Carbon Nanotubes – The Centre of Nanoelectronics

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Abstract - *This paper outlines nano-technology as an important application of miniaturization and fulfillment of Moore's law. This law extends to its limits and is a way out of the nanoelectronics challenge. The field of nanoelectronics has created an enabling environment for the continuous realization of this law. New methods and materials are therefore used to manufacture electronic devices with feature shapes at the nanoscale. The nanometer material reveals interesting unique and useful chemical, physical, mechanical and electrical properties. Of all the nanometers in use, carbon nanotubes play an important role in nanoelectronics because they have very specific properties. They can serve as metals or semiconductors based on specific or discrete ("chiral") angles and tube radii.*

Key Words: Carbon nanotubes (CNT), Nanotechnology, Nanodevices, Nanoelectronics, Moore's Law

1. INTRODUCTION

Being one of the most exciting and vast fields of 21st century research, nanotechnology is a global phenomenon that is changing the way we live, making scientific progress and new products that are smaller, faster, stronger, safer and more Are reliable. This advertising field has entered almost all fields of science and technology. In addition, it is an important application of miniaturization. Indeed, miniaturization occurs in the manufacture of mechanical, optical, and electronic products and equipment using materials and devices on a large scale. This is done with the understanding that items that take up less space are more desirable than items that are bulkier because they are easier to carry, easier to store, and much more convenient to use .

Electronic miniaturization has been the right driving force for nanotechnology research and applications. In electronics, miniaturization was observed by an empirical observation called Moore's Law that predicted that the number of transistors on an integrated circuit doubles every 18 months for minimal component cost. In fact, it was Gordon Moore's empirical observation in 1965 that revealed that silicon transistors were undergoing a continuous process of downward scaling. This observation was later called Moore's law. The purpose of integrated electronics was to shrink electronics devices to include increasingly complex electronic functions in limited space with minimal weight. The minimum feature size has dropped from 10 micrometers to the 28–22 nm range in 2011 since Moore's observation. The field of nanoelectronics has continued to achieve this law, using methods and materials for manufacturing electronic devices with facility sizes at the nanoscale. Thus, nanoelectronics extends to its limits beyond the challenge of Moore's law because semiconductor devices can now be atomized by atom which would also make possible the construction of small semiconductor devices.

Nanotechnology, seen as a 21st-century manufacturing technique, is defined as the understanding and control of matter at dimensions of about 1 to 100 nanometers. Furthermore, it can be defined as the application of science, engineering and technology to develop novel materials and devices in various fields in the nano-range. A nanometer (nm) is a measurement system used to measure small particles such as atoms and molecules and is equal to one billionth (10–9) of a meter. It is one hundred thousand times smaller than the wavelength of visible light and the width of human hair. On this scale, unique properties of materials emerge that can be applied to the production of technologies and products with completely new capabilities and applications. In fact, at the nanoscale, the properties of physical, chemical, optical, and electrical materials differ from properties of matter on a small scale, such as atoms, or large scales. Nanotechnology is expected to impact almost every industry. Therefore, the US National Science Foundation predicts that the global market for nanotechnology will reach $ 1 trillion or more within 20 years.

2. The Evolution of Nanotechnology Nanomaterials

Today, nanotechnology is one of the fields of science and technology that is making rapid progress. Within two centuries, we have experienced many technological revolutions in the fields of industry, agriculture and medicine and information technology. Despite this, we have been able to use only a small part of the total potential in this case, as the matter is being dealt with on a large scale.

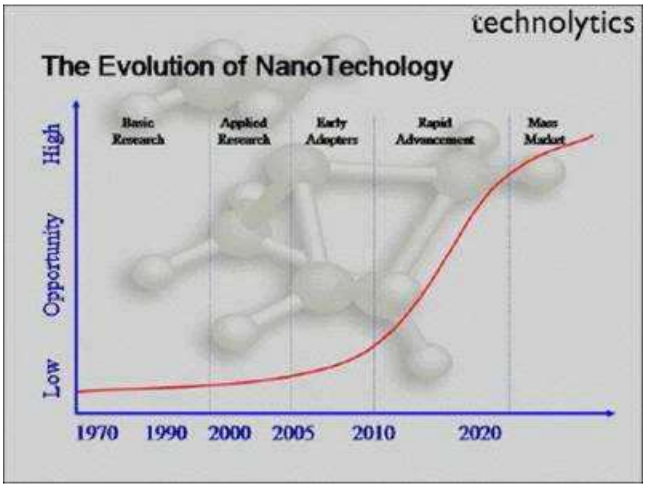

Chart – 1: Evolution of Nanotechnology

Our engineering skills and products are larger than the nano size and therefore have limitations in manipulation. With its ability to manipulate the smallest possible component of the case, nanotechnology has the ability to complete that cycle of technological revolution by dealing with matter by molecule, molecule by molecule. This ability of mankind to deal with matter at the molecular level gives him a new ability to shape the process and create things that were never thought of.

2.1 Concept of Nanotechnology Technology

Nanotechnology is a fundamental technology that allows us to do new things in almost every conceivable technological discipline. Furthermore, it refers to technologies in which matter is manipulated at the atomic and molecular scale to create novel materials and processes. In simple terms, nanotechnology can be defined as technology engineering at a very small level, while in layman terms, it refers to materials, applications and processes designed to operate on extremely small scales. went. This capability also gives us the ability to create materials and equipment or shapes and products on that scale simultaneously. Due to brevity in the operation, smarter and lighter products can be made from molecules of the same substance with each atom at each location. The case exhibits unimaginably different properties when manipulated and structured at the nano scale. 'Nano' in Greek means dwarf. Although nano means small, it is of high potential, and leads to emerging, industrial and technological developments with large applications through all disciplines of knowledge.

2.2 History of Nanotechnology Development

Although nanotechnology is a relatively recent development in scientific research, its central concepts evolved over a long period of time. However, it was a convergence of experimental advances such as the invention of scanning tunneling in 1981 and the discovery of fullerenes in 1985 which resulted in the emergence of nanotechnology in the 1980s.

The scanning tunneling microscope (STM) was developed by Gerd Binnig and Heinrich Rohr at the IBM Zurich Research Laboratory and was a tool for imaging surfaces at the atomic level. On the other hand, fullerene was discovered in 1985 by Honey Crotto, Richard Smalley, and Robert Curl. The invention of the scanning tunneling microscope (STM) allowed the first direct manipulation of individual atoms.

2.3 Applications

Typically, in nanotechnology, we move from simple to complex and an example of this category is the nano coating which can remove dirt and reduce the need for harmful cleaning agents. Among the complex group of applications of nanotechnology is mobile phones, which have changed dramatically over the years, becoming smaller and smaller, while at the same time, growing smarter, faster and cheaper.

In addition, nanotechnology is helping to significantly improve and even bring revolution in many technical and industrial fields such as information technology, energy, environmental science, medicine, homeland security, food security and transportation. With nanotechnology, materials can be effectively strengthened, lighter, more durable, more reactive, or better electrical conductors, among other characteristics.

2.4 Nanomaterials

Nanomaterials reveal extremely attractive and useful properties, which can be used for a wide variety of applications. Typically, this small-scale material behaves differently from their macro-scale counterparts thereby opening up a new field of manufacturing where products are designed and manufactured from below. Thus, with nanotechnology, a larger set of materials and finer products depend on changes in physical properties when feature sizes shrink. For example, nanoparticles use volume ratios to take advantage of their increased surface area. Their optical properties, e.g. Fluorescence becomes a function of particle diameter. When brought into a bulk material, nanoparticles can strongly affect the mechanical properties of a material such as hardness or elasticity. Increasing materials with nanotechnology will allow weight reduction with increased stability and improved functionality.

2.5 Nanodevices

To produce nanodevices, there is a need to understand fundamental phenomena, synthesis of suitable materials, the use of those materials to fabricate working devices, and the integration of these devices into working systems. Nanofabrication refers to the manufacture of machines that operate at the atomic or molecular scale. They are smaller, faster and consume less power than traditional electronics and because you can pack so much on one computer chip, you can have many more tasks. Such technology has huge potential in the fields of communication, data storage, solar cells and medical applications. Nanofabrication is of interest to computer engineers because it opens the door for super-high-density microprocessors and memory chips.

3. CARBON NANOTUBES AND NANOELECTRONICS

Carbon nanotubes (CNTs) are allotropes of carbon with a cylindrical nanostructure constructed with a diameter to diameter ratio of up to 132,000.000: 1 and have unusual properties that range from nanotechnology, electronics, optics and other areas of materials science and technology. Are valued for. In particular, due to their exceptional thermal conductivity, mechanical and electrical properties, carbon nanotubes find application as additives for various structural materials.

A carbon nanotube is a tube-shaped material, made of carbon with a continuous unbroken hexagonal mesh and carbon molecules at the apexes of the hexagons. Carbon Nanotubes have many structures, differing in length, thickness, and in the type of helicity and number of layers. Although they are formed from essentially the same graphite sheet, their electrical characteristics differ depending on these variations, acting either as metals or as semiconductors.

Nanotubes are members of the fullerene structural family, which also includes the spherical buckyballs and the ends of a nanotube may be capped with a hemisphere of the buckyball structure. Their name is derived from their long, hollow structure with the walls formed by one-atom-thick sheets of carbon, called graphene. These sheets are rolled at specific and discrete ("chiral") angles, and the combination of the rolling angle and radius decides the nanotube properties; for example, whether the individual nanotube shell is a metal or semiconductor.

3.1 Types of Carbon Nanotubes

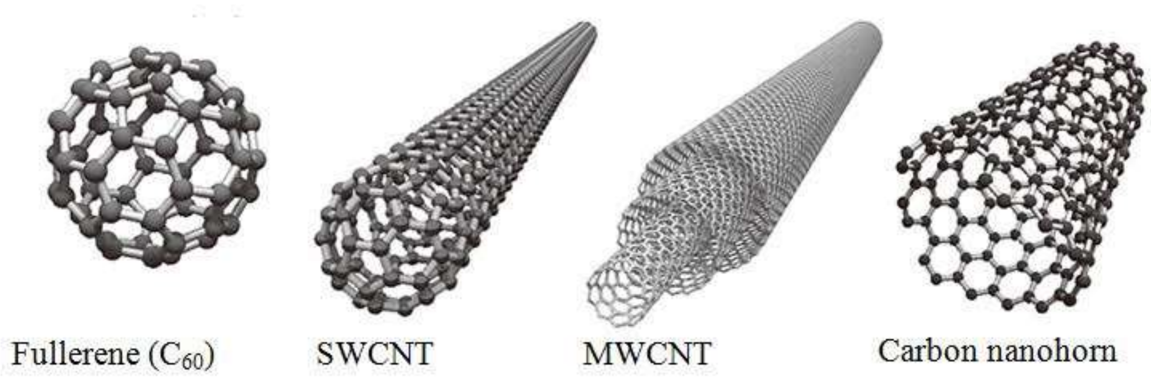

Fig – 1: Types of CNTs

Carbon nanotubes can be classified by their structures: single-wall nanotubes (SWNTs), multi-wall nanotubes (MWNTs) and double-walled nanotubes (DWNTs). A single-walled carbon nanotube (SWNT) can be thought of as a single atomic layer thick sheet of graphite (called graphene). Single-wall carbon nanotubes are hollow cylinders of carbon atoms bonded together in a hexagonal pattern and typically about a nanometer in diameter. Most single-walled nanotubes (SWNTs) have diameters close to 1 nanometer, with a tube length that can be several millions of times longer. Single-walled nanotubes are likely candidates for small-scale electronics. SWNTs can be excellent conductors with a diameter of one order of nanometer. The most basic building block of these systems is the power coil, and a useful application of SWNTs is in the development of the first intermolecular field-effect transistors (FETs).

3.2 Electrical Properties of Carbon Nanotubes

Nanotubes have exceptional electrical properties. The conductive properties of nanotubes depend on both the diameter and the chirality of the hexagonal carbon lattice along the tube. One fascinating feature of nanotubes is that there are many ways to wrap the hexagon sheet into a cylinder, from perfectly even rows of hexagons that wrap around in a ring, to rows that wrap in spirals at various angles called "chiralities." Thus, a nanotube is a function of its diameter and the chiral angle. A slight change in the winding of the hexagons along the tube can transform the tube from a metal into a large gap semiconductor. Chirality is critical to the electronic properties of carbon nanotubes. Some structures are electrical conductors—essentially a nanoscale wire— others are semiconductors. The thermal properties of carbon nanotubes are directly related to their unique structure and small size. ... The thermal conductivity of nanotubes is large, even in bulk samples: aligned bundles of SWNTs show a thermal conductivity of >200 W/m K at room temperature.

Table -1: Thermal and Electrical Properties of Nanotubes

Material	Thermal Conductivity	Electrical Conductivity
Carbon Nanotubes	>3000	10^6 – 10^7
Copper	400	6 x 10^7
Carbon Fiber-Pitch	1000	2 – 8.5 x 10^6
Carbon Fiber-PAN	8 - 105	6.5 - 14 x 10^6

3.3 Nanoelectronics

The use of nano technology on electronic devices, especially transistors, is known as nanoelectronics. The field of nanoelectronics aims at the continued realization of Moore's law by using new methods and materials to manufacture electronic devices with facility sizes at the nanoscale. Nanoelectronics often refer to transistor devices that are so small that the properties of inter-atomic interactions and quantum mechanics need to be varied. In addition to being smaller and allowing more transistors to be packed into a single chip, the uniform and symmetric structure of the nanotube allows for higher electron mobility and a higher dielectric constant.

3.4 Applications of Carbon Nanotubes in Nanoelectronics

Most of the interest generated by carbon nanotubes has been in applications to electronic materials and some of them are:

1) Better Solar Cells: Usually solar cells use silicon semiconductors. However when carbon nanotubes are incorporated into the semiconductor, a change occurs. Now billions of CNTs could be tightly packed onto solar cells and release far more electricity per square inch than silicon because they're so tiny.

2) Better, Thinner TVs: An array of CNTs is used in field emission as they are excellent electron emitters. There is now new process of displaying pictures called field emission display. This miniaturizes the process by using tiny electron emitters positioned behind individual phosphorus dots displays to excite the phosphorus dots, creating bright, high resolution displays. With the help of CNTs we can produce TVs that are only millimetres thick and consume less power than plasma and liquid crystal displays.

3) Better Capacitors that Replace Batteries: The capacitance of a capacitor is a function of the surface area. CNTs have extraordinarily high surface areas, and using them as the dielectrics could increase the storage ability of capacitors to be on par with modern batteries.

4) Electrical Wires and Cables: Electric wires and cables can now be fabricated from pure nanotubes and nanotube-polymer composites. It is interesting to note that in recent times that wires have been fabricated using the highest conductivity carbon nanotube with specific conductivity exceeding copper and aluminium.

5) Paper Batteries: Batteries are essential in electronic components and now there are paper batteries. A paper battery is a type that is designed to use a paper-thin sheet of cellulose infused with aligned carbon nanotubes. The nanotubes act as electrodes and thus allow the storage devices to conduct electricity. This type of battery can provide a long, steady power output comparable to a conventional battery. The paper battery integrates all of the battery components in a single structure, making it more energy efficient.

6) Faster Computers: Carbon nanotubes can now be incorporated into chips in order to improve its speed. With CNTs in computer chips many billions of CNT transistors could be packed onto a single processing chip, making for smaller, faster computers and electronics

4. TRENDS IN NANOELECTRONICS

Being a revolutionary, transformational and powerful technology, nanotechnology is seen as the latest mega trend in science and engineering that will bring a wave of radical innovation, bringing new industrial revolution in various application areas. For nanoelectronics applications, carbon nanotubes are attractive due to their excellent electrical properties. An important area of research is molecular electronics, for which molecules that are quantum electronic devices are designed and synthesized with the ultimate goal of using individual molecules as wires in circuits as switches and carbon nanotubes. Is, resulting in non-volatile memories.

Another trend is in the application of nanowires in electronic, opto-electronic and nanoelectromechanical devices. There is also nanometre which is a molecular device capable of converting energy into movement and nanoelectromechanical systems (NEMS). NEMS typically integrate transistor-like nanoelectronics with mechanical actuators, pumps, or motors, and thus can become physical, biological, and chemical sensors.

Metal carbon nanotubes have also been proposed for nanoelectronics interconnects because they can carry high current densities. Carbon nanotubes have found so much use in NEMS that methods have already been discovered to link suspended carbon nanotubes to other nanostructures. This allows carbon nanotubes to be structurally installed to form complex nanoelectric systems. Furthermore, since some carbon nanotubes are semiconductors, they can be used in transistors. By exchanging silicon in the channel for carbon nanotubes, transistors can be made both smaller and faster than today's transistors. There is now an emerging trend of the Pico technique, which involves the transformation of the structure and chemical properties of individual atoms, usually through the manipulation of the energy states of electrons within the atom, to produce metastable states with unusual properties. Foreigners produce some form of atom. The term pico technology is a neology intended to parallel the term nanotechnology. This is a hypothetical future level of technical manipulation of matter, on a scale of trillions of meters. In addition, there is female-technology which is an imaginary term used in reference to the structure of matter which is 10–15 m. This is a smaller scale than nanotechnology and picotechnology.

5. CONCLUSION

The future of carbon nanotubes looks bright due to the fact that they are extremely versatile. There seems to be no other material that is strong, demeaning, passive and so forth at the same time. The rapid progress with nanotubes is largely driven by its unique combination of properties. A very important property of carbon nanotubes is the very high surface area that increases the amount of charge. Carbon nanotubes are another potential material for use in an ultracapacitor. Ultracapacitors have high density internal, compact size, reliability and high capacitance. This reduction in size makes them increasingly possible to develop much smaller circuits and computers.

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