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The Nanoworld

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Abstract: ***A structure is termed as a nanomaterial when at least one dimension of the particle is less than 100nm. Nanomaterials have led to many developments in almost every known field: rapid performance of microprocessors, cure of cancer, and tumor diagnosis are only some of the developments that nanomaterials are accountable for. This paper begins with the basics of nanomaterials including the production methods, types of nanomaterials and their applications in prominent fields like aerospace, healthcare and electronics. The evolution and role of nanomaterials in respective fields has also been mentioned with examples of companies at the foremost level in the nanomaterial industry. In aerospace applications, to discover unknown knowledge in outer space, the parameters of the spacecraft should not have a single error as lives are at stake; nano sensors allow us to ensure safety int the harshest climates. Biosensors, in the field of healthcare, are nano sensors utilized for medical and as well as food industry due to their high speed and precise results. The complete eradication of the corona virus is now the target of various healthcare organizations, which we can say is most likely to be found through an engineered application of nanomaterials. This paper covers such interesting technological advancements in the nanoworld.***

Keywords: Nanotechnology, nanomaterials, aerospace, healthcare, electronics

1.Introduction

Nanomaterials, since their discovery in 5th Century B. C [1], have influenced various fields and helped them grow massively in the past few decades. With such progressive developments, nanomaterials have the potential to revolutionize technology in different fields: energy, environment, food, textile, electronic, aerospace, healthcare and the list goes on. They have already been commercialized in everyday commodities, for example, nanocoating is used in consumer products like sunscreen, moisturizer, makeup, soaps, lotions and tanning pills among others. These coatings provide UV protection, deeper skin penetration and ensure a long-lasting effect. UV-blocking coatings on glass bottles protect beverages from sunlight and longer-lasting tennis balls use butyl rubber/nano-clay composites [2].

Likewise, in the textile industry, nanoparticles of silica are used in making liquid repellent and wrinkle repellent fabrics; nano coatings are also used in making waterproof and less flammable furniture. They have applications in sensors for enhanced sensitivity and more precision, nanostructures metal oxide sheets are used in this case. Such metal-oxides are also utilized for rechargeable batteries. Nanostructured semiconductors are used as window layers in solar cells. It makes metal-metal bonding easier which helps in making electrical components as metals have good conductivity towards electricity [3]. Thus, the applications of these materials are innumerable. {Figure 1} shows us some of the dominating fields of nano industry.

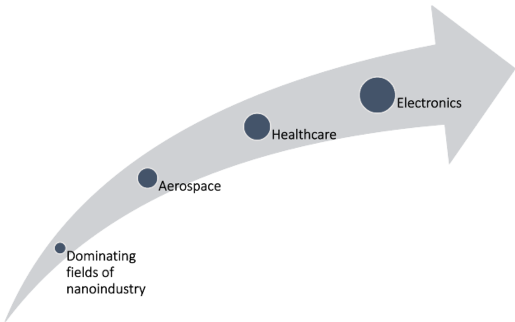

Figure 1: Fields discussed explicitly in the paper with respect to nanomaterials

Nanomaterials are like a small solution to a vast number of problems. They can be defined as substances with at least one dimension less than 100 nanometers. 1 nanometer is one millionth of a millimeter. In simple terms, it can be compared to a substance 100, 000 times smaller than the diameter of a single human hair. Their existence at such minute scales has granted them special properties, thereby allowing them to make significant advancements in fields like electronics, medicine, aerospace and others. For instance, nanophase silicon has a physical and electrical property from which new devices can be made which is not possible in case of normal silicon.

The primary reason for such versatile properties in nanomaterials that make them more special than bulk materials is the high surface area to volume ratio of nanomaterials than their conventional counterparts. This factor has quite a broad application. It provides greater chemical reactivity, improved mechanical and optical properties as well as enhanced electrical and magnetic behavior. Nanomaterials are more ductile at elevated temperatures; ductility is a property to be deformed in the shape of thin wires. Silicon powders act like fluorescents, nanosized metallic powders have cold welding properties and are also very helpful for metallic bonding as they show paramagnetic behavior [3].

Nanomaterials can be in the nanoscale in all three dimensions or only in one dimension. They can be classified based on this as zero-dimensional, one-dimensional, two-dimensional and three-dimensional. Zero-dimensional nanomaterials have all three dimensions in nanoscale (zero dimensions in macroscale). Graphene quantum dots, carbon nanodots, fullerenes are some examples of zero-dimension nanomaterials. Quantum dots are man-made crystals which transport electrons, they emit light when in contact with UV rays which has wide application in solar cells. Quantum dots have their hand in various fields like transistors, solar cells, LED's, lasers etc. One-dimensional nanomaterials include those having two of the three dimensions in the nanoscale (one dimension in macroscale), the other two dimensions do not lie in the nanoscale. Examples are nanowires, nanorods, nanotubes etc. One of the most popular nanotubes are carbon nanotubes; these tubes can be imagined as graphene sheets rolled up into a tube structure made up of a hexagonal network of carbon atoms. {Figure 2} the classification of nanomaterials on the basis of nanomaterials can be seen.

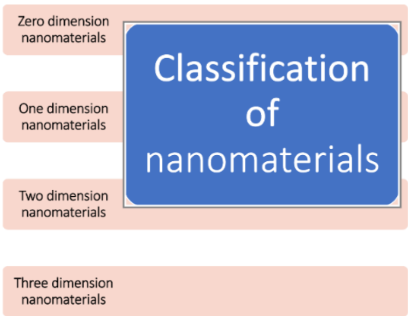

Figure 2: Classification of nanomaterials

Two-dimension nanomaterials are nanomaterials which have only one of the dimensions in nanoscale (two dimensions in macroscale). Popular examples include metal nanosheets and graphene. They provide enhanced physical and chemical functions. Graphene is a sheet of thickness of 1 atom of carbon; it is an allotrope of carbon which has carbon atoms placed in a honeycomb-shaped pattern. Due to the thinness of graphene, it has achieved various results which were unachievable in the case of others, these achievements are in terms of strength, electricity and heat conduction. Three-dimensional nanomaterials do not exist in the nanoscale in any dimension but instead consist of bundles of nanosheets or nanotubes or any nanoparticle [2].

The occurrence of some nanomaterials is natural, whereas commonly used ones are engineered nanomaterials which are designed for a particular application; such as cosmetics, sporting goods, tires or other everyday items. Engineered nanomaterials are resources designed at the molecular (nanometer) level to take advantage of their small size. At present, there are diverse applications of nanocoating and nanocomposites, they are used in many consumer products to increase their efficiency and make their life longer.

Engineered nanomaterials can be produced in few ways; one of them requires a bottom-up approach known as sol-gel process. This process is quite cheap and doesn't require too much energy; it enables the precise control of the material's chemical composition. A sol is colloid in which the solid-state particles are emersed in a liquid. These particles are so small that gravitational forces do not act on them. When the solvent or the liquid from the sol is evaporated, the particles or the surface charges remaining are known as gel. Gel is a semi-rigid mass made up of a network of charges and particles. The removal of fluid affects its properties; sedimentation is done for this step. This gel is then dried to remove the solvent completely, which requires a thermal treatment, to further enhance the mechanical properties and provide structure stability. After this the dried gel is grinded to arrive at the final product. Another technique is known as "top down" in which the nanomaterials are obtained from bulk materials, bulk materials are broken apart till we get nanosized particles. Top-down nanotechnology has positively influenced various electrical and information and communication technology industries.

Research is ongoing in nanomaterials due to the virtue of the mechanical, chemical, optical and magnetic properties they hold. This article presents the vast application of nanomaterials in three major fields significant in today's date: aerospace, healthcare and electronics, how nanomaterials have led to far reaching technological advancements in these domains.

2. Nanomaterials in Aerospace

Nanomaterials, because of their unique properties, are used in applications that need high-strength lightweight components, mostly in sensors and energy-storage systems in the aerospace sector. Engineered Nanomaterials have helped in improving space exploration and aeronautical systems providing features like low weight, good flexibility and strength, power storage and radiation protection. Aerospace applications require the development of sensors to operate in various types of environments. They must have capabilities beyond normal sensors like leak detection, high temperature physical parameter monitoring, fire detection, environmental monitoring and radiation detection. Such sensors are needed to provide better understanding of the engine systems in harsh environments, but developments are required for performance in high temperatures. Efforts are being put by NASA in each of these areas to ensure better safety of commercial air travel, decrease the amount of emissions produced by aeronautic engines and decrease the cost of space travel [4]. Each area has its own challenges and improvements will make lives easier.

A spacecraft cannot take flight while having leaks; hence detection of low concentration of hydrogen which is involved in the launch is necessary as it could lead to explosive conditions harming the spacecraft. Nano sensors which can withstand the exposure of 100% hydrogen, produce precise reading in space and give the location of leak site are required in this area. In outer space, the components exposed to vacuum or the earth's atmosphere face degradation with time, the engine hot section could lead to catastrophic failure. This implies that a better understanding of the spacecraft is needed, and measurement of physical parameters is crucial; nano sensors can be integrated within the engine systems to ensure all the parameters. However, developments are still needed in this area so that spacecrafts perform in even harsher environments. Special sensors based on nanotechnology are used in ultraviolet photodetectors for measuring various parameters like water vapor, temperature, UV radiations etc. They are required for such activities which need to be quick and precise, its distinctive size-qualities that make them better quality and vital to numerous areas of human interest.

In rocket motor propellant systems, nanomaterials provide increased reactivity because of their high surface area to volume ratio. However, balancing increased reactivity with safety is a challenging issue at present. Nanomaterials have also improved thermal stability in the thermal protection system to protect spacecrafts while reentry into earth's atmosphere. Incorporation of carbon nanotubes (CNT) in the system remarkably improved its performance. In the Juno space craft which was sent to orbit around the Jupiter planet, CNTs were used in rocket engine motor. A mission name RAVAN (Radiometer Assessment using Vertically Aligned Nanotubes) had the same fundamentals of utilizing CNTs, its aim was to showcase the technology to measure the earth's radiation imbalance, the imbalance between energy reaching from the sun to the atmosphere of earth and that being reflected. A spacecraft with several CNTs and an extremely accurate radiometer would save us from dramatic climate shifts [5].

3. Nanomaterials in Healthcare

Due to the current advancements in nanotechnology, diseases can now be recognized at an early stage; sensors can now detect as low as a single parasite per microliter of blood. The rapid evolution of the nanomaterial industry is showing up huge potential in the healthcare sector. This is all possible by the help of biosensors made from nanoparticles using electrical, thermal or optical signals. The International Union of Pure and Applied Chemistry (IUPAC) has defined a biosensor as a device to detect chemical compounds by isolated enzymes, tissues or whole cells. Biosensing has a key role in various fields like food toxicity, environmental safety, pregnancy tests and various other areas and provides a rapid sensing platform. An interesting example is the detection of pathogens like anthrax that cause hemorrhagic meningitis that has reduced from 2-3 days to 5 minutes [6]. Moreover, biosensors in the food industry may be used to analyze nutrients, to detect natural toxins and antinutrients, for monitoring of food processing, and for detection of genetically modified organisms.

Most used nanoparticles are Carbon and its allotropes which exist in many forms like graphite, fullerene, diamond and many other natural forms. Each of these forms is highly valued as they possess such unique features leading to its vast application in various processes like cancer therapy, tissue engineering etc. Transitional metals or noble metals also have applications in the nano industry, as it has atoms bonded with incompletely filled orbits due to which unique properties arise. They can be used in combination with various organic and carbon-based materials to make nanocomposites, showing distinct characteristics. Most of the organic nanomaterials exist as polymers in nature, they are thermally stable and require less amount of capital for production, therefore, their application in fields of medical and drug delivery have increased. By manipulation of size, surface characters and the material of the nanoparticle itself, smart systems can be made to deliver drug to specific tissues and to provide controlled release therapy.

Nanomaterials have reached a level now to revolutionize cancer therapy. The diagnosis and treatment of cancer has always been a challenge for humans in the past as the tumor is not detectable until it increases to the next stage which becomes life threatening. Chemotherapy, a way to fight out cancer, is not the best way for treatment as the radiations have an adverse effect on the tissues around the cancer cell causing side effects. Nanotechnology enables us to seek the cancer cells and attach to them using receptors which then generate signals so that the location of the cancer cells in our body could be detected. Conventional medical scans are not able to show us such identification and tell us the location. Special receptors are used to obliterate those cells individually so that other cells are not injured and with time these nanoparticles are eliminated from the body.

Furthermore, nanomaterial's role in addressing covid 19 has been tremendous. Corona Virus has put the whole world in a tight spot, it has had an untoward effect on the economy, healthcare and lifestyle. It has targeted people with weaker immune systems like children, the elderly as well as people suffering from life-threatening diseases. The role of nanomaterials is prominent in the production of the equipment, which is extremely vital to the healthcare system. For disinfecting the surfaces, the Copper environment was the most effective in inactivating the virus; this was due to release of copper ion. So, metals like copper, silver and zinc nanostructures with such characteristics were employed to prevent and curb the contamination and spread of the virus [7]. Additionally, nanotechnology helped us to build strategies to combat such crises, which involves development of disinfectants, protective equipment and sanitizers.

4. Nanomaterials in Electronics

Since the discovery of nanomaterials, there have been tremendous developments in the field of electronics, hence, whenever nanotechnology is brought up, we think of its role in this domain. It has revolutionized developments in the electronic nanochips industry; such chips have improved the potential of electronic devices with enhanced performance, reduced mechanical requirements, decreased power usage and lowered the weight of the devices. The company Nantero in 2006 found methods for production of semiconductors using CNTs; they are now producing a universal memory chip which is promising to increase the application of chips in electronics. These chips are known as (NRAM) non-volatile random-access memory chips which are made by

integrating CNTs with semiconductor technology. IBM, intel and Nanotero are only some of the companies working in this field and producing advancements as well as doing research to overcome the limitations faced.
Microchips require a lot of time for manufacturing as they consist of billions of transistors packed in a small area. These are made from silicon rich sand as silicon acts as an insulator and a conductor depending on the impurities added to it. A seed crystal is added to molten silicon to produce cylindrical-crystal ingot, which is then thinly cut into sheets called wafers, about 1-12 inches in diameter. These wafers are then cut into microchips. Such complex patterns of steps are required to be completely free from contaminants. Till 2015, the size of nanochips used in computers, phones and other devices was 14 nanometers. There is a massive industry now which is responsible for the production of these electrical components due to its high demand and consumption. Carbon nanotubes and quantum dots are some of the most regularly used nanomaterials in these components. Carbon nanotubes or CNTs are used to make transistors which are used as layers for the touch screen of various electronic devices. Having transparency and highly conductive properties at an inexpensive cost CNTs can potentially be used as an alternative for flexible displays and touch screens.

The properties of Carbon nanotubes also play an advantage in lithium-ion battery systems. CNTs are used for producing conductive porous electrodes which is used in lithium-ion batteries. CNTs are also being used in research to enhance the performance of electric double layer capacitors. To make life simpler and minimize human efforts automatism is trying to be included in most everyday areas, for instance in automobiles like tesla and latest launch xuv700 the feature of autopilot is able to perform due to sensors utilized in it, the combination of AI and the nanosensors in tesla makes it one of the best cars yet to exist. The following paragraphs discuss major companies with notable developments and research in nanotechnology.

Intel was founded in 1968 and has been a leading integrated device manufacturer since. It has provided us with microprocessor solutions to major Personal Computer or Laptops. Intel Labs are exploring next generation advancements in hardware and software. Intel is also working on autonomous driving which is popular and desired in today's time. Intel is currently making efforts to attain a level above the Moore's law, intel has produced a lot more transistors in a smaller area with their nano-1o technology. Decreasing the area is also an advantageous factor, it decreases the production cost of the product, intel not only decreases the size of the chips, but they also enhance the features of the chip. There is a 25% improvement in the performance of the nano 10 technology compared to the previous 14 nanometer technology.

In 2004, Nanosys and intel collaborated on memory-based technologies and to overcome the limitations of memory chips at that time. Nanosys has been working on advancing display features and to overcome its production barriers. They utilize a specific type of nano crystal which do the improvement in visual quality and give energy-efficient vibrant products. Nanosys' slide-in quantum dot sheet makes it easy for manufacturers to integrate it into any display stack without having to invest in expensive equipment.

IBM is one of the major players in CNT after 2020. iBM design uses 6 parallel nanotubes to create a transistor and each nanotube is 1.4 nm in diameter, 30nm long and spaced apart by 8nm. The ends of the tube act like 2 terminals of electrodes and provide current. The third terminal is parallel underneath the middle of these nanotubes, which provides control over the 2 electrodes [8]. The market capture of IBM is semiconductor solution to consumer, mobile for high-speed data transmission. IBM researchers have discovered methods in which bacteria which resist the antibodies can be detected and destroyed by special nanostructures.

Nantero is another leading semiconductor company which has its unique technology developed for building memories. Nantero uses carbon nanotubes technology (CNT) which boasts of unique structural and electrical properties. These CNT enable to make ultra-high density and low power consuming memory [9]. Nantero has gone over the edge and made such a technology which would drive the upcoming electronic innovations. The NRAM's (nonvolatile random accessory memory) creation of this company, are advantageous over Dynamic RAM's (DRAM) in terms of speed, and high resistivity to heat which is upto 300 degree C, magnetism, radiation and endurance as well. The NRAM 'S by Nantero also offer low / negligible power consuming solutions and can be processed in any fabrication semiconductor units. The market Nantero offers solutions to consumer electronics, mobile, wearable devices, network systems, automotive [reference].

5. Conclusion

Nanomaterials have been effective in every sphere of life be it sensors, cosmetics, moisturizers, semiconductors, biosensors, microchips and in many other appliances. This article discusses the applications of nanotechnology in three prominent fields: aerospace, healthcare and electronics. It is getting deeper in every field unravelling bigger potentials with time. What is fascinating is a material of such a small size showing huge developments, with a vast number of features and showing results in seconds.

References

[1] Bayda, S. et al. (2019) 'The History of Nanoscience and Nanotechnology: From Chemical-Physical Applications to Nanomedicine', Molecules, 25 (1), p.112. doi: 10.3390/molecules25010112.
[2] Aziz, Z. A. A., Mohd-Nasir, H., Ahmad, A., Mohd. Setapar, S. H., Peng, W. L., Chuo, S. C., Khatoon, A., Umar, K., Yaqoob, A. A. and Mohamad Ibrahim, M. N., 2019. Role of nanotechnology for design and development of cosmeceutical: application in makeup and skin care. Frontiers in chemistry, 7, p.739.

[3] Alagarasi, A. (no date) Chapter-Introduction to Nanomaterials. Available at: https://maken.wikiwijs.nl/userfiles/2/2ee21d1456a928da66dbaee2507257fcb96bbdcf.pdf.
[4] Cabrera, C. R. and MirandaF. A. (2014). Advanced nanomaterials for aerospace applications. Singapore: Pan Stanford Publishing.
[5] Arepalli, S. and Moloney, P. (2015) 'Engineered nanomaterials in aerospace', MRS Bulletin, 40 (10), pp.804-811. doi: 10.1557/mrs.2015.231.
[6] www. mdpi. com. (n. d.). Sensors. [online] Available at: http://www.mdpi.com/journal/sensors.
[7] Afolalu, S. A., Ayodeji, A., Noiki, A. A. A., Emetere, M. E., Omolola, O. and Samuel, O. D., 2021. Application of nanomaterials and nanotechnology in addressing Covid-19 challenges-review. In 2nd South American Conference on Industrial Engineering and Operations Management, IEOM (pp.920-926).
[8] MIT Technology Review. (n. d.). IBM: Commercial Nanotube Transistors Are Coming Soon. [online] Available at: https://www.technologyreview.com/2014/07/01/172177/ibm-commercial-nanotube-transistors-are-coming-soon/ [Accessed 18 Dec.2022].
[9] Nantero. com. (n. d.). Carbon NanoTechnology. [online] Available at: https://www.nantero.com/technology [Accessed 18 Dec.2022].
[10] Grafine. (n. d.). Elastomer | Manchester. [online] Available at: https://www.gra-fine.com/ [Accessed 18 Dec.2022].

Author Profile

As a student studying in the city noida, India, engineering and technology has always fascinated me. I found my interest in nanotechnology, thanks to the amazing electronic gadgets around me. The new features which never fail to astonish me and I am keen to discover the huge potential of these tiny nanomaterials.