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A survey on Nanotechnology and Its Medical Applications

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Abstract*— Nanotechnology is an advanced scientific technique that provides more accurate and timely medical information for diagnosing disease. Nanotechnology is a focal point in diabetes research, where nanoparticles in particular are showing great promise in improving the treatment and management of the disease. Nanotechnology offers some new solutions in treating diabetes mellitus. One of the developing usage fields of nanotechnology is cancer treatment. Nanotechnology can be also used in molecular imaging with tomography and photo acoustic imaging of tumors and therapy of cancer as photo thermal and radiotherapy. Finally, nanotechnology is still developing science can be defined as next generation techniques for cancer disease; at the same time it comes with many advantages to treat cancer patients.

***Keywords*— DNA**

I. Introduction

Nanotechnology (sometimes shortened to "nanotech") is the manipulation of matter on an atomic, molecular, and supramolecular scale. The earliest, widespread description of nanotechnology referred to the particular technological goal of precisely manipulating atoms and molecules for fabrication of macroscale products, also now referred to as molecular nanotechnology. A more generalized description of nanotechnology was subsequently established by the National Nanotechnology Initiative, which defines nanotechnology as the manipulation of matter with at least one dimension sized from 1 to 100 nanometers.

Nanotechnology as defined by size is naturally very broad, including fields of science as diverse as surface science, organic chemistry, molecular biology, semiconductor physics, micro fabrication, etc

II. History of Nanotechnology

The concepts that seeded nanotechnology were first discussed in 1959 by renowned physicist Richard Feynman in his talk *There's Plenty of Room at the Bottom*, in which he described the possibility of synthesis via direct manipulation of atoms. The term "nano-technology" was first used by Norio Taniguchi in 1974, though it was not widely known.

Inspired by Feynman's concepts, K. Eric Drexler independently used the term "nanotechnology" in his 1986 book *Engines of Creation: The Coming Era of Nanotechnology*, which proposed the idea of a nanoscale "assembler" which would be able to build a copy of itself and of other items of arbitrary complexity with atomic control. Also in 1986, Drexler co-founded The Foresight Institute (with which he is no longer affiliated) to help increase public awareness and understanding of nanotechnology concepts and implications.

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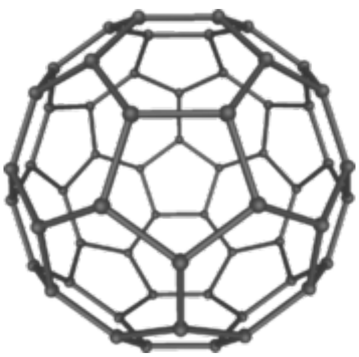
Thus, emergence of nanotechnology as a field in the 1980s occurred through convergence of Drexler's theoretical and public work, which developed and popularized a conceptual framework for nanotechnology, and high-visibility experimental advances that drew additional wide-scale attention to the prospects of atomic control of matter.

For example, the invention of the scanning tunneling microscope in 1981 provided unprecedented visualization of individual atoms and bonds, and was successfully used to manipulate individual atoms in 1989. The microscope's developers Gerd Binnig and Heinrich Rohrer at IBM Zurich Research Laboratory received a Nobel Prize in Physics in 1986. Binnig, Quate and Gerber also invented the analogous atomic force microscope that year.



Fullerenes were discovered in 1985 by Harry Kroto, Richard Smalley, and Robert Curl, who together won the 1996 Nobel Prize in Chemistry. C_{60} was not initially described as nanotechnology; the term was used regarding subsequent work with related graphene tubes (called carbon nanotubes and sometimes called Bucky tubes) which suggested potential applications for nanoscale electronics and devices.

In the early 2000s, the field garnered increased scientific, political, and commercial attention that led to both controversy and progress. Controversies emerged regarding the definitions and potential implications of nanotechnologies, exemplified by the Royal Society's report on nanotechnology. Challenges were raised regarding the feasibility of applications envisioned by advocates of molecular nanotechnology, which culminated in a public debate between Drexler and Smalley in 2001 and 2003.

Meanwhile, commercialization of products based on advancements in nanoscale technologies began emerging. These products are limited to bulk applications of nanomaterials and do not involve atomic control of matter. Some examples include the Silver Nano platform for using silver nanoparticles as an antibacterial agent, nanoparticle-based transparent sunscreens, and carbon nanotubes for stain-resistant textiles.

Governments moved to promote and fund research into nanotechnology, beginning in the U.S. with the National Nanotechnology Initiative, which formalized a size-based definition of nanotechnology and established funding for research on the nanoscale.

By the mid-2000s new and serious scientific attention began to flourish. Projects emerged to produce nanotechnology roadmaps which center on atomically precise manipulation of matter and discuss existing and projected capabilities, goals, and applications.

III.BASICS OF NANOTECHNOLOGY

Nanotechnology is the engineering of functional systems at the molecular scale. This covers both current work and concepts that are more advanced. In its original sense, nanotechnology refers to the projected ability to construct items from the bottom up, using techniques and tools being developed today to make complete, high performance products.

One nanometer (nm) is one billionth, or 10^{-9}, of a meter. By comparison, typical carbon-carbon bond lengths, or the spacing between these atoms in a molecule, are in the range 0.12–0.15 nm, and a DNA double-helix has a diameter around 2 nm. On the other hand, the smallest cellular life-forms, the bacteria of the genus Mycoplasma, are around 200 nm in length. By convention, nanotechnology is taken as the scale range 1 to 100 nm following the definition used by the National Nanotechnology Initiative in the US. The lower limit is set by the size of atoms (hydrogen has the smallest atoms, which are approximately a quarter of a nm diameter) since nanotechnology must build its devices from atoms and molecules. The upper limit is more or less arbitrary but is around the size that phenomena not observed in larger structures start to become apparent and can be made use of in the nano device.These new phenomena make nanotechnology

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distinct from devices which are merely miniaturised versions of an equivalent macroscopic device; such devices are on a larger scale and come under the description of microtechnology

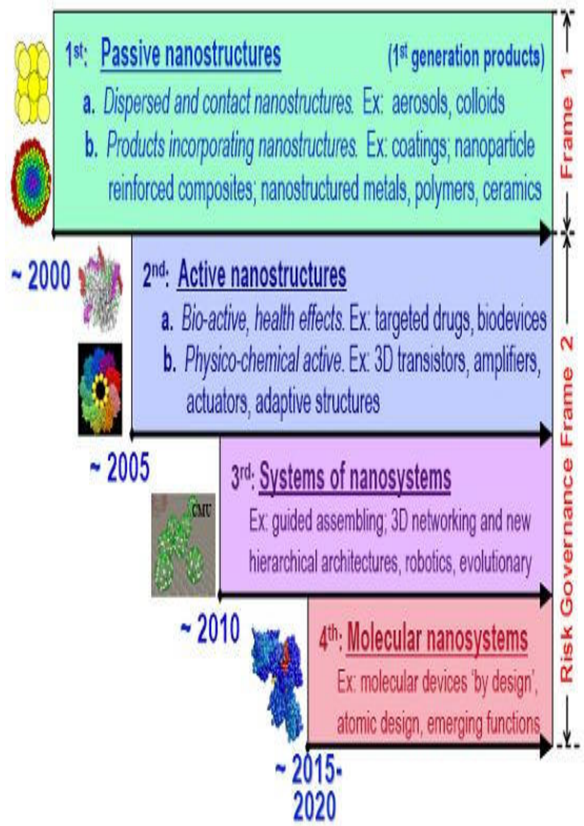
To put that scale in another context, the comparative size of a nanometer to a meter is the same as that of a marble to the size of the earth. Or another way of putting it: a nanometer is the amount an average man's beard grows in the time it takes him to raise the razor to his face.

Two main approaches are used in nanotechnology. In the "bottom-up" approach, materials and devices are built from molecular components which assemble themselves chemically by principles of molecular recognition. In the "top-down" approach, nano-objects are constructed from larger entities without atomic-level control.

Areas of physics such as nanoelectronics, nanomechanics, nanophotonics and nanoionics have evolved during the last few decades to provide a basic scientific foundation of nanotechnology.

IV GENERATIONS OF NANOTECHNOLOGY

Mihail (Mike) Roco of the U.S. National Nanotechnology Initiative has described four generations of nanotechnology development . The current era, as Roco depicts it, is that of passive nanostructures, materials designed to perform one task. The second phase, which we are just entering, introduces active nanostructures for multitasking; for example, actuators, drug delivery devices, and sensors. The third generation is expected to begin emerging around 2010 and will feature nanosystems with thousands of interacting components. A few years after that, the first integrated nanosystems, functioning (according to Roco) much like a mammalian cell with hierarchical systems within systems, are expected to be developed.



V. APPLICATION IN MEDICAL SCIENCE

I. Drug Delivery System

1. What are nanobots and why use them?

Nanobots are robots that carry out a very specific function and are just several nanometers wide. They can be used very effectively for drug delivery. Normally, drugs work through the entire body before they reach the disease-affected area. Using nanotechnology, the drug can be targeted to a precise location which would make the drug much more effective and reduce the chances of possible side-effects.

2. Drug delivery procedure

The drug carriers have walls that are just 5-10 atoms thick and the inner drug-filled cell is usually 50-100 nanometers wide. When they detect signs of the disease, thin wires in their walls emit an electrical pulse which causes the walls to dissolve and the drug to be released. Aston Vicki, manager of BioSante Pharmaceuticals, says “Putting drugs into nanostructures increases the solubility quite substantially”. (Harry, 2005)

3. Advantages of using nanobots for drug delivery

A great advantage of using nanobots for drug delivery is that the amount and time of drug release can be easily controlled by controlling the electrical pulse (Harry, 2005). Furthermore, the walls dissolve easily and are therefore harmless to the body. Elan Pharmaceuticals, a large drug company, has already started using this technology in their drugs Merck’s Emend and Wyeth’s Rapamune (Adhikari, 2005).

II. Disease Diagnosis and Prevention

1. Diagnosis and Imaging

Nanobiotech scientists have successfully produced microchips that are coated with human molecules. The chip is designed to emit an electrical impulse signal when the molecules detect signs of a disease. Special sensor nanobots can be inserted into the blood under the skin where they check blood contents and warn of any possible diseases. They can also be used to monitor the sugar level in the blood. Advantages of using such nanobots are that they are very cheap to produce and easily portable. (Harry, 2005)

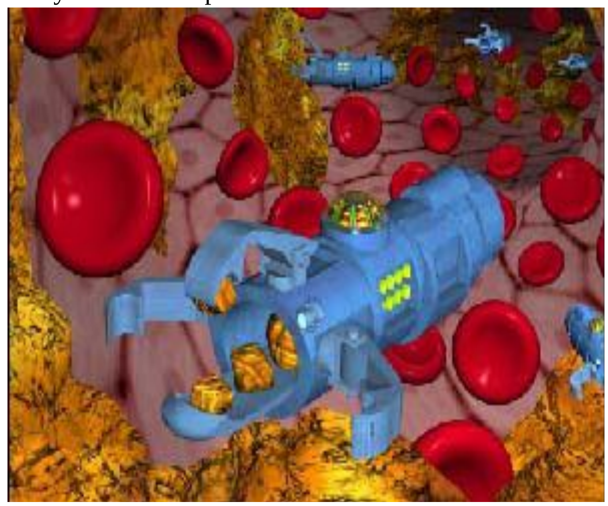
2. Quantum dots

Quantum dots are nanomaterials that glow very brightly when illuminated by ultraviolet light. They can be coated with a material that makes the dots attach specifically to the molecule they want to track. Quantum dots bind themselves to proteins unique to cancer cells, literally bringing tumors to light. (Weiss, 2005)

3. Preventing diseases

a. *heart-attack prevention*

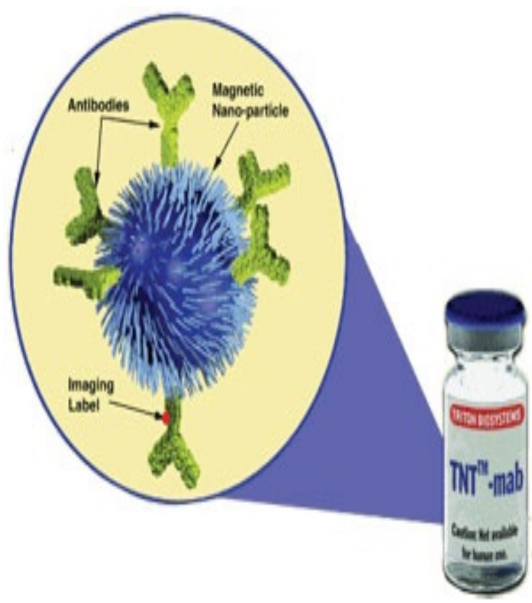
Nanobots can also be used to prevent heart-attacks. Heart-attacks are caused by fat deposits blocking the blood vessels. Nanobots can be made for removing these fat deposits (Harry, 2005). The following figure shows nanobots removing the yellow fat deposits on the inner side of blood vessels.



Nanobots Preventing Heart-attacks (Heart View)

b. *frying tumors*

Nanomaterials have also been investigated into treating cancer. The therapy is based on “cooking tumors” principle. Iron nanoparticles are taken as oral pills and they attach to the tumor. Then a magnetic field is applied and this causes the nanoparticles to heat up and literally cook the tumors from inside out.



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Cancer Cooker- Triton BioSystems is developing an anticancer therapy using antibody-coated iron nanoparticles. (Perkel, 2004)

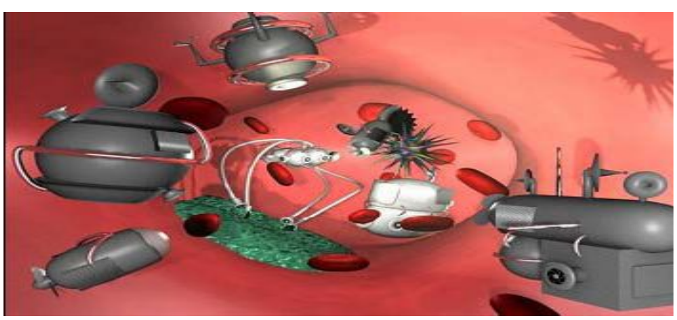
III.TISSUE RECONSTRUCTION

Nanoparticles can be designed with a structure very similar to the bone structure. An ultrasound is performed on existing bone structures and then bone-like nanoparticles are created using the results of the ultrasound (Silva, 2004). The bone-like nanoparticles are inserted into the body in a paste form (Adhikari, 2005). When they arrive at the fractured bone, they assemble themselves to form an ordered structure which later becomes part of the bone (Adhikari, 2005).

Another key application for nanoparticles is the treatment of injured nerves. Samuel Stupp and John Kessler at Northwestern University in Chicago have made tiny rod like nano-fibers called *amphiphiles*. They are capped with amino acids and are known to spur the growth of neurons and prevent scar tissue formation. Experiments have shown that rat and mice with spinal injuries recovered when treated with these nano-fibers. (Weiss, 2005)

IV. MEDICAL TOOLS

Nano-devices are nanoparticles that are created for the purpose of interacting with cells and tissues and carrying out very specific tasks (Silva, 2004). The most famous nano-devices are the imaging tools. Oral pills can be taken that contain miniature cameras. These cameras can reach deep parts of the body and provide high resolution pictures of cells as small as 1 micron in width (A red blood cell is 7 microns wide) (Perkel, 2004). This makes them very useful for diagnosis and also during operations.



. Miniature Cameras Inside Blood Vessels(Blender Battles)

An accelerometer is a very useful nano-device that can be attached to the hip, knee or other joint bones to monitor movements and strain levels. Dressings can be coated with silver nanoparticles to make them infection-resistant. The nanoparticles kill bacteria and therefore reduce chances of infection. (Adhikari, 2005)

VI. PROBLEMS WITH USING

NANOTECHNOLOGY

Nanotechnology is a potentially limitless collection of technologies and associated materials. "[But] the very properties that make nanoparticles useful for new applications are also the very properties that can increase their harmfulness "(Donaldson, Stone, 2004). Furthermore, in developing this technology, little attention is being focused on its environmental and health implications. For example in the year 2004, the US government spent roughly \$1 billion on nanotechnology, less that \$8.5 million (less than 1%) was spent on the environmental and health implications (Balbus et al-2005).

A. Environmental Problems

The greatest risk to the environment lies in the rapid expansion and development of nanoparticles using large scale production (Donaldson, Stone, 2004). A recent Rice University study showed that certain nanoparticles have a tendency to form aggregates that are very water soluble and bacteriocidal(capable of killing bacteria) and that can be catastrophic as bacteria are the foundation of the ecosystem (Balbus et al-2005). Scientists also fear that nanoparticles may damage the ozone layer (Perkel, 2004). Many people fear that nanoparticles may self-replicate and cover the earth's landscape with 'grey goo'. However scientists assure that this cannot happen and is a scientific fantasy (Donaldson, Stone, 2004).

B. Health Problems

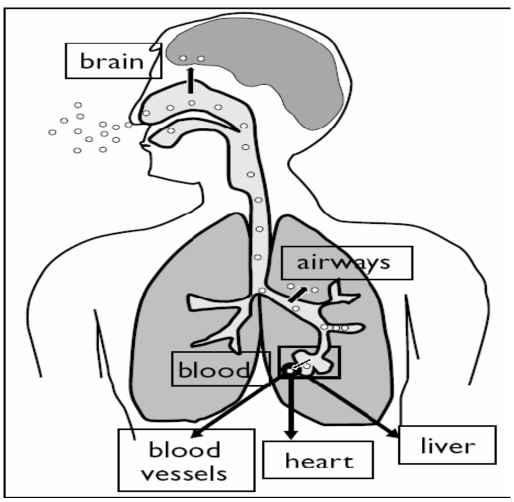
The risk of nanoparticles to the health of human beings is of far greater concern. James Baker, director of the Center for Biologic Nanotechnology at the University of

Michigan, says " Any time you put a material into something as complex as a human being, it has multiple effects " (Perkel, 2004). Nanoparticles are likely to make contact with the body via the lungs, intestines and skin.

1. Risk to Lungs

Nanoparticles are very light and can easily become airborne. They can easily be inhaled during the manufacturing process where dust clouds are a common occurrence. Particles passing into the walls of air passage can worsen existing air disease such as asthma and bronchitis and can be fatal. (Donaldson, Stone, 2004)

The following illustration shows how nanoparticles can be inhaled and travel throughout the body.



Tracing how nanoparticles can be inhaled and travel to the brain, lungs and the bloodstream (Donaldson, Stone, 2004)

2. Effects on Brain

Some nanoparticles that are inhaled through the nose can move upward into the base of the brain. This may damage the brain and the nervous system and could be fatal. (Donaldson, Stone, 2004)

3. Problems in Blood

Nanoparticles flowing thorough the bloodstream may affect the clotting system which may result in a heart-attack. If these nanoparticles travel to organs like the heart or the liver, they may affect the functionality of these organs. (Donaldson, Stone, 2004)

C. Feasibility Problems

1. Expense

Conducting research on nanotechnology is very expensive. An article in the Nanotech Report 2004 claimed that global investment on nanotechnology has reached:

- $8.6 billion: Total investment
- $4.6 billion from government
- $3.8 billion form corporate research and development
- $200 million from venture capitalists (Perkel, 2004).

At present the tools for developing nanotechnology are very basic and we still need more investment to reap the benefits of this great technology.

2. Lack of knowledge and research

Money is not the only problem. There is a lack of qualified individuals who can research and develop the technology. Many of the methods and tools needed to characterize nanomaterials are still in a very early stage of development (Balbus et al-2005). A nationwide survey from North Caroline University in Raleigh found that around 80% of Americans knew nothing about nanotechnology (Perkel, 2004). For there to be further development in this field, more professionals are needed along with large sums of money.

D. Ethical Dilemma

The most important feature of nanotechnology is that it gives us control over individual molecules. " Every patho-physiological process has a molecular origin, and it

is from this basic fact that the [tremendous potential of nanotechnology to medicine arises]" (Silva, 2004). Scientists believe that nanotechnlogy could give man a better quality of life, power to prevent diseases, speed up tissue reconstruction and alter his genetic sequence (Silva, 2004). Unfortunately these promises are coupled with ethical implications which must be considered, if not resolved before the field of nanotechnology reaches its fullest potential.

The question arises, *Who is in control*? Nanotechnology introduces things that are not natural or foreseen, such as genetically modified organisms. At this point there is no established system to regulate nanotechnology and there is no specific entity to control it. With the ability to identify and manipulate specific genetic sequences, people will seek the effects of good genes. People are already using this technology to modify their unborn children to have the right hair or eye color. *In doing this people risk losing their individuality.*

No doubt the benefits of this technology are innumerable but before taking any step we should think about the implications and the focus should be on developing a safe nanotechnology industry.

VII.CONCLUSION

Nanotechnology's greatest promise in medicine is its potential to destroy cancers that until now have been resistant to conventional treatments, one day it replaces radiation and chemotherapy. In future nanorobots could repair specific diseased cells, functioning in a similar wave to antibodies in our natural healing processes. No doubt the next era of the drug development will be greatly influenced by Nanotechnology and the newer aspect of drug delivery will be reliable, effective and safe. Nanotechnology is still in its early stages. Many diseases that do not have cures today may be cured by nanotechnology in the future. If everything runs smoothly, nanotechnology will one day become part of our everyday life and will help save many lives.

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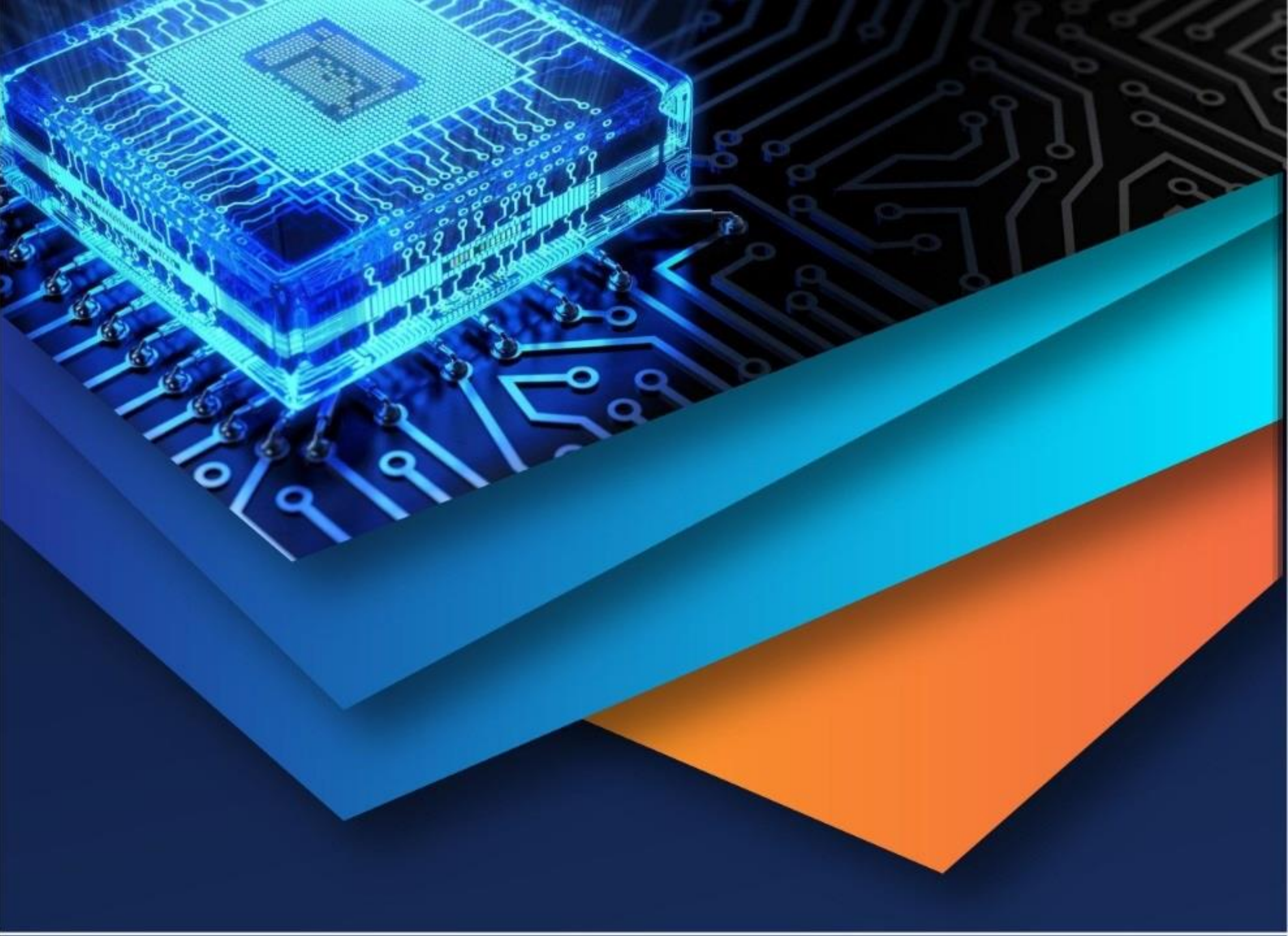

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