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A Review on Applications of Nanotechnology: Triumph of Miniaturization

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Abstract: Nanotechnology is changing the way materials and devices will be made in the future. With the ability to build products and devices atom-by-atom and molecule-by-molecule, according to the National Nanotechnology Initiative (NNI), a federal research and development program, scientists will create new classes of structural materials that are expected to bring about lighter, stronger, smarter, cheaper, cleaner and more precise products. Nanotechnology is rapidly becoming the latest buzz word. Already many products in the market place owe there existence to nanotechnology for example, CDs, air bag, pressure sensors and printers. Even some popular brands of cars now have running boards made out of polymers reinforced with carbon nanotubes. The technology will also change the scenario of war and the warfare will become more precise and small. It will be difficult to prepare adequately for such a powerful technology. For all these reasons, molecular manufacturing technologies should be a current topic in high-level policy and planning.

Key words: Nanomachines · Nanorobots · Nanodots · Grey goo

INTRODUCTION

The essence of nanotechnology is to work at molecular level, which is one-thousandth of a micrometer [1]. It is the engineering of tiny machines, the projected ability to build things from the bottom up inside personal nanofactories (PNs), using techniques and tools being developed today to make complete, highly advanced products. Eventually, nanotechnology will allow control of matter at the nanometer scale, using mechanochemistry. Shortly after this molecular machinery is created, it will result in a manufacturing revolution. It also has got alluring prospects in economic, social, environmental and military implications. The whole concept of advanced nanotechnology molecular manufacturing (MM) is so multifaceted and unfamiliar and so amazing in its implications, that a few scientists, engineers and other pundits have flatly declared it to be impossible. The debate is further confused by science-fictional hype and media misconceptions.

When K. Eric Drexler popularized the word 'nanotechnology' in the 1980's, he was talking about building machines on the scale of molecules, a few nanometers wide motors, robot arms and even whole computers, far smaller than a cell. Drexler spent the next ten years describing and analyzing these incredible devices and responding to accusations of science fiction. Meanwhile, mundane technology was developing the ability to build simple structures on a molecular scale. As nanotechnology became an accepted concept, the meaning of the word shifted to encompass the simpler kinds of nanometer-scale technology. The U.S. National Nanotechnology Initiative was created to fund this kind of nanotech: their definition includes anything smaller than 100 nanometers with novel properties. Much of the work being done today that carries the name 'nanotechnology' is not nanotechnology in the original meaning of the word. Nanotechnology, in its traditional sense, means building things from the bottom up, with atomic precision. Resembling electricity or computers before it, nanotech will offer greatly improved efficiency in almost every facet of life. But as a general-purpose technology, it will be dual-use, meaning it will have many commercial uses and it also will have many military uses making far more powerful weapons and tools of surveillance. Thus it represents not only wonderful benefits for humanity, but also posed risks.

Molecular Manufacturing: Molecular manufacturing is the construction of objects to complex, atomic specifications using sequences of chemical reactions directed by nonbiological molecular machinery [2]. Molecular nanotechnology comprises molecular manufacturing together with its techniques, its products and their design and analysis; it describes the field as a whole [3]. Some of the recent innovations include.

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Nanocomposites: Researchers at Pacific Northwest National Laboratory have developed a coating process to make sponge-like silica latch onto toxic metals in water. Self-Assembled Monolayers on Mesoporous Supports easily captures such metals as lead and mercury, which are then recovered for reuse or controlled in-place forever.

Nanocrystals: Metal nanocrystals might be incorporated into car bumpers, making the parts stronger, or into aluminum, making it more wear resistant. Metal nanocrystals might be used to produce bearings that last longer than their conventional counterparts, new types of sensors and components for the computers and electronic hardware [4]. Nanocrystals of various metals have been shown to be 100 percent, 200 percent and even as much as 300 percent harder than the same materials in bulk form. Because wear resistance often is dictated by the hardness of a metal, parts made from nanocrystals might last significantly longer than conventional parts. Six different quantum dot solutions have been observed to get excited with a long-wave UV lamp. Quantum dots are molecular-scale optical beacons. Qdot™ nanocrystals behave like molecular LEDs (light emitting diodes) by "lighting up" biological binding events with a broad palette of applied colors.

Nanocrystals are an ideal light harvester in photovoltaic devices. They absorb sunlight more strongly than dye molecules or bulk semiconductor material; therefore high optical densities can be achieved while maintaining the requirement of thin films. Fluorescent nanocrystals have several advantages over organic dye molecules as fluorescent markers in biology. They are incredibly bright and do not photodegrade [5]. Drug-conjugated nanocrystals attach to the protein in an extracellular fashion, enabling movies of protein trafficking. These also form the basis of a high-throughput fluorescence assay for drug discovery.

Nanotubes: Carbon nanotubes (CNTs) are allotropes of carbon. A single wall carbon nanotube is a one-atom thick sheet of graphite (called graphene) rolled up into a seamless cylinder with diameter of the order of a nanometer. This results in a nanostructure where the length-to-diameter ratio exceeds 10,000. Such cylindrical carbon molecules have unique properties that make them potentially useful in a wide variety of applications in nanotechnology, electronics, optics and other fields of materials science. They exhibit extraordinary strength and unique electrical properties and are efficient conductors of heat. Inorganic nanotubes have also been synthesized. Nanotubes are members of the fullerene structural family, which also includes buckyballs. There are two main types of nanotubes: single-walled nanotubes (SWNTs) and multi-walled nanotubes (MWNTs).

Nanofilters: Nanoparticles and nanofiltration products, makes a filter that is capable of filtering the smallest of particles. The performance is due to its nano size alumina fiber, which attracts and retains sub-micron and nanosize particles. This disposable filter retains 99.9999% of viruses at water flow rates several hundred times greater than virus-rated ultra porous membranes. It is useful for sterilization of biological, pharmaceutical and medical serums, protein separation, collector/concentrator for biological warfare detectors and several other applications. In the future, for one application, sterilizing drinking water, this product may have an impact on so-called Third World peoples, who only have access to unsure sources of water.

Nanorobots: Nanorobots are nanodevices that will be used for the purpose of maintaining and protecting the human body against pathogens. They will have a diameter of about 0.5 to 3 microns and will be constructed out of parts with dimensions in the range of 1 to 100 nanometers. The main element used will be carbon in the form of diamond / fullerene nanocomposites because of the strength and chemical inertness of these forms. Many other light elements such as oxygen and nitrogen can be used for special purposes. To avoid being attacked by the host’s immune system, the best choice for the exterior coating is a passive diamond coating. The smoother and more the coating less will be the reaction from the body’s immune system.

Nubot is an abbreviation for "Nucleic Acid Robots." Nubots are synthetic robotics devices at the nanoscale. Representative nubots include the several DNA walkers reported by Ned Seeman's group at NYU, Niles Pierce's group at Caltech, John Reif's group at Duke University, Chengde Mao's group at Purdue and Andrew Turberfield's group at the University of Oxford.

Nanotechnology and Environment: Nanotechnology research is forming part of the quest to prevent and reverse environmental damage. Researchers aim to use nanotechnology to provide efficient and effective filters for water and air, leading to reduced pollution. A membrane that can purify water and is also self-cleaning to avoid contamination should be available in the near to medium-term. Improved catalysts, composed of nanoparticles, are already in use in petrol and chemical processing, resulting in less waste in these processes.

Using Carbon Nanotube Fuel Cells to Store Hydrogen: Perhaps the most promising application in both the environmental and energy areas is the development of fuel cells, with many different uses. Research is being undertaken into the effectiveness of carbon nanotubes at storing hydrogen; these have the potential to power cars, amongst other things, with water as the only emission, although this is some way from commercialisation.

Photovoltaics: Photovoltaics are another focus of nanotechnology development, with the ultimate aim being highly efficient, cheap, lightweight, possibly flexible, solar cells made from plastics. A breakthrough in this field is predicted to occur by 2020.

Biomimicry: Biomimicry is one key element in this research, as scientists attempt to copy plants photosynthesis mechanism. The conversion of sunlight to hydrogen would bring together photovoltaics and biomimicry and should be possible in the medium-term. Taken together, improvements in sources of renewable energy, with the development of storage of gaseous hydrogen and the improvement of fuel cells, could lead to a viable 'hydrogen economy' in which the energy needs of society were no longer reliant on fossil fuels.

Managing Technology: It seems like thrilling. A small appliance, about the size of a washing machine, that is able to manufacture almost anything. It is called a nanofactory. Fed with simple chemical stocks, this amazing machine breaks down molecules and then reassembles them into any product you ask for. Packed with nanotechnology and robotics, weighing 200 pounds and standing half as tall as a person, it can produce two tons per day of products. Control is simple: a touch screen selects the type and number of products to produce. It costs very little to operate, just the price of materials fed into it. In one hour, $20 worth of chemicals can be converted into 100 pairs of shoes, or 50 shovels, or 200 cell phones, or even a duplicate nanofactory. Impossible? Today, maybe, but not tomorrow. The technology to create such a machine is speedily being developed. A nanofactory will be the end result of a convergence between nanotechnology (molecular scale engineering), rapid prototyping and automated assembly. These are all present-day technologies. None of them has yet reached its full potential, but each of them is advancing rapidly, driven by powerful economic, social and military forces. The integration of the three technologies will be far more powerful than the sum of the parts.

A technology this powerful has implications in the areas of national security, commercial rights, human rights, global environment and even cultural stability. Any single organization with a narrow focus will create too many regulations while trying to control things that it does not know how to control; too many regulations will create an unregulated black market, which creates unacceptable risks. We believe that MNT must be regulated at a global level, but the regulatory system must be designed with extreme care to be acceptable to the world's population and to avoid the internal corruption that naturally accompanies so much power. The design of such a system is one main concern [6].

The Grey Goo Trouble: *Grey goo* refers to a hypothetical end-of-the-world scenario involving molecular nanotechnology in which out-of-control self-replicating robots consume all living matter on Earth while building more of them (a scenario known as ecophagy). The term "grey goo" is usually used in a science fiction or popular-press context. In the worst postulated scenarios (requiring large, space-capable machines), matter beyond Earth would also be turned into goo (with "goo" meaning a large mass of replicating nanomachines lacking large-scale structure, which may or may not actually appear goo-like). The disaster is posited to result from a deliberate doomsday device or from an accidental mutation in a self-replicating nanomachine used for other purposes, but designed to operate in a natural environment. Fear of runaway nanobots, or "grey goo", is more of a public issue than a scientific problem [7]. Grey goo as a result of out of control nanotechnology played a starring role in an article titled "The Grey Goo Problem" by Lawrence Osborne in today's New York Times Magazine. The idea that nanotechnology manufacturing systems could run amok is based on outdated information.

Defense Nanotechnology: Exploration of nanotechnology will create many new defense related innovations, which are likely to have applications in the civilian sector as well. At the MIT Institute for soldier Nanotechnologies, we see nanotechnology offering war fighters and others in hazardous situations key survivability capabilities through miniaturization, advanced information technology and new materials properties. Numerous other defense applications will benefit from new materials properties attainable through nanoscale engineering. Lightweight, non-bulky materials that protect the torso and extremities against bullets, shrapnel and blast waves are a major goal. Creating materials with dynamic properties those that can change shape or go from liquid to solid reversibly might make possible automatic wound remediation, artificial muscle power, or smart armor systems, all incorporated into a clothing system. Nanoscale coatings just a few molecules thick will offer ways to create multifunctional surfaces those that are water and microbe-resistant, for example, without adding weight. Many of the technologies developed for protecting military personnel will also have significant value for homeland security providers, local police and firefighters and other first responders.

Other Stated Applications Include:

- Information dominance through advanced nanoelectronics,
- More sophisticated virtual reality systems,
- Increased use of enhanced automation and robotics,
- Required improvements in chemical/ biological/ nuclear sensing,
- Design improvements in systems used for nuclear non-proliferation monitoring and management, combined nanomechanical and micromechanical devices for control of nuclear defense systems.

In addition, such nanotechnologies might be 'cleaner' and 'safer' and less likely to cause collateral damage than the technologies they replace, making them especially appealing to military planners. For example, Micro-Electro Mechanical System (MEMS) have many potential uses in the battlefield, largely due to their built-in mechanical functions that allow them to act as sensors and actuators. Actuators in particular extend the functionality of sensors by allowing them to respond to the environment with the usage of force [8]. Applications of MEMS in military systems include ammunition, petroleum, food, as well as enabling a host of other smarter, more efficient logistics operations.

CONCLUSION

Advanced nanotechnology promises the ability to build atomically precise machines and components of molecular size. Using mechanically guided chemistry, rapid prototyping and automated convergent assembly, an integrated system of productive nanosystems hat we call a nanofactory could combine these molecular components into large and complex products, including additional nanofactories. Unfortunately, a technology this powerful could easily be misused. The rapid development cycle and massive manufacturing capability may lead to an unstable arms race between competing powers. Excessive restrictions that limit access to the technology or limit distribution of the benefits may lead to an inhumane gap between rich and poor and may encourage a black market in unsafe molecular manufacturing. Insufficient restrictions may allow small groups and even individuals to produce undesirable products or terrorist tools.

We cannot predict the future and we cannot predict the consequences of our actions. Nevertheless, what we do will make a difference and we can begin by trying to avoid every major blunder we can identify. Beyond this, we can try to understand our situation, weigh our basic values and choose our actions with whatever wisdom we can muster. The choices we make in the coming years will shape a future that stretches beyond our imagining, a future full of danger, yet full of promise [9]. Above all social acceptance of this technology will govern its commercial possibility, which will further provide opportunities to meet sustainable development challenges.

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