Chapter 6

THE NANOTECHNOLOGICAL REVOLUTION IS MAKING ITS WAY TO THE NOBEL PRIZE IN 2023

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INRODUCTION

Nanotechnology deals with materials and structures of very low size ranges from 1 to 100 nanometres, which make it a cutting-edge area in science and technology. A nanometre is one billionth of a metre. On this nanometre scale, the unique properties of materials and their behaviour are revealed[1,2]. They can be manipulated and engineered by scientists and engineers for a variety of purposes. Nanotechnologies are having a major impact in all areas, e.g. electronics, pharmaceuticals, materials science and energy etc. And it has great potential for innovation and solving some of the world's biggest problems. New opportunities for developing innovative materials, devices and systems with unprecedented accuracy and efficiency have emerged in this area. The history of nanoparticles or nanotechnology dates back to 1959, when renowned physicist Richard Feynman first introduced the concept of Nano chemistry [3-5]. In this area, there have been certain developments and incredible growth. And the Nano technological revolution is making its way to the Nobel Prize in 2023.

In relation to this nanotechnology, certain terms are important and their correct interpretation also plays a role. ‘Nanotechnology’ is a study of nanoscales, and such understanding will be implemented and applied through ‘Nanotechnology’. ‘Nano chemistry’ is a discipline that concerns the production, manipulation and application of materials with sizes ranging from 1 to 100 nanometres. 'Nanomaterials' are materials with a size in this range of 100 nanometres or materials that exhibit properties not found in the molecular and bulk solid state due to their size factor.

Electrostatic, Van der Waals, Brownian, Vibrational, Chemical and Quantum mechanical forces are the most powerful force of attraction for nanomaterials. There are two things that happen when a bulk material is transformed into a nanomaterial. The increase in surface area to volume ratio is the first. The surface area changes and volume is unchanged during the transition to a lower size[6]. Therefore, the surface area to volume ratio shall be increased and reactivity also increased. Quantum confinement is another thing that's happen during this transformation. It is the trapping of electrons and holes in tiny regions to restrict their motion which provides a method of tailoring or engineering the band gap of the materials. The quantum confinement effects lead to most fundamental manifestations of nanoscale phenomena in materials and frequently used for the study and development of nanoscience, particularly in semiconductor nanomaterials and quantum dots. As a result, nanomaterials have special chemical characteristics because of the high surface area to volume ratio and their extraordinary optical and electric properties based on quantum confinement.

HISTORY OF NANOTECHNOLOGY

The concept of nanotechnology was introduced by the famous physicist Richard Feynman at his lecture, 'There's Plenty of Room on the bottom'. He explained in this discussion the possibility of chemical synthesis by manipulating atoms directly. In 1974, Norio Taniguchi came up with the term "Nanotechnology". In 1986, inspired by Feynman's ideas, Eric Drexler, author of the book 'Engines of Creation: The Coming Age of Nanotechnologies', coined the term "Nanotechnology." it deals with the concept of a nanoscale assembler capable of creating copies of itself and other objects of arbitrary complexity with atomic precision. He also tried to promote a better understanding of the concepts and implications of nanotechnology among the general public. In the 1980s, his conceptual framework for nanotechnology, combined with high profile experimental developments, has increased public awareness of the potential for atomic control of matter, which has led to nanotechnology as a field of study. In the 1980s, the development of nanotechnology was greatly influenced by two major discoveries. First, a Scanning Tunnel Microscope(STM) was invented in 1981. It was successfully used for the manipulation of atomically different atoms from 1989 onwards. In 1986, the Nobel Prize in physics was awarded to the creators of STM, Gerd Binnig and Heinrich Rohrer. Binnig, Quate and Gerber had also developed an Atomic Force Microscope(AFM) that same year. Secondly, Harry Kroto, Richard Smalley and Robert Curl discovered the fullerenes in 1985. They've shared the Nobel Prize in chemistry in 1996. Nanotechnology was not first used to describe C60, instead, it was used to refer to later research on closely similar carbon nanotubes (also known as graphene tubes or Bucky tubes), which showed possible uses for nanoscale electronics and gadgets. Sumio Iijima was awarded the first Kavli Prize in Nanoscience in 2008 for his role in the discovery of carbon nanotubes[7].

This field attracted more scientific, political, and commercial interest during the last years. The Royal Society's study on nanotechnology is an example of the debates that have arisen around the definitions and potential effects of nanotechnologies. The public argument between Drexler and Smalley in 2001 and 2003 was the result of issues being raised about the viability of the applications that proponents of molecular nanotechnology had envisioned. While this was going on, the commercialization of goods based on developments in nanoscale technologies have emerged. These goods do not involve atomic manipulation of matter and are restricted to mass uses of nanomaterials. Examples include the silver Nano platform, which uses silver nanoparticles as an antibacterial agent, transparent sunscreens based on nanoparticles, silica nanoparticles used to reinforce carbon fibre, and carbon nanotubes used in stain-resistant textiles. Two examples of how governments have taken action to promote and fund nanotechnology research are the National Nanotechnology Initiative in the United States, which has a formal size based definition of nanotechnologies as well as funding for nanoscale research and the European Framework Programme on Research and Technology Development in Europe. In the middle of the 2000s, new and important scientific interests began to emerge.

RECENT ADVANCES IN NANOTECHNOLOGY

Nanotechnology is a rapidly evolving field with continuous advances and breakthroughs. It offers a wide range of benefits and has the potential to impact numerous aspects of our lives. Here are some notable areas of recent progress:

Nano medicine: Advances in targeted drug delivery systems using nanoparticles to improve the precision and effectiveness of cancer treatments. Development of nanoscale imaging agents for earlier and more accurate disease diagnosis.

Nano electronics: Continued efforts to push the limits of Moore's Law by developing nanoscale transistors and memory devices. For electronic components and interconnects, research on new materials such as 2D materials, e.g. graphene.

Quantum nanotechnology: advances in quantum computing and communications using nanoscopic bits. For applications in fields such as metrology and cryptography, development of quantum sensors and detectors.

Energy applications: Advancements in nanomaterials for more efficient solar cells, including perovskite solar cells. Research on nanomaterials for high-capacity and fast-charging batteries and super capacitors.

Nanotechnology in clean energy: research into nanomaterials to improve conversion and storage technologies, such as thermoelectric devices.

Environmental remediation: Use of nanomaterials, such as Nano catalysts, for efficient pollution control and wastewater treatment. Development of nanomaterial-based filtration systems for water purification.

Food and agriculture: Nanotechnologies in food packaging are used to extend shelf life and reduce food waste. Research into nanoscale delivery systems for precision agriculture, including targeted pesticide and nutrient delivery.

Nanorobotics: Progress in the development of nanoscale robots capable of performing tasks at the molecular level, including potential applications in medicine and manufacturing.

Nanotechnologies in space exploration: exploring the use of nanotechnology for spacecraft materials, propulsion systems and sensors that will be applied to future missions. Nano-ethics and safety: Growing attention to ethical considerations, safety protocols, and responsible research practices in nanotechnology[8].

Nanotechnologies have made major advances over the past years only in a couple of areas. With the potential to change various sectors and tackle global challenges, this area is developing at a rapid pace[9]. Nanotechnology provides us with the tools and knowledge to understand fundamental principles of science, making it possible for discoveries. While nanotechnology offers a number of benefits, it is necessary to take into account and address possible security, ethics or environmental concerns related to the field in order to achieve responsible development[10].

THE AMAZING GROWTH OF NANOTECHNOLOGY HAS REACHED THE NOBEL PRIZES

For the discovery and synthesis of quantum dots, Moungi G. Bawendi, Louis E. Brus & Aleksey Yekimov have been awarded a Nobel Prize in chemistry for 2023. Once the size of matter starts to be measured in millionths of a millimetre, strange phenomena start to occur – quantum effects – that challenge our intuition. Nobel Prize winners in chemistry of 2023 were all pioneer researchers into the world of nanotechnology. In the early 1980s, Louis Brus and Aleksey Yekimov were able to independently produce quantum dots, which are nanoparticles so small that they can be determined by quantum effects. In 1993, Moungi Bawendi revolutionized the production of quantum dots, making their quality extremely high, which is a prerequisite for their use in today's nanotechnology. With the laureates' work, we now have a chance to exploit some of the unique characteristics of nanotechnology. Quantum dots are now found in commercial products and used across many scientific disciplines, from physics and chemistry to medicine. These smallest components of nanotechnology now spread their light from televisions and LED lamps, and can also guide surgeons when they remove tumour tissue, among many other things.

The discovery of quantum dots was an important step in the development of nanoscience, and it inspired many chemists to engage in this interdisciplinary field. However, the modern field of nanoscience requires precise and ideally atom-level control of the synthesis of nanostructures. Therefore, the ability to fabricate materials at nanometre size and with sub-nanometre precision and high fidelity, safely, in benchtop chemical batch reactions represents a key milestone in the development of the field of nanoscience. This year’s Laureates played a central role in establishing these capabilities and in this way provided seeds for the rich field of nanoscience to grow.

DISADVANTAGES OF NANOTECHNOLOGY

Nanotechnology has many advantages, but it also brings its share of disadvantages and difficulties, such as:

Impact on the environment: Nanoparticles, due to their behaviour and toxicity may differ from bigger particles, can have an impact on the environment when released in ecosystems. The potential harm to marine and soil ecosystems is raising concerns.

Health concerns: The health effects of nanoparticles in inhalation, ingestion or absorption into the skin are currently being investigated. Some nanoparticles have been found to be associated with undesirable effects on health, raising concerns about worker safety and exposure for consumers.

Regulatory and ethical issues: In terms of setting safety standards and monitoring the release of nanomaterials into the environment, nanotechnology poses a challenge to regulatory authorities. Ethical issues are also brought to light, in particular as regards the use of nanotechnology for its intended purposes, which include improving people's lives and surveillance.

Costs and accessibility: Nanotechnology development and implementation can be costly, which may make it difficult to reach certain sectors or regions. It is a challenge to ensure equitable access to nanotechnology developments.

Risk of Nanoparticle Release: There is a potential for accidental release of nanoparticles into the environment, which may affect ecosystems and human health, while nanomaterial filled products are being produced, used or disposed of.

Nano ethics and governance: Ethical issues related to nanotechnology must be carefully considered and managed. It is still a matter of concern to establish ethical guidelines and frameworks for the management of research and development.

Public perception and awareness: Many people are not fully aware of the potential benefits and risks of nanotechnology. Effective communication and education efforts are needed in order to make informed decisions and take responsibility for the use of nanotechnology.

Security risks: The development of advanced nanomaterials and nanoscale devices may pose security risks if used inappropriately, such as in the development of new weapons or surveillance technologies.

Intellectual property issues: Innovation in research and development is often the basis of nanotechnology progress. Progress and access to critical technologies can be hindered by intellectual property issues.

CONCLUSION

Finally, nanotechnology has become a ground-breaking science discipline with huge implications for different areas. As we've explored, it has a rich history rooted in the manipulation of materials at the nanoscale, with significant contributions from visionaries like Richard Feynman and the coinage of the term "nanotechnology" by Norio Taniguchi in the 1970s. Nanotechnology covers a broad range of applications, from medicine to electronics, energy technology, materials science and the environment. Nanotechnologies are designed to deliberately control and manipulate matter in a range of 1 to 100 nanometres, creating unique properties and behaviours which can be exploited for the development of novel solutions.

It is remarkable that nanotechnology has progressed in such a way recently. Researchers have made progress in the field of Nano medicine, with a focus on targeted drug delivery and early disease detection, as well as promising more effective treatments and diagnostic tools. Nanotechnologies are pushing the limits of miniaturization and computing power, while quantum nanotechnology is a potential game changer in terms of computers and communications. In the area of energy applications, nanomaterials improving Solar Cells and Energy Storage Systems are making progress which will contribute to sustainable energy solutions.

Nanotechnology, with effective pollution control and clean water technologies, can be used for environmental remediation. In addition, nanocomposites are being developed with increased strength, lighter and more flexible properties as a result of material science advances. Nanorobotics, which promises molecular precision in fields such as medicine and manufacturing, is on the horizon. In order to ensure responsible development and use of nanotechnology, ethical considerations and safety protocols are increasingly being taken into account. In addition, the field has broadened to include space exploration where nanotechnology is being explored for various applications.

Finally, nanotechnology's history is marked by visionary thinkers, its scope is limitless, and its recent advances are shaping a future filled with innovative and transformative solutions to some of humanity's most pressing problems. Nanotechnology has the potential to transform industry, improve people's quality of life and tackle a wide range of world challenges as it evolves.

To fully understand the impact of nanotechnology on science, technology and society, it is necessary to keep a close eye on its ongoing research and development. How nanotechnology will affect society in the future is currently being debated by scientists. A wide range of new products, including consumer goods, Nano medicine, nanomaterials, electronics, biomaterial and energy generation can be developed by nanotechnology.

Nanotechnology, on the other hand, raises many of the same problems as any new technology, such as concerns about the toxicity and environmental impact of nanomaterials, as well as their ability to have an impact on the world's economy and the speculative possibility of numerous scenarios, such as the apocalypse. These concerns have led to discussions between activist groups and governments about the need for a specific nanotechnology regulation, which is currently under discussion. It is important to note that, while nanotechnology presents these disadvantages and concerns, the continued development of research, regulation and responsible practices with a view to addressing those challenges and maximising nanotechnologies' benefits as well as minimising their risks are constantly developing. Responsible nanotechnology development is underpinned by ethics and a thorough assessment of the possible consequences.

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