iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 **Issue:** I **Month of publication:** January 2022

DOI: https://doi.org/10.22214/ijraset.2022.39994

Fabrication of Dip Coated ZnO Nanorods for Organic Dye Sensitized Solar Cells

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Abstract: Dye sensitized solar cell (DSSC) are new type of solar cell, has aroused worldwide attention which arises from its merits of low cost, ease of fabrication and environmental friendliness, etc. The development history, basic structure and working principle of the DSSC are introduced briefly, and the classification and development of DSSC are stated in detail. Dye sensitizers are divided into two major categories organic dyes and metal-organic compounds, and organic dyes can roughly be classified into several parts. A new form of solar cell is being investigated using a dye-sensitized solar cell (DSSC) using an inorganic semiconductor, due to the anticipated less costing solution to standard solid-state equipment. The formulation of effective solar cell contains countless semiconducting materials. This was an initiative of the researchers to study the fabricated of the natural dye sensitized solar cells for sol-gel dipping coated zinc oxide nanorod and also more voluminous in surface. Moreover, the corresponding assumptions and measures on how to improve the energy efficiency of the DSSCs are proposed, and finally the trends and promising prospects are presented.
Keywords: ZnO Nanorods, Dye Sensitized Solar Cells (DSSC), Organic Solar Cell, Dip Coating Method.

I. INTRODUCTION

Currently the technology of photovoltaics is growing and solar cells have discovered market places for a number of uses, with consumer electronics as well as small level sent out electric devices through centralized megawatt electricity plant life. Photovoltaic radiation is used to produce electricity and this application is almost a perfect way to use the alternative energy stream of nature. A PV cell produce power close to electric end consumer and thus avoids costs and losses of transmission and solar cells work with no noise along with environment friendly emissions of house gases as well as less maintenance was required. Moreover, it is appealing for widespread use thanks to its enormous theoretical potential along with extremely strong solar power's practical potential. The price of solar cells remained a restricting factor in solar energy implementation on a large scale, even with essential growth over previous years. The conventional solar cell technologies have grown to a level where costs are anticipated by size savings. Cost calculation on the other palm for more or less the same sale of thin film photovoltaic technology in the same range as conventional silicon technology. Therefore, fresh materials and ideas have to be developed to decrease the cost of solar cells in a photovoltaic conversion. Historically, inorganic materials such as silicon have constructed up conventional solar cells. Though, this process needs energy-intensive methods as well as very costly materials. Organic materials are mostly cheap, process able as well as molecular design and chemical synthesis can customize their features. Inorganic semiconductors may be manufactured, because of the detriment of elevated absorption coefficients and tuning size of the nanoparticles and inorganic semiconductors. The band gap may be fine-tuned simply by changing nanoparticles size and thus the absorption range may be adapted.

DSSC are basically a mixture of different materials each carrying out a certain task to the aim of altering the sunlight into electricity. An inorganic natural dye from flower, fruit and plant leaves have many benefits over rare metal along with other natural dyes. Natural dyes usually are quick, simple to remove, needless to further purify, eco-friendly and cheaper. There are many study groups around the globe working to sensitize natural dyes for DSSC. Sunlight is one of the very readily exploitable, infinite and continuous abundant sunny sources of renewable energy, adaptable along with silent to many applications from hundreds of MW of outdoor power plant life, producing electricity along with heat to tiny off grid structures, which provide for rural trade and growth areas. The DSSCs are basically key cell structural design class, for the growth of solar cells the next generation. Compared with the traditional silicon solar cells, it offers an easy manufacturing benefit and low cost. Basically ZnO is a semiconducting oxide, transparent, dielectric as well as piezoelectric with a 3.37 eV band gap and a high energy (60 meV) excitation binding which is 2.4 times as high as efficient heat power.

II. EXPERIMENTAL TECHNIQUES

A. Objective of the Work

The main aim of this current research work is:

1) The dip-coating technique to produce the layers of zinc oxide.
2) This is the hydrothermal technique that has cultivated nanorods of ZnO.
3) The deposited ZnO nanorods were tested for the structural, morphologic and optical characteristics.
4) ZnO Nanorods were manufactured and cell features investigated on the basis of natural DSSC.

All surfaces of the substrates must be regarded contaminated as well as washed before applications of temperature-sensitive substances. Based on this criterion, appropriate substrates are chosen for distinct procedures. In this study well-cleaned 1 mm thick glass / ITO substrates were selected as substrates. In ultrasonic cleaning, residue dissolution is improved by concentrating local shock waves action produced in the solvent. The glass substrates were washed well by this method. In a clean oven, the wet-cleaned glass substrates were finally drained at approximately 70°C.

B. Preparation of ZnO Seed Layer

ZnO nanorods development generally requires a seed layer. As per literature, ZnO films could be utilized for the development of ZnO nanorods as nucleation plants. The acetate bath produced as mentioned elsewhere has been ZnO nano crystals that are basically used as a seed coating. The seed layer has a huge impact on nanorods. Control over nanorod development can be achieved by merely changing the thickness of layers, by applying layer patterns and techniques for ZnO guided nanorod development. A few distinct tasks including radio frequency magnetron sputtering, thermal deposition, chemical bath deposition, spin coating along with sol gel dip coating method were used to ready the seed levels for the improvement of ZnO nanorods. In the present work on preparing ZnO seed layers on glass / ITO substrates for its low price and simple technique, the sol-gel dip coating technique has also been implemented. All of the reagents (Merck 99.99 percent) used in studies were uncleaned along with analytically pure. 0.1 zinc acetate mol has been dissolved into 20 ml ethanol and 0.25 ml of distilled water has been dissolved through the syringe drop by drop. The chemical structure was provided in table 1. When Zn $(Ac)_2$ is inserted in alcoholic beverages, the following impulse takes place initially

$$4Zn(Ac)_2 2H_2O \rightarrow Zn4O + 7H_2O + 2HAc \qquad (1)$$

Zn4O $(Ac)_6$ is viewed as basic zinc acetate. The solutions as H_2O, acetic acid are eradicated by distillation. Zn4O $(Ac)_6$ might be considered a correctly generated molecular ZnO type. The pH of the solution was looked after at 16.5 - 7. This specific cure was stirred constantly for 2 hours at room temperature for obtaining unique homogenous repair. The stirred solution was taken in a beaker along with the correctly cleaned glass substrates are dipped in the solution for 5 events from regular occasions at room temperature with immediate consider dip coating system. After the annealng 5-layer films is performed to crystallize the seed particles at 200°C during 1 hour in a furnace.

Table -1: Chemical composition of ZnO seed layer solution

Chemical Name	Chemical formula	Mole required	Material taken
Zinc Acetate	$Zn(CH_3\,CO_2)_2$	0.1 g	0.439 g
Ethanol	C_2H_5OH	-	20 ml
Deionized water	H_2O	-	0.25 ml

C. Preparation of ZnO Growth Layer

Zinc oxide (ZnO), a wide band gap (3.37 eV) semiconductor is viewed as probably the most promising substance for solar cells. Presently, gas phase technique for the synthesis of hierarchical ZnO nanostructures is now being produced. Gas-phase synthesis generally needs strict response circumstances as elevated temperatures or other supporting templates and is restricted to expenses or equipment. Although the solutions are more appealing because they are simpler, more commercially viable and have excellent scale-up potential. In particular, low-temperature aqueous-phase approaches (typically < 100°C) are especially popular due to their low power demands, safety and eco-friendly environments. Here we report that three different precursor concentrations had an effect of 500°C annealing temperture on the cultivated ZnO nano rods. Zinc oxide dihydrate $Zn(NO_3)_2.6H_2O$, 0.02 mol and hexamethylenetetramine (HMT) $C_6H_{12}N_4$, 0.2 mol have been used at the ratio of 1:10. The other two are 2:10 and 3:10 molar ratios. Above mentioned 3 concentrations were used to grow the ZnO nano rods and annealed for 1 hour at 500°C. The final molar solution structure of zinc nitrate to HMT is 1:10. The same treatment was also performed for levels of 2:10 and 3:10 molars. In Table 2, the chemical compositions of ZnO nanorods were provided.

Table -2: Chemical composition of ZnO growth layer solution with 1:10 molar ratio

Chemical Name	Chemical formula	Mole required	Material taken
Zinc Nitrate	$Zn(NO_3)_2$	0.02 mol	0.119 grams
Hexamethylenetetramine	$(CH_2)_6 N_4$	0.2 mol	0.561 grams
Deionized water	H_2O	-	20 ml

III. RESULTS AND DISCUSSION

A. *Structural Studies*

The structural feature may be achieved by verifying XRD sample pattern. Either a specified material is present in a pure condition or as a mixture component a distinctive diffraction pattern always arises. This reality is the basis for the chemical analysis diffraction technique. The particular advantage of the XRD evaluation is based on the reality it uncovers the presence of a compound because it essentially happens in the test rather than in terminology of the chemical pieces of its. Diffraction assessment is helpful if the state of the chemical mixture of the participating components or the specific stage they take place is to be known. Figure 1 shows the ZnO nanorod arrays of XRD patterns, with 3 different molar levels of 1:10, 2:10 and 3:10 and annealed at 500°C. The (002) peak intensity has risen sharply at 500°C and two peaks (100) and (101) were reduced, as the growth layer concentration rises from 1:10 to 3:10. It means that the highest c-axis nanorod development is seen at concentration of a growth layer of 3:10.

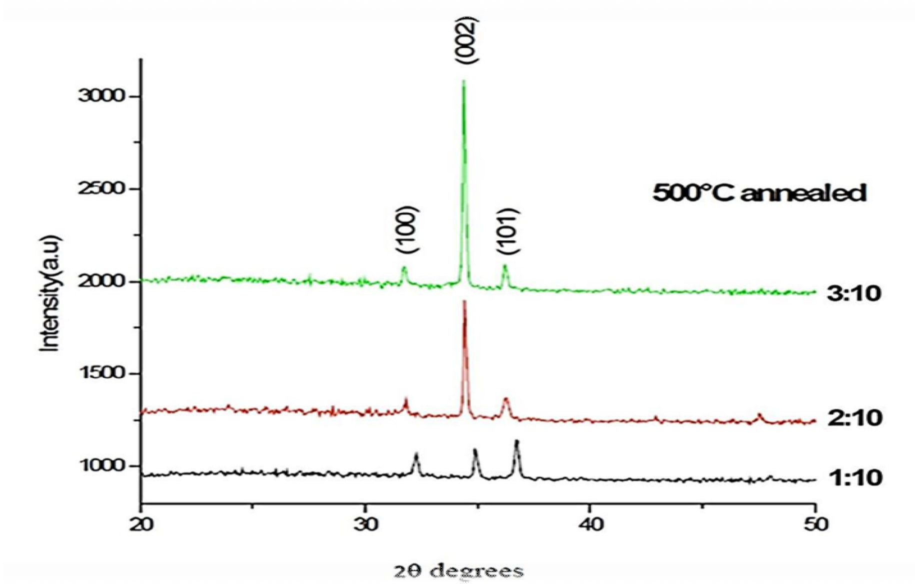


Fig -1: XRD patterns of ZnO nanorods annealed at 500°C in three different molar concentrations

B. *Morphological Studies*

The (SEM) is an electron microscope type. Sample is scanned with a centered high energy electron beam as well as scattered electrons or detecting secondary generates the image in an electron microscope. The electrons are all electrostatic / magnetic because they are used instead of photons. Different interactions happen when the energy electrons hit the sample. Electrons communicate with the atom forming signals that provide data on morphology and sample surface structure. The whole choice of X-rays are collected and analyzed to allow identification of the issue in the region. Energy dispersive X-ray evaluation (EDAX) design of ZnO nanorod thin film ready during 3:10 molar ratio annealed at 500°C is displayed with Fig. 2. The style displays the various peaks corresponding to the components contained concurrently. By this particular, it is easy to identify the focus of the components contained in that particular area.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue I Jan 2022- Available at www.ijraset.com

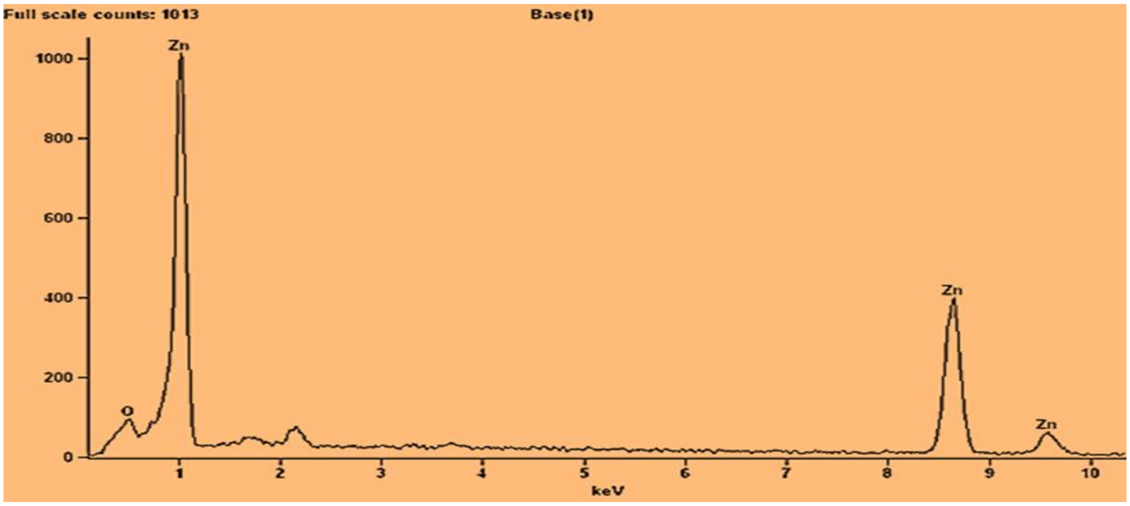


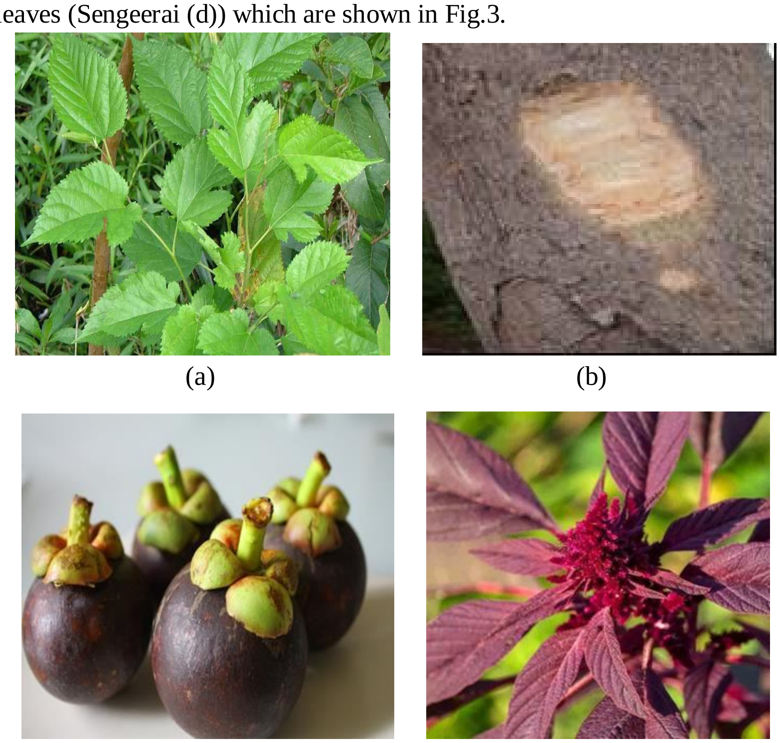
Fig -2: EDAX pattern of ZnO nanorod thin films prepared at 3:10 ratio and annealed at 500°C

In four areas of the film surface the structure of ZnO nanorod thin films was checked. From the information acquired, we discovered that in the greater proportion of Zn and O. The prepared ZnO thin films that are having the structure of Zn-52.53% and O-48.47% are demonstrated in the model.

IV. FABRICATION OF ORGANIC DSSC

A. Selection of Organic Dyes

Many organic coloration colors have been utilized as very sensitive elements for dye sensitized photovoltaic cells from items that are natural, like flowers, fresh fruit and barks. The target of this particular analysis is using all natural colors from 4 types of all-natural plants, they're morus alba leaves (Mulbery (a)), delonix elata barks (Vathanarayan (b)), mangustan mesocop fruit (mangosteen (c)) as well as amaranthus caudatus leaves (Sengeerai (d)) which are shown in Fig.3.



(a) (b)

(c) (d)

Fig -3: Selected natural plants for dye sensitizers

The flowers bark and fruits had been initially washed with de ionized water and dehydrated to the air environment. The dried crops have been parts produced and submerged in an aluminum foil covered ethanol solution for 24 hours to avoid evaporation. The natural dyes solutions were acquired after filtration. The solution can be used directly for absorption measures and as a dye sensitizer.

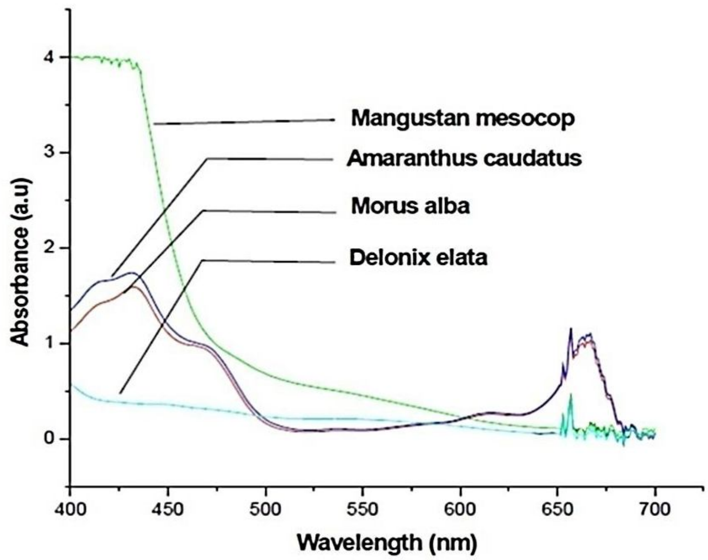


Fig -4: Absorption spectra of four natural dye solutions

Fig.4 four organic plant extracts from morus alba, mangustan mesocop, amaranthus caudatus as well as delonix elata at wavelengths between 400 nm 700 nm are revealed on the UV-VIS absorption spectrum.The chart above clearly showed that for amaranthus caudatus and morus alba extracts, two absorbent maximums vary with the wave length of λ = 430 nm and λ = 670 nm with the intensity of the absorption. It also stated that in mangustan mesocop at 410 nm there is only one absorption peak. The absorption peaks were not discovered in the case of delonix elata.

B. Solar Cell Characterization

The I-V characteristics of natural dye sensitized photovoltaic cells in the deep and beneath lighting had been assessed by semiconductor parameter analyzer (Keithley 4200 SCS). A Xenon light source (Philips) was accustomed present an irradiance of 100 mW / cm2. Fabricated natural dye sensitized solar cells utilizing morus alba along with amaranthus caudatus is shown in figure 5.

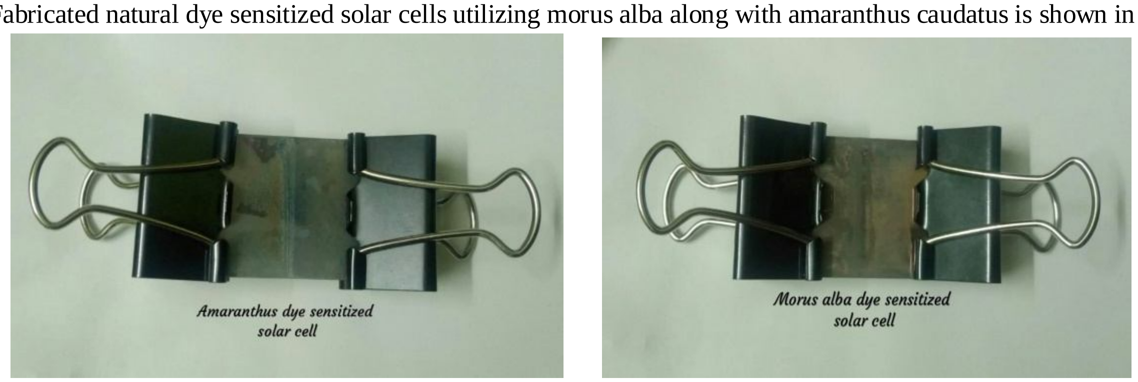


Fig -5: Fabricated natural DSSC using amaranthus caudatus and morus alba

Fig. 6 exhibits the current-voltage (I-V) qualities for DSSCs built utilizing morus alba as well as amaranthus caudatus and calculated under an activated lighting with a light intensity of 100mW / cm2. The fill factor (FF) of the organic DSSC was estimated making use of the below equation,

$$FF = I_{max} V_{max} / I_{sc} V_{sc} \quad (1)$$

and the incident photon to current (IPCE) efficiency (η) was calculated using the below equation

$$\eta(\%) = I_{max} V_{max} / P_{inc}.A \quad (2)$$

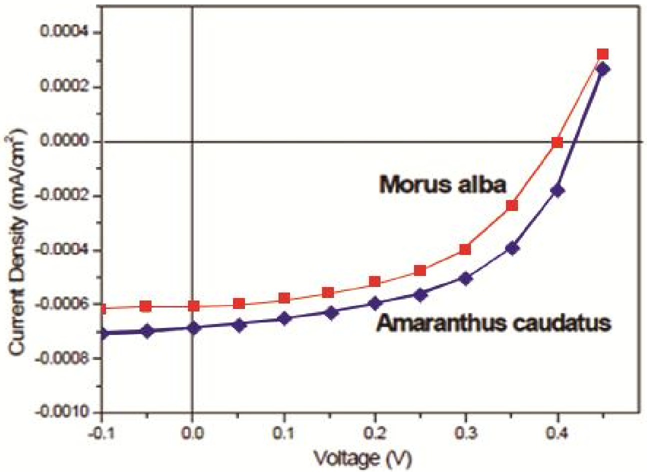


Fig -6: I-V characteristics for natural DSSC of amaranthus caudatus and morus alba

Where Vmax defined voltage, Imax shows current value and Pinc is the intensity of the incident radiation and a represent area. In the present work the incident illumination was 100 mW / cm2 and 0.5 cm x 0.5 cm is the illumination area. In principle, the maximum Isc of a dye-sensitized solar cell is determined by how well the absorption window of the dye overlaps with the solar spectrum.

V. CONCLUSION

One of the simplest sol-gel dip coating technique is used for synthesizing the ZnO nanorod seed layers. At 500°C annealing temperature, three distinct molar concentrations of 1:10, 2:10 and 3:10 were used to grow the ZnO nanorods through hydrothermal method. The ZnO nanorod structural studies, which we have developed thin films, showed that they are nano-crystalline in nature with a c-axis orientation and the grain size of about 1.17 nm to 2.90 nm. The X-ray diffraction method is used to determine the structural studies. In this research, four kinds of natural plants such as amaranthus caudatus leaves (Sengeerai), the mangustan mesocop fruit (mangosteen), delonix elata barks (Vathanarayan) and morus alba leaves (Mulbery), were chosen for fabrication of natural dyes. As the absorption intensity was higher for two dyes extracts of amaranthus caudatus and morus alba they were taken to prepare natural DSSC among four natural dyes. Results from the ZnO nanorods of high quality could be grown with ITO in 3:10 molar concentration at 500°C of annealing temperature. Such ZnO nanorods have been utilized to make DSSC with morus alba well as amaranthus caudatus natural plant extracts. Solar cells based on ZnO nanorod were fabricated with natural dyes and a liquid electrolyte. Due to an enhanced FF and Isc, the efficiency of amaranthus caudatus was 0.60% which was higher than the efficiency of morus alba at 0.48%.

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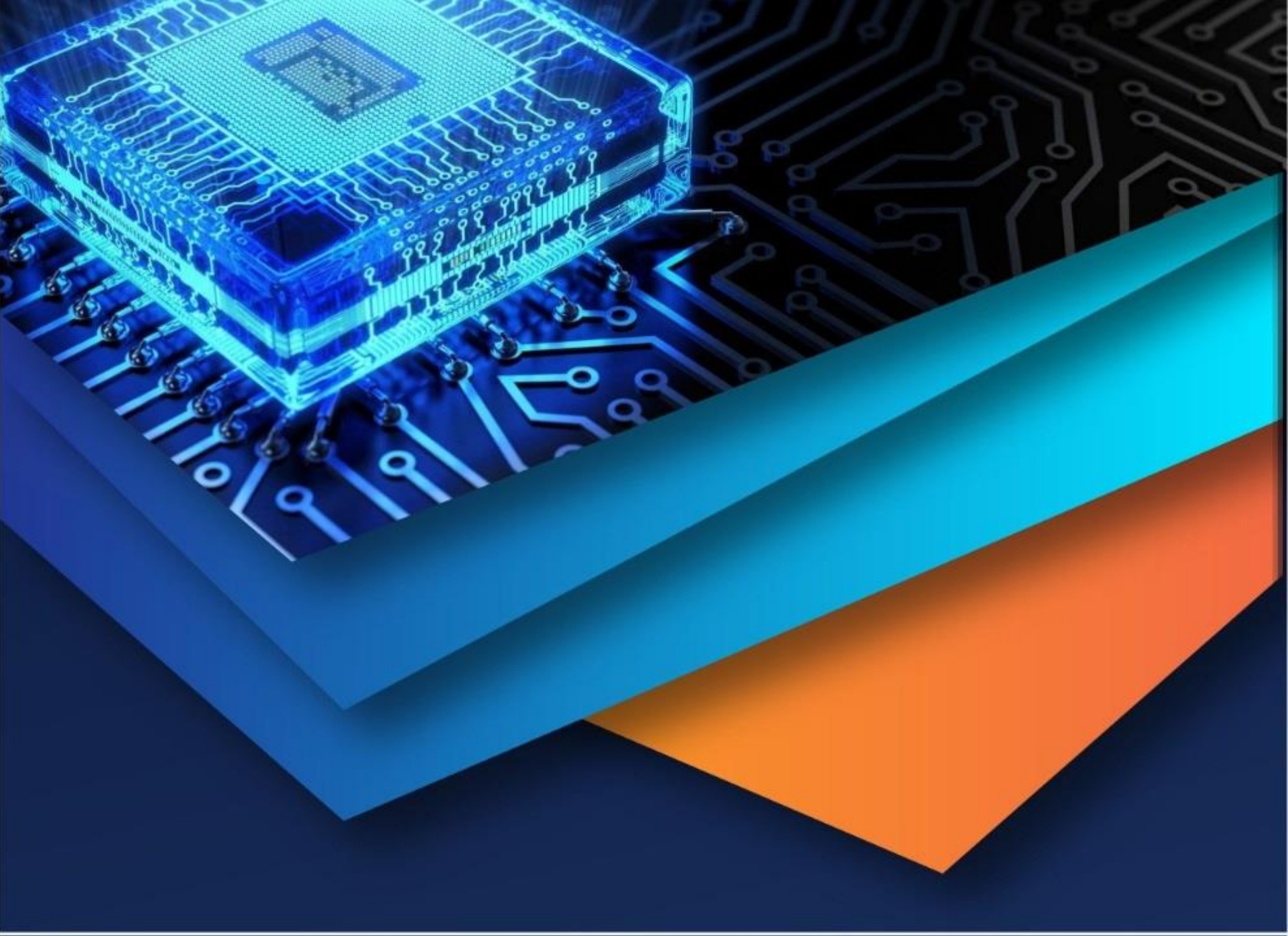

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