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Synthesis and Characterization of rGO/Fe_3O_4 Nanocomposite as Counter Electrode for Dye Sensitized Solar Cell

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Abstract: ***In this project work deals with the synthesis and characterization of rGO/Fe_3O_4 nanocomposite as counter electrode for dye sensitized solar cell . The growing population in the world arouses energy concerns in all kinds of fields. It is mandatory to meet our everyday energy demands from solar, wind, geothermal, and so on. The proposed Dye-Sensitized Solar Cells (DSSC's) belong to the group of thin-film solar cells that have been the subject of research for more than two decades due to their low cost, simple preparation methodology, low toxicity, ease of production, and simple methodology. Still, there is a lot of scope for the replacement of current DSSC's materials due to their high cost, limited abundance, and long-term stability. These cells have the advantages of low-energy and high-throughout processing technologies, low material costs, and the ability to work even in low incident light conditions. To studied about the structural and morphological properties of synthesized rGO/Fe_3O_4 nanocomposite by using various characterization techniques such as XRD analysis, then the efficiency of existing DSSC's may be upto 10-12% by using eosin yellow dyes and optimising material.***

Keywords: Dye Sensitized solar cell, working mechanism of DSSC's, Experimental techniques, XRD analysis.

I. INTRODUCTION

Because of the rapid increase in human population and the depletion of nonrenewable energy sources, the global energy crisis has become a major issue. It is mandatory to meet our everyday energy demands from solar, wind, geothermal, and so on. Solar energy stands out as one of the best candidates for meeting rising energy demand. Edmond Becquerel, a French researcher, discovered the photovoltaic effect in 1839. It converts solar light energy directly into electricity in photovoltaic cells, with no pollution or noise. Dye-sensitized solar cell (DSSC) is a promising solar harvesting technology with a bright future. This technology was invented by B. O'Regan and M. Gratzel around two decades ago. Recently, nanocomposites containing transition metal oxides and carbonaceous materials such as carbon nanotubes (CNTs), graphene, carbon nanofibers, and mesoporous carbon have been discovered to improve the electrocatalytic activity, power conversion efficiency, and cyclic stability of DSSC.

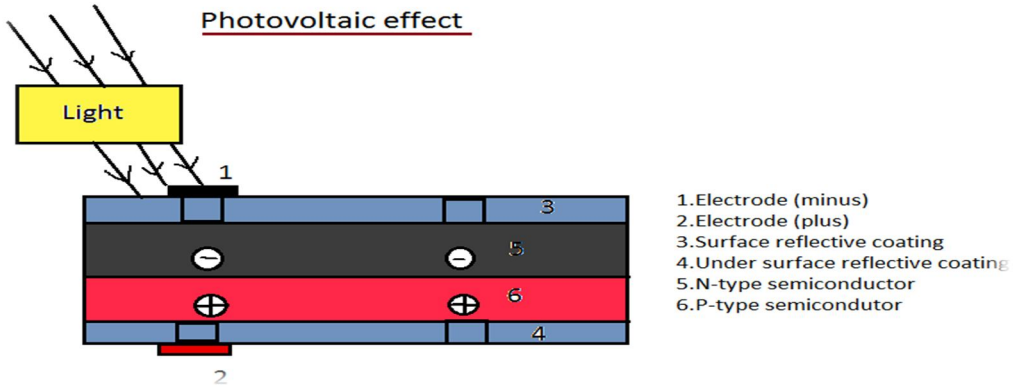

Figure 1: Working principle of photovoltaic effect

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II. DIFFERENT TYPES OF GENERATION IN SOLAR CELLS

A. First Generation Solar Cells

First generation solar cells are mainly based on silicon wafers and typically demonstrate a performance about 15-20%. These types of solar cells subordinate the market. The benefits of this solar cell technology deception in their good performance, as well as their high adherence. However, they are inflexible and require a lot of energy in production. The first generation solar cells that are relatively expensive to produce.

B. Second Generation Solar Cells

The second-generation solar cells are based on amorphous silicon, CIGS, and CdTe, where the typical performance is 10–15%. Because second generation solar cells do not use silicon wafers, they consume less material. It has been possible to reduce the production costs of these types of solar cells compared to the first generation. The second generation of solar cells can also be produced. However, because the production of second-generation solar cells still involves vacuum processes and high temperature treatments, there is still a significant amount of energy consumed. Further, the second-generation solar cells are based on scarce elements, and this is a limiting factor in the price.

C. Third Generation Solar Cells

Third-generation solar technologies may achieve higher efficiencies at a lower cost than first- or second-generation technologies. Some of these next-generation solar cells are nanocrystal solar cells, photo-electrochemical cells, dye-sensitized hybrid solar cells, and polymer solar cells. These cells have the advantages of low-energy and high-throughput processing technologies, low material costs, and the ability to work even in low incident light conditions. The efficiency is still lower than that of silicon wafer-based solar cells.

III. DYE SENSITIZED SOLAR CELLS

Dye-sensitized solar cell (DSSC) are a third-generation solar cell that converts visible light into electrical energy. DSSC is a disruptive technology that can be used to produce electricity in a wide range of lighting conditions, indoors and outdoors, enabling the user to convert both artificial and natural light into energy to power a broad range of electronic devices. A DSSC is a low-cost solar cell that belongs to the group of thin-film solar cells. Also, this technology has more advantages due to its low fabrication cost, environmentally friendly manufacturing materials, and remarkably high power conversion efficiency.

A. Components Of DSSC

DSSCs are composed of four components:

1) Photo electrode
2) Sensitizer (dye)
3) Counter electrode
4) Electrolytes.

Both electrodes (photo electrode and counter electrode) are usually made from a sheet of common float glass coated on one side with a thin transparent conductive layer of fluorine-doped tin dioxide (FTO) or indium-doped tin oxide (ITO).

B. Photoelectrode

In the photo electrode, the transparent conductive electrode is covered with a thin film (7–10 m) of a wide bandgap metal oxide semiconductor, which is generally preferred. This oxide layer can be deposited, starting from a colloidal suspension, by means of a variety of methods, including spraying, screen printing, dip coating, spin coating, or the simple doctor blade technique. After deposition, the layer is sintered in an oven at a temperature of 450°C, a treatment that has the scope of creating a network of interconnected particles through which electrons can percolate.

C. Sensitizers

Sensitizers are an important component of the DSSC's. dye acts as a sensitizer that can be adsorbed onto the semiconductor oxide layer. When dye molecules are exposed to light, they are excited from the ground state to the excited state. The dye molecules inject electrons into the semiconductor oxide material.

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D. Electrolyte

The next layer of dye molecules is the electrolyte, which transports electrons between the working and counter electrodes. The oxidised dye molecules should return to their original states using electrons from the electrolyte.

E. Counter Electrode

In the DSSC system, the counter electrode (CE) acts as a catalyst for the redox couple regeneration as well as an electron collector from the external circuit. The CE materials should possess two advantages: high catalytic activity and electrical conductivity. Generally, platinum (Pt) deposited on F-doped tin oxide (FTO) conductive glass is used as a CE, in which Pt performs as a catalyst and FTO as an electron collector.

F. Working Mechanism of DSSC

Combined heat and power (CHP) fuel cell systems, including micro combined heat and power (Micro CHP) systems are used to generate both electricity and heat for homes (see home fuel cell), office building and factories. The system generates constant electric power (selling excess power back to the grid when it is not consumed), and at the same time produces hot air and water from the waste heat. As the result CHP systems have the potential to save primary energy as they can make use of waste heat which is generally rejected by thermal energy conversion systems. A typical capacity range of home fuel cell is 1–3 kWel, 4–8 kWth . CHP systems linked to absorption chillers use their waste heat for refrigeration.The operating principle of DSSC's is depicted in Fig 2

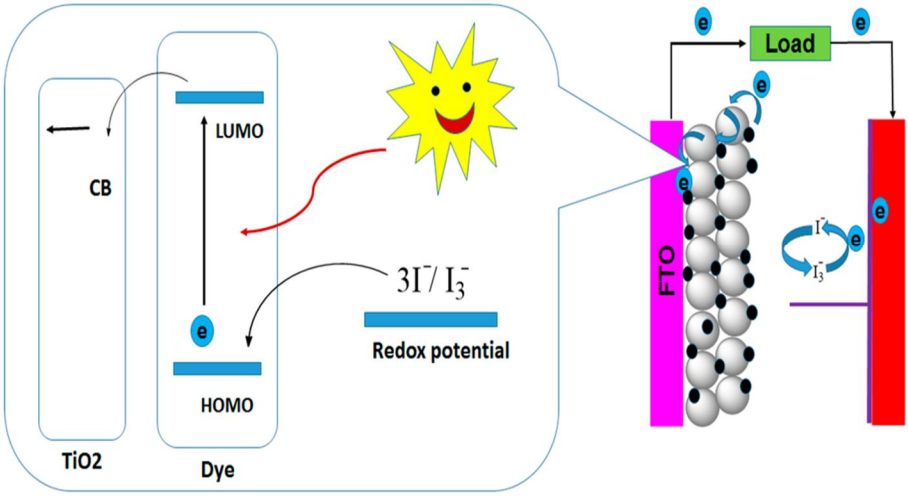

Figure 2: Working mechanism of DSSC

1) Semiconductor oxide materials (TiO2 or ZnO) are deposited on the transparent conducting oxide (FTO or ITO) substrate as a photo electrode to provide the necessary large surface area to adsorb dye molecules (sensitizer).When the sun's light falls onto the photo anode, the dye molecules absorb the photons. Dye molecules are excited from the highest occupied molecular orbital (HOMO) to the lowest unoccupied molecular orbital (LUMO) states as shown in figure.

$$S + photon \rightarrow S^*$$

2) When the excited electron is injected into the conduction band of the TiO2 nanoparticles, the dye molecules become oxidized. The injected electrons can move freely on the semiconductor layer, and the electrons flow toward the transparent electrode, where they are collected for powering a load. After flowing through the external circuit.

$$S^* \rightarrow S^+ + electrons$$

3) The electrolyte, which contains I- and I3- redox ions, is then used as an electron mediator between the TiO2 photoanode and the carbon/Pt coated counter electrode. Therefore, the oxidised dye molecules are regenerated by receiving electrons from the I-ion redox mediator that get oxidized to I_3^- .

$$S^+ + 3/2\ I^- \rightarrow S + 1/2\ I_3^-$$

4) In return, iodide is generated by the reduction of triiodide on the cathode. The process is repeated on the cell

$$1/2\ I_3^- + electrons \rightarrow 3/2\ I^-$$

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IV. EXPERIMENTAL TECHNIQUES

A. Materials Used

Graphite powder, sulphuric acid (H_2SO_4), potassium permanganate ($KMnO_4$), sodium nitrate ($NaNO_3$), hydrogen peroxide (H_2O_2), hydrochloric acid (HCl), iron sulphate heptahydrate ($FeSO_4.7H_2O$), and ethylene glycol were purchased from Merck.

B. IRON (II, III OXIDE) Fe_3O

Iron (II, III) oxide is ferromagnetic by nature. It occurs in nature as the mineral magnetite. It is one of a number of iron oxides, the others being iron (II) oxide (FeO), which is rare, and iron (III) oxide (Fe_2O_3), also known as hematite. It contains both Fe2+ and Fe3+ ions and is sometimes formulated as FeO > Fe_2O_3. Green atoms represent Fe2+, brown atoms represent Fe3+, and white atoms represent oxygen.

It consists of a face-centered, tightly packed array of oxide ions, where all of the Fe2+ ions occupy half of the octahedral sites and the Fe3+ ions are split evenly across the remaining octahedral and tetrahedral sites.

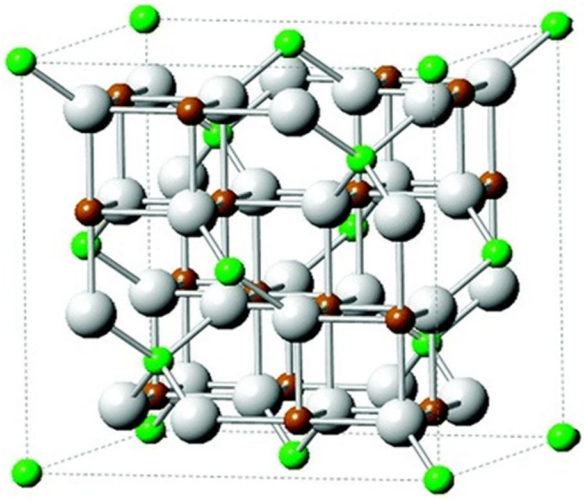

Figure 3: Shows structure of Fe_3O_4

Iron oxide (Fe_3O_4) nanoparticles play a major role in many areas of chemistry, physics, and material science due to their efficiency, economics, scalability, and non-toxicity.

Fe_3O_4 nanoparticles have attracted much interest in many areas, such as magnetic recording media, audio and videotape, and high-density digital recording disks; magnetic fluids; data storage; drug delivery systems; medical applications; radio frequency hyperthermia; photo magnetics; magneto resonance imaging (MRI); medical diagnostics; cancer therapy; microwave devices; sensors; high-frequency applications; catalysis; and magnetic sensing.

TABLE 1: PHYSICAL PROPERTIES OF Fe_3O_4

Chemical formula	$FeO.Fe_2O_3$, Fe_3O_4
Molar mass	231.533 g/mol
Electrical conductivity	10^2 to 10^3S cm^{-1}
Refractive index	2.4
Melting point	1,597ºC
Boiling point	2,623 ºC
Appearance	Solid black powder
Density	5 g/cm^3

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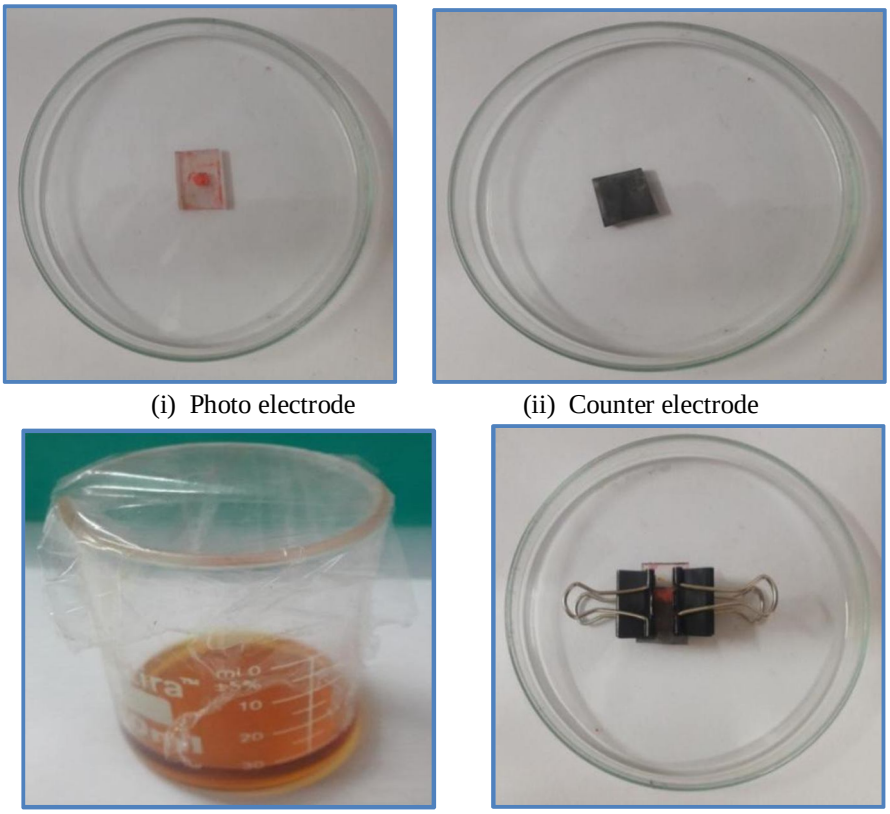
C. Preparation of Electrodes and Cell Assembly

The FTO glass plate was initially cleaned with soap solution, distilled water, and ethanol during the solar cell fabrication process.Then the synthesised TiO_2 nanoparticles were made into a paste by grinding 0.5 g of TiO_2 nanoparticles in a solution of polyethylene glycol (PEG) and Triton X-100. The paste was then coated on the ITO substrate with a doctor blade technique.The photoanode was prepared by immersing the TiO_2-coated ITO substrate in the 0.5 ml Eosin Yellow dye solution for 24 hours. It is called a photoanode. A thin layer of rGO/Fe_3O_4 nanocomposite is coated on the FTO using a drop casting method called the counter electrode. The photo electrode and counter electrode were clamped together (using binder clips) to form a sandwich structure.where potassium iodide was used as an electrolyte. The area of the running electrode was 0.25 cm^2.



(i) Photo electrode (ii) Counter electrode

(iii) Electrolyte (iv) DSSC

Figure 4: Photographs shows the fabrication of DSSC

V. RESULTS AND DISCUSSION

A. XRD Analysis

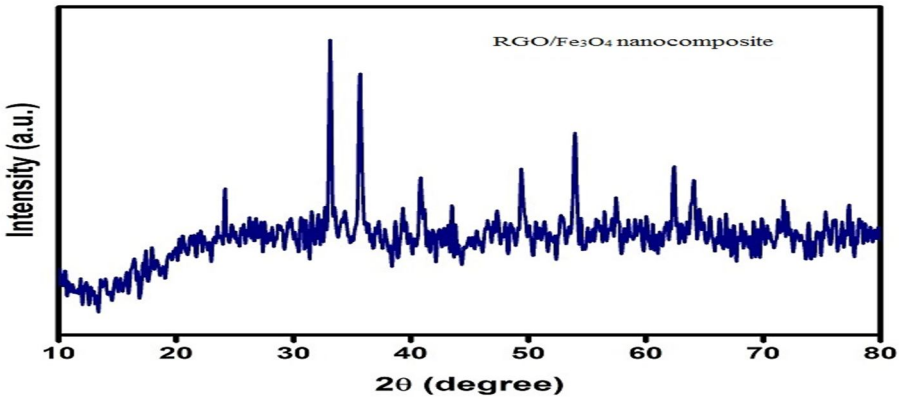


Figure 5: XRD pattern of rGO/Fe_3O_4 nanocomposite

Figure 5.1 shows the XRD pattern of rGO/Fe_3O_4 nanocomposite. The diffraction peaks occur at 33.1, 35.6, 40.8, 49.5, 54.1, 62.3 and 64.0º are indexed to the (104), (110), (113), (024), (116), (214), and (300) planes of Fe_3O_4. This is well matched with JCPDS No. 19-0629. The diffraction peaks reveal the spinel structure of Fe_3O_4. The broad band in the range of 2Ɵ confirms the formation of rGO.

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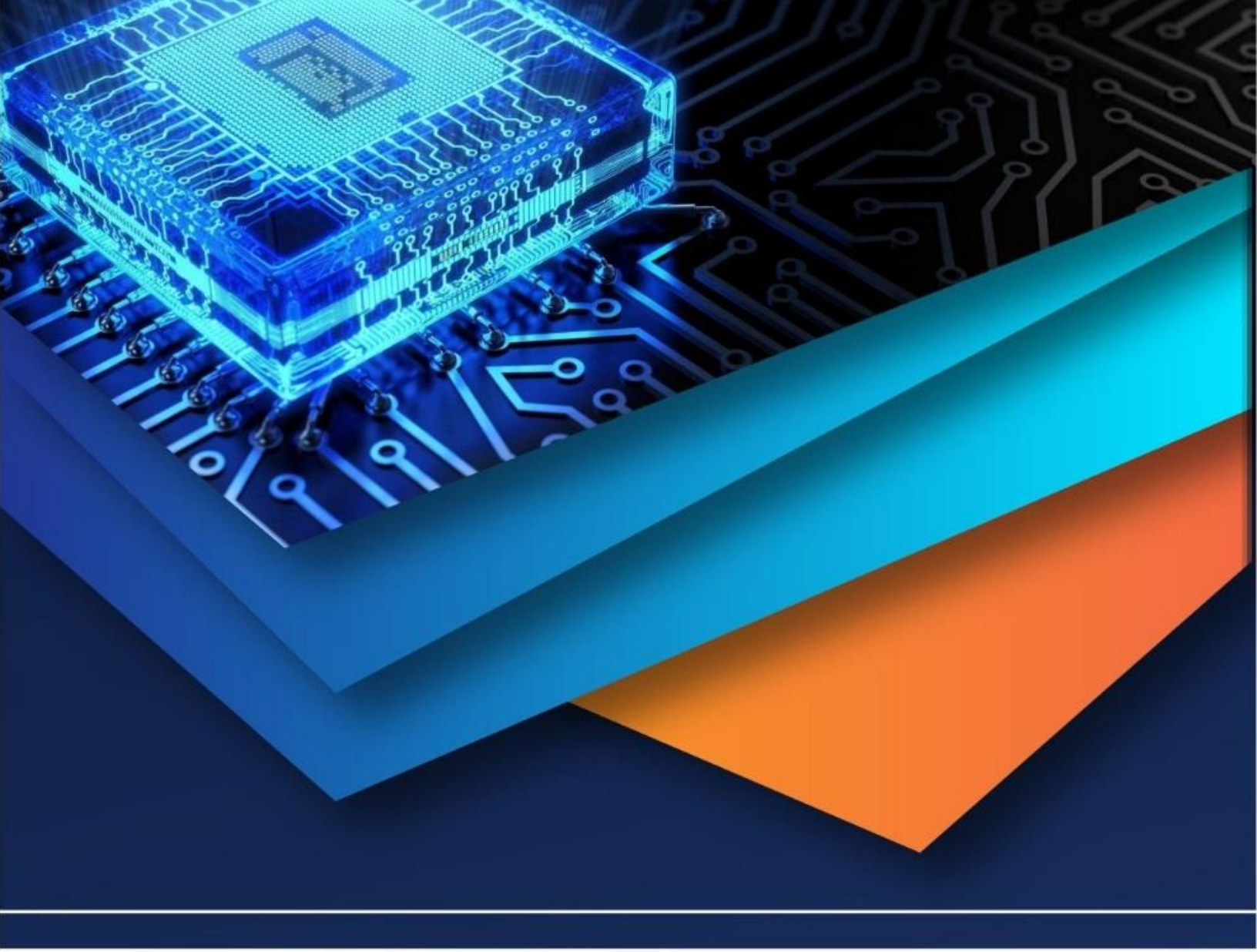

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