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Nanotechnology: Recent Developments, Applications, Risk and Techniques

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Abstract:
Actually nanotechnology is a very broad area of study and research at present. It has been developed by many researchers and includes several fields of study like physics, chemistry, biology, material science, and engineering and computer science. In this paper, we explore the nanotechnology development and application and risks of nanotechnology and identify the needs and opportunities of computer science research in nanotechnology. This paper is intended to benefit computer scientists who are keen to contribute their works to the field of nanotechnology. In this paper, we are mainly concerned with top down approach and bottom up fabrication approach of nanotechnology that directly affects modern computer design and architecture.

Keywords: nanotechnology, nanofabrication, quantum dots, carbon nanotubes, nanodesign, nanomedicine, nanorobots, nanocomputers

1. INTRODUCTION

Nanotechnology is rapidly becoming a ubiquitous technology with a potential to impact on every aspect of modern human civilization. Almost every aspect of human endeavor will be affected, such as agriculture and food, communication, computers, environmental monitoring, textiles, robotics, healthcare and medical technology. More recently computer science has become involved in nanotechnology. Such research is wide ranging and includes: software engineering, networking, internet security, image processing, virtual reality, human- machine interface, artificial intelligence and intelligent systems (5,6). The extensive use of computer and its wide application in the modern world have forced the researchers to improve and manufacture a smaller, faster and a more reliable computer. This objective can be fulfilled by nanotechnology. According to M.C. Roco, the third and fourth generation of nanotechnology would rely heavily on research in computer science. Now, let us try to understand the meaning of nanotechnology and its implication.

I. Definition Of Nanotechnology

Nanotechnology is a term widely talked and written about today but what exactly does it mean? In one sense, nanoparticles and nanostructures are not new. They have been part of nature and of life for thousands of millions of years. What is relatively new, however, is our ability as humans to work, measure and manipulate at the nano-level across a range of disciplines like physics, chemistry and biology, and to be able to create new materials and products with novel nano-level characteristics. Nano comes from the Greek word meaning “dwarf” and means 10-9 or one-billionth.[1,2] Here it refers to one-billionth of a meter, or 1 nanometer (nm). 1 nanometer is about 3 atoms long. Fig 1 shows the scale of things.

II. Man Behind Nanotechnology

K. Eric Drexler has coined or popularized or propounded the term “nanotechnology” in the 1980’s.

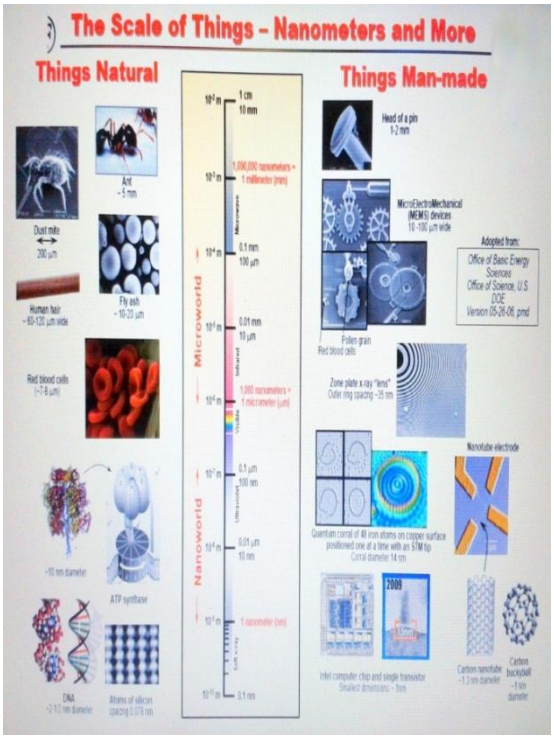

Figure. 1. the Scale of things

III. Generations Of Nanotechnology

Nanotechnology has witnessed four generations till date[3]

a) First generation of nanotechnology: It is called passive nanostructures. Some applications are: Dispersed and contact nanostructures.(e.g- Aerosols, colloids, coatings, nanoparticle reinforced composites, nano structured metals, polymers and ceramics).

b) Second generation of nanotechnology: It refers to active nanostructures. Some applications are: Bio- active, health effects, physico- chemical active (e.g- 3D transistors, amplifiers, actuators, adaptive structures).

c) Third generation of nanotechnology: It is called systems of nanosystems. Some applications are: robotics, guided assembling: 3D networking and new hierarchical architectures.

d) Fourth generation of nanotechnology: It is called molecular nanosystems. Some applications are molecular devices by design, atomic design and emerging functions. Fourth generation of nanotechnology basically deals with the manufacturing and development of nano computer.

IV. Types of nano-objects

Nanotechnology represents an entire scientific and engineering field, and not just a single product or even group of products. As a consequence of this there are several different types of nanotechnology, and many applications associated with each type. There are also several other types of nano-sized objects which exist in our environment, both natural and unnatural. The table 1 below summarises the main types of nanotechnologies and nano-objects and examples of current or future application.

Table 1 types of nano-objects and applications

Types of nano-object	Example of application
Embedded nanotechnology	Electronics, optoelectronics, building materials, sports equipment
Films and coatings	Self-cleaning coatings, waterproofing, anti-microbial coatings e.g. medical equipment, food containers and appliances.
Biologically natural	DNA, viruses
Unintentionally created particles	Metal smelting, burning fossil fuels including petrol and diesel.
Biological nanotechnology	Nano-sized motors, medical diagnostics
Natural particles	Particles emitted from volcanic eruptions and forest fires
Manufactured particles	Food and cosmetic additives including sun screens, anti-microbial uses, pollution clean-up
Nano-electrical mechanical systems (NEMS)	Drug delivery and diagnostics, smart sensors

2. DEVELOPMENT OF NANOTECHNOLOGY

I. Nanomanipulators :

One important concept of nanotechnology is building products using bottom-up technology. Instead of sculpting bulk materials into desired products, bottom-up technology suggests a new method that assembles individual atoms into products. The first step to bottom-up technology is to acquire the ability to manipulate individual atoms at the scale of nanometres as desired. Therefore, the development of a nanomanipulator, which is a tool for manipulating nanoscopic materials, is seen by some as being crucial to the progress of nanotechnology. The first imaging in nanoscale was from the electron microscope developed by M. Knoll and E. Ruska in 1931 [8]. Later in 1981, G. Binnig and H. Rohrer invented the scanning tunnelling microscope (STM)[7] that can image individual atoms, and earned the Nobel Prize [8]. The success of the scanning tunnelling microscope leads to the development of other scanning probe microscopes (SPM) including the atomic force microscope (AFM). Scientists have used the nanomanipulator system to examine the mechanical and electrical properties of carbon nanotubes [6]. Nan manipulators are now commercially available.

II. Nanofabrication:

It is a collection of technologies which are utilised in making micro devices. Micro fabrication is the term that describes processes of fabrication of miniature structures, of micrometer sizes and smaller. For instance, fabrication of IC (Integrated circuit).Nanofabrication or micro fabrication technologies originate from the microelectronics industry and the devices is usually made on silicon wafers. Nanofabrication methods can be divided into two categories: a) top down methods and b) bottom up methods [9]. A top-down method that has been used in the electronics industry is photolithography. Photolithography is the process that transfers the geometric shape on a mask to the surface of a silicon wafer by exposure to UV light through lenses. The computer industry uses this technology to fabricate microprocessor chips [9]. One modification can be made by using electron-beam lithography, which is a technique for creating fine patterns on a thin polymer film with a beam of electrons [9,10] In contrast, bottom-up methods are truly representing a new style of technology. This method is used to assemble atoms or molecules into nanostructures. One innovation created with a bottom-up method is a carbon nanotube discovered by S. Iijima of NEC in 1991 [8, 11]. A carbon nanotube is a tube-shaped carbon material that is measured in nanometre scales.

III. Nanocomputers:

One of the first achievements in nanocomputer research was perhaps the development of single-electron tunnelling (SET) transistors by D. Averin and K. Likharev in 1985(11). Later in 1987, T. A. Fulton and G. J. Dolan at Bell Laboratories fabricated single-electron transistors and made an observation on the quantum properties and effects of electrons when transistors are in operation [12]. As techniques in nanofabrication advances, researchers have successfully created electronic components including transistors, diodes, relays and logic gates from carbon nanotubes [13,14]. The next step is providing the interconnection between components. As the advancement in nanofabrication progresses, the silicon-based nanocomputer will step closer into reality. Another approach to nanocomputers is DNA computing. Apart from silicon-based nanocomputers and DNA computers, researchers believe that quantum computers may be another promising approach that overcomes the limits of conventional computers [15].

IV. Nanorobots:

One vision of a nanoassembler or nanorobot is a device with robotic arms, motors, sensors and computer to control the behaviour, all at the scale of nanometres. In 1992, the book called "Nanosystem" by Drexler gives an analysis of the feasibility of machine components for such nanorobots [16].

3. APPLICATIONS OF NANOTECHNOLOGY

• **Medicine**(Diagnostic, Drug delivery, tissue engineering)[18]: Nanotechnology will provide huge opportunities not only to

improve materials and medical devices but also to create new "smart" devices and technologies. Several medical devices that have already benefited from the application of nano-technology are in use or are currently being commercialised. Examples include:

I. contrast agents incorporating nanoparticles for greatly improved imaging

II. bone replacement materials incorporating nanostructured materials allowing better integration in the body

III. nanostructured biomaterials for use in scaffolds for regenerative medicine

IV. wound dressings incorporating antibacterial nanoparticles

V. orthopaedic implants with nanocontoured surfaces to improve fixation in bone

• Cryonics

•Environment (Filtration)

• Energy(Reduction of energy consumption, Increasing the efficiency of energy production, Nuclear accident clean up and waste storage) :Nanotechnology may produce and improve technologies such as fuel cells, portable energy sources, efficient energy storage, improving power transmission, efficient lighting, renewable energy and clean coal burning[18].

• **Information and communication** (memory storage, novel semiconductor devices, novel optoelectronic devices, quantum computers)

• **Heavy industry** (aerospace, catalysis, construction)

• **Consumer goods** (Food, nanofoods, household, optics, textiles, cosmetics, agriculture and sports

4. NEGATIVE IMPACT/RISK OF NANOTECHNOLOGY

I. Unknown Impacts On Health:

It is unclear whether nanoparticles can cause chronic health effects. There are several ways that nanoparticles can enter the body, these include: inhalation, ingestion, absorption through the skin and direct injection for medicinal purposes[20]. The skin is surprisingly permeable to nanomaterials. Carbon nanotubes are strong and can have a similar shape to asbestos fibres.

a) Inhalation of nanoparticles:

Damage caused by inhalation of nanoparticles was one of the first areas to be researched by toxicologists. The largest hazard posed will come from nanoparticles rather than embedded forms of technology and that some similarities exist between asbestos fibres and carbon nanotubes. This is supported by the increasing association between unintentionally created ultra fine particles, for instance car exhaust, which may trigger breathing related illnesses such as asthma.

Particles breathed into the lungs can cause damage and scarring, which over long periods of exposure can lead to long term breathing difficulties. carbon nanotubes are potentially toxic to humans[23]. Titanium dioxide and carbon nanoparticles also show detrimental effects when inhaled[21].

b) Absorption through skin:

Nanoparticles are being used in a number of products which are placed in direct contact with skin, including clothing, cosmetics and sun cream. Once absorbed through the skin if the nanoparticles(like sliver and carbon) come into contact with blood vessels they may behave in a similar way as if they had been ingested, namely collecting within certain organs or cells within the body[22]. This again is another call to determine the toxicity of widely used nanoparticles.

II. Unknown impacts on the environment:

Removing nanoparticles from the environment may also present a significant problem due to their small size. If absorbed, the particles may travel up the food chain to larger animals in a similar way to DDT though there is no evidence either way that this is a valid mechanism. There is still too little research into the potential negative impacts of this technology on the environment. However, some nanoparticles (such as copper or silver) have been shown to be harmful to aquatic life.

5. Which products use nanotechnology?

I. Nanoparticles in food :

Silver is currently the most common nanoparticle that is used in the food industry. Silver has long been known as an effective anti-microbial agent, and with the introduction of its nanoparticle form it can now be easily impregnated invisibly into almost any product to aid in the destruction of bacteria and viruses. This has important applications in the food industry in terms of manufacturing, preserving and storage[25].

II. Nanoparticles in cosmetics :

The fascinating group of nanoparticles known as fullerenes include C60 which resemble small "footballs" of carbon atoms and are being used in cosmetics in the form of face creams to remove other unwanted particles, such as free radicals, which are believed to cause damage to the body and skin. While these properties of C60 may exist it has also been found to damage human skin, liver and brain cells at doses of 50 parts per billion after only two days of exposure. Sun creams are now available with titanium dioxide nanoparticles[21,22]. There is concern that the nano-sized particles, once rubbed into the skin, would be able to enter cells and damage them. This is because when titanium dioxide is exposed to sunlight it can act as a photo-catalyst, which can make it very toxic to the surrounding cell.

III. Nanotechnology in fabrics:

Clothes are also receiving the nano-treatment. Again, nano-silver is playing a lead role due to its anti-microbial properties, with the risk being that the nanoparticles will be in direct contact with skin over prolonged periods of time. Clothes can also be treated with nano-films to make them stain, water and static resistant. These films, which are only a few atoms thick, could be in contact with skin over prolonged periods.

IV. Nanotechnology in medicine:

The use of silver nano-particles for use in medical devices is a hot topic[17]. Nano-silver kills a broad range of harmful microbes and has been shown to be effective against the MRSA super-bug and the HIV virus. This could prove beneficial in terms of providing sterile equipment, beds and wound dressings that limit the spread of harmful bacteria. However, the same properties in silver that kill bacteria may also prove harmful to cells within the body as highlighted by a recent review paper, and it is important to get the balance right between the two effects. This is especially true for wound dressings where cell health is critical for recovery[24]. Nanotechnology could also be used to produce new sensors that can detect whether a person has certain types of cancer from only a few drops of blood.

6. NANOTECHNOLOGY TECHNIQUES/ TOOLS /MATERIALS THAT DIRECTLY AFFECT MODERN COMPUTER

• Nanofabrication
• Quantum dots
• Carbon Nanotubes
• DNA computing
• NVRAM (non volatile RAM)
• NanoDesign (software system)

a) Nanofabrication: It is a collection of technologies which are utilised in making micro devices.Nanofabrication methods can be divided into two categories: a) top down methods and b) bottom up methods[9].

• Top down method: It involve carving out or adding a small number of molecules to a surface. This method is generally used by electronics industry in a process called photolithography.

• Bottom up method: This method is used to assemble atoms or molecules into nanostructures.

b) Quantum dots: Quantum dots are crystals that emit only one wavelength of light when the electrons are excited. It is a new material made by bottom up method of nanofabrication. In future quantum dots could be used as quantum bits and to form the basis of quantum computers.

c) Carbon nanotubes: It is a tube shaped carbon material that is measured in nanometre scales. With the advancement of nanofabrication technique, researchers used this material to create electronic components like transistors, diodes, relays and logic gates. These electronic components can be directly applied in making advanced computer.

d) DNA computing: It is an approach to nanocomputers. DNA computing uses bottom up approach or method to make DNA molecules and DNA logic gates[15]. Major Events

•In 1994, L. Adleman has tried to solve a complex travelling salesman problem by using DNA computing technique.

• In 1997, researchers at the University of Rochester built DNA logic gates. This development is considered as a step towards a DNA computer.

• Researchers have found that a DNA molecule can store more information than any conventional memory chip and DNA can be used to perform parallel computations.

e) NVR AM (non volatile RAM): Argonne research has developed a NVRAM (non volatile RAM) made up of tiny nano engineered ferroelectric crystals. Since the tiny nano engineered ferroelectric crystals do not revert spontaneously, RAM made with them would not be erased should there be a power failure. Using NVRAM laptop computers would no longer need back up batteries, permitting them to be made still smaller and lighter. This achievement of nanotechnology is considered as a long –standing dream of the computer industry.

f) Nanodesign (software system): A research group at NASA has been developing a software system called Nano Design, for investigating fullerene nanotechnology and designing molecular machines[16]. The software architecture of Nanodesign is designed to support and enable their group to develop complex simulated molecular machines. The main purpose behind developing this software system is design and simulation of materials based on nanotechnology.

7. CONCLUSION

As the development of nanotechnology progresses in several disciplines including physics, chemistry, biology and material science, computer scientists must be aware of their roles and brace themselves for the greater advancement of nanotechnology in the future. This paper has outlined the meaning of nanotechnology, its various generations and development of nanotechnology. This paper also suggested some application and negative impact of nanotechnology. We also suggested the possible nanotechnology techniques that affect computers.

8. REFERENCES

[1]. www.nanotechnology.htm

[2].Council for Science and Technology, "Nanosciences and Nanotechnologies", 2007,http://www2.cst. gov.uk/cst/ business / files/nano_review.pdf

[3].K.E. Drexler, 1986. Engines of creation: the coming era of nanotechnology. Anchor Press

[4].G. M. Whitesides and J. C. Love, 2001. "The Art of Building Small". Scientific American, September.

[5].Introduction to Microfabrication (2004) by S.Fanssila. ISBN 0-470-85106-6

[6].M. R. Falvo, G. J. Clary R. M. Taylor V. Chi F. P. Brooks S. Washburn and R. Superfine, 1997. "Bending and buckling of carbon nanotubes under large strain". Nature, 389, 582-584.

[7].K. E. Drexler, 2001. "Machine-Phase Nanotechnology". Scientific American, September.

[8].G. Stix, 2001. "Little Big Science". Scientific American, September. M. L. Roukes, 2001. "Plenty of Room, Indeed". Scientific American, September.

[9].M. L. Roukes, 2001. "Plenty of Room, Indeed". Scientific American, September.

[10].P. Rai-Choudhury (Ed), 1997. Handbook of Microlithography, Micromachining and Microfabrication.

[11].S. Iijima, 1991. "Helical Microtubules of Graphitic Carbon". Nature, 354.

[12].T. A. Fulton and G. J. Dolan, 1987. "Observation of Single-Electron Charging Effects in Small Tunnel Junctions". Phys.Rev.Lett., 59, 109-112.

[13].C. M. Lieber, 2001. "The Incredible Shrinking Circuit". Scientific American, September.

[14]. M. A. Reed and J. M. Tour, 2000. "Computing with Molecules". Scientific American, June.

[15].N. Gershenfeld, 1998. "Quantum Computing with Molecules". Scientific American, June.

[16].K. E. Drexler, 1992. Nanosystems: Molecular Machinery, Manufacturing, and Computation. Wiley.

[17]. BCC Research. Nanotechnology in Medical Applications: The Global Market (2010)

[18].New Energy and Industrial Technology Development Organisation (NEDO), http://www.nedo.go.jp/english/

[19].Jose Luis Elechiguerra et al, “Interaction of silver nanoparticles with HIV-1”, 2005, Journal of Nanotechnology

[20].R. J. Griffitt et al, “Exposure to Copper Nanoparticles Causes Gill Injury and Acute Lethality in Zebrafish”, 2007, Environmental Science & Technology

[21].Jia-Ran Gurr et al, “Ultrafine titanium dioxide particles in the absence of photoactivation can induce oxidative damage to human bronchial epithelial cells”, 2005, Toxicology

[22].Nancy A. Monteiro-Riviere et al, “Challenges for assessing carbon nanomaterial toxicity to the skin”, 2006, Carbon

[23].Julie Muller et al, “Respiratory toxicity of multi-wall carbon nanotubes”, 2005, Toxicology and Applied Pharmacology

[24].R. Strohal et al, “Nanocrystalline silver dressings as an efficient anti- MRSA barrier: a new solution to an increasing problem”, 2005, Journal of Hospital Infections

[25].Environment Protection Agency, “Nanotechnology White Paper”, 2007, http://es.epa. gov/ncer/nano /publications/ white paper 12022005.pdf

[26].Food and Drug Administration (FDA), “FDA Regulation of Nanotechnology Products”, http://www.fda.gov/ nano technology /regulation.html