Applications of Nano-Technology: A Review

Rangaswamy R,
Assistant Professor, Department of Physics,
Government Sri Krishnarajendra Silver Jubilee Technological Institute,
K R Circle, BENGALURU 560001, Karnataka

ABSTRACT:

Nanotechnology is a fascinating and quickly evolving aspect of engineering that enables us to interact at the radioactive and molecular levels to explore, manage, and apply nanometer-dimensional. It has opened up new prospective applications in biotechnology and molecular biology. Nanotechnology has revolutionized nearly all of the veterinary and animal science disciplines specifically in the developed countries by providing in-depth information and showing what is going on inside the deeper body of an organism. Nano particles used for disease diagnosis, treatment, and delivery of drugs, animal breeding, and reproduction include quantum dots, magnetic nano particles, nano pores, polymeric nano particles, nano shells, fullerenes, liposomes, and dendrimer. Nanotechnology is helping to considerably improve, even revolutionize, many technology and industry sectors like information technology, homeland security, medicine, transportation, energy, food safety, and environmental science, among many others. This paper focusses on applications of Nanotechnology.

Keyword: Nanotechnology, Nanopracticles, nanofood, fabrics, energy applications, medical applications

Introduction

Nanotechnology can be defined as the science and engineering involved in the design, synthesis, characterization, and application of materials and devices whose smallest functional organization, in at least one dimension, is on the nanometer scale or one billionth of a meter. At these scales, consideration of individual molecules and interacting groups of molecules in relation to the bulk macroscopic properties of the material or device becomes important, as it has a control over the fundamental molecular structure, which allows control over the macroscopic chemical and physical properties. Nanotechnology has found many applications in medicine and this article outlines some of its applications.

The term nanotechnology refers to the nano scale-level ability to calculate, function, and organize the matter. The scale usually refers to the matter in the size range of 1–100 nm in at least one dimension but is often extended to include materials in size below 1nm. It is not limited to a specific sector; rather, it is an enabling collection of technologies, which cross all sectors of activity and scientific disciplines. Nanotechnology uses the philosophy and techniques of the nano-scale to understand and transform bio-systems, which use biological concepts and materials to build new nano-scale devices and systems. Rationally engineered nanostructures are among the most impressive man-made materials and unveil distinctive chemical, physical, and/or biological characteristics. Such characteristics make it possible to use the nanostructures for an exceptional number of applications in various sectors including electronics, agriculture, and health care. One of the key benefits of nanotechnology is to close the gap between the worlds of macroscopy and microscopy, where nano particles are the perfect medium to communicate with biological systems.

Nanoparticles have different properties that differentiate them from bulk materials that include large active surfaces, easily controllable surface chemistry that allows binding to small molecular drugs, imaging labels, and ligands such as antibodies, peptides, nucleic acids. Also, their small size allows for exclusive intracellular and extracellular interactions, such as extravasation via endothelial cells and increased permeability and retention in tumor tissues. In this paper, we opt to review the applications of nanotechnology in various fields.

Nanotechnology is the understanding and control of matter at the nanoscale, at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications. Matter can exhibit unusual physical, chemical, and biological properties at the nanoscale, differing in important ways from the properties of bulk materials, single atoms, and molecules. Some nano structured materials are stronger or have different magnetic properties compared to other forms or sizes of the same material. Others are better at conducting heat or electricity. They may become more chemically reactive, reflect light better, or change color as their size or structure is altered.

Although modern nanoscience and nanotechnology are relatively new, nanoscale materials have been used for centuries. Gold and silver nanoparticles created colors in the stained-glass windows of medieval churches hundreds of years ago. Nanotechnology encompasses nanoscale science, engineering, and technology in fields such as chemistry, biology, physics, materials science, and engineering. Nanotechnology research and development involves imaging, measuring, modeling, and manipulating matter between approximately 1–100 nanometers. After more than 20 years of basic nano science research and more than fifteen years of focused R&D under the NNI, applications of nanotechnology are delivering in both expected and unexpected ways on nanotechnology's promise to benefit society.

Nanotechnology is helping to considerably improve, even revolutionize, many technology and industry sectors like information technology, homeland security, medicine, transportation, energy, food safety, and environmental science, among many others. Described below is a sampling of the rapidly growing list of benefits and applications of nanotechnology.

Nanotechnology Applications:

Medicine: Researchers are developing customized nanoparticles the size of molecules that can deliver drugs directly to diseased cells in your body. When it's perfected, this method should greatly reduce the damage treatment such as chemotherapy does to a patient's healthy cells. Nano medicine and nano delivery systems are a relatively new but rapidly developing science where materials in the nanoscale range are employed to serve as means of diagnostic tools or to deliver therapeutic agents to specific targeted sites in a controlled manner.

Cancer nanotechnology is a branch of nanotechnology concerned with the application of both nanomaterials (such as nanoparticles for tumour imaging or drug delivery) and nanotechnology approaches (such as nanoparticle-based theranostics) to the diagnosis and treatment of cancer.Most harmful side effects of treatments such as chemotherapy are a result of drug delivery methods which do not pinpoint their intended target cells accurately.

Electronics:

Nanotechnology has greatly contributed to major advances in computing and electronics, leading to faster, smaller, and more portable systems that can manage and store larger and larger amounts of information. Transistors, the basic switches that enable all modern computing, have gotten smaller and smaller through nanotechnology. At the turn of the century, a typical transistor was 130 to 250 nanometers in size. In 2014, Intel created a 14 nanometer transistor, then IBM created the first seven nanometer transistor in 2015, and then Lawrence Berkeley National Lab demonstrated a one nanometer transistor in 2016!

Using magnetic random access memory (MRAM), computers will be able to "boot" almost instantly. MRAM is enabled by nanometer-scale magnetic tunnel junctions and can quickly and effectively save data during a system shutdown or enable resume-play features. Ultra-high definition displays and televisions are now being sold that use quantum dots to produce more vibrant colors while being more energy efficient. Flexible, bendable, foldable, rollable, and stretchable electronics are reaching into various sectors and are being integrated into a variety of products, including wearables, medical applications, aerospace applications, and the Internet of Things. Flexible electronics have been developed using, for example, semiconductor nanomembranes for applications in smartphone and e-reader displays. Other nanomaterials like graphene and cellulosic nanomaterials are being used for various types of flexible electronics to enable wearable and "tattoo" sensors, photovoltaics that can be sewn onto clothing, and electronic paper that can be rolled up. Making flat, flexible, lightweight, non-brittle, highly efficient electronics opens the door to countless smart products.

Other computing and electronic products include Flash memory chips for smart phones and thumb drives; ultra-responsive hearing aids; antimicrobial/antibacterial coatings on keyboards and cell phone casings; conductive inks for printed electronics for RFID/smart cards/smart packaging; and flexible displays for e-book readers. Nanoparticle copper suspensions have been developed as a safer, cheaper, and more reliable alternative to lead-based solder and other hazardous materials commonly used to fuse electronics in the assembly process.

Nanotechnology holds some answers for how we might increase the capabilities of electronics devices while we reduce their weight and power consumption. Scientists have been studying and working with nano particles for centuries and they were unable to see the structure of nano particles. With the development of microscopes in recent decades, scientists got the ability to see nano-sized materials which are as small as atoms and this had opened up a world of possibilities in a variety of industries and scientific endeavors. Designers Face hurdles for the future of Nano electronics. High-performance logic circuits and Semiconductor memory had been the technology drivers to architect the miniaturization of the MOS transistor. The scaling of MOS transistor in nano electronics explores new materials like high-k gate dielectrics such as $HfO2$, $Er2O3$, $Gd2O3$; new channel materials such as germanium and grapheme and finally new device structures like double-gate FET, FinFET, Schottky source/drain FET.

Medical Applications:

Nanotechnology is already broadening the medical tools, knowledge, and therapies currently available to clinicians. Nanomedicine, the application of nanotechnology in medicine, draws on the natural scale of biological phenomena to produce precise solutions for disease prevention, diagnosis, and treatment. Below are some examples of recent advances in this area:

- Commercial applications have adapted gold nanoparticles as probes for the detection of targeted sequences of nucleic acids, and gold nanoparticles are also being clinically investigated as potential treatments for cancer and other diseases.
- Better imaging and diagnostic tools enabled by nanotechnology are paving the way for earlier diagnosis, more individualized treatment options, and better therapeutic success rates.
- Nanotechnology is being studied for both the diagnosis and treatment of atherosclerosis, or the buildup of plaque in arteries. In one technique, researchers created a nanoparticle that mimics the body's "good" cholesterol, known as HDL (high-density lipoprotein), which helps to shrink plaque.
- The design and engineering of advanced solid-state nanopore materials could allow for the development of novel gene sequencing technologies that enable single-molecule detection at low cost and high speed with minimal sample preparation and instrumentation.
- Nanotechnology researchers are working on a number of different therapeutics where a nanoparticle can encapsulate or otherwise help to deliver medication directly to cancer cells and minimize the risk of damage to healthy tissue. This has the potential to change the way doctors treat cancer and dramatically reduce the toxic effects of chemotherapy.

Research in the use of nanotechnology for regenerative medicine spans several application areas, including bone and neural tissue engineering. For instance, novel materials can be engineered to mimic the crystal mineral structure of human bone or used as a restorative resin for dental applications. Researchers are looking for ways to grow complex tissues with the goal of one day growing human organs for transplant. Researchers are also studying ways to use graphene nanoribbons to help repair spinal cord injuries; preliminary research shows that neurons grow well on the conductive graphene surface. Nanomedicine researchers are looking at ways that nanotechnology can improve vaccines, including vaccine delivery without the use of needles. Researchers also are working to create a universal vaccine scaffold for the annual flu vaccine that would cover more strains and require fewer resources to develop each year.

Energy Applications:

Nanotechnology is finding application in traditional energy sources and is greatly enhancing alternative energy approaches to help meet the world's increasing energy demands. Many scientists are looking into ways to develop clean, affordable, and renewable energy sources, along with means to reduce energy consumption and lessen toxicity burdens on the environment:

- Nanotechnology is improving the efficiency of fuel production from raw petroleum materials through better catalysis. It is also enabling reduced fuel consumption in vehicles and power plants through higher-efficiency combustion and decreased friction.

- Nanotechnology is also being applied to oil and gas extraction through, for example, the use of nanotechnology-enabled gas lift valves in offshore operations or the use of nanoparticles to detect microscopic down-well oil pipeline fractures.
- Researchers are investigating carbon nanotube “scrubbers” and membranes to separate carbon dioxide from power plant exhaust.
- Researchers are developing wires containing carbon nanotubes that will have much lower resistance than the high-tension wires currently used in the electric grid, thus reducing transmission power loss.
- Nanotechnology can be incorporated into solar panels to convert sunlight to electricity more efficiently, promising inexpensive solar power in the future. Nano-structured solar cells could be cheaper to manufacture and easier to install, since they can use print-like manufacturing processes and can be made in flexible rolls rather than discrete panels. Newer research suggests that future solar converters might even be “paintable.”
- Nanotechnology is already being used to develop many new kinds of batteries that are quicker-charging, more efficient, lighter weight, have a higher power density, and hold electrical charge longer.
- An epoxy containing carbon nano-tubes is being used to make windmill blades that are longer, stronger, and lighter-weight than other blades to increase the amount of electricity that windmills can generate.
- In the area of energy harvesting, researchers are developing thin-film solar electric panels that can be fitted onto computer cases and flexible piezoelectric nano-wires woven into clothing to generate usable energy on the go from light, friction, and/or body heat to power mobile electronic devices. Similarly, various nanoscience-based options are being pursued to convert waste heat in computers, automobiles, homes, power plants, etc., to usable electrical power.
- Energy efficiency and energy saving products are increasing in number and types of application. In addition to those noted above, nanotechnology is enabling more efficient lighting systems; lighter and stronger vehicle chassis materials for the transportation sector; lower energy consumption in advanced electronics; and light-responsive smart coatings for glass.

Food: Nanotechnology is having an impact on several aspects of food science, from how food is grown to how it is packaged. Companies are developing nano materials that will make a difference not only in the taste of food, but also in food safety, and the health benefits that food delivers. Nanotechnology can be used to enhance food flavor and texture, to reduce fat content, or to encapsulate nutrients, such as vitamins, to ensure they do not degrade during a product's shelf life. In addition to this, nano materials can be used to make packaging that keeps the product inside fresher for longer.

Inorganic nanomaterials for application in food food additives, food packaging or storage include ENMs of transition metals, such as silver and iron; alkaline earth metals, such as calcium and magnesium; and non-metals, such as selenium and silicates. Other ENMs that can potentially be used in food applications include titanium dioxide. Food packaging is the major area of application of metal (oxide) ENMs. Nanoselenium is being marketed as an additive to a green tea product, with a number of (proclaimed) health benefits resulting from enhanced uptake of selenium. Nanocalcium salts are the subject of patent applications for intended use in chewing gums. Nanocalcium and nanomagnesium salts are also available as health supplements

Nano food:

Nano food has, in fact, been part of food processing for centuries, since many food structures naturally exist at the nanoscale. The purpose of nanofood is to improve food safety, enhance nutrition and flavor, and cut costs. Although nanofood is still in its infancy, nano particles are now finding application as a carrier of antimicrobial polypeptides required against microbial deterioration of food quality in the food industry. The current nanotechnology applications in food science provide the detection of food pathogens, through nano sensors that are quick, sensitive and less labor-intensive procedures.

Nanotechnology is being used to reduce the cost of catalysts used in fuel cells to produce hydrogen ions from fuel such as methanol and to improve the efficiency of membranes used in fuel cells to separate hydrogen ions from other gases such as oxygen. Fuel cells contain membranes that allow hydrogen ions to pass through the cell but do not allow other atoms or ions, such as oxygen, to pass through. Companies are using nanotechnology to create more efficient membranes. There are many limitations preventing fuel cells from reaching widespread commercial use, however. Expensive materials such as platinum are needed for the electrode catalysts. Fuels other than hydrogen can cause fouling of the electrodes, and hydrogen is costly to produce and difficult to store. The most efficient types of fuel cell operate at very high temperatures, which reduces their lifespan due to corrosion of the fuel cell components. Nanotechnology may be able to ease many of these problems. Recent nanotechnology research has produced a number of promising nanomaterials which could make fuel cells cheaper, lighter and more efficient. The electrocatalytic activity of these modified nanotubes can actually be superior to that of platinum - the power output of a fuel cell using carbon nanotube electrodes is equal to or greater than that from the platinum equivalent.

Companies have developed nanotech solar cells that can be manufactured at significantly lower cost than conventional solar cells. Nanotechnology solar cell which absorbs both sunlight and indoor light and converts it into electricity. The basic concept is that Plastic is made using nanoscale titanium particles coated in photovoltaic dyes, which generate electricity when they absorb light. Reduced manufacturing costs as a result of using a low temperature process similar to printing instead of the high temperature vacuum deposition process typically used to produce conventional cells made with crystalline semiconductor material. Reduced installation costs achieved by producing flexible rolls instead of rigid crystalline panels. Cells made from semiconductor thin films will also have this characteristic. Currently available nanotechnology solar cells are not as efficient as traditional ones, however their lower cost offsets this. In the long term nanotechnology versions should both be lower cost and, using quantum dots, should be able to reach higher efficiency levels than conventional ones.

Companies are currently developing batteries using nanomaterials. One such battery will be a good as new after sitting on the shelf for decades. Another battery can be recharged significantly faster than conventional batteries. Increasing the available power from a battery and decreasing the time required to recharge a battery. These benefits are achieved by coating the surface of an electrode with nanoparticles. This increases the surface area of the electrode thereby allowing more current to flow between the electrode and the chemicals inside the battery. This technique could increase the efficiency of hybrid vehicles by significantly reducing the weight of the batteries needed to provide adequate power. Increasing the shelf life of a battery by using nanomaterials to separate liquids in the battery from the solid electrodes when there is no draw on the battery. This separation prevents the low level discharge that occurs in a conventional battery, which increases the shelf life of the battery dramatically. Ultra-capacitors using nanotubes may do even better than batteries in hybrid cars. Electrical generator built with nanostructured material that can produce watts of electrical power from walking.

Nanotechnology may hold the key to making space-flight more practical. Advancements in nanomaterials make lightweight spacecraft and a cable for the space elevator possible. By significantly reducing the amount of rocket fuel required, these advances could lower the cost of reaching orbit and traveling in space. Nanotechnology may hold the key to making space flight more practical. Advancements in nanomaterials make lightweight solar sails and a cable for the space elevator possible. By significantly reducing the amount of rocket fuel required, these advances could lower the cost of reaching orbit and traveling in space.Researchers are looking into the following applications of nanotechnology in space flight:

Employing materials made from carbon nanotubes to reduce the weight of spaceships like the one shown below while retaining or even increasing the structural strength. Photo courtesy of NASA Using carbon nanotubes to make the cable needed for the space elevator, a system which could significantly reduce the cost of sending material into orbit. Working with Nano sensors to monitor the levels of trace chemicals in spacecraft to monitor the performance of life support systems.

Nanotechnology can address the shortage of fossil fuels such as diesel and gasoline by making the production of fuels from low grade raw materials economical, increasing the mileage of engines, and making the production of fuels from normal raw materials more efficient. Making the production of fuels from low grade raw materials economical. Increasing the mileage of engines. Making the production of fuels from normal raw materials more efficient.

Nanotechnology can do all this by increasing the effectiveness of catalysts. Catalysts can reduce the temperature required to convert raw materials into fuel or increase the percentage of fuel burned at a given temperature. Catalysts made from nanoparticles have a greater surface area to interact with the reacting chemicals than catalysts made from larger particles. Nanotechnology, in the form of genetic engineering, can also improve the performance of enzymes used in the conversion of cellulose into ethanol. Currently ethanol added to gasoline in the United States is made from corn, which is driving up the price of corn. The plan is to use engineered enzymes to break down cellulose into sugar, is fermented to turn the sugar into ethanol. This will allow material that often goes to waste, such as wood chips and grass to be turned into ethanol.

Nanotechnology can improve the performance of catalysts used to transform vapors escaping from cars or industrial plants into harmless gasses. That's because catalysts made from nanoparticles have a greater surface area to interact with the reacting chemicals than catalysts made from larger particles. The larger surface area allows more chemicals to interact with the catalyst simultaneously, which makes the catalyst more effective. Nanotechnology is being used to develop solutions to three very different problems in water quality. One challenge is the removal of industrial wastes, such as a cleaning solvent called TCE, from groundwater. Nanoparticles can be used to convert the contaminating chemical through a chemical reaction to make it harmless. Studies have shown that this method can be used successfully to reach contaminates dispersed in underground ponds and at much lower cost than methods which require pumping the water out of the ground for treatment.

Nanotechnology can enable sensors to detect very small amounts of chemical vapors. Various types of detecting elements, such as carbon nanotubes, zinc oxide nanowires or palladium nanoparticles can be used in nanotechnology-based sensors. Because of the small size of nanotubes, nanowires, or nanoparticles, a few gas molecules are sufficient to change the electrical properties of the sensing elements. This allows the detection of a very low concentration of chemical vapors.

Chemical sensor using Nano cantilevers that are oscillating at their resonance frequency. When the chemical attaches to the cantilever it stops the oscillation, which triggers a detection signal. Nano cantilevers can also be used to detect biological molecules, such as viruses. The cantilever is coated with antibodies that capture the particular virus, when a virus particle attaches to the an antibody the resonance frequency of the cantilever changes. Sensors using nanoporous silicon detection elements that could be incorporated into cell phones. This might allow a very widespread network of sensors to detect chemical gas leaks or release of a toxin. Sensors powered by electricity generated by piezoelectric zinc oxide nanowires. This could allow small, self contained, sensors powered by mechanical energy such as tides or wind.

Fabrics: Making composite fabric with nano-sized particles or fibers allows improvement of fabric properties without a significant increase in weight, thickness, or stiffness as might have been the case with previously-used techniques. Nanotechnology fabrics are textiles manufactured to have special qualities like hydrophobicity and high durability. These characteristics are created by weaving nano fibers that have certain properties and which creates dirt and water resistance. Nanotechnology fabrics are a relatively new and expanding field. They have applications in bioengineering, electrical engineering and computer science.

Nanotechnology fabrics can be produced using a number of different procedures. One of these processes is called Sol-gel and it immerses fabrics in a gel solution to deposit nanoparticles into the material. Another process uses plasma to create nanotechnology fabrics. Plasma creates radical sites on the fabric and can be used to insert nanoparticles onto the surface as well. Some important and useful applications for nanotechnology fabrics include wrinkle and stain resistant clothing and antimicrobial clothing for hospitals. These effects can be produced on fabrics using Thierry plasma systems with a fast and effective microwave plasma process.

- In addition to the ways that nanotechnology can help improve energy efficiency (see the section above), there are also many ways that it can help detect and clean up environmental contaminants:

- Nanotechnology could help meet the need for affordable, clean drinking water through rapid, low-cost detection and treatment of impurities in water.
- Engineers have developed a thin film membrane with nanopores for energy-efficient desalination. This molybdenum disulphide (MoS_2) membrane filtered two to five times more water than current conventional filters.
- Nanoparticles are being developed to clean industrial water pollutants in ground water through chemical reactions that render the pollutants harmless. This process would cost less than methods that require pumping the water out of the ground for treatment.
- Researchers have developed a nanofabric "paper towel" woven from tiny wires of potassium manganese oxide that can absorb 20 times its weight in oil for cleanup applications. Researchers have also placed magnetic water-repellent nanoparticles in oil spills and used magnets to mechanically remove the oil from the water.
- Many airplane cabin and other types of air filters are nanotechnology-based filters that allow "mechanical filtration," in which the fiber material creates nanoscale pores that trap particles larger than the size of the pores. The filters also may contain charcoal layers that remove odors.

Nanotechnology-enabled sensors and solutions are now able to detect and identify chemical or biological agents in the air and soil with much higher sensitivity than ever before. Researchers are investigating particles such as self-assembled monolayers on mesoporous supports (SAMMS™), dendrimers, and carbon nanotubes to determine how to apply their unique chemical and physical properties for various kinds of toxic site remediation. Another sensor has been developed by NASA as a smartphone extension that firefighters can use to monitor air quality around fires.

Nanotechnology offers the promise of developing multifunctional materials that will contribute to building and maintaining lighter, safer, smarter, and more efficient vehicles, aircraft, spacecraft, and ships. Nano-engineering of aluminum, steel, asphalt, concrete and other cementitious materials, and their recycled forms offers great promise in terms of improving the performance, resiliency, and longevity of highway and transportation infrastructure components while reducing their life cycle cost. New systems may incorporate innovative capabilities into traditional infrastructure materials, such as self-repairing structures or the ability to generate or transmit energy.

Nanoscale sensors and devices may provide cost-effective continuous monitoring of the structural integrity and performance of bridges, tunnels, rails, parking structures, and pavements over time. Nanoscale sensors, communications devices, and other innovations enabled by nanoelectronics can also support an enhanced transportation infrastructure that can communicate with vehicle-based systems to help drivers maintain lane position, avoid collisions, adjust travel routes to avoid congestion, and improve drivers' interfaces to onboard electronics.

A preliminary analysis performed for NASA has indicated that the development and use of advanced nanomaterials with twice the strength of conventional composites would reduce the gross weight of a launch vehicle by as much as 63 percent. Not only could this save a significant amount of energy needed to launch spacecraft into orbit, but it would also enable the development of single stage to orbit launch vehicles, further reducing launch costs, increasing mission reliability, and opening the door to alternative propulsion concepts.

Conclusion

Nanotechnology has made enormous progress over the past few decades. Nanotechnology is a fascinating and quickly evolving aspect of engineering that enables us to interact at the radioactive, and molecular levels to explore, manage, and apply nanometer-dimensional. It has opened up new prospective applications in nanotechnology or systems / device manufacture at the molecular level, is a multidisciplinary scientific field undergoing explosive development. The genesis of nanotechnology can be traced to the promise of revolutionary advances across medicine, communications, genomics and robotics biotechnology and molecular biology. Nanotechnology has revolutionized nearly all science disciplines specifically in the developed countries by providing in-depth information. While nanotechnology is considered one of the big advances now applied in various fields, relative to other sister disciplines, it is still in the early stages of its application to all aspects. Furthermore, the complexity of the technology to use and its high cost rendered particularly the developing countries to apply the technology in their all sectors.

Nanotechnology has been widely studied for its potential to advance the field of biotechnology and medical research. Regulatory agencies such as the FDA have decided to oversee the emerging field of nanotechnology through existing legislative arrangements. The decision to refrain from introducing nano specific regulatory policies seems to be aimed at encouraging safe and effective innovations by avoiding unnecessary regulatory hurdles. As the nanotechnology advances and more scientific information becomes available regarding its potential benefits and undesirable consequences, more stringent governance may be needed for certain product types to safeguard the public health. What is required to create valuable regulatory policies are coordinated global communications and information sharing between academic, industry, and government entities that are concerned with nanotechnology. This could facilitate responsible development of nano materials that could potentially prolong and enhance the human lives.

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