**Nanotechnology**

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**Nanotechnology**

Nanotechnology is a broad field that includes physics, chemistry, biology, materials science, and engineering which is devoted to manipulation, and application of materials and devices at the nanoscale level, which is typically defined as being between 1 and 100 nanometers in size and involves the understanding and controlling of nanometer-scale design. At this scale, the properties and behavior of materials can differ significantly from those at larger scales, due to phenomena such as quantum effects, surface area effects, and the dominance of surface forces over volume forces. It can increase the surface area of a material. This allows more atoms to interact with other materials. An increased surface area is one of the chief reasons nanometer-scale materials can be stronger, more durable, and more conductive than their larger-scale (called bulk) counterparts.

Nanotechnology has the power to transform a wide range of sectors and professions, including medical, electronics, energy, and environmental studies. However, there are a lot of concerns that have been expressed regarding the potential risks and consequences of nanotechnology on human health and the environment. There is a lot of continuing research and debate in this area to ensure the safety and responsibility of nanotechnology development in our environment, such as "Nanotechnology in Agriculture and Food Science" (Axelos & Grumezescu, 2017) it explores the usage of nanotechnology in agriculture and food science, including the development of nanosensors for food safety and the use of nanoparticles for crop protection.

**Diving into the History of Nanotechnology**

Nanotechnology is a rapidly growing field that has the potential to revolutionize various industries, including medicine, electronics, and materials science. The history of nanotechnology can be traced back to ancient civilizations, where artisans unknowingly used nanomaterials to create intricate artwork and pottery. The modern era of nanotechnology, however, began with the visionary ideas of physicist Richard Feynman and the development of advanced imaging techniques, such as the scanning tunneling microscope.

Written below is the fascinating history of nanotechnology, its origins, significant milestones, and the potential impact on our future.

**Early Examples of Nanotechnologies**

Many early examples of nanostructured materials were based on the empirical understanding and manipulation of materials by craftsmen. These artisans often used high heat to produce materials with novel properties.

**The Lycurgus Cup**

The Lycurgus Cup, dating back to the 4th century, is a prime example of dichroic glass. This Roman artifact is made from colloidal gold and silver, which allows it to appear opaque green when lit from the outside, but translucent red when light shines through the inside. This unique property is due to the nano-sized particles of gold and silver suspended within the glass.

**Luster Ceramic Glazes**

From the 9th to 17th centuries, glowing and glittering "luster" ceramic glazes were used across the Islamic world and later in Europe. These glazes contained silver, copper, or other metallic nanoparticles, which gave the ceramics their characteristic shiny appearance.

**Stained Glass Windows**

During the 6th to 15th centuries, European cathedrals showcased vibrant stained glass windows. The rich colors of these windows were due to nanoparticles of gold chloride and other metal oxides and chlorides. Interestingly, gold nanoparticles also served as photocatalytic air purifiers within the cathedrals.

**Damascus Saber Blades**

Damascus saber blades, produced between the 13th and 18th centuries, contained carbon nanotubes and cementite nanowires. This ultrahigh-carbon steel formulation provided the blades with strength, resilience, and the ability to hold a keen edge. The unique moire pattern in the steel is a distinguishing feature of these blades.

**Modern Era Discoveries and Developments in Nanotechnology**

The modern era of nanotechnology is marked by increasingly sophisticated scientific understanding, instrumentation, and experimentation.

**Colloidal "Ruby" Gold**

In 1857, Michael Faraday discovered colloidal "ruby" gold, demonstrating that nanostructured gold under certain lighting conditions produces different-colored solutions. This discovery laid the foundation for future research into the properties of nanomaterials.

**Field Emission Microscope**

In 1936, Erwin Muller invented the field emission microscope, allowing scientists to obtain near-atomic-resolution images of materials. This invention was a significant milestone in the development of nanotechnology.

**Semiconductor Transistor**

The discovery of the semiconductor transistor in 1947 by John Bardeen, William Shockley, and Walter Brattain at Bell Labs greatly expanded scientific knowledge of semiconductor interfaces. This breakthrough laid the foundation for the electronic devices and information age that we know today.

**Monodisperse Colloidal Materials**

Victor La Mer and Robert Dinegar developed the theory and process for growing monodisperse colloidal materials in 1950. This controlled fabrication of colloids enabled a wide range of industrial applications, including specialized papers, paints, thin films, and even dialysis treatments.

**Field Ion Microscope**

In 1951, Erwin Muller pioneered the field ion microscope, which allowed scientists to image the arrangement of atoms at the surface of a sharp metal tip. Muller first imaged tungsten atoms using this innovative technique.

**Molecular Engineering**

In 1956, Arthur von Hippel at MIT introduced the concept of molecular engineering, which he applied to dielectrics, ferroelectrics, and piezoelectrics. This marked the beginning of nanotechnology as a distinct field of study.

**Integrated Circuit**

Jack Kilby of Texas Instruments created the first integrated circuit in 1958, for which he received the Nobel Prize in 2000. This groundbreaking invention paved the way for the miniaturization of electronic devices and the development of modern computing technology.

**Richard Feynman's Vision**

In 1959, Richard Feynman gave a seminal lecture titled "There's Plenty of Room at the Bottom" at the California Institute of Technology. This lecture, which is considered the first on technology and engineering at the atomic scale, inspired the conceptual framework for the goals of nanotechnology.

**Moore's Law**

Gordon Moore, co-founder of Intel, predicted in 1965 that the density of transistors on an integrated chip would double every 12 months (later amended to every 2 years). This observation, known as Moore's Law, has held true for over 50 years, largely due to the semiconductor industry's increasing reliance on nanotechnology as integrated circuits and transistors have approached atomic dimensions.

**The Term "Nanotechnology"**

In 1974, Norio Taniguchi, a professor at Tokyo Science University, first coined the term "nanotechnology" to describe precision machining of materials within atomic-scale dimensional tolerances.

**Scanning Tunneling Microscope**

The invention of the scanning tunneling microscope (STM) in 1981 by Gerd Binnig and Heinrich Rohrer at IBM's Zurich lab allowed scientists to create direct spatial images of individual atoms for the first time. Binnig and Rohrer were awarded the Nobel Prize for this discovery in 1986.

**Quantum Dots**

In 1981, Alexei Ekimov discovered nanocrystalline, semiconducting quantum dots in a glass matrix and conducted pioneering studies of their electronic and optical properties.

**Buckyballs**

In 1985, researchers at Rice University, including Harold Kroto, Sean O'Brien, Robert Curl, and Richard Smalley, discovered the Buckminsterfullerene (C60), more commonly known as the buckyball. This molecule, composed entirely of carbon, has a soccer ball-like shape and is part of the fullerene class of molecules. The team was awarded the 1996 Nobel Prize in Chemistry for their work.

**Colloidal Semiconductor Nanocrystals**

In 1985, Louis Brus from Bell Labs discovered colloidal semiconductor nanocrystals, also known as quantum dots. Brus shared the 2008 Kavli Prize in Nanotechnology for this groundbreaking discovery.

**Atomic Force Microscope**

Gerd Binnig, Calvin Quate, and Christoph Gerber invented the atomic force microscope in 1986. This innovative tool allows for the viewing, measurement, and manipulation of materials down to fractions of a nanometer in size, including the measurement of various forces intrinsic to nanomaterials.

**IBM Logo Spelled with Xenon Atoms**

In 1989, Don Eigler and Erhard Schweizer at IBM's Almaden Research Center manipulated 35 individual xenon atoms to spell out the IBM logo. This demonstration of the ability to precisely manipulate atoms marked the beginning of applied nanotechnology.

**Early Nanotechnology Companies**

The 1990s saw the emergence of early nanotechnology companies, such as Nanophase Technologies in 1989, Helix Energy Solutions Group in 1990, Zyvex in 1997, and Nano-Tex in 1998.

**Carbon Nanotubes**

In 1991, Sumio Iijima of NEC discovered carbon nanotubes, which are tubular structures composed entirely of carbon. Carbon nanotubes exhibit extraordinary properties in terms of strength, electrical and thermal conductivity, and have been explored for various applications in electronics, photonics, multifunctional fabrics, and biology.

**Nanostructured Catalytic Materials**

In 1992, C.T. Kresge and colleagues at Mobil Oil discovered nanostructured catalytic materials MCM-41 and MCM-48. These materials are now used extensively in refining crude oil and have other applications in drug delivery, water treatment, and more.

**Controlled Synthesis of Nanocrystals**

In 1993, Moungi Bawendi at MIT invented a method for the controlled synthesis of nanocrystals, paving the way for applications in computing, biology, and high-efficiency photovoltaics and lighting.

**National Nanotechnology Initiative**

In 2000, President Clinton launched the National Nanotechnology Initiative (NNI) to coordinate federal research and development efforts and promote U.S. competitiveness in nanotechnology.

**Gold Nanoshells**

In 2003, researchers at Rice University developed gold nanoshells, which can be tuned in size to absorb near-infrared light. These nanoshells have promising applications in the integrated discovery, diagnosis, and treatment of breast cancer without invasive biopsies, surgery, or systemically destructive radiation or chemotherapy.

**European Strategy for Nanotechnology**

In 2004, the European Commission adopted the Communication "Towards a European Strategy for Nanotechnology", which proposed institutionalizing European nanoscience and nanotechnology research and development efforts within an integrated and responsible strategy.

**College of Nanoscale Science and Engineering**

In 2004, SUNY Albany launched the first college-level education program in nanotechnology in the United States, the College of Nanoscale Science and Engineering.

**DNA-Based Computation and Algorithmic Self-Assembly**

In 2005, Erik Winfree and Paul Rothemund from the California Institute of Technology developed theories for DNA-based computation and "algorithmic self-assembly". These concepts involve embedding computations in the process of nanocrystal growth, potentially revolutionizing nanoelectronics.

**Nanoscale Car**

In 2006, James Tour and colleagues at Rice University built a nanoscale car made of oligo(phenylene ethynylene) with alkynyl axles and four spherical C60 fullerene (buckyball) wheels. When heated, the nanocar moved about on a gold surface due to the turning of the buckyball wheels, similar to a conventional car.

**Virus-Loaded Lithium-Ion Battery**

In 2007, Angela Belcher and colleagues at MIT built a lithium-ion battery using a common type of virus that is nonharmful to humans. This low-cost and environmentally benign process resulted in batteries with the same energy capacity and power performance as state-of-the-art rechargeable batteries being considered for use in plug-in hybrid cars and personal electronic devices.

**Nanosensors and Nanotechnology Knowledge Infrastructure**

In 2012, the NNI launched two more Nanotechnology Signature Initiatives (NSIs), focusing on nanosensors and the Nanotechnology Knowledge Infrastructure (NKI).

**DNA-Like Robotic Nanoscale Assembly Devices**

In 2009 and 2010, Nadrian Seeman and colleagues at New York University created several DNA-like robotic nanoscale assembly devices, which have potential applications in electronics, photonics, and biology.

**The Future of Nanotechnology**

Nanotechnology continues to make significant strides in various fields, promising to revolutionize industries and improve our quality of life. As our understanding of nanoscience and nanotechnology grows, so too does the potential for new applications in medicine, electronics, materials science, and beyond. The future of nanotechnology is undoubtedly bright, and its impact on our world will be profound.

**Explain how Nanotechnology works in different focus areas.**

Nanotechnology operates in many kinds of fields by using the unique features and behavior of materials at the nanoscale level. Here's how nanotechnology works in different focus areas:

1. Medicine: "Nanotechnology in Medicine'' (Freitas Jr., 2011) the usage of nanotechnology in medicine, that includes the drug delivery, imaging, and diagnostics In drug delivery, nanoparticles can be used to selectively target certain cells or tissues, increasing the treatment efficacy while reducing side effects. Nanoparticles can also be utilized as contrast agents in imaging modalities like magnetic resonance imaging (MRI) and computed tomography (CT), allowing for more accurate visualization of tissues and organs. Biosensors and nanochips are also available. Biosensors can detect specific biomolecules or organisms in biological samples, whereas nanochips can be utilized for high-throughput drug or biomolecule screening.

2. Electronics and computing: Nanotechnology has dramatically impacted the world of electronics and computers by enabling the development of smaller, faster, and more efficient electronic components such as transistors, memory systems, and sensors. This is made possible by the use of nanoscale materials such as graphene and carbon nanotubes, which have promising properties perfect for flexible electronics and high-performance computers.

3. Energy and the Environment: According to Lui (2013), nanotechnology has the potential to revive the field of sustainable energy by developing more efficient and cost-effective energy solutions. Examples of its applications include the use of nanomaterials like carbon nanotubes in solar cells, the development of nanomaterial-based batteries with faster charging rates and higher energy density, and the creation of nanotechnology-based catalysts for fuel cells that convert hydrogen and oxygen into energy. Environmental cleanup, water purification, and air filtration can all benefit from the usage of nanomaterials.

4. Material Science: Nanotechnology is being used in materials science to produce new materials with unique features and behaviors. For instance, by manipulating the size, content, and structure of materials, nanoparticles can create new functions like increased electrical conductivity or mechanical strength. Self-assembling materials, which may spontaneously create intricate structures and patterns at the nanoscale, are another application of nanotechnology.

**Applications of Nanotechnology**

Nanotechnology can significantly improve our lives by transforming different technologies and industrial sectors in unique ways. Scientists and engineers have made rapid progress in application areas of nanotechnology;

**Medical and Healthcare**

* Nanomedicine has the potential to improve medical tools, knowledge, and therapies. It can provide new ways for disease prevention, diagnosis, and treatment. One example is the use of nanoparticles as drug delivery vehicles, which can target specific cells or tissues in the body, resulting in more precise drug delivery. This reduces the side effects that can be caused by medicines, as it minimizes the exposure of healthy cells to the drug.

**Electronics and IT**

* Nanotechnology has the potential to create smaller, faster, and more energy-efficient devices. Examples of these devices include transistors, which can be made from materials like silicon or carbon nanotubes to create more powerful and energy-efficient computer processors. Shrinking the size of transistors can increase the processing power of devices while reducing their size and energy consumption. Other examples of applications of nanotechnology include magnetic random-access memory, ultra-high-definition displays, flexible electronics, and nano sensors.

**Energy Applications and Environmental**

* Nanotechnology offers alternative energy solutions to traditional energy sources, helping to meet the increasing energy demands of the world. This technology can contribute to cleaner, more affordable, and renewable energy sources, reducing environmental impact. One application of nanotechnology in this field is the development of more efficient solar panels, which are cheaper to produce and easier to install. Nanotechnology also helps to improve energy efficiency and offers energy-saving products such as lightweight, quick-charging batteries with higher power density and longer charge lives.
* In addition, nanotechnology can detect and clean up environmental contaminants. Nanoscale sensors and solutions are capable of identifying chemical or biological agents in the air and soil with greater sensitivity than before. It can also help detect impurities in water, promoting affordable and clean drinking water.

**Materials and processes**

* Nanotechnology has also led to the development of new commercial products by using nanoscale materials and processes. Nanoparticles, nanofibers, and nanotubes are being used in a wide range of products, such as cosmetics, textiles, and electronics. Nanotechnology-based processes, such as nanopatterning and self-assembly, are being used to create new materials with unique properties. For example, nanoscale films applied to eyeglasses, computer and camera screens, windows, and other surfaces can provide various benefits such as water and residue repellence, anti-reflection, self-cleaning, resistance to ultraviolet or infrared light, anti-fogging, antimicrobial properties, scratch resistance, and electrical conductivity. In addition, by adding nanoscale additives or surface treatments to fabrics, they can be used as lightweight personal body armor to deflect ballistic energy. Nanotechnology can also improve the properties of fabrics, making them resistant to wrinkling, staining, and bacterial growth.

**Foods and Agriculture**

* Nanotechnology in food and agriculture works by creating new materials and devices that can help enhance food safety, quality, and production. Nanoparticles can be employed to make more effective food packaging materials that prevent spoiling and contamination, while nanoscale sensors can be used to monitor crop health and soil conditions and detect contaminants in food and water. Nanotechnology can also do crop protection; nanoparticles can be utilized as a pesticide, herbicide, and fertilizer delivery mechanism. This can help reduce the amount of chemicals needed for crop protection while also minimizing their environmental impact by targeting specific locations. Lastly, nanoparticles can act as vehicles for delivering nutrients, such as vitamins and minerals, to improve their absorption and bioavailability. This has the potential to enhance nutrient delivery efficiency and improve overall health outcomes.

**Pros and Cons of Nanotechnology**

Due to the development of nanotechnology, people are very excited and hopeful of the inventions that it will create and the benefits that it will give us, however it is important to note that nanotechnology is not fully understood by humans being thus there are still potential risks that could be found in nanotechnology. Here are the pros and con of nanotechnology.

**Pros**

1. **Improved medical advancements.**
   * Nanotechnology has the potential to bring major advancements in medical treatments. It can potentially cure cancer, make surgeries faster and more accurate, repair injuries cell by cell, use nanobots to clear away blockages in patients' arteries, and more. This technology can help improve and prolong human life.
2. **Energy Efficiency**
   * Nanotechnology can provide alternative ways to obtain energy. The development of more effective energy-producing, energy-absorbing, and energy storage products is more possible with this technology. Products created with nanotechnology can reduce energy consumption, lower greenhouse gas emissions, and mitigate the impacts of climate change.
3. **Environmental Benefits** 
   * The use of nanotechnology in environment will make it easier to prevent pollution and reduce waste, doing that will allow us to have sustainable manufacturing processes as reducing waste will improve our product quality.
4. **Improved Materials**
   * Nanotechnology can create products such as nanotubes, aerogels, and nanoparticles that result in upgraded materials. These materials can have properties such as increased strength, hardness, and flexibility, which can be used in a wide range of applications.

**Cons**

1. **Health Risks**
   * Nanotechnology has the potential to provide significant benefits, including the hope of curing hard-to-beat diseases. However, the risks associated with its use are not well understood, and the development of regulations to ensure its safe use is lagging behind its development. Exposure to nanoparticles can lead to respiratory problems, allergies, and toxicity, which can be harmful to people who are exposed repeatedly.
2. **Environmental Risks**
   * The creation of nanomaterials has led to the accumulation of nanoparticles in the environment, which can have a detrimental effect on humans and animals.
3. **Economic**
   * Nanotechnology provides alternative sources of energy, which could lead to decreased demand for fossil fuels. This could have an impact on the economy, as the value of resources like oil and diamonds may decrease. In addition, there is a concern that some jobs may be lost as a result of technological advancements.
4. **Security Risks**

* The ability of nanotechnology to create a wide range of objects poses a security risk. It can be used to create weapons, surveillance devices, counterfeit products, and computing devices that pose a threat to cybersecurity. It is important to have regulations and monitoring in place to prevent misuse and protect public and national security.

1. **Cost and Accessibility**

* While nanotechnology has potential benefits in medical, engineering, and material science disciplines, the cost of the raw materials used in the technology is high, making it expensive for the average person. This may limit access to its benefits for some individuals.

In conclusion, nanotechnology has the potential to provide significant benefits, such as medical advancements, improved energy efficiency, and environmental benefits, as well as the development of stronger and more flexible materials. However, it is important to note that there are also risks associated with its development, such as potential health and environmental risks, ethical concerns, economic concerns, and security risks. To ensure that the benefits of nanotechnology are not outweighed by its potential risks, it is important to implement proper regulations and safeguards to address these concerns. This will help to ensure that the development and use of nanotechnology are safe and not harmful to individuals or the environment.

**Conclusion**

To sum up, the potential of nanotechnology to revolutionize different fields and improve our lives is enormous. By manipulating matter at the atomic and molecular level, nanotechnology offers endless opportunities for progress in areas such as medicine, electronics, and energy. Ongoing research and development in this field are likely to lead to the creation of new materials, devices, and applications that will drive innovation and address global challenges. However, it is important to prioritize responsible and ethical practices to ensure that nanotechnology is implemented safely and sustainably for the benefit of humanity.