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Research Article

Mechanical Properties of Epoxy Composite Using Papaya Slice Biochar and Areca Nut Chopped Fibre

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In this work, the effects of amino silane-grafted areca fibre and papaya slice biochar particle on the mechanical, thermal conductivity, and dielectric properties of epoxy resin biocomposite were shown. The goal of the study was to find out how the way fibres are treated affects their properties and how those properties affect the composite as a whole. The acid hydrolysis process is used to treat the raw chopped fibre and slice-dried particles with amino silane and then air-dry them in an oven. The oven-dried areca nut fibre and charcoal particles are then used with a hand-layup method to make composites that meet ASTM standards. According to the results, the tensile and flexural strengths got better by 64% and 50%, respectively, and the impact resistance got better by 93%. The use of reinforcing materials gradually improved the dielectric properties and the way heat moved through the material.

1. Introduction

The reinforcement of composites in natural fibres exhibits more beneficial in composite characteristics and improving in characteristics, similarly more heat dissipation with high mechanical strength material [1]. Hybrid biobased composites that exploit the collaboration between natural fibres in a nanoreinforced in a nanosupported biobased polymer can prompt superior properties alongside keeping up with natural allure. Because of their biocompatibility, biocomposites are employed in a variety of restorative uses like domestic sector and circuit boards [2]. Typically, composites are strengthened by changing the matrix phase by adding fibre and particle, either treated or untreated, to increase the overall strength of the composite [3]. They [4] explore woven natural fibre composites, focusing on woven designs, chemical manipulation, and the underlying theory. The authors concluded that woven banana/kenaf fibres and their composites outperform woven banana/kenaf fibres and their composites in terms of mechanical and other load-bearing properties. Furthermore, [5] discovered that untreated natural areca nut fibre in biocomposites is best suited for structural and nonstructural applications due to its high load-bearing ability. This work [6] conducted a study employing areca nut husk fibre to create a biocomposite panel for a specific use. According to the authors, adding areca fibre between two glass fibres improved the composite's tensile, flexural, and time-dependent behaviour. Natural fibres, on the other hand, have been shown in multiple studies to have inferior thermal characteristics due to the presence of cellulose and loose lignin on their surfaces, and the applications are shown in Figure 1.

Recent researches have used hard particles or biochar-based compounds to improve the thermal characteristics of natural fibre composites. Many researchers have sought to develop new biofillers to improve matrix phases. Eggshell powder, wood apple and peanut shells, wheat and oat straw, tamarind seeds, papaya, banana, and apple slices may be used. The abrasion wear resistance behaviour of waste papaya slice (biowaste) particle into the polymer matrix was investigated by [7]. According to the authors, using papaya slice particles as a filler enhanced the wear properties of the pure epoxy material significantly. They [8] investigated the incorporation of discarded coconut shell biochar

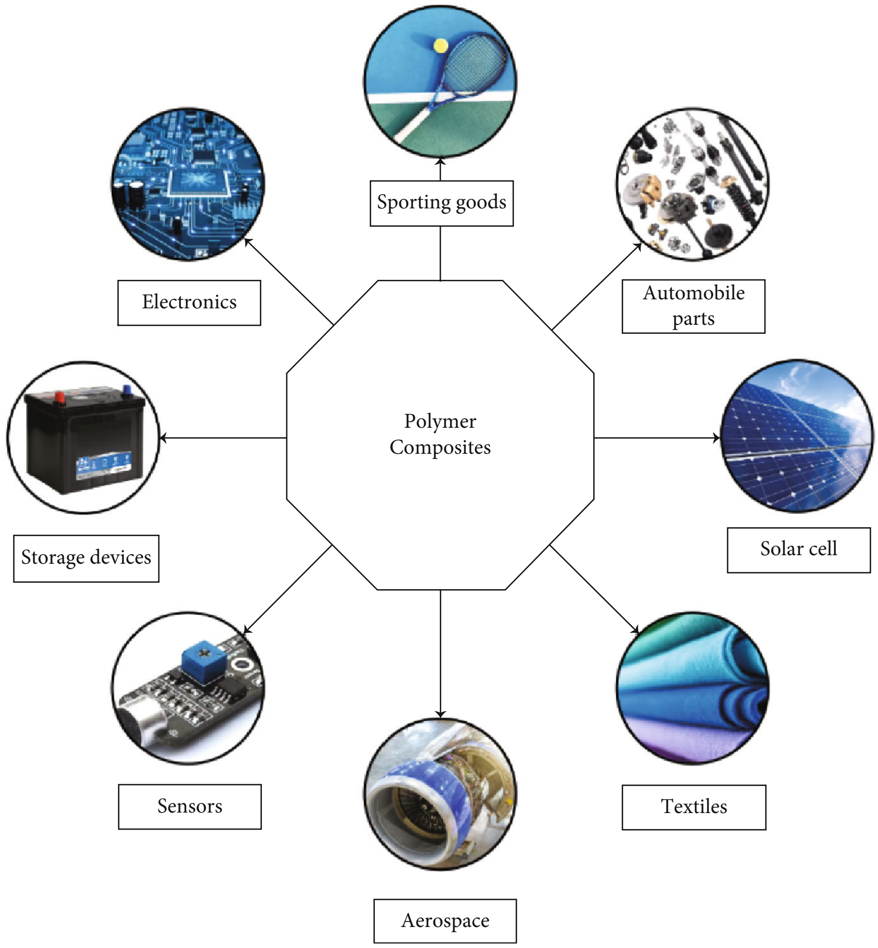


FIGURE 1: Application of polymer composites.

and papaya slice wastes into the resin and created composites for residential use. The SEM photos for OPB indicated a highly desirable diverse void-based structure, whereas the images for CSB revealed cylindrical fissures linked. Similarly, [9] developed an epoxy biocomposite covering for air ducts utilising biosilica. The addition of silane-treated biosilica to an epoxy matrix reduces heat conductivity while boosting viscoelastic properties, according to the author. As a result, past research suggests that particle silane surface treatment is essential for optimal performance in natural fibre composites.

As a result, it is clear that there is a significant research gap, prompting the conduct of this study, which aims to demonstrate the significant benefit of surface modification process on a novel papaya slice biochar and areca nut chopped fibre in composite preparation, as well as its significant impact on mechanical, thermal conductivity, and dielectric properties. The papaya slice is sustainable and biodegradable because it is an agriculture waste. Similarly, areca nut fibre is a long-lasting substance with a great economic value. A hand layup approach with basic process parameters and procedures could be used to produce natural fibre epoxy composites [10]. Such mechanically strengthened and impact-resistant as well as more thermally stable good dialectical characteristic composites could be employed in more cutting edge latest application [11].

2. Materials and Methodology

2.1. Materials. In this work, an epoxy resin generated from Bisphenol-A is used as the matrix, while an aliphatic curing hardener, Triethylenetetramine, is used as the curing hardener. 3-Aminopropyltrimethoxysilane (APTMS) and acetic acid were used. Metro composites in Chennai, India, provided chopped areca nut fibres as areca husks are made of a tough, fibrous substance with a length of 50 mm and a diameter of 100 m. MERCK India Ltd supplied the additional chemicals used in the silane surface treatment.

2.2. Biochar Preparation. After creating fine powders of dried papaya slice, waste papaya biochar was prepared utilising a low temperature and cycle pyrolysis procedure in this study. To make a fine particle, the dried waste papaya slices were first dried and ground for many hours. To avoid oxidation, the particles are pyrolyzed at 400 degrees Celsius in an inert environment. Figure 2 depicts the waste-to-slice powder preparation routes.

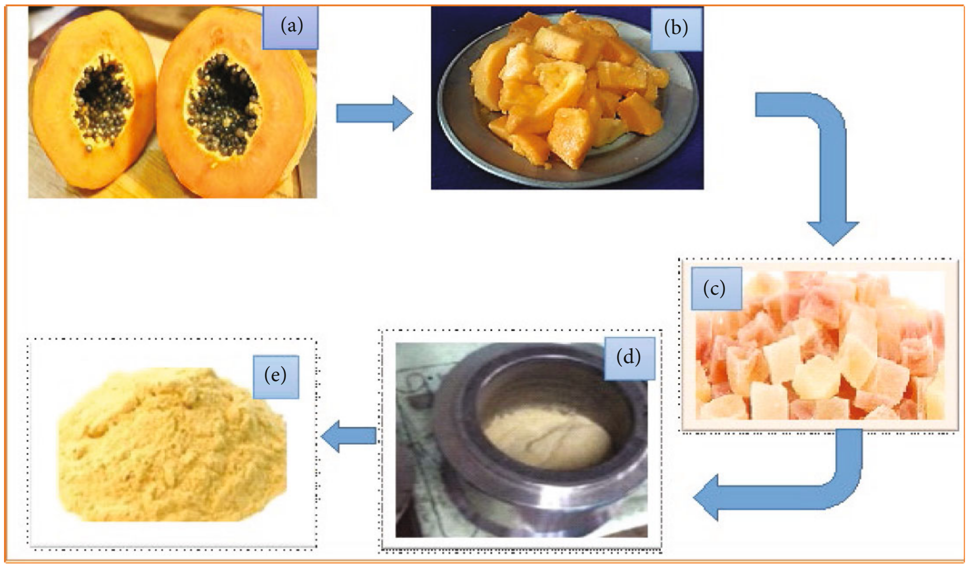


Figure 2: Papaya slice powder preparation. (a) Papaya fruit, (b) extracted slices, (c) sundried slices, (d) ball milling of papaya slice, and (e) papaya slice powder.

Fruit slices were pyrolyzed in a pyrolysis reactor with a 120 mm diameter quartz reactor heated by a muffle furnace. The papaya fruit slice was heated to 400°C at a rate of 10°C/min for 10 minutes [12, 13]. The residue that resulted was collected, sorted, and subjected to additional tests. Environmentally friendly biochar may be produced by using the ball milling procedure. Figure 3 depicts the biochar created during the current study.

2.3. Preparation of Silanized Biochar and Fibres. A suitable amount of 3-aminopropyltriethoxysilane coupling agent with varied concentration was mixed with aqueous solution for silane treatment of volume 90 percent ethanol and ten percent deionized water, followed by 5 minutes of moderate stirring. After that, the biochar was submerged in the ethanol–silane solution and steeped for 10 minutes. After that, the treated biochar was dried for 10 minutes at 110°C to eliminate moisture and produce Si–O–Si structures [14, 15].

2.4. Fabrication of Composite Laminate. A manual layup process was used to produce the composite material in the mould. The surface of the mould was lightly waxed to make composite removal easier. After thorough stirring for 30 minutes, a fine admixture was achieved using varying amounts (1, 2, and 4 vol. percent) of papaya slice biochar and chopped fibre (40 vol. percent). TETA, a curing hardener, was added to the resin-reinforcement admixture and stirred until the hardener was ready to create covalent connections with the resin chains. The admixture was then poured into the silica rubber mould and allowed to cure at room temperature before being postcured in a hot oven at 120°C for 4 hours [16, 17]. The designation and composition of manufactured composites are listed in Figure 4.

3. Characterization

The composites were tensile and flexural tested according to ASTM D-3039 and 790, respectively, with 3 samples in this study. The Izod impact test on composite was performed with a 20 J capacity machine in line with ASTM D-256. The Lee disc method was used to determine the heat conductivity of epoxy biocomposite material. A circular sample with a diameter of 11.2 cm was used to assess thermal conductivity. Similarly, an LCR HI-Tester was used to assess the dielectric constant and loss of composite material in line with ASTM D-150.

4. Results and Discussion

4.1. Mechanical Properties. Tensile testing was used to determine the tensile strength and modulus of the various volume composition composites. Figures 5(a) and 5(b) show the results of the tests for tensile strength and tensile modulus, respectively. The specimens' tensile strength and modulus for composite designation R are roughly 64 MPa and 2588 MPa, respectively, which is an extremely low figure for tensile strength and modulus [18]. The pure epoxy and lack of reinforcement in the composite designation R are due to this lower value. It demonstrates a lack of ductility and is a brittle substance. However, when we added 40 percent silane-treated areca fibre to the matrix material, a significant increase in composite designation RA was found. The results demonstrate that areca fibres have a higher load-absorbing ability than epoxy matrix during testing. The addition of 40% fibres results in a 54-percent increase in tensile strength and modulus. Further insertion of papaya slice silane-treated biochar (1 vol. percent, 2 vol. percent, and 4 vol. percent) improves tensile strength and modulus for composite designations RAB1, RAB2, and RAB3,

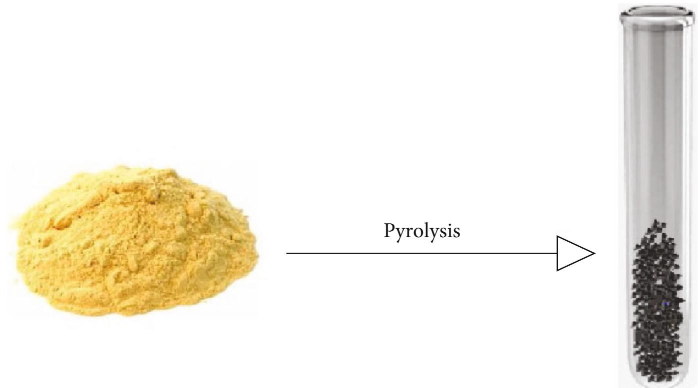
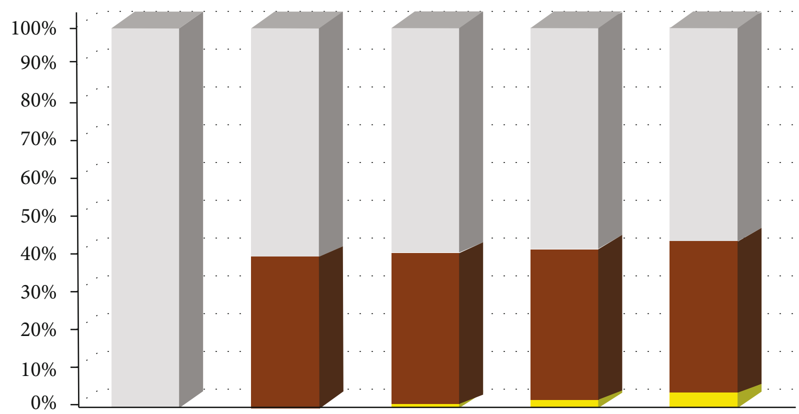


Figure 3: Biochar obtained after pyrolysis process.



Composite designations	R	RA	RAB1	RAB2	RAB3
Resin (vol.%)	100	60	59	58	56
Areca fiber (vol.%)	0	40	40	40	40
Biochar (vol.%)	0	0	1	2	4

Figure 4: Material compositions for different composites.

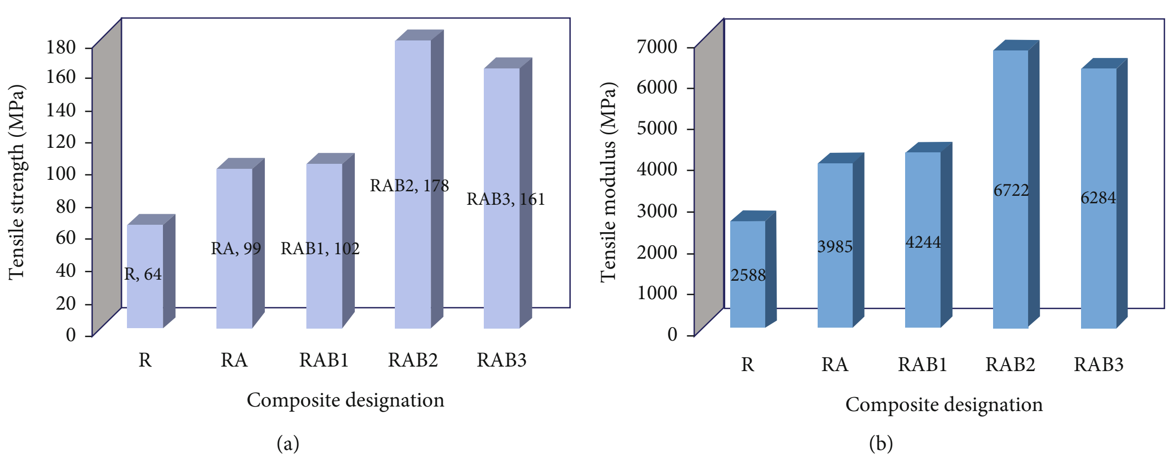


Figure 5: Tensile properties of composites.

respectively. When compared to the composite designation R [19], the increase in tensile strength and tensile modulus for RAB1 and RAB2 is roughly 60% and 64 percent for tensile strength and 60% and 61 percent for tensile modulus. Because of this, papaya slice biochar has been added to natural fibre epoxy composites. These silane-treated biochars have a maximum tensile strength and modulus of 178 MPa and 6722 MPa, respectively, and increase fibre-

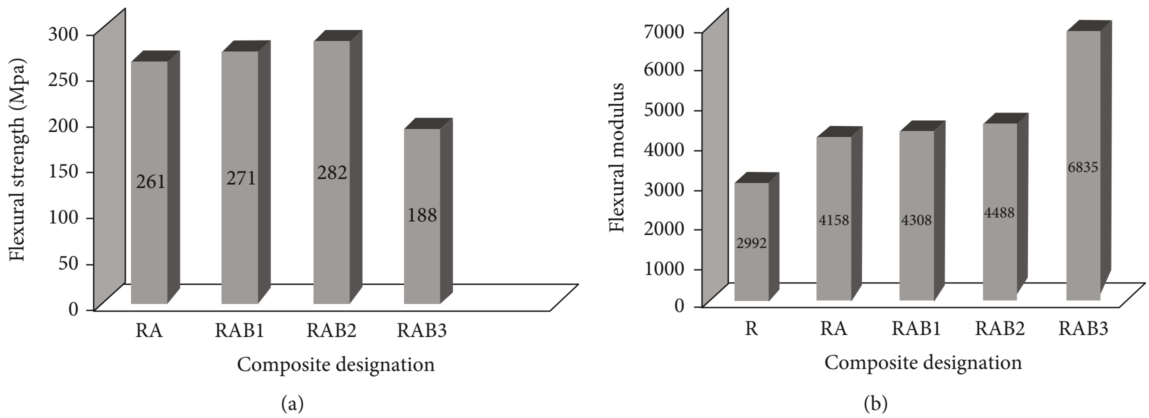


Figure 6: Flexural properties of composites.

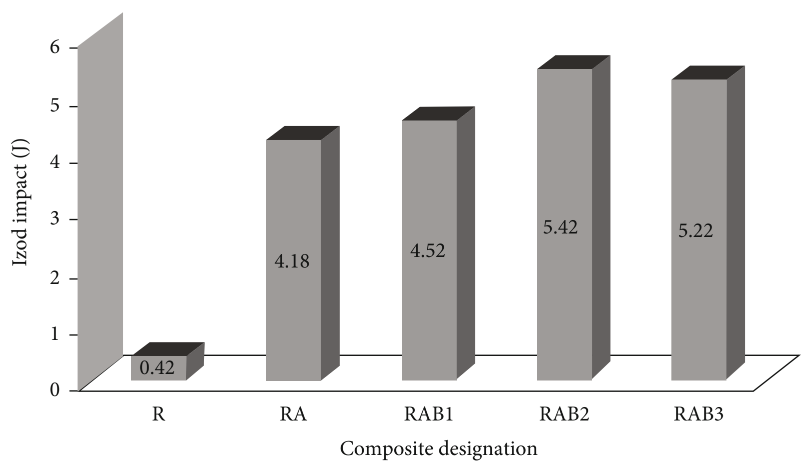


Figure 7: Izod impact of composites.

matrix adhesion. However, with the composite designation RAB3, there is a sharp decrease. It has a tensile strength of 161 MPa and a tensile modulus of 6284 MPa. It demonstrates that adding around 4% papaya slice biochar to a matrix material causes amalgamation in the matrix material, which reduces polymer bonding [20]. As a result, tensile strength and modulus are reduced.

Similarly, the addition of reinforcement boosted flexural strength and modulus, resulting in an improvement in epoxy resin's abrupt load bearing capabilities, as illustrated in Figures 6(a) and 6(b). When compared to composite designation R, the flexural strength of composite designations RA, RAB1, and RAB2 increased by 39 percent, 44 percent, and 50 percent, respectively, which yields flexural strength and modulus of just 102 MPa and 2992 MPa, respectively. Even at lower applied loads, these higher order cross linked molecular chains of epoxy cannot stretch and deform plastically when bending pressure is applied, resulting in these dismal values [21]. For strength and flexural modulus, RAB3 indicates a decrease of roughly 6835 MPa and 188 MPa, respectively. This is the result of clustering of biochar due to increment in volume fraction of papaya slice biochar in epoxy matrix natural fibre composites [22].

Figure 7 depicts an observation for impact testing. Due to the brittle nature of pure epoxy composites, it demonstrates relatively low impact resistances of roughly 0.42 J for composite designation R. However, as the amount of reinforcement, such as areca chopped fibre and papaya slice biochar, was increased, there was a noticeable improvement in impact resistance. For composites with the designations RA, RAB1, and RAB2, the increase in values is around 91 percent, 92 percent, and 93 percent, respectively. The enhanced adhesion of areca chopped fibre and papaya slice biochar with epoxy resin is attributed to the reactivity of the NH2 functional group produced through silane treatment [23]. However, impact resistance ratings for composites with the designation RAB3 have fallen to roughly 5.22 J. This is the reason of addition of 4.0 vol. % biochar in natural fibre epoxy composites which reduces the interlocking boding of epoxy by forming cluster in matrix material [24].

4.2. Thermal Conductivity. Figure 8 depicts the thermal conductivity values of reinforced epoxy composites. Composites (RA, RAB1, RAB2, and RAB3) were claimed to have improved thermal conductivity by 7%, 34%, 41%, and 47%,

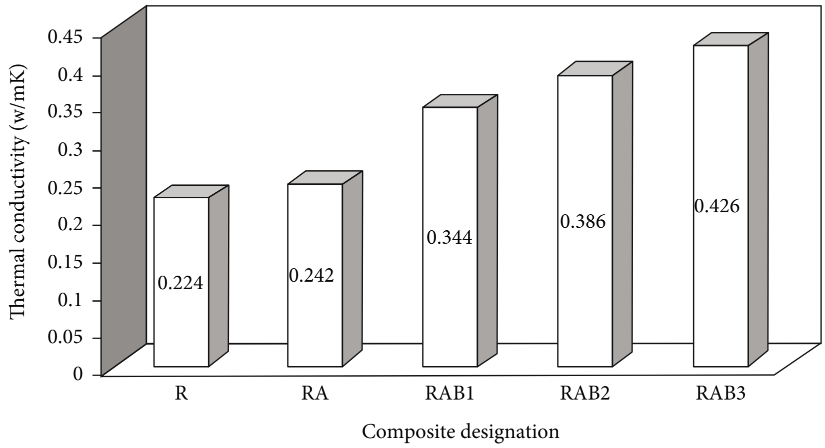


Figure 8: Thermal conductivity of composites.

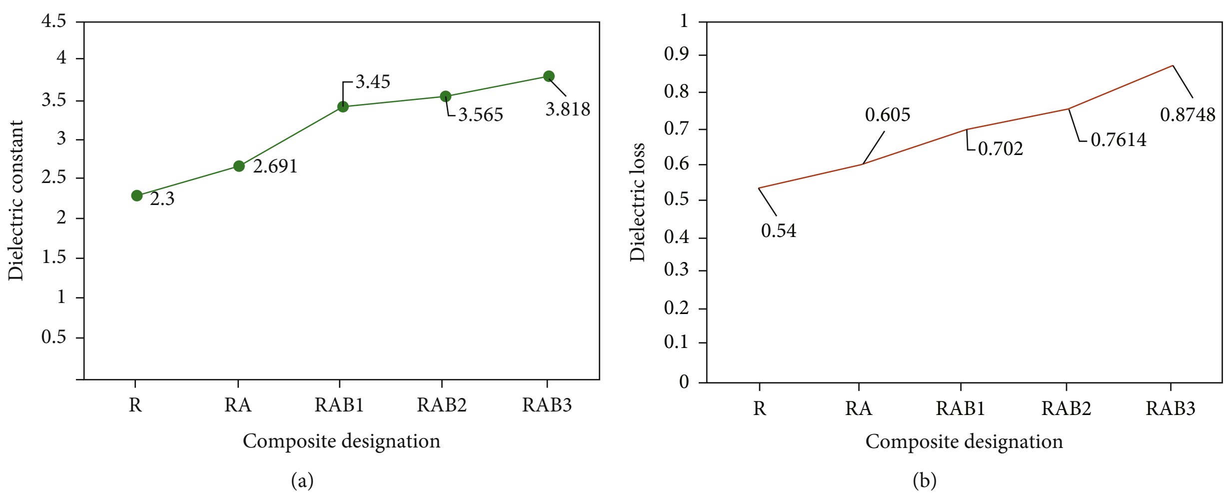


Figure 9: (a) Dielectric constant and (b) dielectric loss for different composite designation.

respectively. As the percentage of papaya slice biochar was raised, thermal conductivity rose as well. This is owing to the development of a heat-conducting biochar network in an epoxy matrix. Thermal conductivity reduces when biochar volume percent declines; this is because less biochar forms a poor network, whereas a greater volume percent impacts the rate of heat transfer by producing a better network, which enhances the epoxy matrix's heat conduction behaviour [25, 26].

4.3. Dielectric Properties. Dielectric study was performed on the epoxy matrix natural fibre composites to investigate the influence of papaya slice biochar and areca chopped fibre in epoxy resin, and the findings are displayed in Figure 9. The parallel plate capacitor approach was utilised, which entails sandwiching a dielectric material between two conductors and providing a 10 mV A.C voltage at a different frequency to each conductor. Polarization must be used to conduct the charges. According to tests, pure epoxy matrix has a dielectric constant of 2.3 and a dielectric loss of roughly 0.54. The low dielectric constant and loss are due to the epoxy molecular structure's hydrophobic properties. The mobility of electrons in any conductor causes heat due to mobility resistance; the same result was reported in the biochar distributed epoxy composite [27]. The dielectric constant and dielectric loss rise by 17 and 12 percent, respectively, when silane-treated areca chopped fibre is added. The dielectric characteristics gradually improved as more silane-treated papaya slice biochar was added. The dielectric constant is improved by 50 percent, 55 percent, and 66 percent, and the dielectric loss is improved by 30 percent, 41 percent, and 62 percent. This is due to the presence of biochar particles in the epoxy resin composite, which improves the dipole moment with respect to frequency [28].

5. Conclusions

This study uses areca chopped fibre and papaya slice biochar as reinforcing materials to create natural fibre and biochar with epoxy composites which was designed for the preparation and characterization of sustainable material technologies. The laminates are created and characterised by hand layup, and the following conclusions are made.

(i) Mechanical testing showed a 62-percent improvement in tensile qualities and a 50-percent improvement in flexural capabilities. This improvement is due to the addition of 2% papaya slice biochar to the mix

(ii) Similarly, when the percentage of the population grows, impact resistances grow as well, peaking at roughly 5.88 J

(iii) Thermal conductivity in an epoxy matrix demonstrates an effective network that can conduct heat at 0.426 W/mk

(iv) The addition of reinforcement to the epoxy matrix boosted the dielectric characteristics gradually as well

Data Availability

The data used to support the findings of this study are included within the article. Further data or information is available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

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References

[1] J. J. Joglekar, Y. S. Munde, A. L. Jadhav, D. S. Bhutada, S. Radhakrishnan, and M. B. Kulkarni, "Studies on effective utilization of Citrus maxima fibers based PVC composites," *Part*, vol. 42, pp. 578–583, 2021.

[2] M. Kirve, Y. Munde, A. Shinde, and I. Siva, "Evaluation of mechanical properties of bamboo epoxy bio-composite filled with montmorillonite nanoclay," *Materials Today: Proceedings*, vol. 62, Part 2, pp. 806–810, 2022.

[3] V. Mohanavel, S. Suresh Kumar, J. Vairamuthu, P. Ganeshan, and B. NagarajaGanesh, "Influence of stacking sequence and fiber content on the mechanical properties of natural and synthetic fibers reinforced penta-layered hybrid composites," *Journal of Natural Fibers*, vol. 2021, pp. 1–13, 2021.

[4] M. R. Chethan, S. G. Gopala Krishna, R. Chennakeshava, and D. Mahesh, "Study on tensile analysis of untreated chopped natural areca sheath fiber reinforced polymer matrix bio-composites," *International Journal of Engineering Research and Advancement Technology*, vol. 2, pp. 338–393, 2016.

[5] A. Alavudeen, M. Thiruchitrambalam, V. Narayanan, and A. Athijayamani, "Review of natural fiber reinforced woven composite," *Advanced Materials Science*, vol. 27, pp. 146–150, 2011.

[6] N. Muralidhar, V. Kaliveeran, V. Arumugam, and I. Srinivasula Reddy, "A study on areca nut husk fibre extraction, composite panel preparation and mechanical characteristics of the composites," *Journal of The Institution of Engineers (India): Series D*, vol. 100, no. 2, pp. 135–145, 2019.

[7] P. Naik, S. K. Acharya, P. Sahoo, and S. Pradhan, "Abrasive wear behaviour of papaya slice (biowaste) particulate reinforced polymer composites," *Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology*, vol. 235, no. 10, pp. 2099–2109, 2021.

[8] K. U. Devens, S. Pereira Neto, D. L. D. A. Oliveira, and M. S. Gonçalves, "Characterization of biochar from green coconut shell and papaya slice wastes," *Revista Virtual de Quimica*, vol. 10, no. 2, pp. 288–294, 2018.

[9] M. Karthigairajan, P. K. Nagarajan, R. Raviraja Malarvannan et al., "Effect of silane-treated rice husk derived biosilica on visco-elastic, thermal conductivity and hydrophobicity behavior of epoxy biocomposite coating for air-duct application," *Silicon*, vol. 13, no. 12, pp. 4421–4430, 2021.

[10] M. A. Murugan, V. Jayaseelan, D. Jayabalakrishnan et al., "Low velocity impact and mechanical behaviour of shot blasted SiC wire-mesh and silane-treated aloevera/hemp/flax-reinforced SiC whisker modified epoxy resin composites," *Silicon*, vol. 12, no. 8, pp. 1847–1856, 2020.

[11] A. P. VR and M. V. Depoures, "Effect of silicon coupling grafted ferric oxide and e-glass fibre in thermal stability, wear and tensile fatigue behaviour of epoxy hybrid composite," *Silicon*, vol. 12, no. 11, pp. 2533–2544, 2020.

[12] K. Ismail, M. A. M. Ishak, Z. Ab Ghani et al., "Microwave-assisted pyrolysis of palm kernel shell: optimization using response surface methodology (RSM)," *Renewable Energy*, vol. 55, pp. 357–365, 2013.

[13] M. Uchimiya, L. H. Wartelle, K. T. Klasson, C. A. Fortier, and I. M. Lima, "Influence of pyrolysis temperature on biochar property and function as a heavy metal sorbent in soil," *Journal of Agricultural and Food Chemistry*, vol. 59, no. 6, pp. 2501–2510, 2011.

[14] M. Bartoli, R. Arrigo, G. Malucelli, A. Tagliaferro, and D. Duraccio, "Recent advances in biochar polymer composites," *Polymers*, vol. 14, no. 12, p. 2506, 2022.

[15] V. R. Arun Prakash and R. Viswanathan, "Fabrication and characterization of silanized echinoidea fillers and kenaf fibre-reinforced Azadirachta-indica blended epoxy multi-hybrid biocomposite," *International Journal of Plastics Technology*, vol. 23, no. 2, pp. 207–217, 2019.

[16] S. Sathees Kumar, "Effect of natural fiber loading on mechanical properties and thermal characteristics of hybrid polyester composites for industrial and construction fields," *Fibers and Polymers*, vol. 21, no. 7, pp. 1508–1514, 2020.

[17] T. Merizgui, A. Hadjadj, M. Kious, and V. R. Arun Prakash, "Effect of temperature and frequency on microwave shielding behaviour of functionalized kenaf fibre-reinforced MWCNTs/iron(III) oxide modified epoxy hybrid composite," *Transactions on Electrical and Electronic Materials*, vol. 21, no. 4, pp. 366–376, 2020.

[18] K. Devendra and T. Rangaswamy, "Strength characterization of E-glass fiber reinforced epoxy composites with filler materials," *Journal of Minerals and Materials Characterization and Engineering*, vol. 1, no. 6, pp. 353–357, 2013.

[19] P. Anand, D. Rajesh, M. Senthil Kumar, and I. Saran Raj, "Investigations on the performances of treated jute/Kenaf

hybrid natural fiber reinforced epoxy composite," *Journal of Polymer Research*, vol. 25, no. 4, pp. 94–99, 2018.

[20] K. G. Sathish, B. Siddeswarappa, and K. M. Kaleemulla, "Characterization of in-plane mechanical properties of laminated hybrid composites," *Journal of Minerals and Materials Characterization and Engineering*, vol. 9, no. 2, pp. 105–114, 2010.

[21] M. Nobrega, L. Carvalho, and V. Fonseca, "Tensile and Impact ´ Properties of Macambira and Caroa Fiber Reinforced Unsaturated Polyester Composites," *Science and Technology for Sustainable Development*, vol. 1, p. 191, 2006.

[22] A. Bandyopadhyay and G. M. Odegard, "Molecular modeling of crosslink distribution in epoxy polymers," *Modelling and Simulation in Materials Science and Engineering*, vol. 20, no. 4, article 045018, 2012.

[23] M. Rahman, M. Puneeth, and D. A. Aslam, "Impact properties of glass/Kevlar reinforced with nano clay epoxy composite," *Composite Part B: Engineering*, vol. 107, pp. 50–61, 2017.

[24] M. S. Landowski, G. Strugała, M. Budzik, and K. Imielińska, "Impact damage in SiO2 nanoparticles enhanced epoxy carbon fibre composites," *Composites Part B Engineering*, vol. 113, pp. 91–99, 2017.

[25] J. K. Nelson and J. C. Fothergril, "Internal charge behaviour of nanocomposites," *Nanotechnology*, vol. 15, no. 5, 2004.

[26] Z. Guo, K. Shin, A. B. Karki, D. P. Young, R. B. Kaner, and H. T. Hahn, "Fabrication and characterization of iron oxide nanoparticles filled polypyrrole nanocomposites," *Journal of Nanoparticle Research*, vol. 11, no. 6, pp. 1441–1452, 2009.

[27] A. Joshi and S. Datar, "Carbon nanostructure composite for electromagnetic interference shielding," *Pramana*, vol. 84, pp. 1099–1116, 2015.

[28] K. Sever, M. Sarikanat, Y. Seki, V. Cecen, and I. H. Tavman, "Effects of fiber surface treatments on mechanical properties of epoxy composites reinforced with glass fabric," *Journal of Materials Science*, vol. 43, no. 13, pp. 4666–4672, 2008.