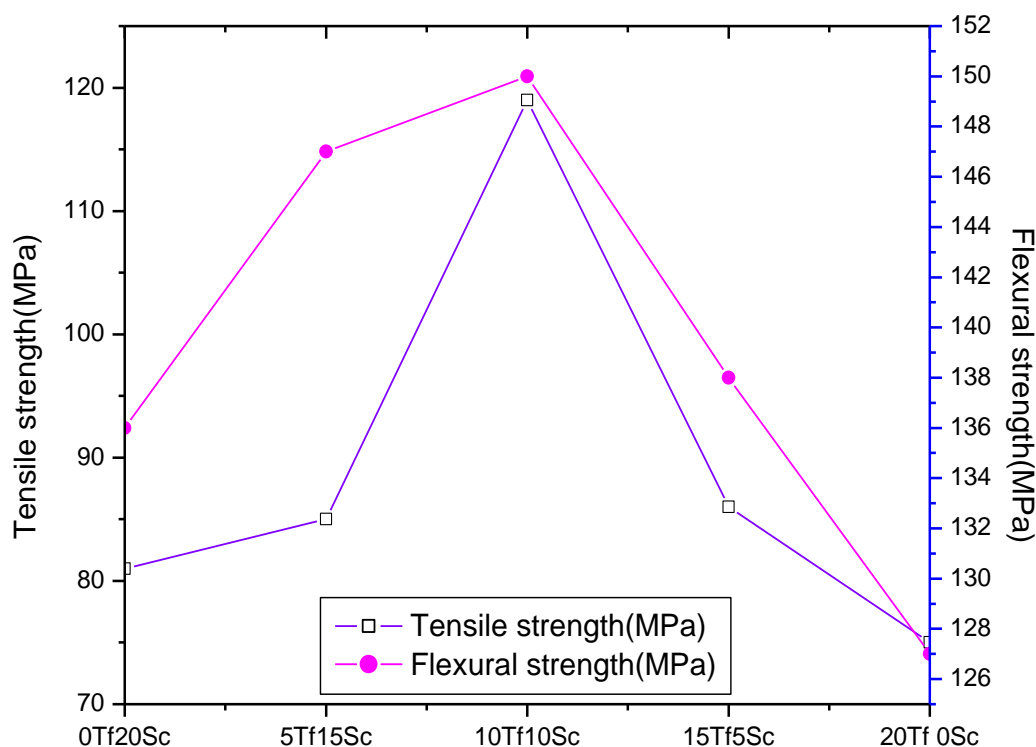


Figure 1. Variation of the tensile and flexural strengths of the hybrid composites.

Figure 2 is also shows the variation of tensile and flexural modulus with varying Tf/Sc composition. The tensile modulus increased the incorporation of Tf in combinations of Sc hybrid composites. In the constant weight of filler loading (20 wt %) with varying

combinations of Tf/Sc shows increased tensile modulus. The drastic increase in flexural modulus of epoxy 5Tf15Sc composition decreases at high composition of Tf fiber composites. With the addition of 5 wt. % Tf in 15 wt. % Sc (5Tf15 Sc), the flexural modulus increases 102 % compared to epoxy Sc composites (0Tf 20Sc). The increase in flexural modulus is because the modulus of Tf is higher than Sc fiber, therefore the combination of the two fillers increases the flexural modulus of composites.

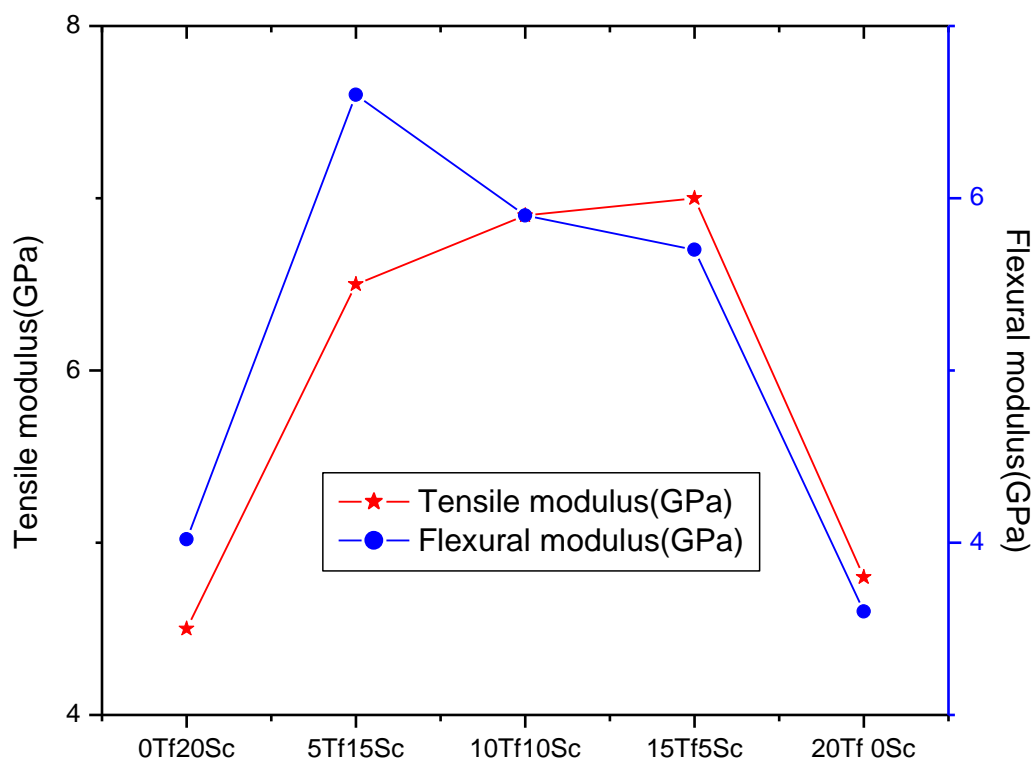


Figure 2. Variation of the tensile and flexural modulus of the hybrid composites.

The variation in percentage elongation with varying concentrations of Tf/Sc is presented in **Figure 3** is also observed that the Charpy impact strength decreases with varying combination of Tf/Sc filled composition of epoxy Tf/Sc hybrid composites. It is also observed that the percentage elongation shows the sinusoidal behavior with varying concentrations of Tf/Sc. Percentage elongation was found maximum at 0Tf 20Sc; decreases at further addition of Tf with Sc composition. Ashok Kumar et al. [9] proved that the greater interaction between the reinforcer and matrix could result in better and more efficient stress transfer which intern could increase the tensile strength of the composite when the size of the reinforcer becomes smaller. John et al. [2] were investigated that performance of the sisal/glass hybrid fibers were based on the alkali and it was optimized when the glass percent was 100 %.

At 10Tf10Sc composition, an increase in percentage elongation may be due to the case of orientation of Sc the direction of applied force with the help of small Tf particles. Especially, the composite of epoxy 10Tf10Sc seems to be the optimum filler composition whose tensile strength, tensile modulus and percentage elongation are highest. Venkata Reddy et al. [5] assessed that impact strength behaviour of fiber lies in the treatment; interface is all

about using kapok and glass hybrid fibre reinforced on the polyester. Impact strength was increased when Tf content rises with Sc fiber upto 10Tf but found big let down when goes beyond 10 wt. %.

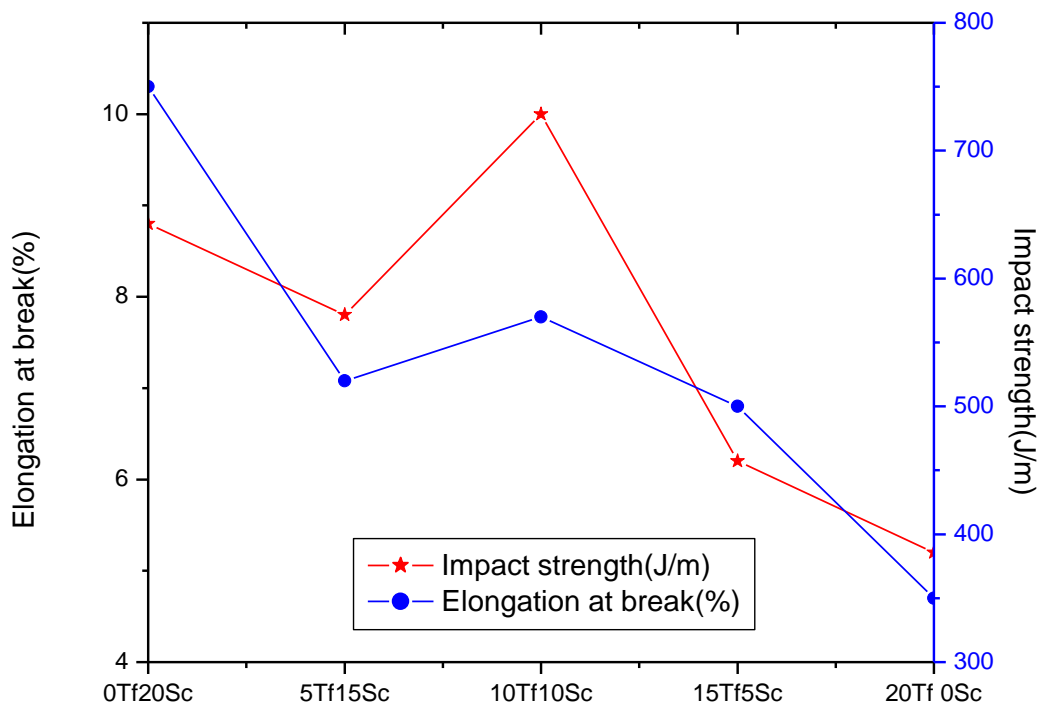


Figure 3. Variation of the elongation at break and impact strengths of the hybrid composites.

3. 2. Thermal

TGA analysis was carried out to estimate the amount of resin present in the hybrid composite and their thermal stability. **Figure 4** shows the weight loss curves of various hybrid composite materials of different combinations as a function of temperature. It is clear that the decomposition temperature of the composite shifted towards the lower temperature due to increase in Tf. The derivative weight loss shows only one peak. The decomposition temperature is 353 °C for 20Tf0Sc, 398 °C for 5Tf 15Sc, 400 °C for 10Tf 10Sc hybrid composite whereas not much variation was found for other loadings. It is clearly noted that decomposition temperature was increased up to 2 °C. It is clear that the decomposition temperature of the composite is shifting towards higher temperature indicating higher thermal stability of the polymer with higher Sc loading. The existence of inorganic materials present in the polymer matrix, generally enhance thermal stability of the composite. In the present case also, the thermal stability increases due to presence of inorganic phase and its interaction with the polymer. The weight loss vs temperature curves shows that the residue left after 450 °C is in line with the epoxy content of each sample. Thermal transition of the pure polymer and the hybrid composites were also investigated by DSC. Jagadesh et al. [12] explored that tensile properties were also found to increase on alkali treatment, polystyrene coating and triethoxymethylsilane coupling agent. The elimination of amorphous hemicellulose by alkali-treatment and filling up of the void regions of the fabric by polymer may be responsible for this behavior.

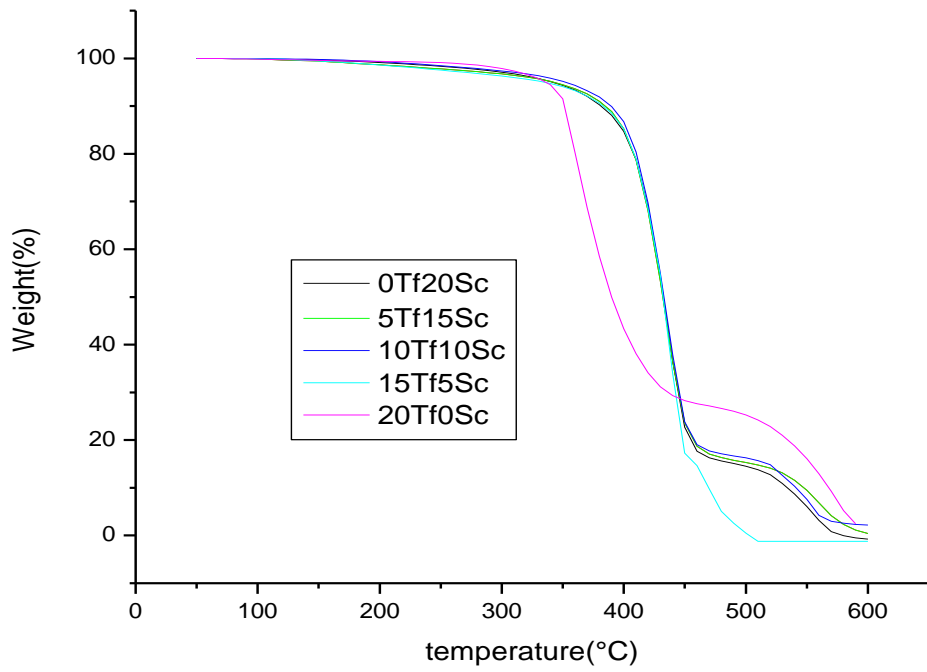


Figure 4. TGA curves of the different samples positions in a hybrid composite.

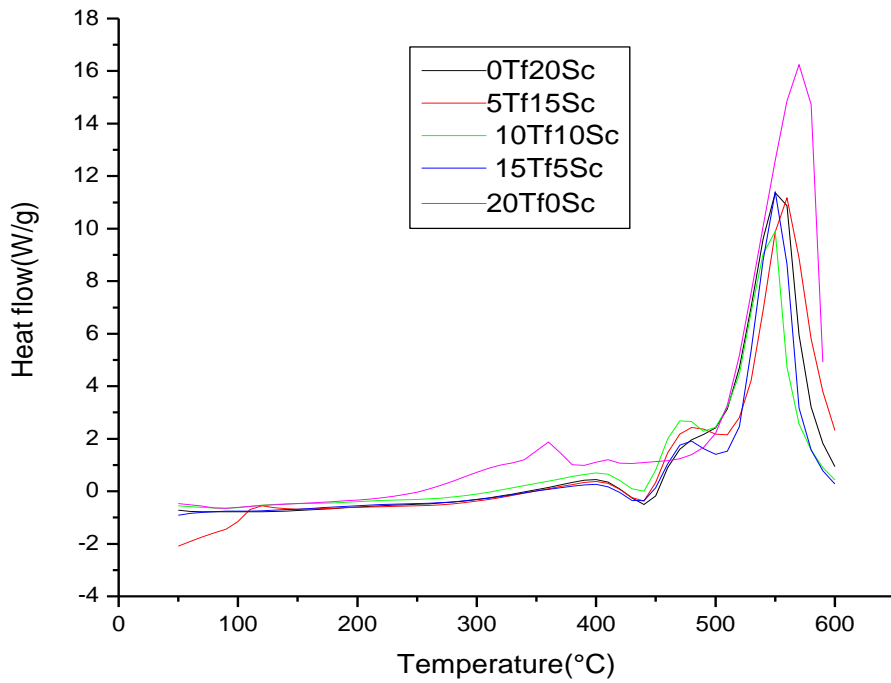


Figure 5. DSC curves of the different samples positions in a hybrid composite.

A typical thermogram for epoxy with two different duo fiber loadings is shown in the **Figure 5**. The glass transition temperature (T_g) of hybrid composite was observed at a temperature of 550 °C for 15Tf5Sc; 555 °C for 20Tf0Sc, while the T_g of the other hybrid combinations were not lived up to the expectations. However, with fiber loading the T_g values do not shift. From the above figures it was clearly noted that 5 °C rise in glass transition temperature was observed. An endothermic peak at 450 °C is observed for 10Tf 10Sc hybrid composite.

3. 3. Electrical

Figure 6 depicts the variation in the dielectric strength with varying compositions of Tf/Sc epoxy hybrid composites. The dielectric strength increases with varying composition of Sc upto 0Tf 20Sc. The leakage of current in Tf is less but when platy, filler-like Sc improves the dielectric strength. Ashok Kumar et al. [9] explored that addition of natural fiber into the polymer were increased upto 30 wt. %. The dielectric strength increases due to the combination of uniform size and the less diameter of fiber improved electrical insulation.

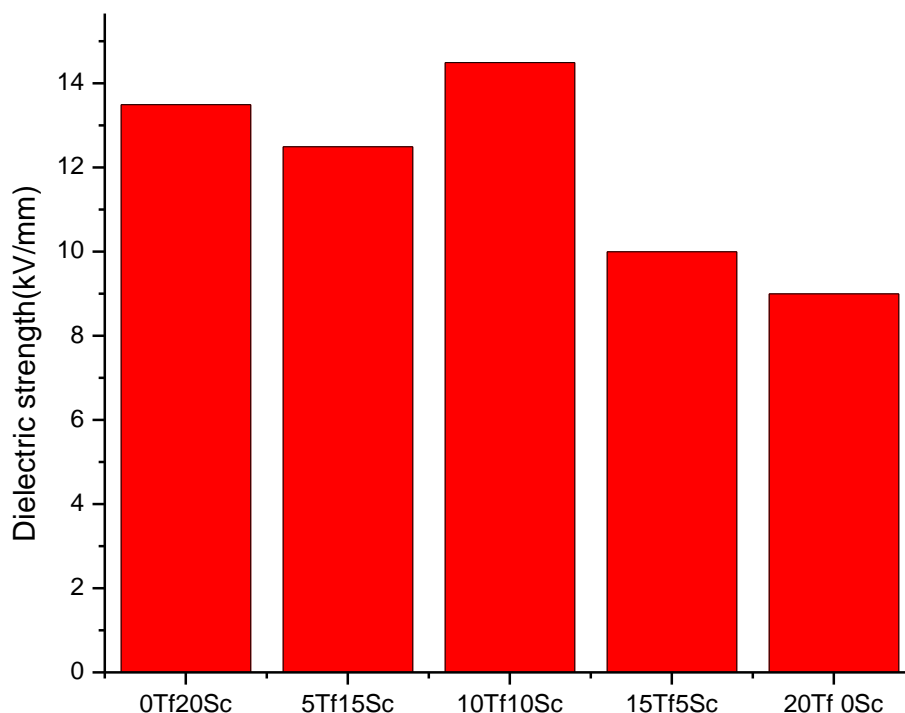
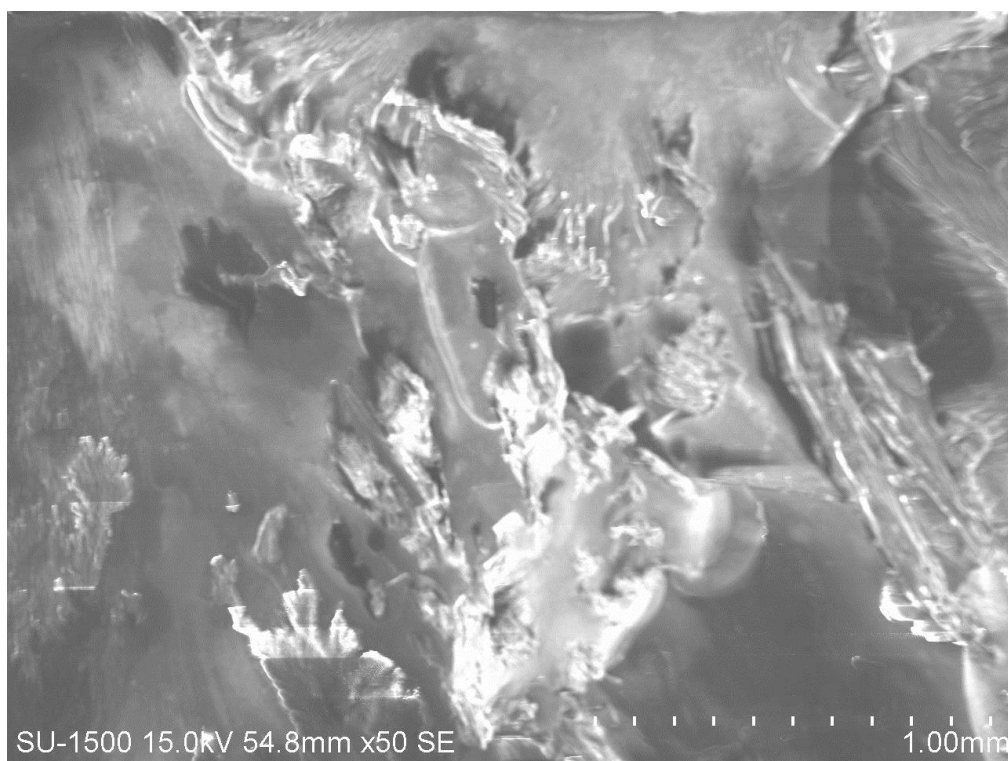


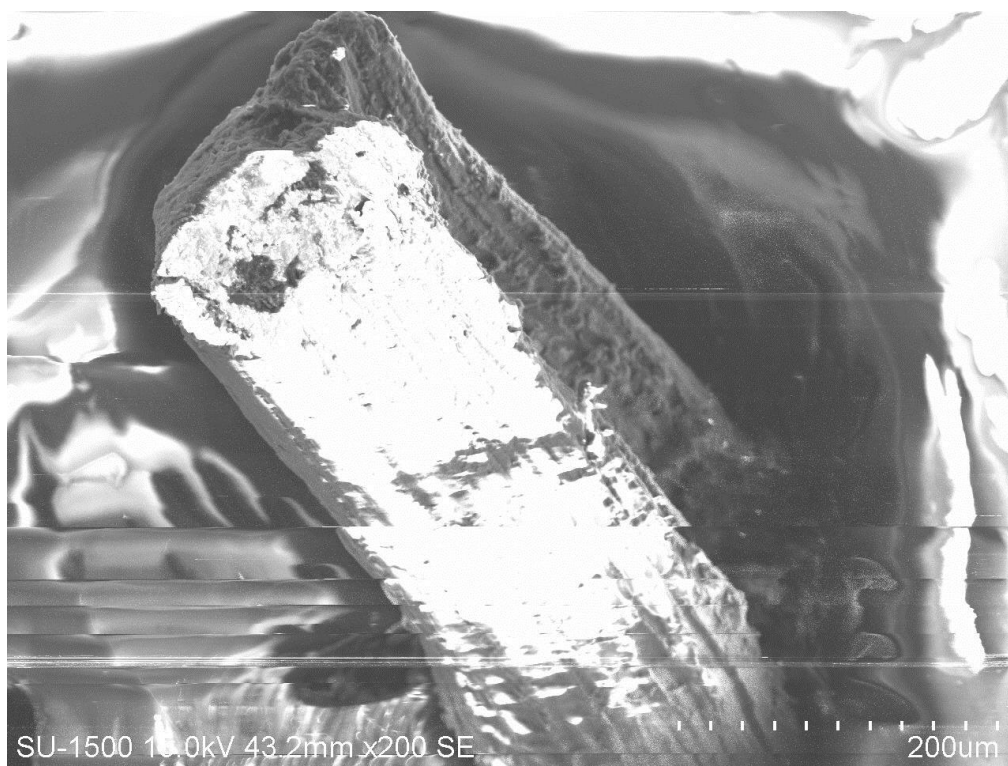
Figure 6. Dielectric strength of the different samples positions in a hybrid composite.

3. 4. Fractured surface observations

To investigate the failure mechanism of hybrid epoxy composites, the fractured surfaces of specimens of are examined. Fractured surfaces of duel fiber reinforced hybrid composites are described for both 0Tf 20Sc (500x, 1000X) & 20Tf0Sc (500x, 100x) magnifications respectively. In **Figure 7 (a & b)** indicates increased surface roughness implies that the path of crack tip is distorted because of the Sc fiber, making crack propagation more difficult.



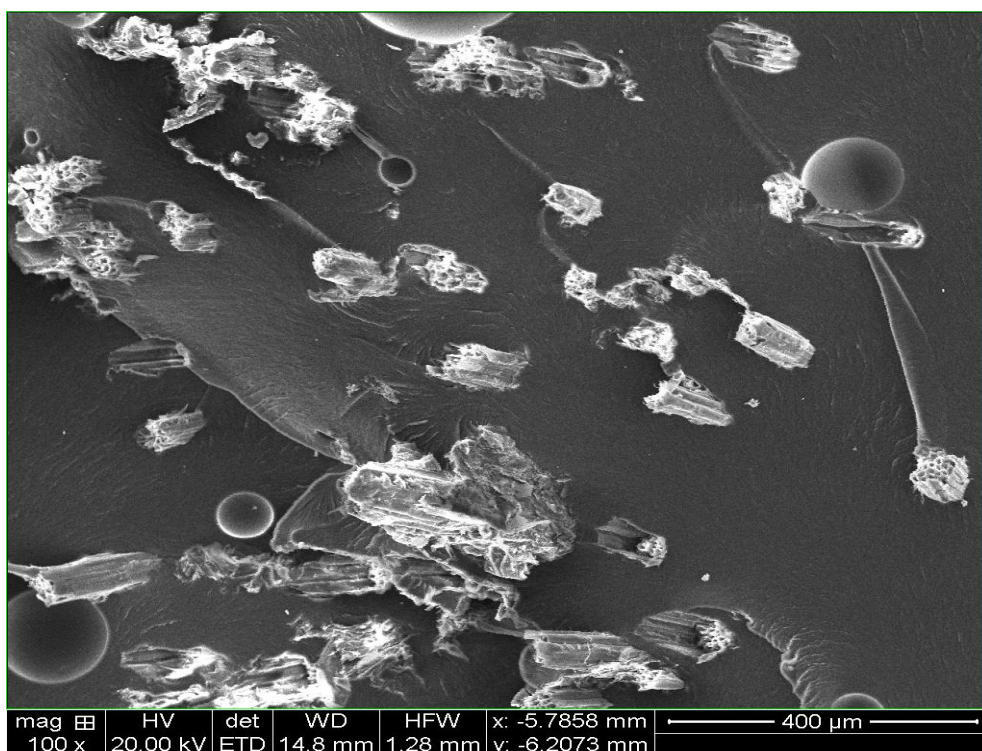
(a)



(b)



(c)



(d)

Figure 7. SEM microgram of (from left); a) 0Tf 20Sc (magn: 500x); b) 0Tf 20Sc (magn: 1000x); c) 20Tf 0Sc (500x); d) 20Tf 0Sc (100x).

It clearly shows that in the **Figures (c & d)** Tf fiber loading system are well separated and uniformly embedded in the epoxy system. In **Figure c** shows less pull out marks was observed as it indicate strong interface Tf fiber and matrix. Venkata Reddy et al. [4] shown that long uniaxial kapok fiber equally strong due to the orientation of unidirectional long fiber when compared with the co-hosting glass fiber. Ashok Kumar et al. [8] observed that performance of hybrid attributed due to alkali treatment and 2cm length of the fiber is more appropriate than the 1 cm and 3 cm lengths of the fibers. Jayaramudu et al. [14] thus proved that performances of natural fiber were improved due to the alkali and coupling agent on SEM analysis. It also indicates high Tf fiber concentration, relatively higher fractions of fiber agglomerations were observed as a result it voids (has been found in the **Figure d**) which act as a stress concentration factors and facilitates shear yielding in the system and therefore, reduced mechanical properties are observed.

4. CONCLUSION

The following conclusions have been drawn from the present study. The tensile and flexural properties of epoxy Tf/Sc hybrid fiber composites was improved by the incorporation of 20 wt. % filler. The optimum strength improvement was observed in the composition of 10Tf10Sc (10 wt. % Tf and 10 wt. % Sc) filled epoxy hybrid composites. Epoxy filled with Tf and Sc showed remarkable improvement in flexural strength and modulus. Hybrid reinforcement of filler in polymer shows significant improvement in the dielectric strength of composites. Finally, it can be concluded that the addition of the small and stiff uniform fiber played the vital role in bringing up the performance as hybrid reinforcement in optimum amount and structure can be adjusted so that the composites act as an effective damper at that temperature range of interest with high processing and mechanical performance. Decomposition and glass transition temperatures were also lifted on TGA and DSC respectively.

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