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Review on Nanomaterials

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***Abstract:** Nanomaterials are rapidly gaining the importance as the most powerful material of this century. The chemical, physical, and the mechanical properties of these materials have enhanced their performances and emerging as the versatile platform that could provide efficient, cost effective and environment-friendly solutions to the global challenges such as water purification, greenhouse gases management and many more. This paper stretches a view about history, applications, benefits, and limitations of nanomaterials.*
***Keywords:** Nanomaterials, Applications, Benefits, Limitations*

I. INTRODUCTION

Over the last century nanotechnology branch is flourishing to a great extent. And today many types of research are directly or indirectly related to the nanotechnology.[1]. The emerging field of nanoscience and nanotechnology is leading to a technological revolution in the new millennium.[2].

Nanotechnology isn't a totally new field; however, it's only recently that discoveries during this field have advanced thus far on warrant examination of their impact upon the world around us. Nanoparticles fall under three major groups: natural, incidental, and engineered, noted Vicki Colvin, Rice University. Naturally occurring nanomaterials like volcanic ash, ocean spray, magneto tactic bacteria, mineral composites. exist in our surroundings. Incidental nanoparticles, also referred to as waste particles, are produced as a result of some industrial processes [3].

Nanomaterials are cornerstones of nanoscience and nanotechnology. Nanostructure science and technology is a broad and interdisciplinary area of research and development activity that has been growing explosively worldwide in the past few years [4]. R&D of nanotechnology has been accelerated worldwide since the U.S. announced its National Nanotechnology Initiative strategic plan in 2000.

In Europe, the EU increased its budget for nanotechnology in the 6th R&D Program Framework, while in Asia, South Korea set up a 10-year master plan for nanotechnology in 2001 [14].

This led to the development of Kelvin-probe, electrostatic, and magnetic-force microscopy../../../../../../SANIKA/Desktop/R/12.htm - cit12 Currently, nanotechnology is rapidly evolving and becoming part of almost every field related to materials chemistry. The field of nanotechnology is evolving every day, and now powerful characterization and synthesis tools are available for producing nanomaterials with better-controlled dimensions [9].

Most compounds have atoms with radii smaller than one nano-meter. Approximately 25 atoms make up a cluster with a 1 nm radius.

Unbelievable facts include the following:

1) A human hair has a diameter of 75000 nm.
2) Hydrogen atoms have a diameter of 0.1 nm and a [1] of 1. Its nucleus is just 0.00001 nm in size [10].

A structure made up of connected building blocks at the nanoscale. Nanostructured materials are defined as having either an interior or external nanostructure [11].

Nanotechnology, being an enabling technology of emerging techno-economic paradigm, is still in the nascent phase of its research, development and innovation [12]. Nanotechnology is the process of manipulating the shape and size of structures, electronics, and systems at the nano-meter scale, i.e., 1 nm to 100 nm (10-9m). The unit of nano-meter takes its prefix nano from the Greek word "nano" which means "very little" [13].

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II. HISTORY OF NANOMATERIALS

Fig. 1: Nanomaterial in the Environment [2]

The history of nanomaterials began immediately after the big bang when Nanostructures were formed in the early meteorites. Nature later evolved many other Nanostructures like seashells, skeletons etc. Nano scaled smoke particles were formed during the use of fire by early humans. The scientific story of nanomaterials however began much later. One of the first scientific report is the colloidal gold particles synthesized by Michael Faraday as early as 1857. Nanostructured catalysts have also been investigated for over 70 years. By the early 1940's, precipitated and fumed silica nano particles were being manufactured and sold in USA and Germany as substitutes for ultrafine carbon black for rubber reinforcements [4].

As determined in his quote (above), he chose to end with a "final question" that wasn't fully realized until the ‟80s and ‟90s. Finally, then, it was during these two decades, when the term "nanotechnology" was coined and researchers, starting with Eric Drexler, built up this field from the bedrock that Feynman made in 1959. But, some researchers such as Chris Toumey neglect the gravity of Feynman in the formation of the intellectual breakthrough for nanotechnology [5].

Nanotechnology and Nanoscience got a boost in the early 1980‗s with two major developments: the birth of cluster science and the invention of the Scanning Tunnel Microscope. These developments led to the discovery of Fullerene in 1985 and Carbon Nanotubes after some few years [2].

III. NANOMATERIALS

Nanoscale materials are defined as a set of substances where at least one dimension is less than approximately 100 nano-meters. A nano-meter is one millionth of approximately 100,000 times smaller than the diameter of a human hair. Nanomaterials are of interest because at this scale unique optical, magnetic, electrical, and other properties emerge. These emergent properties have the potential for great impacts in electronic medicine, and other fields [4]. The International Organization for Standardization defines nanoscale materials as having "approximately" between 1 nm and 100 nm in size. This includes materials with nanoscale exterior dimensions as well as those with nanoscale interior structures. A particle-containing substance meets European Commission standards if at least 50% of its particles have one or more external diameters between 1 and 100 nm. A lower barrier (between 1% and 50%) for the distribution of feasible number sizes may be created in circumstances when worries about the environment, human health, safety, or competitiveness are needed [10].

IV. CLASSIFICATION OF NANOMATERIALS

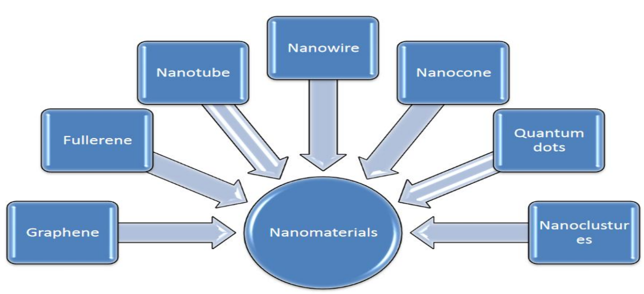

Fig. 2: The number of dimensions [7]

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The classification of nanomaterials is based on the number of dimensions as shown in Fig. 2. According to Siegel, nanostructured materials are classified as: zero-dimensional (0D), one-dimensional (1D), two-dimensional (2D) and three-dimensional (3D) nanomaterials [7].

1) *Zero-dimensional Nanomaterials:* Here, all dimensions (x, y, z) are at nanoscale, i.e., no dimensions are greater than 100 nm. It includes nanospheres and nanoclusters [7].
2) *One-dimensional Nanomaterials:* Here, two dimensions (x, y) are at nanoscale and the other is outside the nanoscale. This leads to needle shaped nanomaterials. It includes nanofibers, nanotubes, nanorods, and nanowires [7].
3) *Two-dimensional Nanomaterials:* Here, one dimension (x) is at nanoscale and the other two are outside the nanoscale. The 2D nanomaterials exhibit plate like shapes. It includes nanofilms, nanolayers and nanocoating with nanometre thickness [7].
4) *Three-dimensional Nanomaterials:* These are the nanomaterials that are not confined to the nanoscale in any dimension. These materials have three arbitrary dimensions above 100 nm. The bulk (3D) nanomaterials are composed of a multiple arrangement of nano-size crystals in different orientations. It includes dispersions of nanoparticles, bundles of nanowires and nanotubes as well as multiple nanolayer (polycrystals) in which the 0D, 1D and 2D structural elements are in close contact with each other and form interfaces [7].

Nanomaterials have extremely small size which having at least one dimension 100 nm or less. Nanomaterials can be nanoscale in one dimension (eg. surface films), two dimensions (eg. strands or fibres), or three dimensions (eg. particles). They can exist in single, fused, aggregated or agglomerated forms with spherical, tubular, and irregular shapes. Common types of nanomaterials include nanotubes, dendrimers, quantum dots and fullerenes. Nanomaterials have applications in the field of nano technology, and displays different physical chemical characteristics from normal chemicals (i.e., silver nano, carbon nanotube, fullerene, photocatalyst, carbon nano, silica) [4].

V. APPLICATIONS OF NANOMATERIALS

Nanotechnology has become the talk of the scientific community from the time it bloomed in the 2000s. Nanotechnology has found various daily life and industrial applications already and many major applications are yet in research and development It is not wrong to say that Nanotechnology has taken the technological world by storm. Of all the applications discussed all over the world, here are the major fields in which nanotechnology is being used and the ones in R&D [5].

Nanomaterials having wide range of applications in the field of electronics, fuel cells, batteries, agriculture, food industry, and medicines, etc. It is evident that nanomaterials split their conventional counterparts because of their superior chemical, physical, and mechanical properties and of their exceptional formability [4]. These nanoparticles seem to be everywhere Nanomaterials may be ubiquitous in the natural world. As an additional note, considering how often we use nanoparticles, it's reasonable to believe that life would be challenging without them [10].

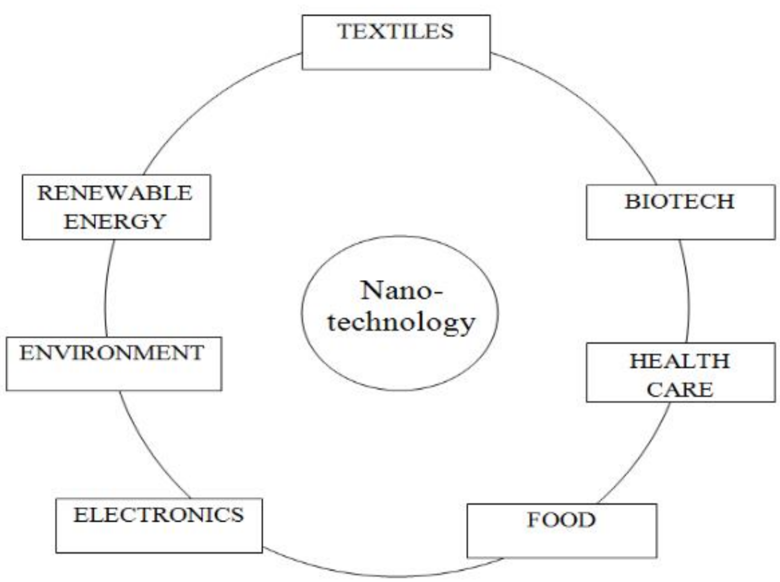

Fig.3: Various fields affected by Nanotechnology [5]

A. Medicine

Nanoparticles have made major contributions to clinical medicine in the areas of medical imaging and drug/gene delivery. Iron oxide particles such as magnetite (Fe3O4) or its oxidized form magnetite (Fe2O3) are most commonly employed for biomedical applications. Ag NPs are being used increasingly in wound dressings, catheters and various households' products due to their antimicrobial activity. Gold nanoparticles are emerging as promising agents for cancer therapy, as drug carriers, photothermal agents, contrast agents and radiosensitisers (Cai, W., Gao, T., Hong, H., & Sun, J., 2008; Jain, S., Hirst, D. G., & O'Sullivan, J., 2012; Sztandera, K., Gorzkiewicz, M., & Klajnert-Maculewicz, B., 2018). Over past few decades there has been considerable interest in developing biodegradable NPs as effective drug delivery devices. Various polymers have been used in drug delivery research as they can effectively deliver the drugs to the target site thus increases the therapeutic benefit, while minimizing side effects [8].

B. Electronics

Unique structural, optical and electrical properties of one-dimensional semiconductor and metals make them the key structural block for a new generation of electronic, sensors and photonic materials [8].

C. Food

Nanoparticles have been increasingly incorporated into food packaging to control the ambient atmosphere around food, keeping it fresh and safe from microbial contamination (Bhardwaj M. & Saxena D.C., 2017). Now-a-days, inorganic & metal NPs are extensively used as alternatives to petroleum plastics in the food packaging industry as they can directly introduce the anti-microbial substances on the coated film surface (Hoseinnejad, M., Jafari, S. M., & Katouzian, I., 2018) [8]. Nanomaterials having wide range of applications in the field of electronics, fuel cells, batteries, agriculture, food industry, and medicines, etc... It is evident that nanomaterials split their conventional counterparts because of their superior chemical, physical, and mechanical properties and of their exceptional formability [4]. The nanoscale, materials have novel properties like increased strength, resiliency, electrical conductivity. One of the most common examples of nanodevice is the iPod Nano which uses microscopic memory chips for increasing the storage capacity [15]. Life sciences combined with nanotechnology has given rise to nanobiotechnology that has been given insights in to disease processes, hence identifying more efficient biomarkers and understanding the mechanism of drug action [15].

1) Nanomaterials in electronics
- In electrical circuits, as an electrical cable wire, as a paper battery, in display technologies, in the solar cells.

2) Nanomaterials in the environment
- In hydrogen storage.
- In catalysis.

3) Nanomaterials in medical
- Nanoscale devices can be employed for drug delivery.
- Nanoparticles can be used to deliver drugs in a targeted fashion to specific cells in the body [3].

VI. BENEFITS OF NANOMATERIALS

1) The space required for nanomaterials is so much less due to their small size [2].
2) Human life is getting more suitability due to utilization of nanomaterials in their daily life.
3) Humans got a remedy on Cancer in the roll of nanotechnology [2].
4) With nanomaterials, we can create unique materials and products which are stronger, lighter, cheaper, durable, precise [3].
5) Less pollution [3].
6) Mass production in food and consumables [3].
7) Manufacturing at very low cost or no cost [3].
8) Automatic pollution clears up [3].
9) In the medical world, nanotechnology is also seen as a boon since these can help with creating what is called smart drugs. These-help cure people faster and without the side effects that other traditional drugs have. You will also find that the research of nanotechnology in medicine is now focusing on areas like tissue regeneration, bone repair, immunity and even cures for such ailments like cancer, diabetes, and other life threaten diseases [16].

VII.LIMITATIONS OF NANOMATERIALS

1) To observe the nanomaterials, a high-power electron microscope is required which is very costly.
2) Due to large surface area per volume of nanomaterial, it is harmful for the human skin and lungs [2].
3) Impurity - Because nanoparticles are highly reactive, they inherently interact with impurities as well. In addition, encapsulation of nanoparticles becomes necessary when they are synthesized in a solution (chemical route). The stabilization of nanoparticles occurs because of a non-reactive species engulfing the reactive nano-entities. Thereby, these secondary impurities become a part of the synthesized nanoparticles, and synthesis of pure nanoparticles becomes highly difficult. Formation of oxides, nitrides, etc can also get aggravated from the impure environment/ surrounding while synthesizing nanoparticles. Hence retaining high purity in nanoparticles can become a challenge hard to overcome [4].
4) Recycling and disposal - There are no hard-and-fast safe disposal policies evolved for nanomaterials. Issues of their toxicity are still under question, and results of exposure experiments are not available. Hence the uncertainty associated with affects of nanomaterials is yet to be assessed in order to develop their disposal policies [4].
5) Fine metal particles act as strong explosives owing to their high surface area coming in direct contact with oxygen. Their exothermic combustion can easily cause explosion [4].
6) Biologically harmful - Nanomaterials are usually considered harmful as they become transparent to the cell-dermis. Toxicity of nanomaterials also appears predominant owing to their high surface area and enhanced surface activity. Nanomaterials have shown to cause irritation, and have indicated to be carcinogenic. If inhaled, their low mass entraps them inside lungs, and in no way they can be expelled out of body. Their interaction with liver/blood could also prove to be harmful (though this aspect is still being debated on) [4].

VIII. CONCLUSION

We can conclude that at present Nanotechnology is the growing and developing technology and has a potential to increase the development of many sectors. Nanomaterials can be differentiated from the other materials that give them an increase in mechanical properties as a result of their uniform distribution of molecules. The use of nanotechnology is continuously transforming daily use products, making ample amount of consumer goods inexpensive and highly durable. So in this way nanomaterials will change our present and future.

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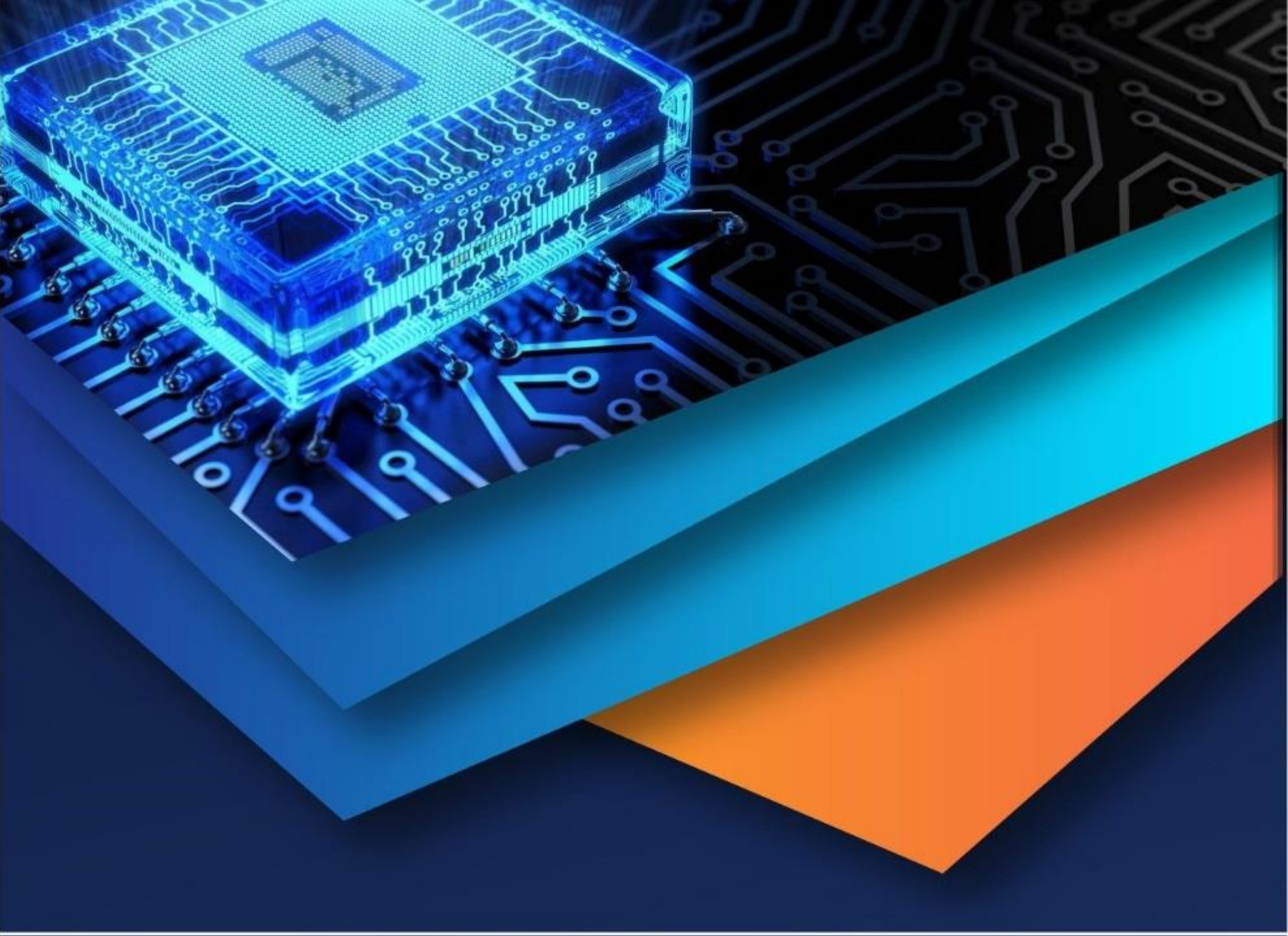

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