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Design and Implementation of Triboelectric Generator for energy generation

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Abstract: Intelligent electronics, such as smart wearable electronic devices, implantable devices, wireless sensor networks, and so on, have significantly increased the development of renewable and sustainable power sources on a small scale. At the moment, batteries are used to power these electronic devices, which have a limited lifespan and cause environmental issues, and monitoring and replacing all of the batteries used for the wireless sensor networks distributed around the world is a massive and impossible task. Among these novel energy harvesting technologies, the triboelectric nanogenerator (TENG) has demonstrated significant potential to address power issues due to its advantages of high energy-conversion efficiency, high power output, good reliability, low cost, and environmental friendliness. In this paper, we examine the progress made in TENG as a flexible power source.
Keywords: Triboelectric nanogenerators, wireless sensor networks, hybrid energy cells.

I. INTRODUCTION

Triboelectric nanogenerators convert mechanical energy harvested from the environment into electricity, which can then be used to power small devices like sensors or to recharge consumer electronics. Except for the fact that piezoelectricity involves permanent electrostatic charge and triboelectricity involves temporary electrostatic charge, triboelectricity is unrelated to piezoelectricity. Triboelectricity is simply the frictional generation of a static electrical charge. The triboelectric effect describes the generation of frictional charge when certain materials are separated from a second material with which they were in contact. The triboelectric charge is created by rubbing the two materials together, which increases the contact between their surfaces. Triboelectricity is simply the frictional generation of a static electrical charge. The triboelectric effect describes the generation of frictional charges that occurs when certain materials become electrically charged after being charged.

The triboelectric charge is created by rubbing the two materials together, which increases the contact between their surfaces. The triboelectric effect is thought to be related to the phenomenon of adhesion, in which two materials stick together due to molecular attraction. Adhesion is not a chemical bond between atoms, but rather an electron exchange between different materials.,resulting in They are held together by electrostatic attraction. Friction is caused by the physical separation of adhered materials. Because electron transfer between materials is not immediately reversible, electrons on one material are in excess while electrons on the other are depleted, resulting in one material acquiring positive and the other negative charges. The triboelectric charge on the materials is eventually neutralised by free electrons from the atmosphere, and they return to their neutral uncharged state.

II. WORK DESCRIPTION

A. Triboelectric Effect

A Nanogenerator is a technology that converts mechanical/thermal energy generated by small-scale physical change into electricity. There are three types of nanogenerators: piezoelectric, triboelectric, and pyroelectric. Mechanical energy can be converted into electricity by both piezoelectric and triboelectric nanogenerators. Triboelectric nanogenerators convert mechanical energy harvested from the environment into electricity, which can then be used to power small devices like sensors or to recharge consumer electronics. Using the concept of electrostatic induction and the triboelectric effect, triboelectric nanogenerators can harvest mechanical energy with ease, cost-effectiveness, and robustness.

B. Methods to generate triboelectric effect

1) Vertical contact separation mode
2) Contact sliding mode
3) Single electrode mode
4) Freestanding mode

C. Polydimethylsiloxane

Polydimethylsiloxane (PDMS), also known as dimethylpolysiloxane or dimethicone, is a polymeric organosilicon compound that belongs to the silicone family. Because of its versatility and properties, PDMS is the most widely used silicon-based organic polymer.

D. PA6(Nylon6)

It's a polyamide that's semicrystalline. Unlike most other nylons, nylon 6 is formed by ring-opening polymerization rather than condensation polymerization, making it a special case in the comparison of condensation and addition polymers. Nylon 6 is derived from caprolactam, which has six carbons.When caprolactam is heated at 533 K in an inert nitrogen atmosphere for 4–5 hours, the ring breaks and polymerization occurs. The molten mass is then passed through spinnerets to form nylon 6 fibres.

III. EQUATIONS FOR THE NANOGENERATOR

A. Maxwell's equation for nanogenerators

$$\nabla . D = \rho$$

$$\nabla . B = 0$$

$$\nabla \times \mathrm{E} = -\frac{\partial B}{\partial t}$$

$$\nabla \times \mathrm{H} = J + \frac{\partial D}{\partial t}$$

$$J_D = \frac{\partial D}{\partial t} = \epsilon \frac{\partial E}{\partial t}$$

$$J_D = \frac{\partial D}{\partial t} = \varepsilon \frac{\partial E}{\partial t} + \frac{\partial P_s}{\partial t}$$

$$\varepsilon \nabla . E = \rho - \nabla . P_s$$

$$\nabla . B = 0$$

$$\nabla \times \mathrm{E} = -\frac{\partial B}{\partial t}$$

$$\nabla \times \mathrm{H} = J + \varepsilon \frac{\partial E}{\partial t} + \frac{\partial P_s}{\partial t}$$

B. General theory for the polarisation Ps

The polarization Ps created by the electrostatic surface charges can be expressed by the following equation, when defining the charge density function σs (r,t) on the media surface by a shape function of f(r, t) = 0.

$$\nabla . P_s = -\sigma_s(r,t)\delta(f(r,t))$$

where the delta function δ(f(r,t)) is introduced to confine the media shape.Through solving the scalar electric potential from the surface charges

$$\emptyset_s(r,t) = \frac{1}{4\pi}\int \frac{\sigma_s(r',t')}{|r-r'|}$$

$$P_s = -\nabla \emptyset_s(r,t)$$

$$= \frac{1}{4\pi}\int \sigma_s(r',t') \frac{r-r'}{|r-r'|^3} ds' + \frac{1}{4\pi c}\int \frac{\partial \sigma_s(r'',t')}{\partial t'} \frac{r-r'}{|r-r'|^2} ds'$$

C current transport equation for nanogenerators

$$I_D = \int J_D . ds = \int \frac{\partial D}{\partial t} . ds = \frac{\partial}{\partial x} \int \nabla . D \, dr = \frac{\partial}{\partial t} \int \rho \, dr = \frac{\partial Q}{\partial t}$$

$$\emptyset_{AB} = \int_A^B E . dL = \frac{\partial Q}{\partial t} R$$

$$\emptyset_{AB} = \int_A^B E . dL = \frac{\partial Q}{\partial t} R$$

$$AR \frac{\partial \sigma(z,t)}{\partial t} = -\sigma(z,t) \left[\frac{d_1}{\varepsilon_1} + \frac{d_2}{\varepsilon_2} \right] - \frac{H(t)[\sigma(z,t) - \sigma_T]}{\varepsilon_0}$$

IV. FULL BRIDGE RECTIFIER

The V–Q plot and the direct charging cycle's physical process The V-Q plot (a). The system's circuit diagram is shown in the inset of a. The dashed lines in a represent the cycle with the greatest energy output and the least resistance. (b) The physical process's schematic diagrams. The diodes drawn with solid and dashed lines in b represent the on and off states, respectively. (c)The direct charging cycles (the second and subsequent cycles) for various charging voltages.

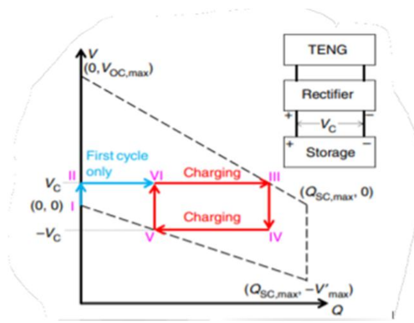

Fig 1.V-I characteristics of Teng

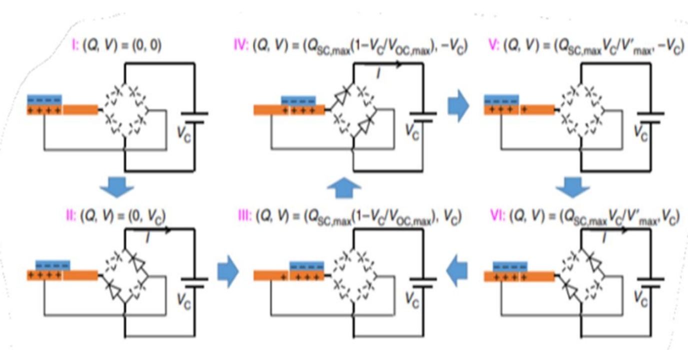

Fig 2.Full bridge rectifier

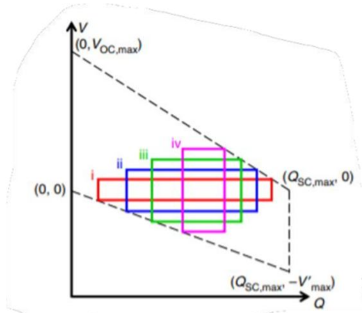

Fig 3.Designed charging cycle

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V. SOFTWARE

A. Comsol Multiphysics

The COMSOL Multiphysics® software brings a user interface and experience that is always the same, regardless of engineering application and physics phenomena. Add-on modules provide specialized functionality for electromagnetics, structural mechanics, acoustics, fluid flow, heat transfer, and chemical engineering.Choose from a list of Live Link products to interface directly with CAD and other third-party software. Deploy simulation applications with COMSOL Compiler™ and COMSOL Server,

1) General-purpose simulation software based on advanced numerical methods.
2) Fully coupled Multiphysics and single-physics modelling capabilities.
3) Complete modelling workflow, from geometry to postprocessing.
4) User-friendly tools for building and deploying simulation apps.

Engineers and scientists use the COMSOL Multiphysics® software to simulate designs, devices, and processes in all fields of engineering, manufacturing, and scientific research. COMSOL Multiphysics® is a simulation platform that provides fully coupled Multiphysics and single-physics modelling capabilities. The Model Builder includes all of the steps in the modelling workflow — from defining geometries, material properties, and the physics that describe specific phenomena to solving and postprocessing models for producing accurate results.

When you have developed a model, you can use the Application Builder to turn it into a simulation application with a dedicated user interface that can be used by collaborators and customers who are not experts in simulation software. To help keep your models and applications organized, the COMSOL Multiphysics® platform also includes the Model Manager, which is a tool for simulation data management that provides version control and efficient storage.

VI. MATERIAL SELECTION AND PROPERTIES

A. Polydimethysiloxane

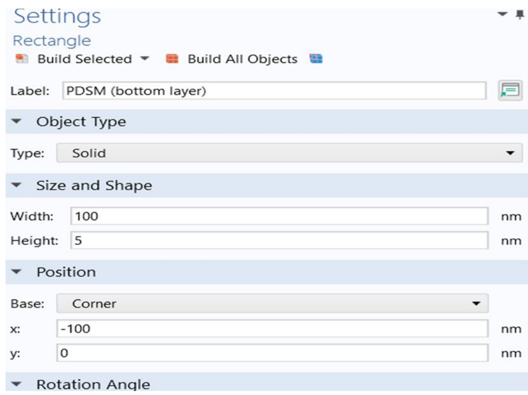

Fig.4 Material Property

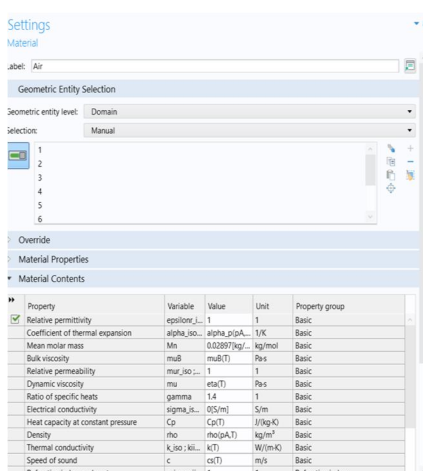

Fig 5.Dimension of Polydimethysiloxane

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B. PA6

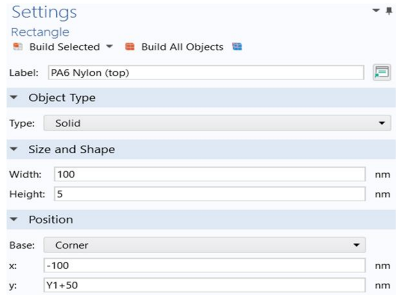

Fig 6. Material property of PA6

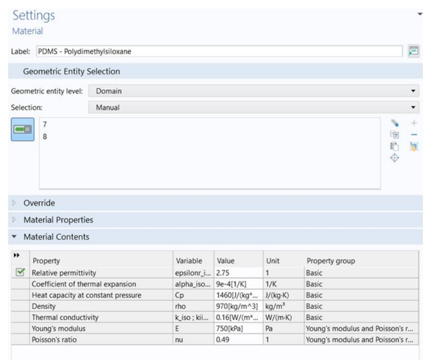

Fig 7.Dimension of Polycaprolactam(PA6)

C. Material selection for Triboelectric effect

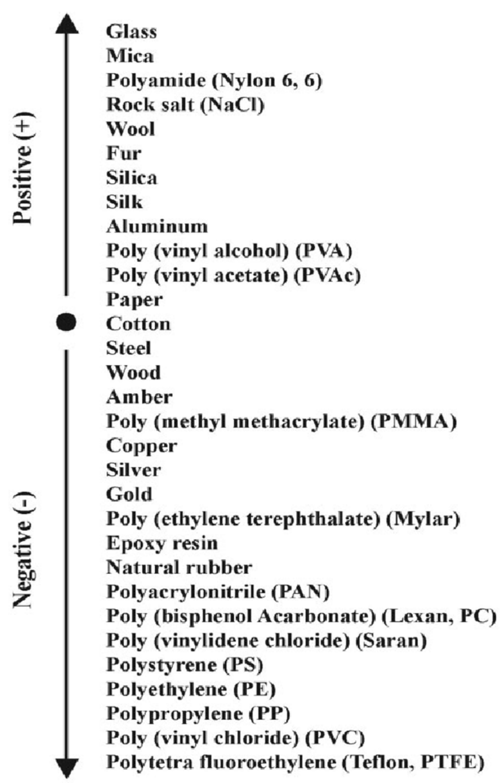

Fig 8. Material selection

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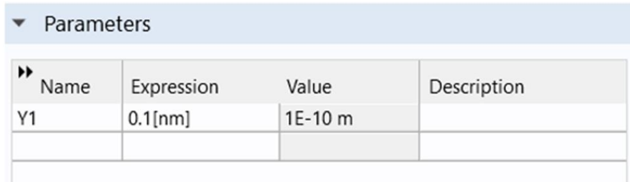
VII. SIMULATION RESULTS

COMSOL Multiphysics have been instrumental in simulating triboelectric effect now let us see the simulation working and result The materials chosen are PDMS and PA6 due to their high positive and negative polarity.


Parameters

Name	Expression	Value	Description
Y1	0.1[nm]	1E-10 m	

Fig 9. Initial parameters

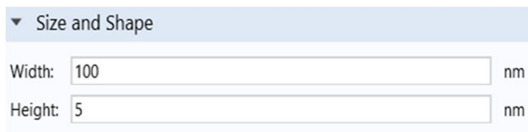


Fig 10.Dimensions of material

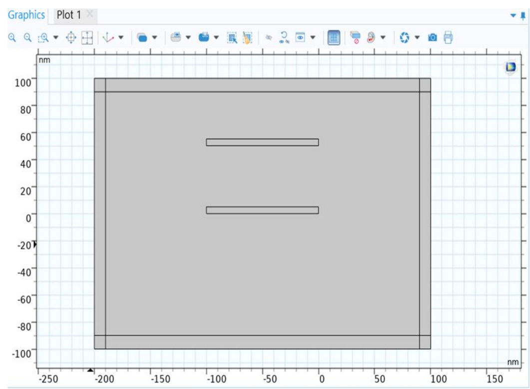
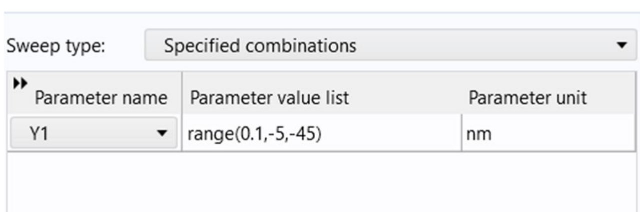


Fig 11.Simulation Diagram of Triboelectric generator


Sweep type: Specified combinations

Parameter name	Parameter value list	Parameter unit
Y1	range(0.1,-5,-45)	nm

Fig 12.Vertical Displacement

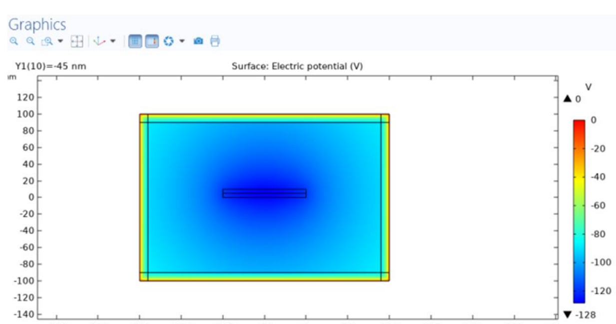


Fig 13.Result of Triboelectric Nanogenerator

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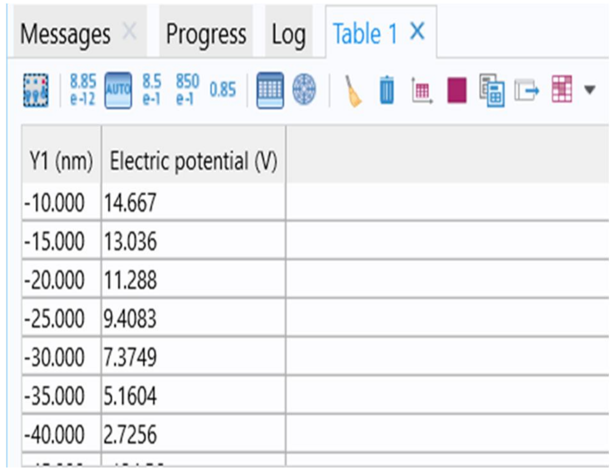

Y1 (nm)	Electric potential (V)
-10.000	14.667
-15.000	13.036
-20.000	11.288
-25.000	9.4083
-30.000	7.3749
-35.000	5.1604
-40.000	2.7256

Fig 14.Voltage Generated from Teng

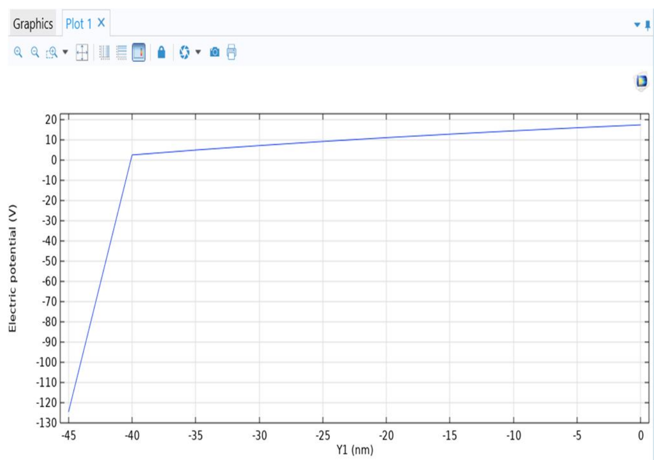

Fig 15.Voltage Generation from Teng

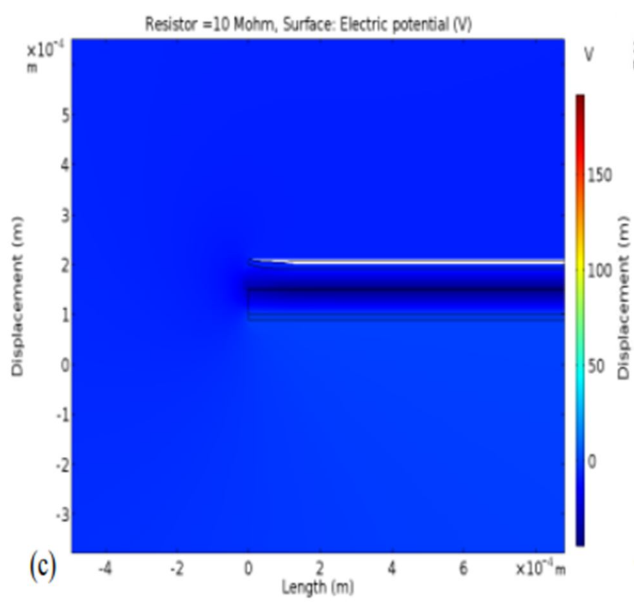

Fig 16.Simulation before contact

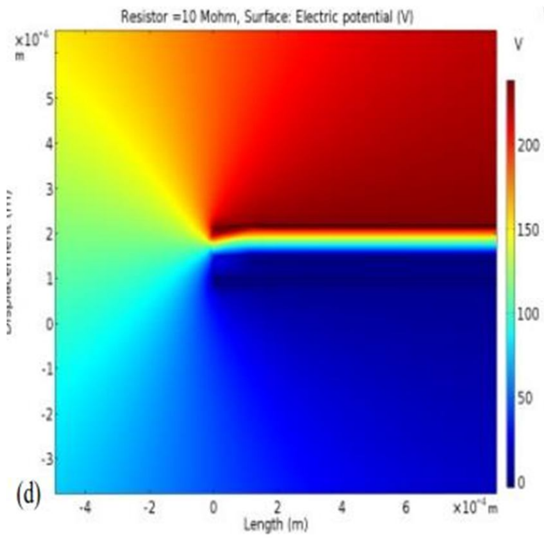

Fig 17.Simulation after contact

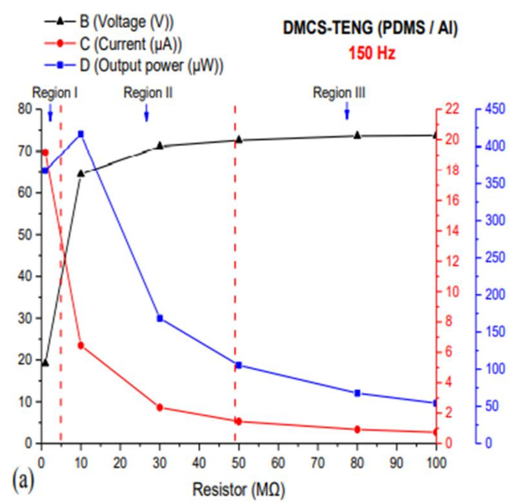

Fig 18.Graph for PDMS/Al

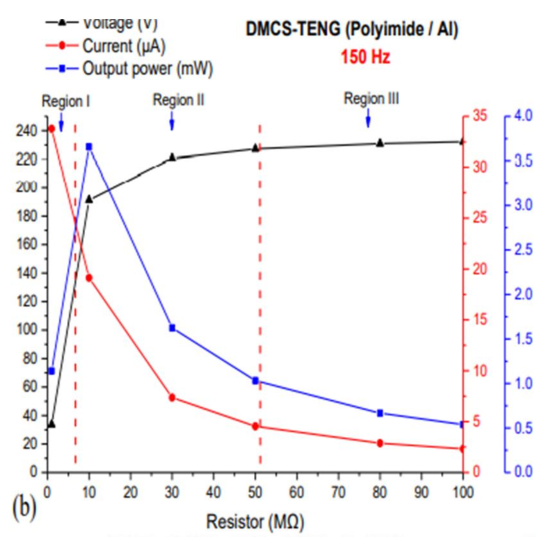

Fig 19.Graph for Polyimide/Al

VIII. CONCLUSION

Finally, a flat-surfaced C-PDMS/PA6 TENG with greatly improved triboelectric performance was successfully fabricated using elaborately selected conductive carbon tape as electrodes. With an output voltage of 1760 V, a short-circuit current density of 240 mA m-2, and a maximum power density of 120 W m-2 in ambient conditions, the C-PDMS/PA6 TENG outperforms the micro-/nano-structure patterned, chemical functionalized, and charge injected TENGs. This research presents a promising simple and low-cost strategy for selecting and preparing electrode materials with special micro/nanostructures to interact with triboelectric layers to generate additional triboelectric charges for high-performance applications. performance TENGs. In addition, in consideration of the flexibility and anti-corrosive.

Triboelectric effect and triboelectric nanogenerator simulation and generation are completed. I learned COMSOL Multiphysics software and used it to simulate the triboelectric effect quality; carbon electrode-based TENGs have a broader application potential than other types of TENGs.

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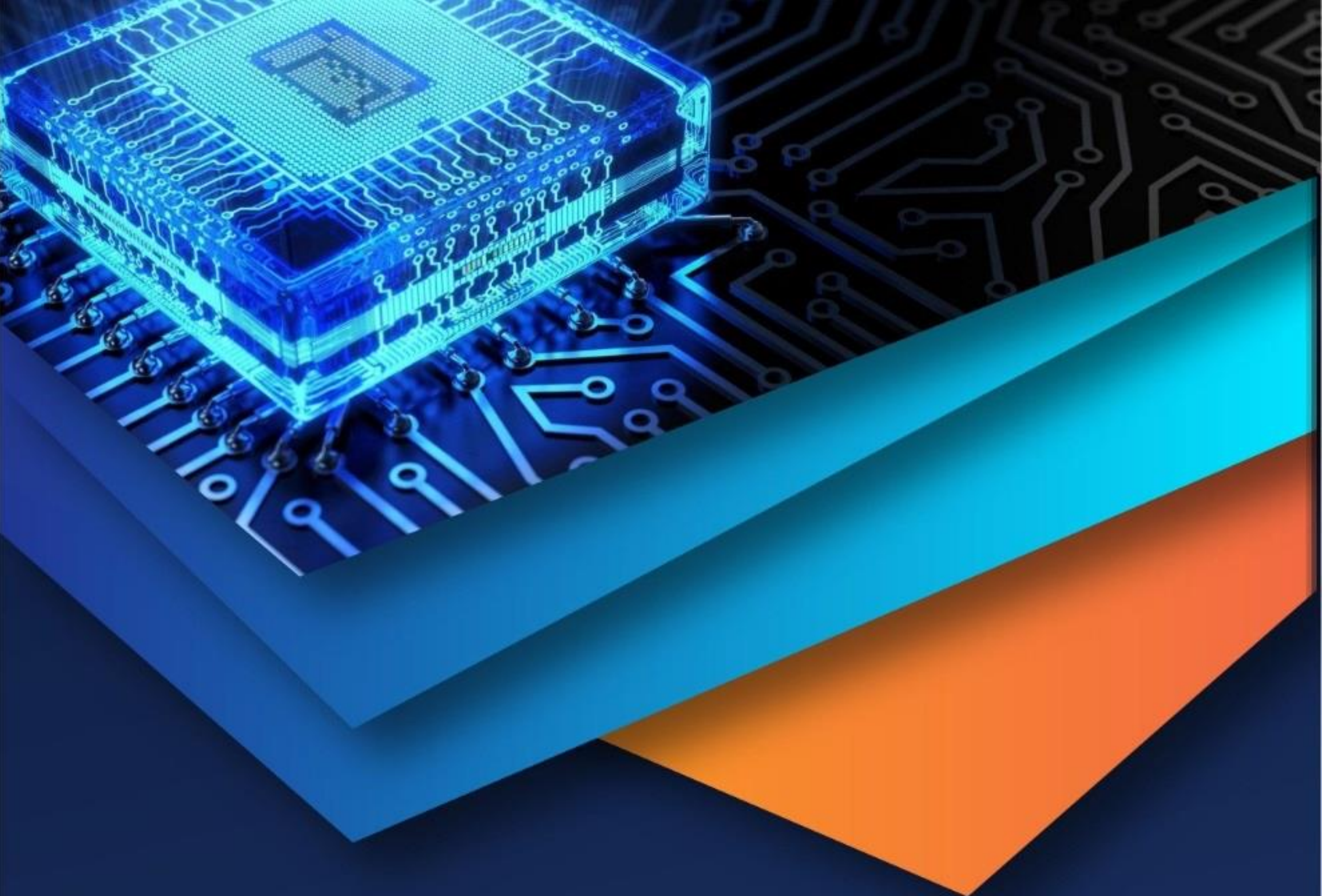

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