Nanotechnology: Social and Ethical Considerations

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Abstract* – Science, Engineering and Technology developments in the 21st. Century, and with the challenges of finite global resources, environmental and economic impacts, we are faced with wide applications of scientific discovery, and research opportunities of "Nanotechnology" breakthroughs. Nanotechnology research, developments and innovations has already made many positive and promising implications … but, also comes with a number of ethical, moral, environmental and societal issues. This paper and presentation is designed to explore and lead the International Conference on Engineering Education (ICEE) discussion on the important scientific, engineering, technological and societal interaction and/or impacts of Nanotechnology.

Index Terms – Engineering Ethics, International Education, Global Trends, Engineering Education, Nanotechnology, Technology Assessment and Forecasting

INTRODUCTION

Nanotechnology is a rapidly progressive field of research and development impacting areas like material science, electronics, precision manufacturing and medicine. Nanotechnology offers the possibility of many societal benefits, such as reduced energy use, lower cost for computing, material reuse and recycling, and effective medical treatments. However, as Nanotechnology makes rapid advances, there are growing concerns about risks associated in the areas of environmental, privacy, security, ethical, moral, social and political impacts of its use and applications. The objectives of this paper are as follows:

- Provide a brief introduction to Nanotechnology
- Provide a brief analysis of Nanotechnology research and its impact on global technology transfer.
- Provide a brief synopsis of social and ethical considerations of Nanotechnology

The prefix ***"Nano"*** signifies a billionth: A billionth of a second is a *Nanosecond*; a billionth of a meter is a Nanometer. Therefore ***Nanotechnology*** and/or Nanoscience are the study of the ecology around us at one of the smallest of the particle levels, commonly known to us as ***Nanostructure of Materials*** **[1]**. The terminology and/or the concept of *Nanotechnology* and Nanoengineering use the fundamentals of atoms and molecules as the basic building blocks to create new materials, perform molecular functions, design embedded systems, and also create minute machines and devices.

Nanotechnology research and development brings the possibility of material science, for example, the fabrication of composites with ten (10) times the strength of steel and with only a fraction of the weight. Research of miniaturization (due to *Nanotechnology*), will bring new innovations and inventions impacting the emerging field of digital technology, communication and information science, ICE cluster (instrumentation, controls and electronics), polymer science, fibers and synthetics, semi conductor chips *(including sensors, optical devices, mirrors, actuators and embedded chips)* **[2].**

Nanotechnology innovations will create materials at the atomic level, thus creating the technological ability to fabricate precision machines, devices and systems (such as: molecular sized computers and robots) to substantially change various sectors of our emerging 21st Century economy, such as fiber optics, biotechnology, MEMS, manufacturing, medicine, pharmaceutical science, environmental science, automation, genetic engineering, cloning, nuclear physics, and the science of warfare **[3].** Nanotechnology's promise and potential is to create a world of abundance in an ecology challenged by finite resources with an accelerated need for adequate food, safe water, a clean environment, abundant power and energy supply, and increased need for goods and services. With this major developments and inherent research capabilities impacting the field of Nanotechnology, the applied science and engineering discipline must strongly examine the socio-economic and ethical considerations of Nanotechnology.

NANOTECHNOLOGY RESEARCH AND ITS IMPACT ON GLOBAL TECHNOLOGY TRANSFER

Researchers in the field of Nanotechnology has determined that "cells" (or cellular structures) are not just the building blocks of living organism, but they have noticed that by placing certain atomic scale particles into organic and inorganic materials causes the particles to form patterns creating building blocks such as super strong coatings and miniature circuits. Therefore, question arises that given the threshold of Nanotechnology research and developments:

- How powerful can computers become?
- Can artificial brain be created?
- Can integrated chips (IC) have true cognitive abilities?
- Can servers have intellectual capabilities superior to human beings?
- How small can computer chips become?

Nanotechnology can best be considered as a 'catch-all' description of activities at the level of atoms and molecules that have applications in the real world. A nanometer is a billionth of a meter, that is, about 1/80,000 of the diameter of a human hair, or 10 times the diameter of a hydrogen atom. Nanotechnology is an umbrella term that covers many areas of research dealing with objects that are measured in nanometers. A nanometer (NM) is a billionth of a meter, or a millionth of a millimeter. Nanotechnology is a hybrid science combining engineering and chemistry. Atoms and molecules stick together because they have complementary shapes that lock together, or charges that attract. Just like with magnets, a positively charged atom will stick to a negatively charged atom. As millions of these atoms are pieced together by nanomachines, a specific product will begin to take shape. The goal of Nanotechnology is to manipulate atoms individually and place them in a pattern to produce a desired structure. There are three steps to achieving Nanotechnology-produced goods:

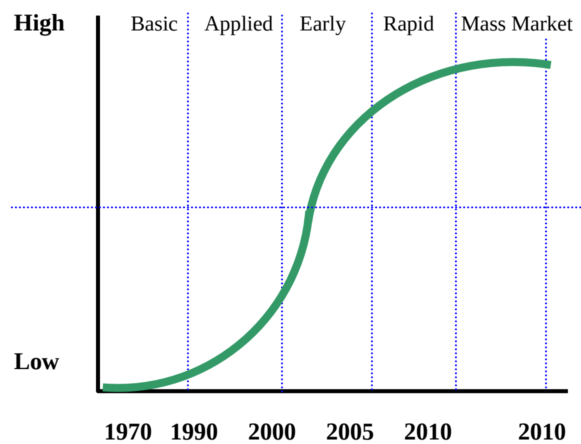
- Scientists must be able to manipulate **individual atoms.** This means that they will have to develop a technique to grab single atoms and move them to desired positions. In 1990, IBM researchers showed that it is possible to manipulate single atoms into the fabrication of nanoscale IC-chips. They positioned 35 xenon atoms on the surface of a nickel crystal, using an atomic force microscopy instrument**. [4]**

- The next step will be to develop nanoscopic machines, called **assemblers,** that can be programmed to manipulate atoms and molecules at will, making them logically bonded and artificially intelligent.

- In order to create enough assemblers to build consumer goods, some nanomachines, called **replicators**, will be programmed to build more assemblers that can be cross linked and operate with cognitive abilities.

With the US federal government's National Nanotechnology Initiative (NNI), the Nanotechnology research and development activities have dramatically impacted its growth and market penetration.. Figure I below shows the evolution of Nanotechnology from its conceptual base in 1970 to its current stage of rapid development. It is predicted that Nanotechnology products and devices will have a mass market penetration by the year 2010.

Figure I: The Evolution of Nanotechnology



~ 30 years of evolution and its market impact ~

Nanotechnology has the potential to become a more significant revolutionary force for business than the industrial revolution or the information technology revolution. In fact, many believe that the combined impact of both the industrial and information revolution may approach the magnitude of change that could result from the commercialization of Nanotechnology. Currently, Nanotechnology is moving from the basic research stage of its evolution into the applied research stage of technology maturity. Today there are several Nanotechnology companies already being traded on the public marketplace. Research and development activities in Nano structured materials spans a significant spectrum of areas. Examples are:

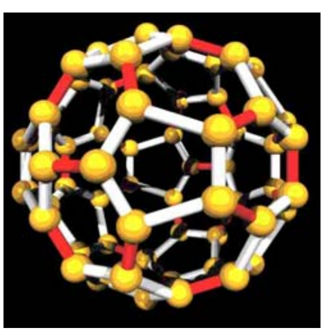
- *Nanotechnology*: Carbon-tubes (many times stronger than steel)
- *Nanotechnology*: Wires and Poly-fibers (Fiber optics)
- *Nanotechnology*: Computer switches and sensors (Electro-optic sensors)
- *Nanotechnology*: Silicon-crystals and its application to optics,
- *Nanotechnology*: Optical computing, and Optical communications.
- *Nanotechnology:* Chemical sensors, heat conductors, fuel cells for storing hydrogen

- *Nanotechnology*: in electronic filaments for efficient light bulbs
- *Nanotechnology* : Advanced materials for industrial powders, coatings, and chemicals
- *Nanotechnology:* Robot applications in medicine and biomedical sciences.
- *Nanotechnology*: Biosensors for environmental monitoring
- *Nanotechnology*: Bio-metrics for forensic science and security.
- *Nanotechnology* and intelligent materials for semi conductors, transistors, MEMS (Micro-electromechanical systems), and MPG (Micro-Power Generating Devices)
- *Nanotechnology*: Computer chips and ultra-dense electronic computer logic

Central to Nanotechnology are molecular-scale machines designed and developed from concepts of genetic engineering and bio-medical research. "DNA" has proven to be very useful for designing and constructing these machines. DNA is more than just the secret of life. It is also a versatile component for making nanoscopic structures and devices. The helix of DNA has a diameter of about two Nanometers, and it twists full circle one every 3.5 Nanometers or so, a distance of about 10 base pairs, which forms the rungs of the DNA ladder **[5]** The strands of DNA interact in the most logical and programmable way. Their enormous variabilities provide ample scope for designing molecules. A crucial goal for Nanotechnology based on DNA is to extend the successes of Nanostructures from two dimensions to three dimensions.

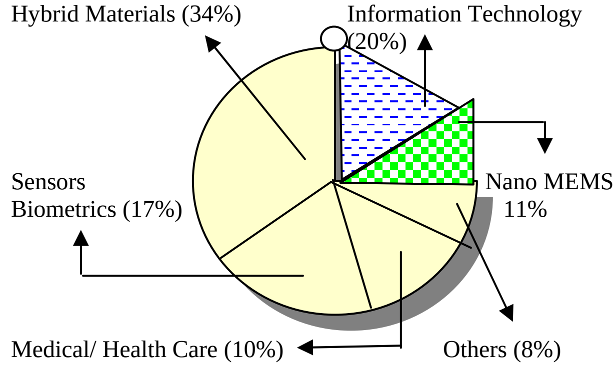
DNA based Nanotechnology research is currently in the following areas: **[5]**

- DNA in a material world
- DNA as an engineering material
- DNA-fuelled molecular machines
- Logical computation using algorithmic self-assembly of DNA
- Robust DNA mechanical device controlled by hybridization technology



Nanotechnology has the potential to become a more significant revolutionary force for business and industry than the industrial revolution or the information technology revolution. In fact many believe that the combined impact of both industrial and information revolution may approach the magnitude of change that could result from the commercialization of Nanotechnology. Figure II shows the breakdown of the current industry focus in various sectors of the economy.

Figure II: Nanotechnology Industry Focus



NANOTECHNOLOGY: SOCIAL BENEFITS AND ETHICAL CONSIDERATIONS

Nanotechnology presents a wide range of problems and opportunities. However, the impact of nanotechnology has many serious moral, ethical and environmental implications immersed in the concerns related to genetic engineering, cloning, nuclear physics, harnessing of immense energy, and the science of warfare. Nanotechnology, with its staggering implications, will create a set of ethical quandaries which should be carefully examined. Therefore, let us examine the positive and the negative implications of this revolutionary science called Nanotechnology.

The promise of *Nanotechnology* is material abundance and rapid improvement of high technology at low cost and high convenience. Potential societal benefits in the following sectors are:

❖ **Manufacturing Systems :**

- Precision manufacturing
- Miniaturization
- Material Reuse
- Mass production at low cost

- **Medicine and Bio-medical sciences:**
  - Pharmaceutical creation
  - Nano-Robots: Medicine of the future
  - Biometrics and medical imaging
  - Nano Medicine assisted surgery
  - Delaying of aging

- **Environment and the Ecological Systems:**
  - Toxin cleanup
  - Reuse and recycling of materials\
  - Resource consumption reduction
  - Low cost pollution sensors

- **Molecular electronics and photonics:**
  - Nano structured computer chips
  - Ultra dense electronic computer logic
  - Micro transistors
  - miniaturized sensors with intelligence and logic

- **Material Science:**
  - Overcoming material scarcity
  - nearly unlimited energy supply
  - Inexpensive raw materials
  - Molecular food synthesis (end of famine and starvation)
  - Realistic space travel and exploration

The problems and the negative aspects of Nanotechnology are many. The ethical issues fall into the areas of equity, privacy, security, environment and metaphysical questions concerning human-machine interactions.

- **Societal Equity:**
  - Digital Divide
  - Genomics Divide
  - intelligence based knowledge society

- **Privacy and Security:**
  - Surveillance and tracking devices
  - New weapons
  - Forensic science
  - Miniaturized equipment

- **Environmental Impact :**
  - Rampant Nanomachines
  - The Gray-Goo Scenario
  - Miniature weapons and explosives
  - Bioterrorism
  - Encryption software and super computers

- **Human-Machine Interface:**
  - Artificial materials and machines
  - implanted organs, cells and sensors
  - Artificial intelligence
  - delaying of aging and increase of life span

CONCLUSION:

Nanotechnology is a rapidly progressive field. It is difficult to deny the potential benefits of this emerging technology. If approached with pessimism then it will appear to be too dangerous to be allowed to develop to anywhere near its full potential. But Nanotechnology, if viewed positively, responsively and with optimism, will be viewed as the next technological revolution. The responsibility of this new technology will still be under the domain of the socio-ethical consideration of use and application of Nanotechnology.

This paper provides a balanced overview of the emerging field of Nanotechnology with a comprehensive analysis of the societal benefits and the much needed moral, ethical and environmental considerations of its application.

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