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Impact of SiC on The Mechanical and Thermal Properties of Banana Fiber Reinforced Epoxy Composites

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Abstract: This work investigates the mechanical properties (Tensile Strength & Impact Strength) and thermal properties (Thermal conductivity & diffusivity) of a natural fiber composite that includes banana fiber as reinforcement in epoxy (LY 556) matrix as the base material with the addition of silicon carbide particles by 5% and 10% by weight. This Banana Fiber Reinforced Epoxy Composite (BFREC) prepared by hand lay-up technique. After curing for a sufficient period, samples taken out and tested. The results suggest that on increasing SiC wt% in the matrix, there is enhancement of its tensile strength, impact strength, and thermal conductivity. Bulk density also increases while thermal diffusivity decreases. Due to low density as compared to metals, improved tensile and impact strength and low elongation at break of banana fibers, BFREC composite with SiC have very good potential use in the various sectors.
Keywords: Banana fiber, SiC, hand layup technique, mechanical characterization, thermal conductivity, thermal diffusivity

I. INTRODUCTION

The application of natural fiber reinforced polymer composites and natural -primarily dependent resins for exchanging existing artificial polymer or glass fiber reinforced materials is enormous. High specific properties with less cost of natural fiber composites are producing tempting use for multiple applications [1, 2]. The applications of natural fibers are producing in various sectors that include building and construction firms, auto trade, packing, and furnishings. It is specifically because of its benefits compared to manmade fibers, i.e. low cost, low weight, less damage to processing equipment, the enhanced surface finish of molded elements composite, essentials relative mechanical properties, generous and renewable resources [3]. Natural fiber composites exhibit better specific properties, but there is a large range in their properties. Their drawback point can and might be triumph over with the improvement of the advance processing of natural fiber and their composites.

Banana i.e. Musa sapientum is a commercial herbaceous plant of genus Musa mainly cultivated for its edible fruit in most of the developing countries [4,5] but banana-trees also produce commonly 30 big leaves (almost 2m long and 30-60cm wide) and fibrous stem [6]. India accounts for more than 31% of global banana production. The average yield of banana in India is about 37.79 t/ha which is much higher than that of most of the countries [7]. Tamil Nadu, Maharashtra, Gujarat, Karnataka, Andhra Pradesh are the states where banana production rate is as high as 19%, because of that in India banana fibers are easily available in the form of cultivation waste and can be extracted. Fundamental natural constituents of banana fiber are cellulose, hemicelluloses, gelatin, lignin, and some extractives. Among different natural cellulosic fibers, banana fibers are one of the unexplored high potential fibers. The use of banana fiber for industrial and engineering applications has not yet been effectively utilized. [7]. Because banana fiber composite has moderate mechanical properties as compared to synthetic fiber composites, thus a filler material should be used for property improvement. Silicon carbide particles as additive provide improved strength, stiffness, wear resistance, fatigue resistance, thermal conductivity, and reduced thermal expansion properties to composites.

The present experimental study explores the changes in mechanical properties (tensile strength and impact strength) and thermal properties (thermal conductivity and diffusivity) of banana fiber reinforced epoxy composite fabricated by hand layup technique without silicon carbide and adding 5%, 10% silicon carbide by weight. The effect of adding SiC reported in this manuscript for various mechanical and thermal properties of banana fiber reinforced epoxy composite.

II. MATERIALS AND METHODS

The BFRC has been prepared in a glass mold of dimensions 250 mm x 180 mm x 3 mm using hand lay-up technique as shown in Figure 1. In the processing, hardener Tri-ethylene-tetra-mine (TETA) which is an aliphatic essential amine with business assignment HY 951(supplied by Universal Enterprise Kanpur India), consistency of 10-20 balance at 25°C and epoxy LY 556 (supplied by Universal Enterprise Kanpur India) which synthetically has a place with the "epoxide" family and basic name of Bisphenol-A-Diglycidyl-Ether (regularly contracted to DGEBA or BADGE) were mixed in the ratio of 1:10 by weight to give a dissolvable free room temperature restoring framework. For the creation of polymer composite characteristic fibers i.e. banana fibers (Logical name "Musa acuminate") are utilized as support material (procured from Sanna Enterprises Tamilnadu, India). Banana fibers are thought to be wonderful reinforcement due to their low thickness (0.2 gm/cm^3), non-toxic, biodegradable, ecological neighbourly nature, and low warm conductivity (0.09 W/m-K). Silicon carbide which isn't assaulted by any acids or antacids or liquid salts up to 800°C and provides improved strength, stiffness, wear resistance, fatigue resistance, thermal conductivity, and reduced thermal expansion properties to composites is used as a filler material. In step1 Silicon Carbide is mixed with the epoxy and hardener mixture in the appropriate ratio. The one-third portion of the above mixture was poured inside the mold. In step 2 a layer of chopped banana fiber was spread uniformly and again one-third portion of the hardener and epoxy mixture was poured over the prepared banana fibers layer and repeat the step one more time. In step 3 mold is covered by an OHP sheet of A4 size and a flat marble stone subjected with a deadweight of 40 kg. Finally, the mold was left for curing at room temperature for 24 hours. After 24 hours of curing the casted composite was taken out of the mold. Three samples A, B, C respectively were prepared using the same process [Figure 1] with different weight percentage of constituents as shown in Table 1.

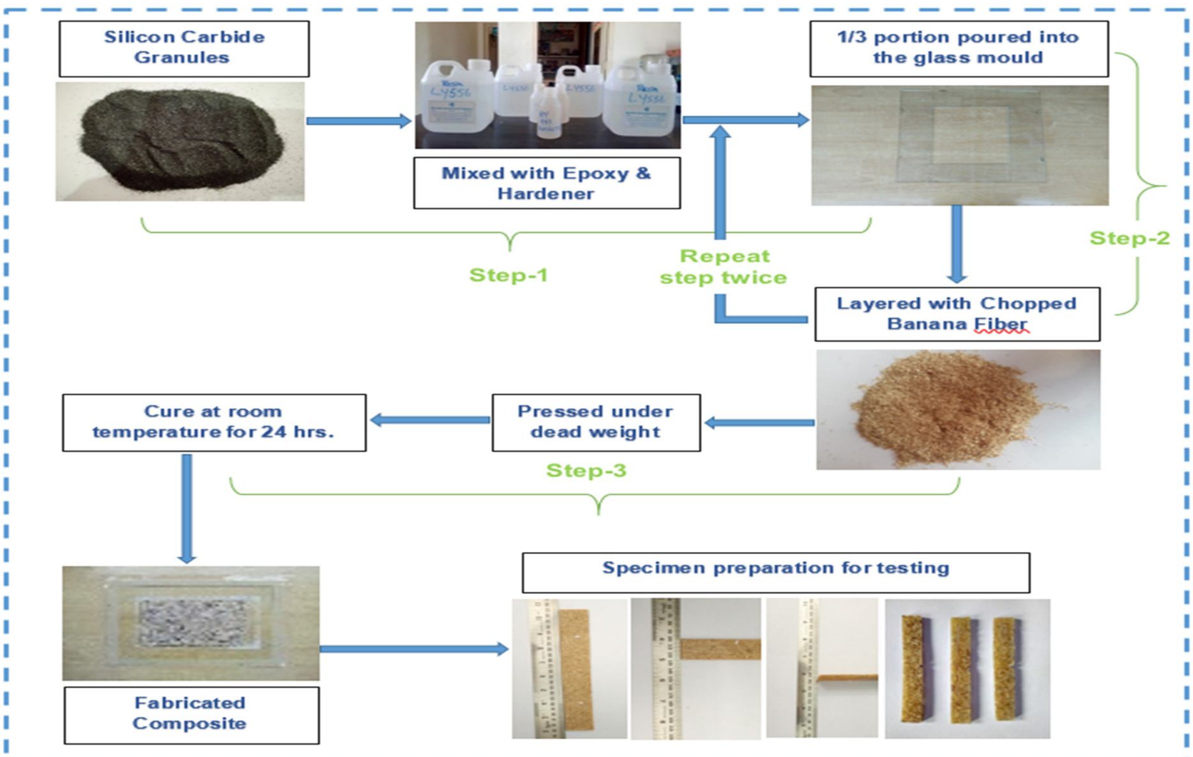

Figure 1: Steps involved in the fabrication of Banana Fiber Reinforced Epoxy Composite.

Table-1: Composition of constituents Banana Fibre Reinforced Epoxy composite with different wt% of Silicon Carbide as a filler material.

SAMPLE	EPOXY & HARDENER (wt%)	BANANA FIBER (wt%)	SILICON CARBIDE (wt%)
A	90	10	0
B	85	10	5
C	80	10	10

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A wire hacksaw blade used to cut prepared samples for Mechanical testing and Thermal testing as per ASTM standards. Tensile test (ASTM D-3039) conducted on an electronic Universal Testing Machine with crosshead speed 9.7 mm/min and the sample range length of 120 mm. IZOD impact test (ASTM D-256A) also performed on composite samples using a computerized impact testing machine.

Thermal Conductivity test using The LFA 447 Nano-Flash (ASTM E 1461) was conducted for the fabricated composite samples. For testing, samples were cleaned with acetone, and to dry samples were heated for 60 minutes in the oven. The samples were coated with a thin layer of graphite to attain unit emissivity. In argon atmosphere front side of samples was subjected to Xenon flash lamp (Lamp voltage 304 V and pulse width 0.31ms). The energy of the pulse was recorded at the rear side of the samples by the In-Sb photodetector. Three identical specimens were tested from each sample of prepared composite and an average value is reported in the results.

III. RESULTS AND DISCUSSIONS

Observed values of tensile strength during the uniaxial tensile test (the term "uniaxial" defines the pulling or pushing along one axis of the sample only) in UTM have been mentioned in Table-2.

Table: 2 Average tensile strength of BFRC samples with different wt% of SiC along with average strain and maximum load.

Sample	Specimen Shape	Length (mm)	Width (mm)	Thickness (mm)	Test Speed (mm/m)	Avg. Tensile Strength (MPa)	Avg. Strain	Avg. Max. Load (N)	Avg. % Elongation
BFREC without SiC	Rectangle	120	25	3	9.7	3.349	0.036	251.20	3.611
BFREC with 5% SiC by wt.	Rectangle	120	25	3	9.7	4.678	0.033	350.83	3.333
BFREC with 10% SiC by wt.	Rectangle	120	25	3	9.7	7.599	0.033	569.9	3.333

BFREC- Banana Fiber Reinforced Epoxy Composite

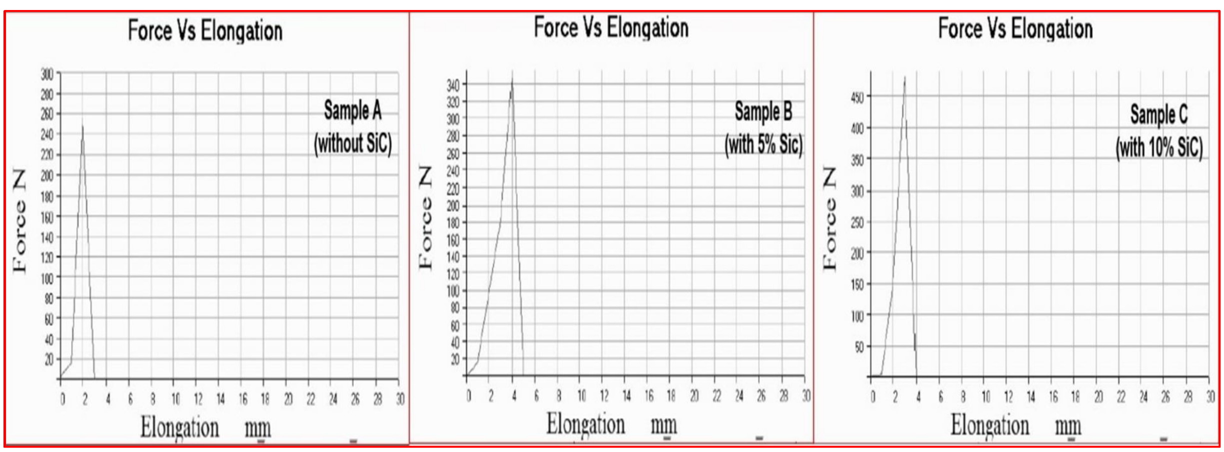

Figure 2: Force Vs Elongation graph of one specimen from each Banana Fiber Reinforced Epoxy Composite samples with different wt% of SiC .

IZOD impact test on the R3 scale has been performed on a V-notched specimen of BFRC samples with different wt% of SiC. Obtained average values of impact strength of BFRC samples with different wt% of SiC as per ASTM standard and as per IS/ISO standard were mentioned in Table-3. Figure-3 shows the amount of impact energy concerning the angular displacement of the specimen.

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Table: 3 Average impact strength of BFRC samples with different wt% of SiC along with average angular displacement as per ASTM and IS/ISO Standards.

Sample	Type of Test	Length (mm)	Width (mm)	Thickness (mm)	Scale/Hammer	Angular Displacement (Degree)	IZOD Impact Energy	Impact Strength	
								As per ASTM Standard (J/m)	As per IS/ISO Standard (J/mm^2)
BFREC without SiC	IZOD	63.5	12.5	3	R3	139	0.644	214.66	0.017
BFREC with 5% SiC by wt.	IZOD	63.5	12.5	3	R3	138	0.711	237.00	0.019
BFREC with 10% SiC by wt.	IZOD	63.5	12.5	3	R3	137	0.779	259.66	0.021

BFREC- Banana Fiber Reinforced Epoxy Composite

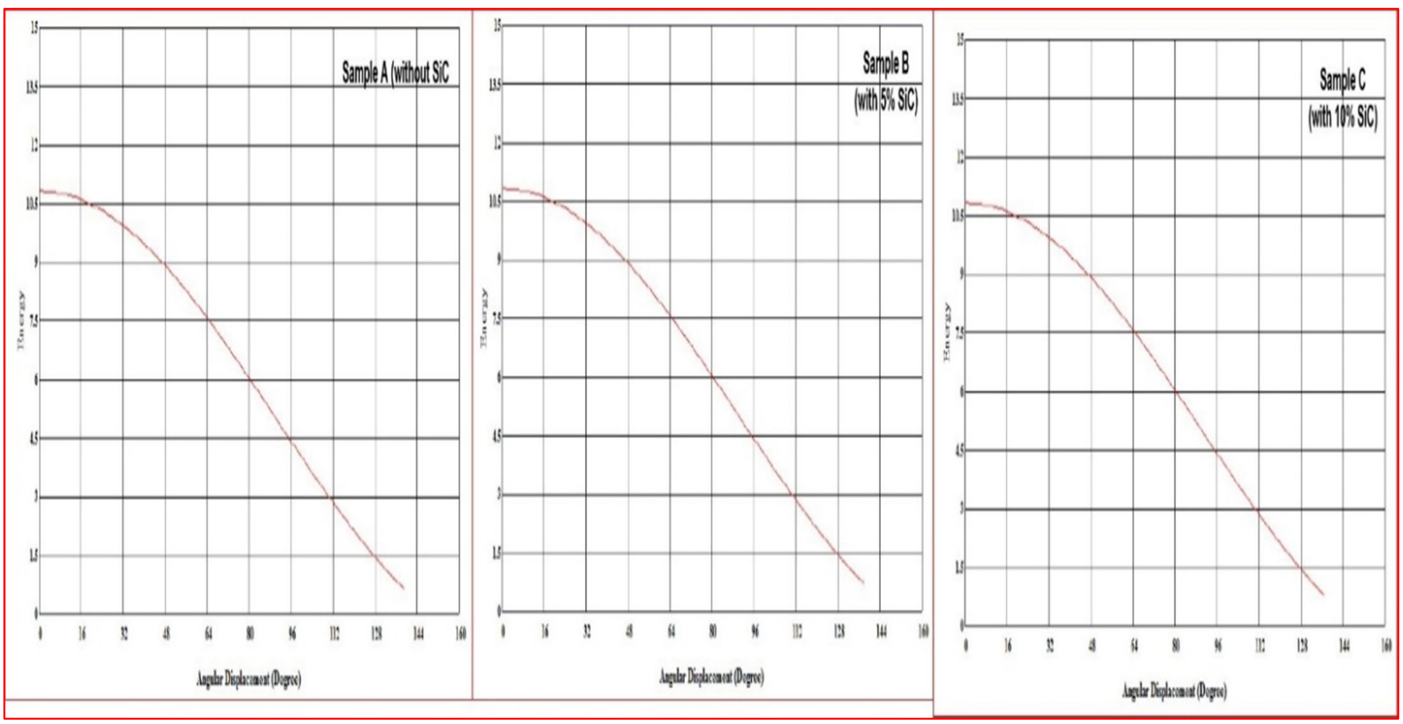

Figure 3: Impact Energy Vs Angular Displacement graph of one specimen from each Banana Fiber Reinforced Epoxy Composite samples with different wt% of SiC.

Resulted values of thermal conductivity, thermal diffusivity, and bulk density mentioned in Table-4. Figure-4 shows the Voltage-Time plot and the corresponding value of thermal diffusivity obtained from the test.

Table: 4 Operating parameters for testing of thermal conductivity and the resulted value of the thermal conductivity along with thermal diffusivity of BFRC samples with different wt% of SiC.

Sample	BFREC without SiC	BFREC with 5% SiC by wt.	BFREC with 10% SiC by wt.
Sample Temperature (˚C)	25.1	25.1	25.1
Cp (J/g/K)	1	1	1
Bulk Density (g/cm^3)	0.85	1.125	1.130
Current Thickness (mm)	1.1	1.1	1.1
Pulse Type	3 (long)	3 (long)	3 (long)
Lamp Voltage (V)	304	304	304
Pulse Width (ms)	0.31	0.31	0.31
Pulse Integral	60.55	60.55	60.55
Ampl. Gain	50020.0 (10x5002)	50020.0 (10x5002)	50020.0 (10x5002)
Optical Filter (%)	100	100	100
Duration (ms)	500	500	500
No. of Points	2000	2000	2000
Diffusivity Model	Cape-Lehmen + pulse correction	Cape-Lehmen + pulse correction	Cape-Lehmen + pulse correction
Baseline	Linear	Linear	Linear
Diffusivity (mm^2/s)	0.303±3.7996e.007	0.291±1.6770e.005	0.334±3.5880e.006
$T_{infin.}$	0.8232168±3.7996e.006	0.30383±1.6770e.004	3.232859±3.5880e.005
Thermal Conductivity (W/m˚K)	0.257	0.328	0.377

BFREC- Banana Fiber Reinforced Epoxy Composite

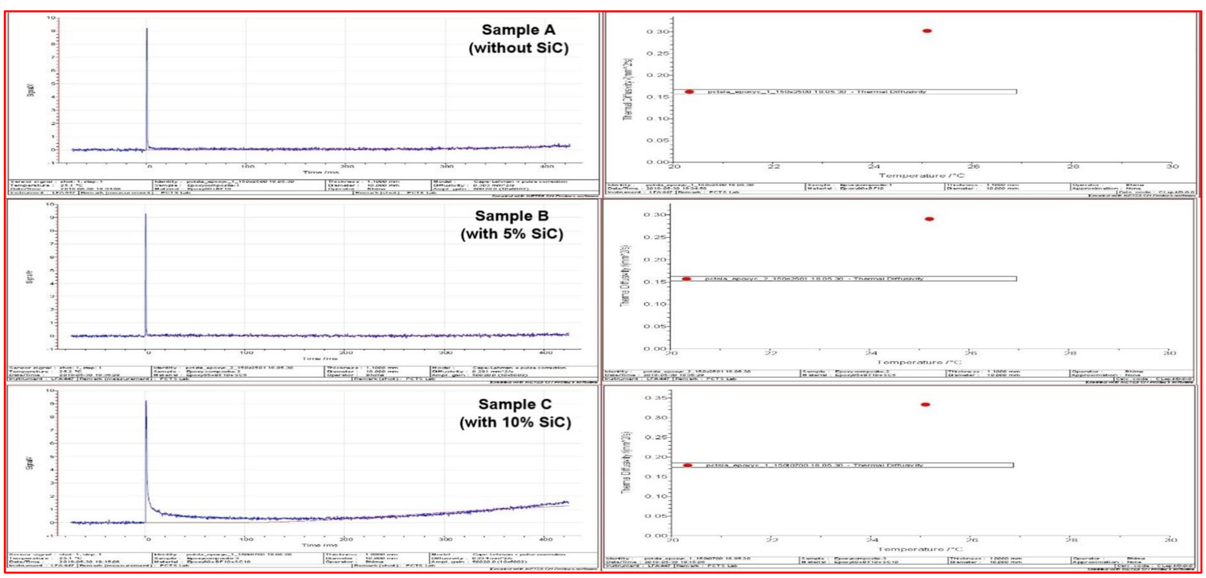

Figure-4: Voltage-Time plot and corresponding value of thermal diffusivity of Banana Fiber Reinforced Epoxy Composite samples with different wt% of SiC obtained from test setup.

The resulting output from the tensile test recorded as a load versus displacement/elongation graph (figure-2). These graphs show that the value of maximum load corresponding to point of failure increased with an increase in wt% of SiC hence the tensile strength of BFREC also increased. IZOD Impact tests measure the resistance to failure of a material to a suddenly applied force. Impact energy is an amount of the work done to breakage a test sample.

Impact strength is given by different units in ISO and ASTM standards. ISO standards report impact strengths in J/mm2, where the impact energy is divided by the cross-sectional area at the notch. ASTM standards show the values in J/m, where the impact energy is divided by the length of the notch. For BFREC samples the impact energy seen to increase so the impact strength with the increase of wt% of SiC shown in Table 3.

Thermal conductivity shows the ability of a material to transport heat energy. Heat can be transported through two mechanisms in solids. The first mechanism is lattice vibrations and the second is the flow of free electrons. In composites (non-metals), the lattice vibrations effect plays a dominant role. Natural fiber-based composites generally have high electric resistance, which obstructs the flow of electrons having low thermal conductivity hence BFREC samples without SiC having lowest thermal conductivity while samples with 5% & 10% SiC by wt. having increased value of thermal property shown in Table 4.

The thermal diffusivity of a material can be observed as the ratio of the heat conducted through the material to the heat stored per unit volume. While measuring thermal diffusivity of BFREC samples heat capacity (C_p) is taken constant at a constant temperature but due to the addition of SiC bulk density of samples increasing with increased wt% of SiC. As a result, there is a slight decrement in the thermal diffusivity when 5% & 10% of SiC added by wt.

BFREC composite with SiC have very good potential use in the various sectors like Automobile industries, floor topping of houses, railway coach interiors, cyclist helmets, housing panels, and windmill fins. It is expected that thermally conductive BFREC papers can be used as heat exhaust base materials for flexible electronics, such as printed circuit boards and light-emitting diodes.

IV. CONCLUSIONS

Based on the experimental work reported above, key conclusions are listed as:

1) Epoxy/banana fiber composites with an influence of SiC are successfully fabricated by a simple hand lay-up technique.
2) The investigations confirmed that the mechanical properties are significantly enhanced at higher SiCwt%. Obtained results suggested that tensile strength increased by 39.6% & 126.9%, Impact strength increased by 10.4% & 20.9%, and thermal Conductivity increased by 27.6% & 46.6% with 5% and 10% addition of silicon carbide by weight in BFREC respectively.
3) Bulk density of fabricated composite is also increased with increasing % of silicon carbide which results in a decrease in thermal diffusivity of the composite.

With improved mechanical and thermal properties, increased utilization of BFREC can diminish the use of synthetic fibers and reduce greenhouse gas emissions however synthetic resins are not readily biodegradable so further studies are necessary to discover biodegradable resin with expected properties to considerably reduce the environmental effect.

A. Declaration of Competing Interest

The author declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

V. ACKNOWLEDGMENTS

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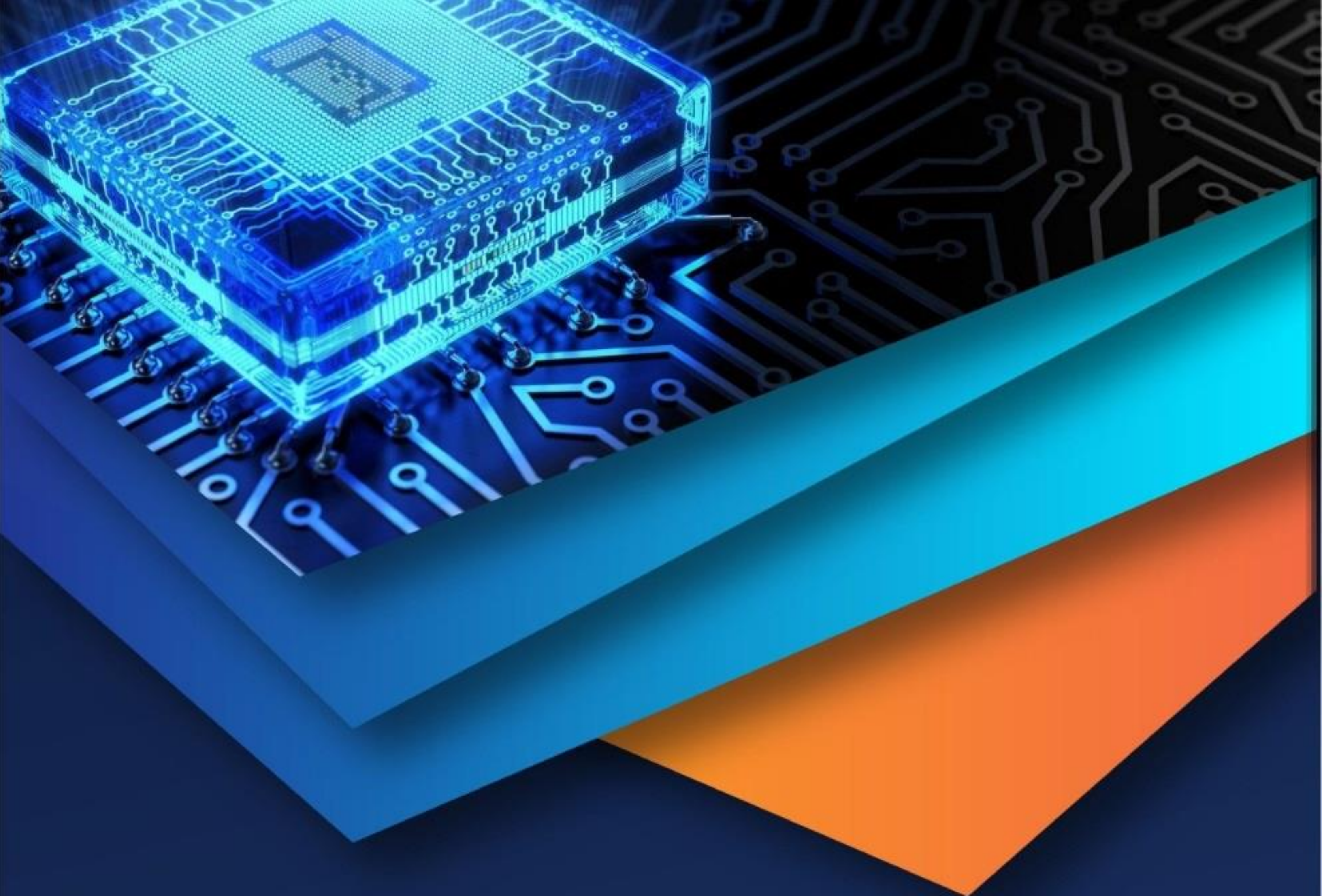

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