iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 Issue: VII Month of publication: July 2022

DOI: https://doi.org/10.22214/ijraset.2022.45385

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 VII July 2022- Available at www.ijraset.com

Nanorobotics in Medical Field

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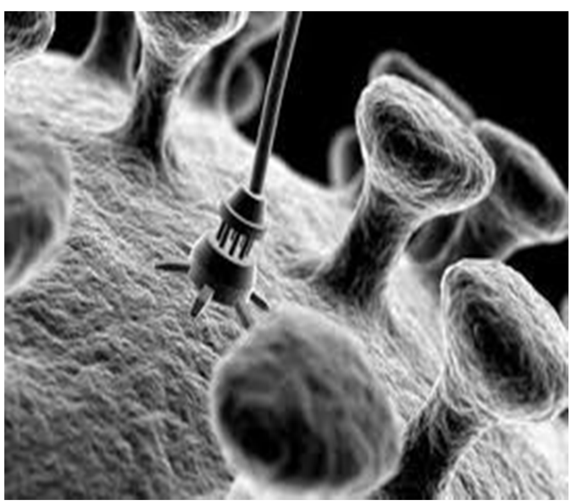
Abstract: Robotics is a rapidly growing field, and the innovative idea to scale down the size of robots to the nano meter level has paved a new way of treating human health. Nanorobots have become the focus of many researchers aiming to explore their many potential applications in medicine. This focuses on manufacturing techniques involved in the fabrication of nanorobots and their associated challenges in terms of design architecture, sensors, actuators, powering, navigation, data transmission, followed by challenges in applications. Nanorobots could carry and deliver drugs into defected cells. These nanorobots will be able to repair tissues, clean blood vessels and airways, transform our physiological capabilities, and even potentially counter act the aging process. In addition, an overview of various nanorobotic systems addresses different architectures of a nanorobot. Moreover, multiple medical applications, such as oncology, drug delivery, and surgery, are reviewed and summarized.

I. INTRODUCTION

Nanoid robotics, or for short, nanorobotics or nanobotics, is an emerging technology field creating machines or robots whose components are at or near the scale of a nanometer (10−9 meters). More specifically, nanorobotics (as opposed to micro robotics) refers to the nanotechnology engineering discipline of designing and building nanorobots with devices ranging in size from 0.1 to 10 micrometres and constructed of nanoscale or molecular components. The terms nanobot, nanoid, nanite, nanomachine and nanomite have also been used to describe such devices currently under research and development.

Nanomachines are largely in the research and development phase, but some primitive molecular machines and nanomotors have been tested. An example is a sensor having a switch approximately 1.5 nano meters across, able to count specific molecules in the chemical sample. The first useful applications of nanomachines may be in nanomedicine. For example, biological machines could be used to identify and destroy cancer cells. Another potential application is the detection of toxic chemicals, and the measurement of their concentrations, in the environment. Rice University has demonstrated a single-molecule car developed by a chemical process and including Buckminster fullerenes (buckyballs) for wheels. It is actuated by controlling the environmental temperature and by positioning a scanning tunnelling microscope tip. Nanorobots can offer a number of advantages such as:

1) Nanorobot in diagnosis and targeted drug delivery for cancer.
2) Nanorobot in Biomedical instrumentation.
3) Nanorobot in Surgery, Pharmacokinetics.
4) Monitoring of diabetes and health care.
5) More Accuracy.



Fig(1) Nanorobot

II. HISTORY

According to Richard Feynman, it was his former graduate student and collaborator Albert Hibbs who originally suggested to him (circa 1959) the idea of a medical use for Feynman's theoretical micro-machines. Hibbs suggested that certain repair machines might one day be reduced in size to the point that it would, in theory, be possible to (as Feynman put it) "swallow the surgeon". The idea was incorporated into Feynman's 1959 essay “There's Plenty of Room at the Bottom”. Since nano-robots would be microscopic in size, it would probably be necessary for very large numbers of them to work together to perform microscopic and macroscopic tasks.

These nano-robot swarms, both those unable to replicate and those able to replicate unconstrained in the natural environment (as in grey goo and synthetic biology), are found in many science fiction stories, such as the Borg nano-probes in Star Trek and The Outer Limits episode "The New Breed". Some proponents of nano-robotics, in reaction to the grey goo scenarios that they earlier helped to propagate, hold the view that nano-robots able to replicate outside of a restricted factory environment do not form a necessary part of a purported productive nanotechnology, and that the process of self-replication, were it ever to be developed, could be made inherently safe.

They further assert that their current plans for developing and using molecular manufacturing do not in fact include free-foraging replicators.

A detailed theoretical discussion of nanorobotics, including specific design issues such as sensing, power communication, navigation, manipulation, locomotion, and onboard computation, has been presented in the medical context of nanomedicine by Robert Freitas. Some of these discussions remain at the level of unbuildable generality and do not approach the level of detailed engineering.

III. ARCHITECTURE OF THE NANO ROBOT

The architecture is based on two criteria, which are means of nanorobot navigation and methods to attach to the cancerous cells. The way a nanorobot moves in a liquid environment is the main consideration during the design. It is important that the device is able to have a smooth trajectory path while navigating in the blood environment and at the same time does not cause any damage to other cells.

The tentacles need to have a very high responsive rate in order to move its tentacles forward just in time to capture the cancerous cell once it is detected. On the other hand, a microcomputer consisting of a miniature processor might be needed to provide a “brain” to the nanorobot.

The body of the nanorobot will be constructed from carbon nanotube due to its intrinsic property where they tend to absorb near infrared light waves, which pass harmlessly through human cells. Ultrasonic sensors are attached around the body of the nanorobot for collision avoidance purposes. This is to prevent nanorobot from knocking onto each other as well as other cells in the blood vessels. Folate materials on the body of the nanorobot act as an agent that will cause the attraction of the nanorobot to the cancerous cells, which is also known as the folate-receptor cells. For modelling purposes, the folate material is modeled as an object attached to the nanorobot, rather than a coating so that the viewer can have a better visualization of the treatment process. The flagella provide the movement the nanorobot in the blood environment. It is powered by flagella motors, which is a set of rotary motor that is able to generate an impressive torque, driving a long, thin, helical filament that extends several cell bodies into the external medium. These are necessary to help the cell decide which way to go, depending on the change of concentration of nutrients in the surroundings.

The rotary motion imparted to the flagella needs to be modulated to ensure the cell is moving in the proper direction as well as all flagella of the given nanorobot are providing a concerted effort toward it.

When the motors rotate the flagella in a counter clockwise direction as viewed along the flagella filament from outside, the helical flagella create a wave away from the cell body. Adjacent flagella subsequently intertwine in a propulsive corkscrew manner and propel the nanorobot. When the motor rotates clockwise, the flagella fly apart, causing the bacteria to tumble, or change its direction.

The flagella motors allow the nanorobot to move at speed as much as 25 μm/s with directional reversals occurring approximately 1/s. The assembled nanorobot is roughly approximate to be within the range of 0.5 microns to 0.8 microns, taking into consideration the size of the smallest blood vessels, which is the capillary.

The size of a capillary is found to be around 5-10 μm in diameter. Having to design a nanorobot within that range, the nanorobot can definitely navigates in the blood stream.

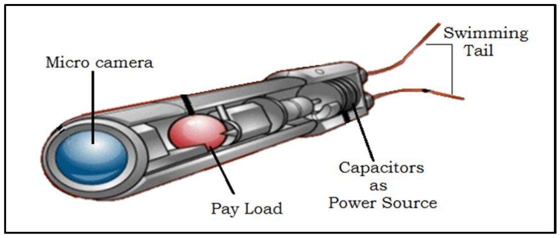
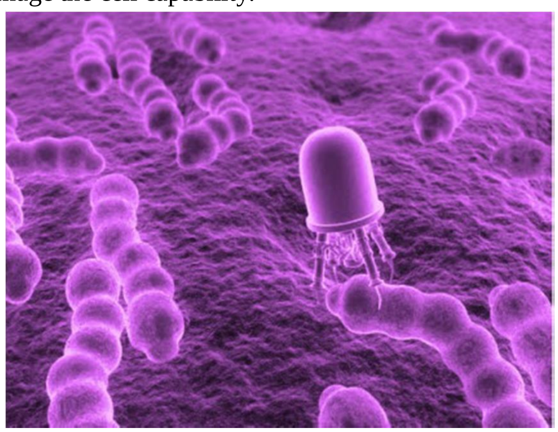


Fig (2) Architecture of Nanorobot

IV. APPLICATIONS

A. Nanorobotics in Surgery

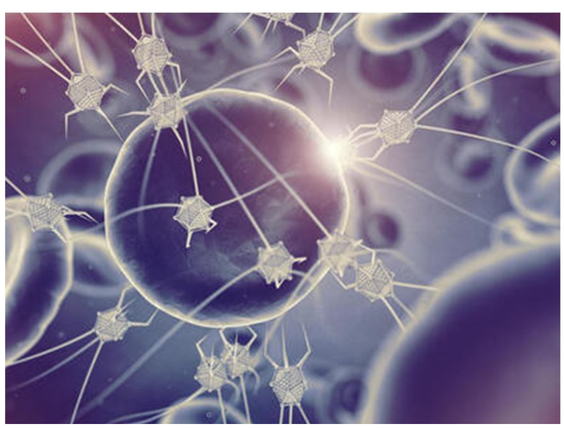
Surgical nanorobots are introduced into the human body through vascular systems and other cavities. Surgical nanorobots act as semi-autonomous on-site surgeon inside the human body and are programmed or directed by a human surgeon. This programmed surgical nanorobot performs various functions like searching for pathogens, and then diagnosis and correction of lesions by nano-manipulation synchronized by an on-board computer while conserving and contacting with the supervisory surgeon through coded ultrasound signals. Nowadays, the earlier forms of cellular nano-surgery are being explored. For example, a micropipette rapidly vibrating at a frequency of 100 Hz micropipette comparatively less than 1 micron tip diameter is used to cut dendrites from single neurons. This process is not ought to damage the cell capability.



Fig(3) Nanorobotics in Surgery

B. Diagnosis and Testing

Medical nanorobots are used for the purpose of diagnosis, testing and monitoring of microorganisms, tissues and cells in the blood stream. These nanorobots are capable of noting down the record, and report some vital signs such as temperature, pressure and immune system’s parameters of different parts of the human body continuously.



Fig(4) Detecting and Testing

C. Nanorobotics in GENE Therapy

Nanorobots are also applicable in treating genetic diseases, by relating the molecular structures of DNA and proteins in the cell. The modifications and irregularities in the DNA and protein sequences are then corrected (edited). The chromosomal replacement therapy is very efficient compared to the cell repair. An assembled repair vessel is inbuilt in the human body to perform the maintenance of genetics by floating inside the nucleus of a cell. Supercoil of DNA when enlarged within its lower pair of robotic arms, the nanomachine pulls the strand which is unwounded for analysis; meanwhile the upper arms detach the proteins from the chain. The information which is stored in the large nano computer’s database is placed outside the nucleus and compared with the molecular structures of both DNA and proteins that are connected through communication link to cell repair ship. Abnormalities found in the structures are corrected, and the proteins reattached to the Deoxy Nucleic Acid chain once again reforms into their original form.

Fig(5) Nanorobot in gene repairing

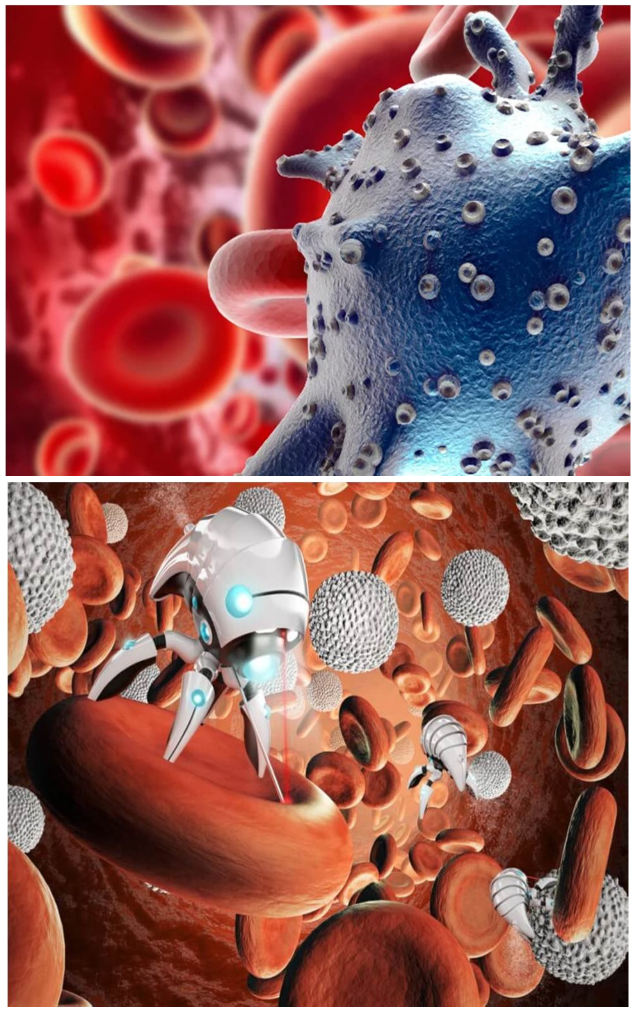
D. Nanorobotics in Cancer Detection and Treatment

The current stages of medical technologies and therapy tools are used for the successful treatment of cancer. The important aspect to achieve a successful treatment is based on the improvement of efficient drug delivery to decrease the side-effects from the chemotherapy. Nanorobots with embedded chemical biosensors are used for detecting the tumor cells in early stages of cancer development inside a patient’s body. Nanosensors are also utilized to find the intensity of E-cadherin signals.

Nanotechnology uses therapeutic agents that target specific cells and deliver their toxin in a controlled, time-released manner. As a syringe is today used to inject medication into the patient’s bloodstream, tomorrow, nanorobots could transport and deliver chemical agents directly to a target cell. Nanokiller (i.e., nanorobot) could find and repair damaged organs, detect and destroy a tumor mass. They would be able to communicate their positions, operational statuses, and the success or failure of the treatment as it progresses. They would tell you how many cancer cells they have encountered and inactivated. Respirocytes identify tumors and then allow the nanokiller to kill cancerous cells with a tiny but precise amount of a chemotherapy drug. It would not only find cancers in their earliest stages before they can do damage or spread, but also deliver a small amount of a drug targeted directly at tumors, which would cause little or no side effects. Nanomedicine could result in non-invasive devices that can enter the body to determine glucose levels, distinguish between normal and cancerous tissue, and destroy the tumor in the initial stage itself. This nanorobot has vibrating cilia like structures with inbuilt nanosensors to [9:40 am, 09/06/2022] Sudhakar: detect the cancerous tissue. This nanorobot shells are specially coated with gold that allow them to attach to malignant cells and they can deliver the drug internally.There are three main considerations need to focused on designing a nanorobot to move through the body --navigation, power and how the nanorobot will move through blood vessels. For directing the nanorobots to the cancerous cells we can make use of ultrasonic signals which are emitted by the nanorobot. These ultrasonic waves are detected by ultrasonic sensors. Nanorobots can also be fitted wit a small miniature camera assuming the nanorobot isn't tethered or designed to float passively through the bloodstream, it will need a means of propulsion to get around the body. Because it may have to travel against the flow of blood, the propulsion system has to be relatively strong for its size. Another important consideration is the safety of the patient, the system must be able to move the nanorobot around without causing damage to the host.

For locomotion we can mimic Paramecium, It moves through their environment using tiny tail-like limbs called cilia. By vibrating the cilia, the paramecium can swim in any direction.

Similar to cilia are flagella, which are longer tail structures. Organisms whip flagella around in different ways to move around. The nanorobot would move around like a jet airplane. Miniaturized jet pumps could even use blood plasma to push the nano robot forward, though, unlike the electromagnetic pump, there would need to be moving parts. For powering a nanorobot we could use the patient's body heat to create power, but there would need to be a gradient of temperatures to manage it. Power generation would be a result of the Seebeck effect.



Fig(6) Detecting Cancer and Treatment

E. Nano Dentistry

Nanodentistry is one of the topmost applications as nanorobots help in different processes involved in dentistry. These nanorobots are helpful in desensitizing tooth, oral anesthesia, straightening of irregular set of teeth and improvement of the teeth durability, major tooth repairs and improvement of the appearance of teeth, etc.

Many clinical dentistry applications exist in the nanomaterials domain. Possibilities include nano-impressions, nanoceramics, and nanocomposites. Nanotechnology is now being used with nanofillers to create impressions that more precisely reflect patients' dental details. These nanofillers have superior hydrophilic characteristics, better flow, and less spacing at the dental margins compared to traditional fillers. Ceramics are widely used in prosthodontics, where they are used to manufacture dentures and dental crowns. Although they provide a high level of strength and low electrical and thermal conductivity, they are quite brittle. Here is where nanotechnology can play a role. Nano-zirconia ceramic can be used to improve toughness and hardness, as well as confers better translucency and resistance to corrosion.

The esthetics and strength of composite materials are important considerations. Both are largely dependent on the size of filler particles. Traditionally improvement in one feature has come at the expense of the other. More often, esthetic properties are improved at the expense of strength.

However, nanocomposites are flexible materials in that they can be used to improve strength and esthetics using a variety of filler components: barium glass, discrete silica non-agglomerate nanoparticles, and pre-polymerized fillers. These materials all have superior characteristics compared to their traditional counterparts. Similarly, novel developments in this area include nanocomposite artificial teeth and the use of nanotechnology to create materials for nano-bone grafts.

Fig(7) Repairing teeth by Nanorobotics

V. MODELLING AND SIMULATION

Uncertainty plays a crucial role in nanorobotic systems. The design of nanorobotic systems requires the use of information from a vast variety of sciences ranging from quantum molecular dynamics to kinematics analysis. As the field of nanotechnology is still considered rather new, there is a lot of on going experiments and research done on the issues regarding the implementation of the nanorobot in medicine. Since nanoscale devices have not yet been fabricated, evaluating possible designs and control algorithms is required, using theoretical estimates and virtual interfaces or environments. Due to the lack of expertise and experience in this field, the development of nanorobot can only be made possible taking into account several assumptions made during the design as listed below.

A. The patient had already been diagnosed with Leukemia

As discussed, leukemia itself can be subdivided into various subtypes. Also, there is no standard treatment for all patients. Thus it is rather difficult to implement a nanorobot that is able to differentiate the type of leukemia that the patient is suffering from and the severity of the disease in the given time period. More biological knowledge and support is needed in order to make this criterion possible.

B. The nanomaterials needed in the design are available

On going research is still being carried out in search for nanomaterials that can be used in human bodies. It is also assumed that the components of a nanorobot are made of biological components.

C. The Nanorobot will not Replicate.

This is to prevent the replication of nanorobots to be out of control. This may cause more harm to the patients rather than providing them with a more effective treatment. As the saying goes, too much of a good thing might not do you good.

D. The nanorobot will not react with the Human body Immune System.

In most cases, the body's immune system will react to any foreign matters that are introduced into the body, as its main function is to act as a protection mechanism to the body. It is specifically designed to defend the body against millions of bacteria, microbes, viruses, toxins and parasites that invades into the body. More research is needed to actually understand to what extent our body will react with the nanorobot, which is considered as a stranger to the body.

E. Primarily focusing on Cancerous Cells

The main focus of this thesis is to focus on designing a nanorobot model that is able to kill cancerous cells, living the normal cells unharmed, as an alternative to chemotherapy.

VI. LIMITATIONS

A. The High cost of Development

The high research and development cost of nanotechnology applications is a significant point of concern. These new technologies thriving in the medical field are not feasible financially for the poor section of the society. In most cases, they are inaccessible and unaffordable. In fact, nanotechnology in medicine and its applications is also beyond the reach of the middle-class people. Unless you have the resources to meet the huge expenses or have a good sponsorship, nanomedicine is undoubtedly not for you.

B. Misuse

Indeed, nanomedicine can also be used negatively; thus, there remains the need to be extra cautious regarding its use. As these medicines are micro-sized, they can be embedded inside anyone's body leading to misuse of the original purpose of these medicines.

C. Neurodegenerative Diseases and other Diseases

It is found that nanoparticles generate oxidative stress and ROS, leading to degenerative diseases like Parkinson's and Alzheimer's. Though nanomedicine has shown immense potential for improving the efficiency of drug delivery, one major drawback here is that nanoparticles possess the power to cause damage to the human lungs. They can also cause immune effects, systemic effects, and pulmonary inflammation.

Uptake of nanoparticles via the olfactory epithelium can again happen, and this may result in epithelial cell injury, which can disrupt the proper functioning of the nose.

D. Detrimental Effects on the Environment

Nanomedicine and nanoparticles are known to cause harmful effects not only to patients but also to the environment. Therefore, it needs proper processing before its disposal.

Non-biodegradable nanoparticles are known to cause air, water, and land pollution. Also, it is difficult to forecast their ill effects on the environment, and it has not been ascertained whether it has a detrimental impact on the biome. It is seen that if they enter the bio network through plants, it would be highly challenging to eliminate them.

VII. CONCLUTION

Nanorobots holds such a vast scope that, the above mentioned ideas do become reality any time sooner or later, such that every branch of medicine ought to benefit.

Nanorobot hold both advantages and disadvantages characteristics, but it depends upon the field that it is being used. Nanorobots applied to medication hold an abundance of guarantee from annihilating infection to turning around the maturing procedure (wrinkles, age-related conditions are altogether treatable at the molecular level). This incorporate greater bioavailability, directed treatment, less human interface, arrive at remote regions in human life systems, enormous interfacial region for mass exchange, unmistakable method, less side effects and greater speed of drug action with better precision. Nanorobots are also candidates for industrial applications.

They will furnish joined activity – drugs marketed with diagnostics, imaging agents acting as drugs, surgery with instant diagnostic feedback. Therefore Nanorobot becomes a major element in future medical field to ease the human interaction in molecular level surgeries.

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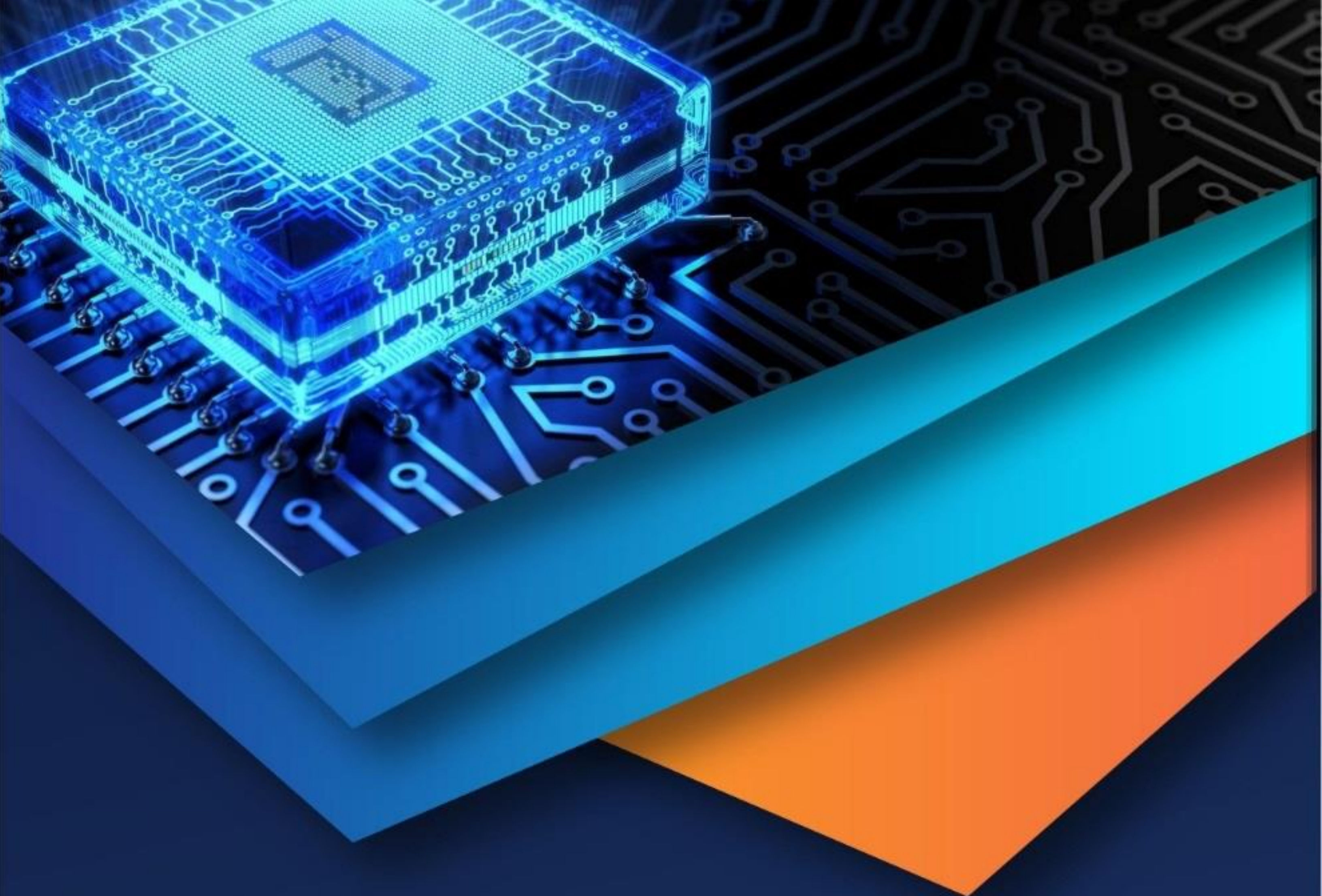

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