Nanotechnology Applications: an Analytic Comparison

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ABSTRACT

It is very important to consider the fast development of nanotechnology when it comes to life applications. Creating something tiny with special properties designed to fasten up duration time to accomplish any goal with high accuracy is what nanotechnology all about. During the time, there were a lot of studies on nanotechnology in general and its applications in many fields. The main purpose of this paper survey is to identify the scientific definitions of nanotechnology, historical background, benefits, approaches, and more specifically studying a Nano particle named Nano Carbon Tube (CNT). CNT is highly used in nanotechnology applications as Central Processing Unit (CPU) cooling system, data storage devices (memory), and sensors. This study will also cover usage of nanotechnology in wireless signals named 5G and toxicity of Nano materials, which is too important to ensure humans and environment safety. Studies showed various results on the impact of CNTs on general health. Some studies showed signs of lung disease and others showed no toxicity. Future research and more detailed experiments should be made to make a closure in the case of CNT materials toxicity.

Keywords: CNT, nanofluids, nanotechnology, 5G nanocore, nano chips, CPU, toxicity, nano sensors, nano materials, carbon nano tubes, nano particles, nanotube, storage device, applications, military, food, medical, nanotechnology approaches.

1. Introduction

Nanotechnology has the power of changing the world to a better place to live in just if it is being used for good purposes. This technology will affect directly the economy due to its major possibilities. Recently, Nanotechnology is involved in many fields and changed all the traditional views of devices and materials taking the concept of thinking out of the box to further limit. It is widely used in electronics felid in designing mobile phones and computers to create a new design that can be folded without breakage.

Nanotechnology is also used in animal products, especially in feeding industry. Its high impact was noticeable in feeding efficiency to minimize environmental burden. It is also used to produce clean water to humans by processing the waste water to enhance water quality, availability, and improve general health. Nanotechnology is also used to preserve the freshness of many processed food like dairy products, vegetables, and fruits (Ditta, 2012).

Nanotechnology has a major impact in the medical field. It evolves in many techniques and devices to participate in treating major diseases like cancer, autoimmune diseases, infections, inflammations, and metabolic system diseases (Couvreu & Christine, 2006).

Nanotechnology will be used in the military field to design new weapons with unique properties like small self-guided missiles with mini robots and creating devices that can gather water in any place (Altman & Gubrud, 2004). Imagine how powerful is nanotechnology and its great impact in our world. If this technology is used for evil purposes, the damage will occur on our planet. Dealing with nanotechnology is all about testing our humanity, ethics and knowledge.

CNTs are referred to nanotube materials that are used in many applications. According to its high strength, they can produce fibres that are one hundred times stronger than steel. They can be widely used in spacecraft structures, elevators, sea vehicles, land vehicles, and combat jackets (Lam et al., 2006). In future, CNT will replace aluminium and copper in wiring field. CNT enter the most important application in our life. Studying nanotechnology in information technology field will bring us to study the importance of CNT.

2. Definition of Nanotechnology

A. The General Definition of Nanotechnology:

Nanotechnology is an application of nanoscience in which molecules and atoms of materials can be manipulated, controlled, separated and processed on small scale named (nanometer scale). These materials can be invested in many devices that serve many fields of engineering, science, medical, economics, etc.

In general, the term (Nano) means one billionth. The nanometer is one billionth of meter as shown (Ratner & Ratner, 2003):

$$1\ (\text{nm}) = 1/\ 1{,}000{,}000{,}000 \text{ of meter}$$

B.Drexler's' Definition of Nanotechnology:

A scientist named Eric Drexler had his own definition of nanotechnology as "the control of matter based on molecule-by-molecule control of products and processes of molecular machinery" (Quan & Behrouz, 2014).

3. Historical Background of Nanotechnology

The real start of nanotechnology was in the second half of the twentieth century. On the evening of December 29, 1959, The American physicist Richard P. Feynman

reviled to the world the possibility of atomic manipulation. Feynman defined the endless capability of manipulating and controlling things on a small scale without referring to the term (nanotechnology) itself at the meeting held.

The term (nanotechnology) was first used in 1974 by the Japanese scientist Norio Taniguchi to describe his own study named (The Basic Concept of Nanotechnology).

An American scientist named Eric Drexler made his own theories about molecular manipulation. He published his first journal article in 1981. Five years later, Drexler wrote his first book called (Engines of Creations) explaining nanotechnology and how molecular manufacturing could be used in many applications that serve humanity in general. In 1992, another book was published named (Nano systems) (Melnik & Shagalina, 2011; Osuwa & Anusionwu, 2011).

4. Benefits of Nanotechnology

Nowadays, Nanotechnology have entered many fields to serve consumers. Manufacturing small sized particles will step up the productivity of devices used in many fields like (Bhushan, 2010):

1. Stain-resistant-clothing.
2. Tires.
3. Sun screen products.
4. Biomedical devices.
5. Silicon based sensors.

5. Nanotechnology Approaches

Nanotechnology has two main approaches as shown in Table1 (Osuwa & Anusionwu, 2011; Tseng, 2008):

A. Bottom-up Approach.

B. Top-down Approach.

Table 1: Nanotechnology Approaches

Comparisons	**Bottom-up Approach.**	**Top-down Approach.**
Definition	A Fabrication strategy that assembles basic units of materials into larger structures.	A fabrication strategy that is used to transform a bulk material into the smaller structure by removing bits of it.
How it is Used	• Self-Assembly of atoms and molecules. • Uses of chemical, physical and biological process. • Building blocks such as adding molecule to molecule or atom to atom.	No Assembly of atoms and molecules because the parts or chips are patterned in place.
Size Rang in (nm)	0.1-1 nm to 10-100 nm	10-1000 nm to 10-100 nm

Applications	• Formation of quantum dots (Indium Gallium Arsenide). • Carbon nanotubes. • Nanowires. • Biomedical and chemical sensors and actuators.	Integrated circuits to fabricate computer chips by making use of thin films known as a mask are etched away and deposited on a silicon wafer.

6. Nano Carbon Tubes (CNT)

CNTs are members of the carbon family (carboxylic-acid) groups. They were discovered in 1991 by Lijima. Detailed of structural information, Structural Families, Properties and applications of CNTs are described below.

A. Structural Information of CNTs:

1. CNTs are built from sp2 carbon units.
2. CNTs have a seamless structure with Hexagonal honeycomb lattices, as shown in Figure 1.

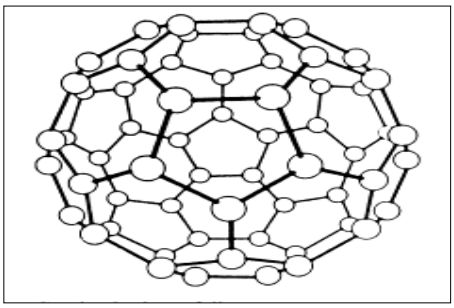

Figure 1: Carbon Structure [9].

3. CNTs have a tubular structure.

B. Structural Families of CNT:

According to Harris (2009), there are two structural families of CNTs:

1. Single-Walled Carbon Nanotubes (SWNTs), as shown in Figure 2 and Table 2.

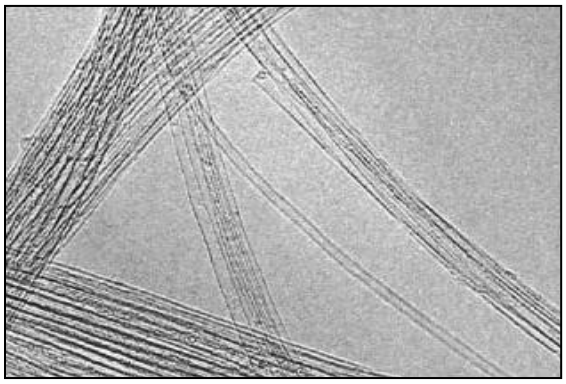

Figure 2: Single-Walled Carbon Nanotube (Source: Harris, 2009)

2. Multi-Walled Carbon Nanotubes (MWNTs) as shown in figure 3 and table 2.

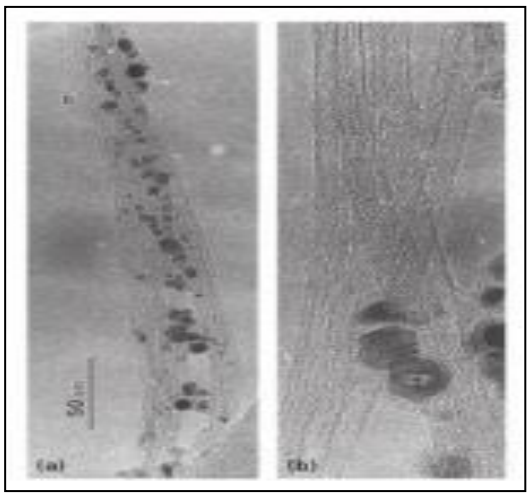

Figure 3: Multi-Walled Carbon Nanotube (source: Harris, 2009)

Table 2: Types of CNTs

Types of CNTs	Consists of	Tubule Structure	Diameter Range	Distance between sheets	How it is produced
SWNTs	Single graphite sheet	Rolled Seamlessly	1-2 nm	-	Laser-vaporization-ion
MWNT-s	Concentric and closed graphite tubules	rolled graphite sheet forms range of diameters	2 – 25 nm	0.34 nm	Arc-vaporization-ion

C. The Properties of CNTs:

CNTs became the top position Nano-material used in many applications in the nanotechnology field. CNTs have the following properties:

1. CNTs have unique mechanical and electronic properties combined with chemical stability.
2. Depending on diameter and helicity, CNTs behave electrically as metals or semiconductors.
3. CNTs have electronic properties like the ability to mediate electron transfer reactions with electroactive species in electrodes which enable them to be widely used in sensors and CPUs.
4. CNTs make devices easy to recycle which can prevent environmental pollution.

D. Applications of CNTs:

CNTs have been used in many applications in the field of sensors and sensing (Soheli et al., 2014; Anjum et al., 2009).

1. Nano-electrical and mechanical systems (NEMS): that integrates electrical and mechanical components with critical dimensions within 100 nm size.
2. Sensors.
3. CPU.
4. Storage Devices (Memory).

7. Sensors Applications in Nanotechnology

There are a lot of nanomaterials used in sensors in the field of nanotechnology to build a Nano sensor as:

1. Carbon Nanotubes (CNT).
2. Nano structured metal oxides.
3. Polymers.

A. CNT Sensing Application:

"A sensor is a device that responds to a stimulus by a functional output induced by a change in some intrinsic properties" (Brugger, 2009). The character of any Nano sensor can be determined based on the following properties (Quan & Behrouz, 2014):

1. The size of the sensor in nanoscale.
2. The sensitivity of the sensor in nanoscale.
3. Interaction distance between the sensor and the object being detected in nanoscale.

Some sensors use CNTs to detect ozone in water and air. There are noticeable drawbacks in using CNTs as sensing elements because of the following reasons:

1. Lack of specificity of different gases analyses.
2. Low Sensitivity towards analyses that have no affinity to CNTs.
3. Although the studies about CNTs are considerable, some of the properties are still not understood as (optical, magnetic, and magneto-optical) properties.

B. Classifications of nano-sensor :

The Nano- sensor can be classified based on the type of variable being detected. In electrical Nano-sensors, current and electrical conductivity are the variables detected. The changes made in Nano sensors will include enhancing the following properties as heat capacity, magnetic field, and thermal conductivity which will make the new designed Nano sensor highly sensitive detector (Van et al., 2009; Quan & Behrouz, 2014).

8. Nano Fluids in CPU Cooling System

The main Nano fluids used in CPU cooling system are:

1. Ethylene Glycol.
2. Alumina.
3. CNT.

Researchers made an experiment to test the previous Nano fluids. The results showed that CNT has the highest heat transfer compared with the other two Nano fluids, as shown in Table 3.

Table 3: Nano Fluids in CPU System (Nazari et al., 2014)

Nano Fluid	Volume Fraction%	Heat Transfer
Ethylene Glycol	50%,30%	4%
Alumina	0.1%,0.25%,0.5%	6%
CNT	0.25%	13%

The best heat transfer enhancement was about 13% with a volume fraction of 0.25% for a flow rate of 21 ml/s.

The main advantage of using Nano fluids in CPU cooling systems is to decrease operational temperature and reducing the volume of the cooling system which was successfully accomplished by using the CNT. CNT is nontoxic and environmental friendly (Nazari et al., 2014).

9. Storage Devices (Memory) Applications in Nanotechnology

Due to the fast evolution of mobiles and computers technology, new characteristics of data storage devices must be produced to coup with modern technology. The new memory devices should be (Hu, 2009):

1. Cheap.
2. Compact.
3. Low power operation.
4. Low batteries drain.

Nowadays, three types of memory devices available in the market and they are (Bichoutskaia et al., 2008):

1. Dynamic Random Access Memory referred as (DRAM).
2. Static Random Access Memory referred as (SRAM).
3. Flash Memory.

A. CNT in Data Storage Devices:

CNT is being used to produce three types of memory.

Table 4: Types of CNT Data Storage Devices

Types of device	Operational Characteristics	Approach used	Example
Based on Cantilever CNTs	1- Continuum Models. 2- Molecular Dynamics. 3- Combined molecular Dynamics and Continuum Models.	Bottom-Up approach	-
Based on Suspended CNTs	1- Continuum Models. 2- Static and Dynamics Models.	Bottom-Up approach	Nanotube-based nonvolatile Random Access Memory referred as NRAM
Based on Telescoping CNTs	Fully Reversible.	Bottom-Up approach	-

B. CNT Application in Data Storage Devices:

An experiment made to test the characteristics of using CNTs in data storage devices. A connective paper is coated with a single –walled carbon nanotube and silver wire films are used to accomplish that goal. The priority of using regular paper than other materials like plastic or glass because of the special properties of the paper which is shown in the small comparison between the following characteristics as shown in Table 5.

Table 5: Comparison between paper and plastic or glass

Comparison Name	Connective Paper	Plastic or Glass
Process Level	Simpler	Not simple
Cost	Lower cost	High cost
Properties of Nano materials	Maintained	-
Fabrication Process	Much Simpler	Complicated

Results showed that the connective paper coated with CNT has also mechanical properties like:

1. Strong Bending.
2. It can be folded without any change in electrical conductivity.
3. Stability against damage and breakage.

This application will allow producing more efficient data storage devices have the following advantages (Hu, 2009):

1. Low cost.
2. Light weight.
3. High performance.
4. Nanotechnology in 5g.

"5G is an upgraded version of the existing and establishing network 4G which is known as Long Term Evolution" (Nair, 2013).

C. Advantages of using 5G:

It's Capability of crossing the existing bench marks of:

1. Speed.
2. Connectivity.

D. Nano Core:

The vision of using nanotechnology in the 5G communication field is to enhance mobile phones performance to which they referred as Nano-equipment. The main goal is to improve the following properties:

1. Sensing.
2. Computing.
3. Communication.
4. Actuation.
5. Radio.
6. Intelligence.
7. Memory.
8. Energy Source.
9. Human Interaction.

Because of these enhancements, new properties of mobile phones will be created as:

1. Self-Cleaning: the phone cleans by itself.
2. Self-Powered: the phone energy is taken from the sun, water, or air.
3. Sens to Environment: the phone will indicate the amount of air pollution.
4. Flexible: phones can be bent easily without breaking it.
5. Transparent: you can see through your phone.

E. Current Applications of Nanotechnology in Mobiles:

One of the famous companies has new applications of nanotechnology in their mobile phones. The following properties of smart mobiles will be considered:

1. Size.
2. Storage.
3. Weight.
4. Hardness.
5. Speed.

10. Nanoparticles and Health Concerns

Because of the noticeable development of nanotechnology, it is very important to protect the consumer from the health concerns that Nano-particles may cause. Some studies showed that a toxicity effect may occur due to the nanoscale size variation "smaller means more toxic" (Matsuda & Geoffrey, 2005). In this section, early studies of nanoparticles toxicity and toxicity levels are discussed (Nel, 2006).

A. Early Studies of Nanoparticles Toxicity:

Researchers showed that some nanoparticle can cause humans disease, as shown in Table 6.

Table 6: Toxicity effects of Nanoparticles on humans' body

Nanoparticle Name	Causes
Gold	Moving across the placenta from mother to fetus.
Cadmium Selenide (Quantum dots)	Breaking human body causing cadmium poising
Bulky Balls	Brain damage after 48 hours.
Titanium dioxide (Ti2O)	Lung injury.
Carbon	Lung injury.
Asbestos	Lung cancer.

B. Toxicity Level Standards:

The toxicity level depends on the following standards (Matsuda & Geoffrey, 2005; Buzea et al., 2007):

1. The arrangement of the atoms.
2. The shape and chemical composition.
3. Size.
4. Particle ageing.

Some studies were made to test the influence of CNT on body organs. These studies were made on animals like rats, mice and pigs. A brief description of each study is formed, as shown in Table 7 (Lam et al., 2006).

Table 7: Studies on CNT Toxicity.

Name of Study/ Year	**Experimenter Name**	**Tested on**	**Results**	**Study Shortfalls**
Carbon Nanotube Product/ 2001	Huczko et al.	Guinea Pigs	No health risks were found.	No pulmonary toxicity tests were applied
Single-Walled Carbon Nanotube/ 2000	Lam et al.	Mice	Not toxic	The size of particles that reached the mice lungs was not defined
Pilot Study/ 2000	Lam and McCluskey	Mice	High doses of CNT cause air blockage leading To immediate death.	-
Core study/ 2004	Lam et al.	Mice	Low doses of CNT had no death results on mice.	-
Single-Walled Carbon Nanotube 2004	Warheit et al.	Rats	A granuloma is produced in Rats' lunges.	-
Single-Walled Carbon Nanotube 2004	Shvedova et al.	Mice	Granuloma and lesion are produced in Rats' lunges.	-
Multi-Walled Carbon Nanotube 2005		Rats	Inflammation in lung tissues was found.	-

Previous studies showed that CNT products can cause the following signs in lungs:

1. Inflammation.
2. Fibrosis.

3. Toxicity changes.

The studies didn't show the accessibility of CNT dust to lungs. More studies should be made to determine whether the dust can access humans' lung and cause the toxicity or not (Lam et al., 2006).

11. Conclusion and Future Work

Conclusion

Nanotechnology in information technology is implemented in many fields not only in computer and mobile devices. It is also implemented in medical fields, which can preserve human health by combining intelligent with low-cost products. Solving the mystery of CNT toxicity and proving that it's not toxic will step up the applications in nanotechnology fields. Testing CNT is more important than developing a new device that holds many risks on humans' health.

Future work

1. Our college should consider nanotechnology course as part of the Science computer student's schedule.
2. Offering Nano-labs with all equipment needed for experimental and research work.
3. Investigating more about the CNT toxicity.
4. Attending conferences and communicating with nanotechnology experts.
5. Conducting further search regarding CNT applications especially in the field of 5G technology.

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