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Electricity Generation from Domestic Waste Water by Microbial Fuel Cell

G. Shyamala[1], B. Ajithkumar[2], M. Aravindhasamy[3], R. Manojkumar[4], K. S. Thirumalai Nambi[5]
[1, 2, 3, 4, 5] Department of Civil Engineering, Sree Sakthi Engineering College/ Anna University

Abstract: In recent decade's microbial fuel cell sets a new trend of converting chemical energy or bio energy to electricity from waste water(domestic and industries) at the same time accomplishing biological wastewater treatment (removal of chemical oxygen demand). Electrical energy generated from MFCs could be used for small electrical device such as biosensors etc. Anode, cathode, salt bridge are main components of MFC. It contains two chamber to separate electrodes from long distance for production of electricity, use of waste water in anaerobic chamber facilities growth of the native microorganisms. Which denote the electrons to the anode the anaerobic chamber must be air tightened. . Adding substrates increase productivity the electrons are move from anode chamber to cathode chamber by salt bridge. Bioreactors based on power generation in MFCs may represent a completely new approach to wastewater treatment. Power generation & current is modulate in this system. If it is optimised, MFC's would prove to be new method to offset wastewater treatment plants operating costs
Keywords: ***power density, current density, voltage, Consortium bacteria.***

I. INTRODUCTION

Microbial fuel cell is one of the electricity generation method. The MFC are bioreactors which converts chemical energy stored in the bonds of organic matters into electricity through biocatalysts of microorganisms [2]. The two chambers of anodic chamber and cathodic chamber are separated by salt bridge. That allows transport protons while blowing oxygen and other components[1]. The anodic chamber degrade organic matter and produce electrons, protons and $co_{2.}$ The electrons and protons are to be transported through salt bridge [2]. In the cathodic chamber protons and electrons react with oxygen which is allowed to pass through the external load to generate electricity [7].MFC bio-electrochemical system that harnesses the natural metabolisms of microbes to produce electrical power. Microbes consume the nutrients in their surrounding environment and release a portion of the energy contained in the food in the form of electricity. MFC technology real-world applications of MFCs yet limited because of their low power density level of several thousand mW/m^2[1].We hope that the result of this study can be used to create more efficient on a large as a new sustainable energy sources.

II. MATERIAL

Construction of MFC Using domestic Wastewater has the advantage of samples contain bacteria of mixed strains. The types of anode and cathode used were same material. Waste water sample were taken into an anode chamber. Using salt bridge anode and cathode chamber was connected. Carbon rod inserted in both chamber and the voltage was measured using multimeter (DT830D) and the output power was taken on a daily basis. Salt bridge was made by dissolving 6 g agar-agar in 150 mL distilled water.

Carbon fibres shows an unusual mechanical strength under a tensile load. These carbon fibres are used to increase the mechanical strength of electrical contacts which are subject to compressive or tensile loads during operation. These carbon fibres also reduce the wear and tear of electrical contacts. Moreover, carbon being a conductor of electricity, contributes for carrying current passing through electrical contact in terms it reduces the contact resistance

The anode and cathode used are of different material. The material used such as copper and zinc. Here zinc plate inserted in anode chamber and then copper inserted in cathode chamber and the voltage was measured. It is also used for salt bridge connected to the anode and cathode.

Zinc act as the anode by corroding away as it passes electric current to the steel pipe line also used to cathodically protect metals that are exposed to sea water. The relative reactivity of zinc and it is ability to attract oxidation to itself makes it an efficient sacrificial anode in catholic protection of buried pipeline can be achieved by connecting anodes made from zinc to the pipe.In an application similar to the sacrificial anode, zinc is used as a component in battery production.

Carbon is chemical element and it is soft malleable and ductile metal with very high thermal and electrical conductivity. It is the same as a small electrical resistance. The electrons can move freely through the metal for it is reason they are known as free electron

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because they help copper to be a good conductor. Many common applications also rely on one or more beneficial properties. Its common uses are for electrical purposes.

Aluminium is one of the lightest metal in the world It is almost three time lighter than iron but it is also very strong extremely flexible and corrosion resistant because it is surfaces always corroded in an extremely thin and yet very strong layer of Exide it does not magnetize it is very good conductor of electricity and heat. Aluminium has also been adapted for use as rigid electrical conduit. (An electrical conduit is a tubing system used for protection and routing of electrical wiring.) Unlike steel conduit, rigid aluminium does not spark, resists corrosion and will not rust. These properties of aluminium are vitally important for electrical applications within coal mines, grain elevators and refineries (where sparking can lead to catastrophic outcomes).

A. *Electrical Parameters and Measurements*

Digital multimeter (DT830D) was used to measure the voltage of the current, which was generated during the experiments. Daily test base, readings were recorded for a maximum of 124hrs.

III. MICRO FUEL CELL METHOD

A fuel cell is a device that generates electricity by a chemical reaction. Every fuel cell has two electrodes called the anode and cathode. The reactions that produce electricity take place at the electrodes. Every fuel cell also has an electrolyte, which carries electrically charged particles from one electrode to the other, and a catalyst, which speeds the reactions at the electrodes.

Hydrogen is the basic fuel, but fuel cells also require oxygen. One great appeal of fuel cells is that they generate electricity with very little pollution–much of the hydrogen and oxygen used in generating electricity ultimately combine to form a harmless by-product, namely water. In practice, many fuel cells are usually assembled into a stack.

The purpose of a fuel cell is to produce an electrical current that can be directed outside the cell to do work, such as powering an electric motor or illuminating a light bulb or a city. Because of the way electricity behaves, this current returns to the fuel cell, completing an electrical circuit.

Oxygen enters the fuel cell at the cathode and, in some cell types (like the one illustrated above), there it combines with electrons returning from the electrical circuit and hydrogen ions that have travelled through the electrolyte from the anode. In other cell types the oxygen picks up electrons and then travels through the electrolyte to the anode, where it combines with hydrogen ions.

The electrolyte plays a key role. It must permit only the appropriate ions to pass between the anode and cathode. If free electrons or other substances could travel through the electrolyte, they would disrupt the chemical reaction. They combine at anode or cathode, together hydrogen and oxygen form water, which drains from the cell. As long as a fuel cell is supplied with hydrogen and oxygen, it will generate electricity.

Table1**:**Microbial fuel cell and chamber details

Anode	Cathode	Bacteria	System configuration	Max power density
Aluminium	Aluminium	Consortium bacteria, activate sludge	Two chamber	219.3mV
Carbon	Carbon	Streptobacillus	Two chamber	230.24mV
Graphite	Graphite	Consortium bacteria, activate sludge	Two chamber	175.5mV
Zinc	Copper	Escherichia coli bacteria	Two chamber	157.8mV

A. *Electrical power equation*

Power $P = I \times V = R \times I2 = V2 / R$

Where,

P is in watts, voltage V is in volts and current I is in amperes (DC).

If there is AC, look also at the power factor PF = cos φ and φ = power factor angle

(Phase angle) between voltage and amperage.

Electric Energy is $E = P \times t$ – measured in watt-hours, or also in kWh. $1J = 1N\times m = 1W\times s$

IV. MECHANISM

Without need of combustion, a fuel cell can convert chemical energy of the fuel into electric energy. MFC is the one type of fuel cell. The organic matter which is present in the waste water is oxidized by microorganisms. Conventional MFCs design consist of anode and cathode chamber separated by salt bridge or membrane. The bacterial biofilm produced at anode acts as catalyst to convert the chemical energy of the organic molecule into electrons while the oxygen gets reduced to form water at cathode [17, 18].

The various factors involving in output of MFC such as type of organic matter present in the wastewater, electron transfer rate from bacteria to the anode and the efficiency of the membrane(nafion and poly) or salt bridge to transfer hydrogen ions [19,20,22]. Some microorganisms are known to deliver electrons from their oxidative metabolic pathways to their external environment, such microorganisms are called exoelectrogens [22].There are three way to transfer the electrons to electrodes:

A. Direct electron transfer

B. Electron transfer through mediators and

C. Electron transfer through nanowires.

1) Using carbon material

Table 1.Power output while using carbon electrodes

Days	Electricity output
Day 1	179.45mV
Day 2	187mV
Day 3	200.63mV
Day 4	230.24mV
Day 5	150.20mV

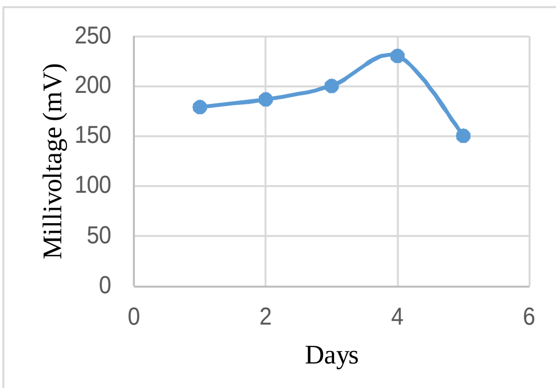

Fig 1.Graphical view of power output

Table 2.Day by day COD removal(mg/l)

Days	COD result
Day 1	155 mg/l
Day 2	170 mg/l
Day 3	232 mg/l
Day4	270 mg/l
Day5	300 /l

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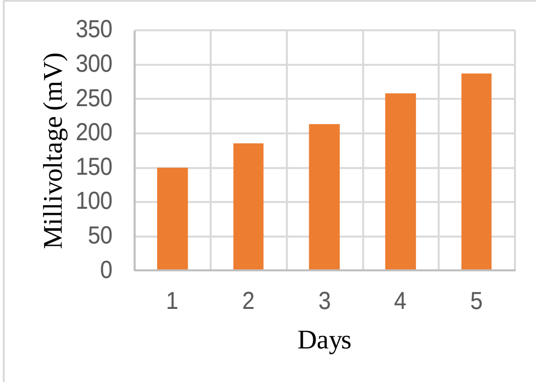

Fig 2.Graphical representation of COD removal (mg/l)

2) Using aluminium material

Table 3.Power output by using aluminium mess steel

Days	Electricity output
Day 1	89 mV
Day 2	126.7 mV
Day 3	189.5 mV
Day 4	219.3 mV
Day 5	193.2 mV

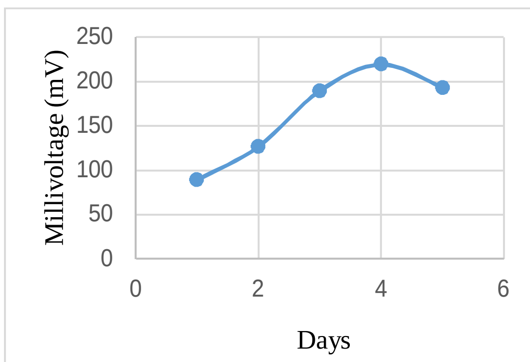

Fig 3.Graphical view of power output of using aluminium mess steel

Table 4.COD removal (mg/l)

Days	COD result
Day 1	143 mg/l
Day 2	180 mg/l
Day 3	210 mg/l
Day 4	255 mg/l
Day 5	235 /l

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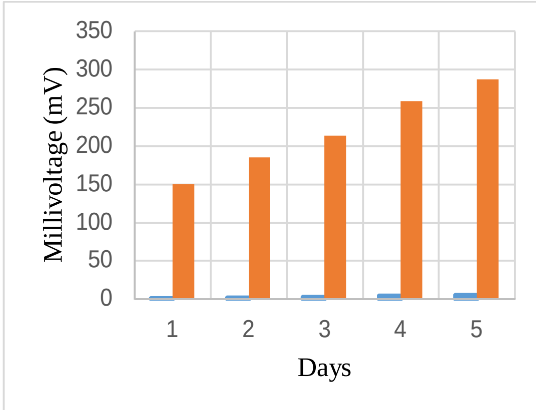

Fig 4.COD removal(mg/l)

3) Using graphite result

Table 5.Power output for using graphite electrodes

Days	Electricity output
Day 1	126.3 mV
Day 2	137.2 mV
Day 3	170.5 mV
Day 4	175.5 mV
Day 5	145.7 mV

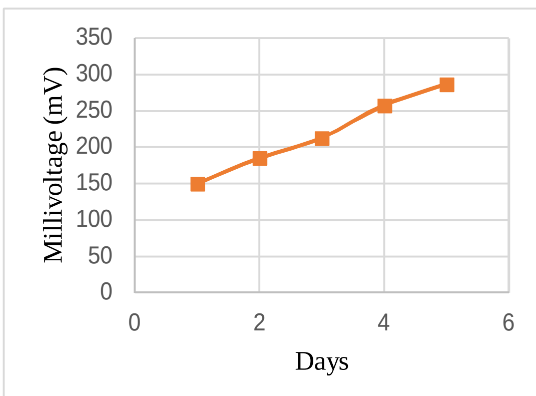

Fig 5.Poweroutput by using graphite electrodes

Table 6.COD removal (mg/l)

Days	COD result
Day 1	80 mg/l
Day 2	136 mg/l
Day 3	192mg/l
Day 4	254 mg/l
Day 5	291 mg/l

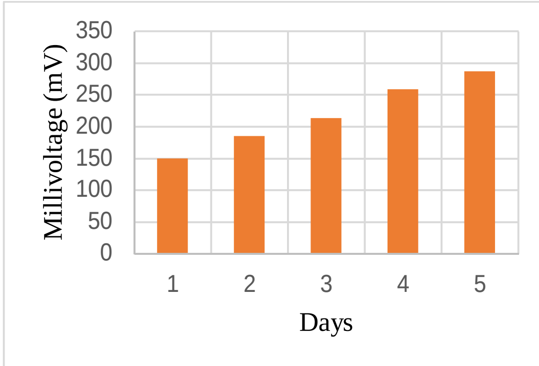

Fig 6.COD result

4) Using zinc and copper material

Table 7.Power output using by zinc & copper

Days	Electricity output
Day 1	46 mV
Day 2	69.4 mV
Day 3	102.8 mV
Day 4	120.1 mV
Day 5	157.8 mV

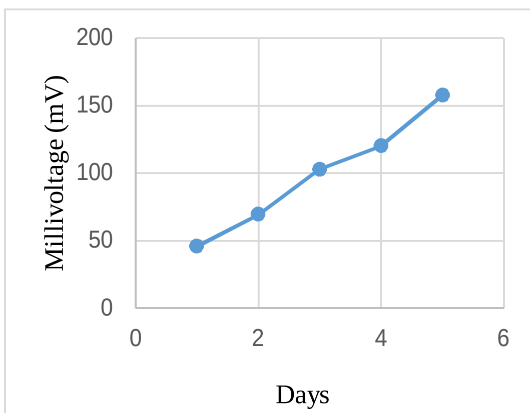

Fig 7.Power output using by zinc & copper

Table 8.COD removal

Days	COD result
Day 1	150 mg/l
Day 2	185 mg/l
Day 3	213 mg/l
Day 4	258 mg/l
Day 5	287 mg/l

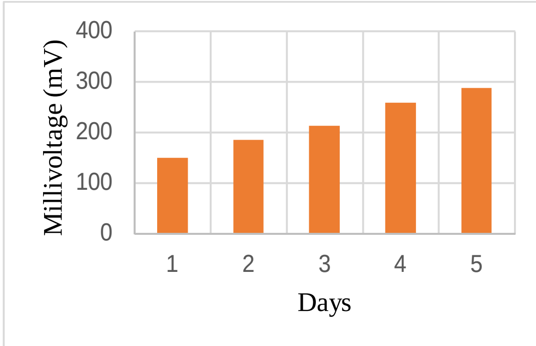

Fig 8.COD removal (mg/l)

V. RESULT

Electricity in the MFC as generated using domestic waste water in proportion to waste water strength. Even though the sample is same, the concentration and using of materials and procedure is differ from each other.

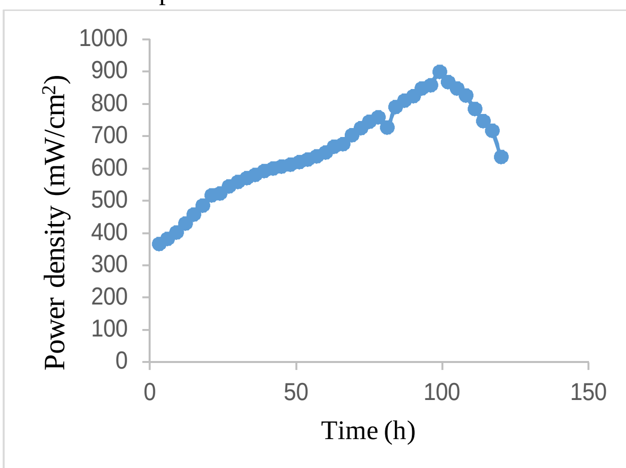

Fig 1: power density vs time

The test conducted with using of aluminium mesh steel as an electrodes. While connecting of circuit the result displayed 149mW/m² at 27°c atmosphere temperature. It is absorbed continuously between certain periods throughout the day. COD removal from the sample range is 20-50% because the more removal of COD not associated with power generation. To increase the oxidation at anode oxidation substrate was added at the rate of 0.5ml/min.

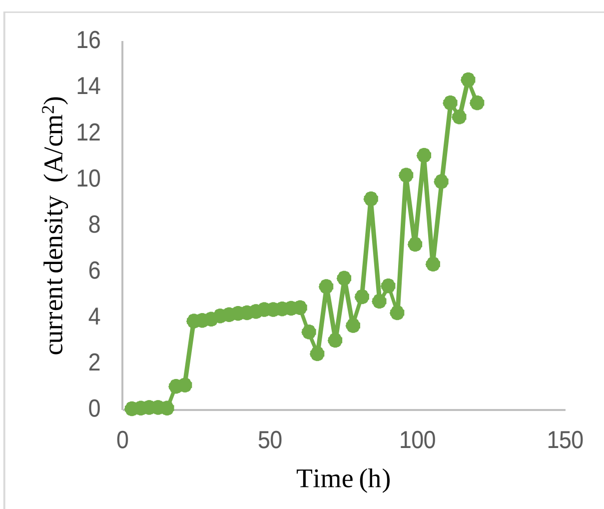

Fig 2: current density vs time

COD removal at beginning stage is 78mg/l. Active air flow maintained at 2.5 l/min. The test on COD removal is conducted each day of beginning stage at 30°c temperature. Average limit of COD removal is 25±8% from HRT of 1-72h. Power production rate is decreased at initial stage, then it will increased gradually. While motivating of oxidation process he flow of electrons in circuit is slightly increased. The stable reading is achieved at the end of the day in HRT 1h-72h. Presence of hydrogen is tested from the waste water at the early stage of the each day to promoting the electron flow. PH value is noted as 6.45 at first day and it's differ ranges from 20±5. Decreasing the temperature resulted in a greater change in the cathode potentials than the anode potentials. Compared with BOD removal, COD removal shows quick response in supplying of electrons in electric circuit. By adding of chemical substances electrons are separated from the bacteria, which is presented in waste water.

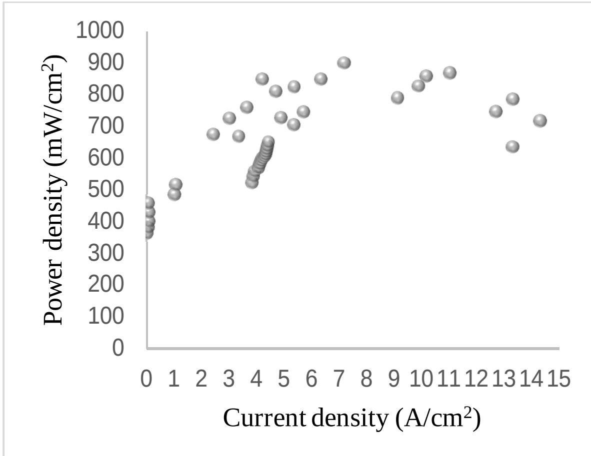

Fig 3:power density vs current density

The alternative material carbon rod was used instead of aluminium mesh steel. Mostly the carbon materials like carbon rod, carbon paper, stack of carbon sheets and carbon plates etc., used for producing high rate of electricity from microbial fuel cell.

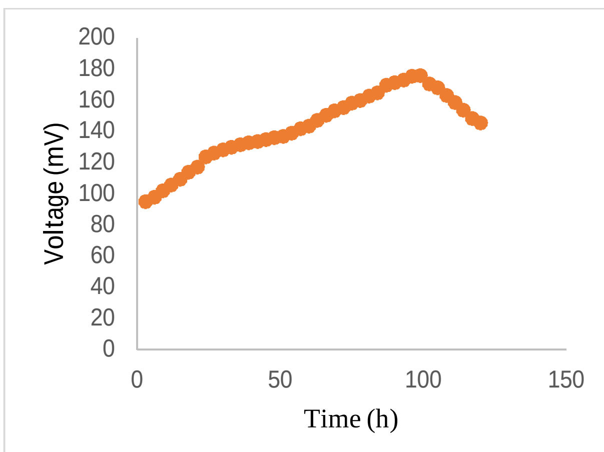

Fig 4: voltage vs time

The same tests which is practiced in using of aluminium is conducted for carbon rod. PH value reported 6.87 of HRT=12h. COD removal helps to achieve better electric producing. COD removal of 213mg/l at initial stage and the current density achieved as 190.4mV. COD removal increased 20% at a HRT 3h to a maximum of 80% at HRT 24h. The active air flow maintained as well as 2.5 l/min. COD removal and power were a function of hydraulic detention times of the waste water in the reactor. COD removal increased from 30% at a HRT 3h to a maximum of 80% at a HRT of 72h. When the circuit was disconnected, COD removal ranged from 20% to 50% over the same range of HRT (3 – 72h), with an average of 30±17% of the COD removal not associated with power generation. Power density decreased from 30 to 45 mW/m^2 over this range of HRTs. The columbic efficiency of the system ranged from 4 to 13%.indicating there was substantial COD that was not associated with power generation. While this achieve as much as 88% of the COD removal at the longest detention time (72h), it could only produce a total of 18% of the COD removal at the 3 h HRT. There could have been a loss of COD using other electron acceptors (oxygen) present in the waste water. Biomass production could account for additional COD removal, but it is not possible to establish a complete mass balance of COD in this system.

VI. DISCUSSION

The generation of electricity can be done by using microbial fuel cell. The two chamber MFC is widely using traditional method and inexpensive. Output of the MFCs power depends upon the type of waste water used in experiment, type of presence of bacteria in waste water, using of electrode materials and oxidation efficiency [19]. The graphical plots shows that the power production rate differ based on cathode and anode material used. The amount of power generated in these system is affected by surface area of the electrodes and the surface area of membranes [23, 24, 25]. In cathode chamber the ferricyanide is can be used as an electron acceptor at high concentrations. But it is restricted to use in studying laboratories and for student research. Compared to platinum –catalyst it enhance the power level by 1.5 to 1.8 times, But compared to that oxygen is more suitable for using as electron acceptor in low cost [25].

The materials which is used as anode must have good conductive property, biocompatible and chemically stable. Metal anodes also can be used [26], but the toxicity of even trace copper ions to bacteria copper is not useful. The above declared properties are matched with most versatile materials of carbon products. The graphite shows low output compared with carbon because, in some graphite materials are mould with copper.

From the graphical plots we observe more outputs with using of carbon rod at from startup time to end. Due to its observe capacity the biofilm was formed in the anode chamber while oxidation takes place. In first day overall highest value noted of 179.45mV. Temperature is important factor in the MFC, while reducing temperature output also decreased slightly. Also increasing volume of the flow rate production will be raise. From all waste water samples power output was changed depends on atmosphere temperature, COD removal, anode catalyst and rate of oxidation. The food waste water contains enormous amount of microorganisms. Zinc have low conductive property. While the amount of COD increase as well as power produce will increase. At the day of 5 oxygen consume is low, at the same time power production is decreased. So, the using of electrodes and methods are most important in current generation.

VII. CONCLUSION

From this concept enormous amount of waste water utilize for production of electricity and can easily take to next water treatment. Implementation this method is cost effective in anyone direction. The performance of microbial fuel cell could be considered in terms of microbiology. In this stud the polarization curve method was employed to optimize the performance of MFC. The optimal operations conditions for the MFC with the anode working volume of 20ml were a fuel concentration of 300 mg/l, a fuel feeding rate of 0.5 ml/min, at a temperature of 30°c. Using of domestic waste water for, it contains expense microorganisms from various sources. It can be move to next level of treatment plant.

VIII. ACKNOWLEDGEMENT

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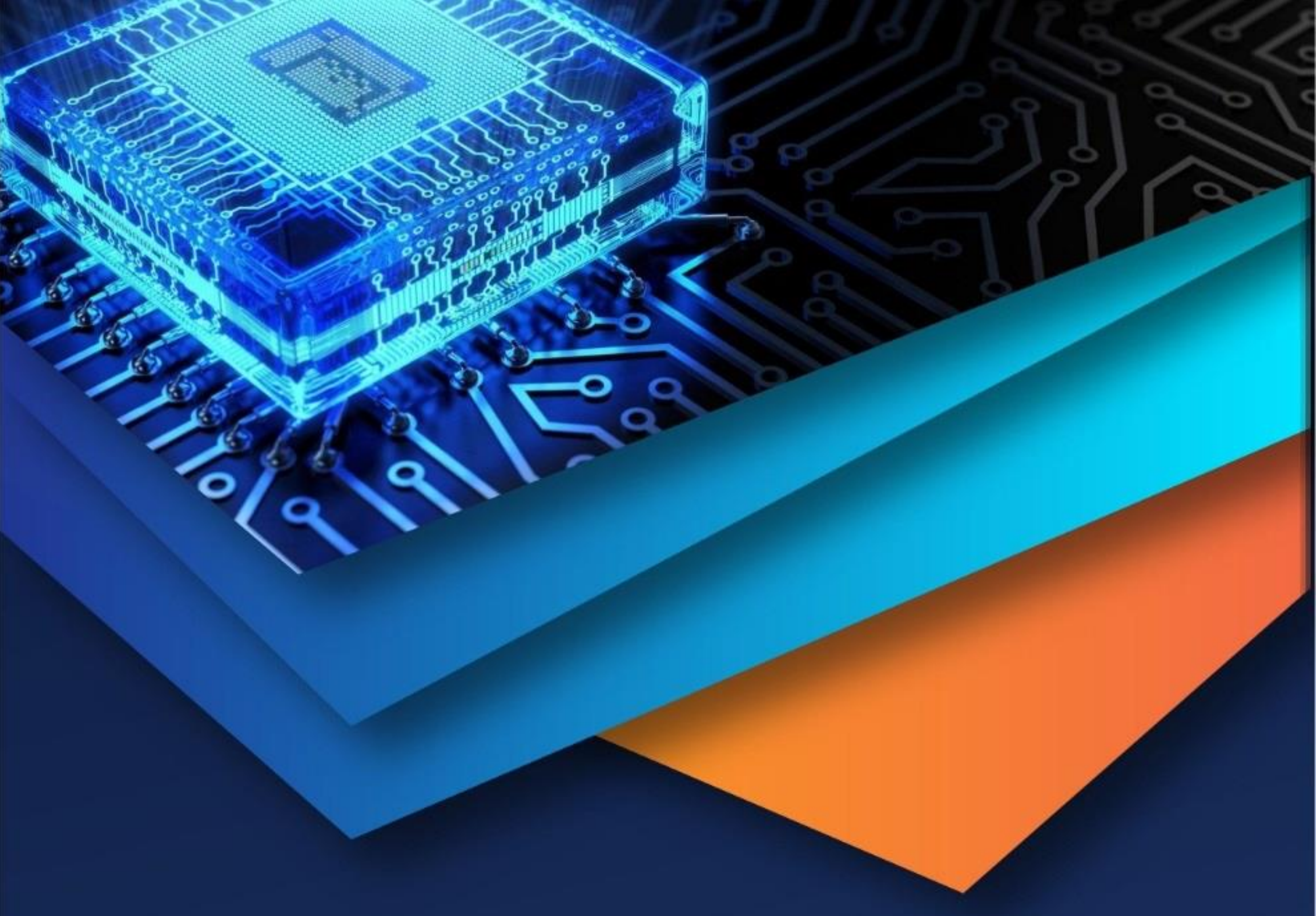

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