Nano Technology

A biological system can be exceedingly small. Many of the cells are very tiny, but they are very active and they manufacture various substances; they walk around; they wiggle, they do all kinds of marvelous things- all at a very small scale. Some biological cells are in nanoscale. Generally nanotechnology deals with structures of the size 100 nanometers or smaller, and involves developing materials or devices within that size. Therefore, to understand the reality of biological and some other phenomenon in the universe I am sure that this new nano-science will play a great role.

Back Ground and Definition of Nanotechnology

On December 29, 1959, at the California Institute of Technology, Nobel Laureate Richard P Feynman gave a talk at the annual meeting of the American Physical Society that has become one of the twentieth century's classical science lectures titled "There's Plenty of Room at the Bottom". He presented a technological vision of extreme minimurisation several years before the word "chip" became part of the lexicon. He talked about the problem of manipulating and controlling things at a small scale. According to the new physical laws, Feynman envisioned a technology using the ultimate toolbox of nature, building nano-objects by atom and atom or by molecule and molecule. Since 1980s, many inventions and discoveries in the fabrication of nano-objects have become a testament to his vision. As a result, in order to recognize this reality, the National Science and Technology Council (NSTC) of the White House created the interagency working group on Nanoscience, Engineering and Technology (IWGN in 1998).

Nanotecnology literally means any technology performed at a nanoscale that has applications in the real world. Nanotechnology encompasses the production and application of physical, chemical, and biological systems at scales ranging from individual atoms or molecules to submicron dimensions, as well as the integration of the resulting nanostructures into larger systems. Nanotechnology is likely to have a profound impact on the economy and society of Sri Lanka in the early twenty-first century, comparable to that of semiconductor technology, information technology, or cellular and molecular biology. Basically there are two important nanomolecule structures. These are,

1. Fullerene (Buckyball)
2. Carbon nanotube (CNT)

Fullerenes (C_{60})

The discovery of fullerenes and carbon nanotubes has opened a new research area in physics, chemistry and material science. Nanostructured materials may be defined as those materials whose structural element clusters, crystallites or molecules have dimensions in the 1 to 100 nm range. Clusters of atoms consisting of typically hundreds to thousands on nanometer (nm) scale are commonly called as nanoclusters. These small groups of atoms, in general, go by different names such as nanoparticles, nanocrystals, quantum dots and quantum boxes. Substantial work is being carried out in the domain of nanostructured materials and nanotubes in the past decade. The explosion in both academic and industrial interest in these nanomaterials over the past decade arises from the remarkable variations in fundamental electrical, optical and magnetic properties that occur as one progresses from an 'infinitely extended' solid to a particle of material consisting of a countable number of atoms. Nanostructured materials have led to new basic science phenomenon and several short, medium and long term applications. Examples are: nanoelectronic devices, quantum wires, electron field emitters for ultra-thin TV screens, nanoprobes, and high resolution tips for scanning and atomic force microscopes, sensors, ultrahigh strength composites, gas devices, nanodevices, and parts of nanomachines. Carbon-based nanomaterials and nanostructures including fullerenes and nanotubes play an increasingly pervasive role in nanoscale science and technology.

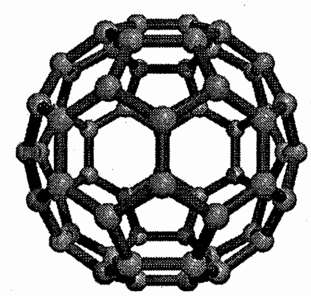

Fig. 1:The structure of C_{60} molecule

In the case of fullerenes, graphite acquires curvature due to the presence of pentagonal rings in the hexagonal graphite sheet. Fullerene exists in discrete molecular form and consists of a hollow spherical cluster of sixty carbon atoms; a single molecule is denoted by C_{60}. Each molecule is composed of groups of carbon atoms bonding to one another to form both hexagon (six-carbon atom) and pentagon (five-carbon atom) geometrical configurations. One such molecule (Figure 1) is found to consist of 20 hexagons and 12 pentagons which are arrayed such that no two pentagons share a common side; the molecular surface thus exhibits the symmetry of a soccer ball. The material composed of C_{60} molecules that contain sixty carbon atoms in a network of sp^2 bonding which forms a spherical structure, is known as buckminsterfullerene. However, from a number of perspectives, a molecule is almost 'custom built' for nanoscience. Discovered in 1985 by H.W. Kroto et al., C_{60} is approximately 1 nm in diameter. The term fullerene is used to denote the class of molecule. Therefore, simply we can say "Fullerenes are made up of hexagonal and pentagonal rings of carbon arranged exactly as those of a football".

Carbon Nanotubes (CNT)

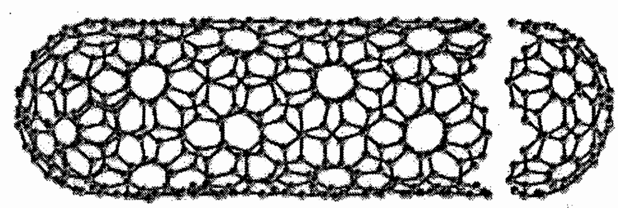

Fig 2: The structure of CNT

Another molecular form of carbon has recently been discovered as carbon nanotube (CNT-that has some unique and technologically promising properties). Ijiyama of NEC Japan in 1991 first announced the synthesis of carbon nanotubes. In his experiments on the arc discharge between graphite electrodes, along with the collected shoot particles there were some fine tube like structures. This on careful analysis revealed that they are carbon nanotubes (CNTs). Its structure consists of a single sheet of graphite, rolled into a tube, both ends of which are capped with C_{60} fullerene hemispheres. The tubes can be either open at their ends or capped at one or both ends with half spherical fullerene. A schematic representation of a carbon nanotube is shown in Figure 2.

Carbon nanotubes are currently being studied in an effort to understand their novel structural, electronic and mechanical properties to explore their immense potential for many applications in nanoelectronics as actuators and sensors. At the beginning scientist constructed a single walled and multiwalled nanotubes without branch. Nowadays, they have performed their research works to design branched CNTs also. The world already dreams of space-elevators tethered by the strongest cables, hydrogen-powered vehicles and artificial muscles, which would be made possible by the emerging carbon nanotube science.

As I have mentioned earlier, there are two types of carbon nanotubes. They are,

1.Single walled carbon nanotube (SWNT)

It has only one layer of carbon honey cone structure (Figure 2).

2.Multi walled carbon nanotube (MWNT)

Multi-walled nanotubes (MWNT) consist of multiple rolled layers (concentric tubes) of graphite.

Basically there are three types of nanatubes depending on their rolling vector. They are:

1. Chilral (Figure 4)
2. Helical (Figure 5)
3. Arm chair (Fig 6)

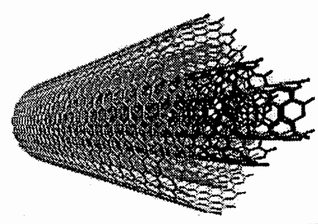

Fig 3: Multi Walled CNT

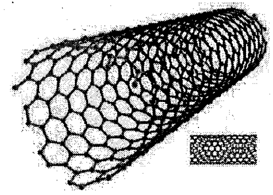

Fig 4: Chiral type nanotube

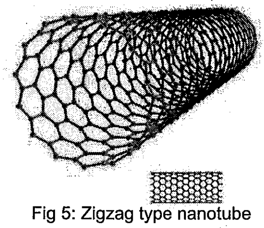

Fig 5: Zigzag type nanotube

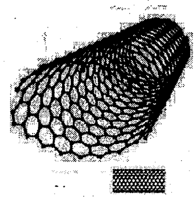

Fig 6: Armchair type nanotube

Properties of CNT are a very broad topic and therefore they have to be discussed under another title. Thus at this stage it is enough to discuss their names only. There are many methods used to synthesize carbon nanostructures and two important methods of those are Arc Discharge method and Laser Ablation method.

Applications

Nanotechnology is new to the world, but it is not an entirely new field. Nature has many objects and processes that function at a micro to nanoscale. Billions of years ago, molecules began organizing themselves into complex structures that could support life. Photosynthesis harnesses solar energy to support plant life. Molecular assembles are present in plants, which include light harvesting molecules, such as chlorophyll, arranged within the cells on a nanometer to micro scales. These structures capture light energy, and convert it into the chemical energy that drives the biochemical machinery of plant cells. Live chemical organs use chemical energy in the body. The flagella, a type of bacteria, rotates over 10,000RPM. This is an example of a biological molecular machine. The flagella motor is driven by the proton flow caused by the electrochemical potential differences across the membrane. The diameter of the baring is about 20-30 nm, with an estimated clearance of about 1nm.

The properties of carbon nanotubes have caused researchers and companies to consider using them in several fields. For example, because carbon nanotubes have the highest strength to weight ratio of any known material, researchers at NASA are combining nanotubes with other materials into composites that can be used to build lightweight spacecraft.

Another property of nanotubes is that they can easily penetrate membranes such as cell walls. In fact, nanotube's long, narrow shape makes them look like miniature needles, so it makes sense that they can function like a needle at the cellular level. Medical researchers are using this property by attaching molecules that are attracted to cancer cells to nanotubes to deliver drugs directly to the diseased cells

Another interesting property of nanotubes is that their electrical resistance changes significantly when other molecules attach themselves to the carbon atoms. Companies are using this property to develop sensors that can detect chemical vapors such as carbon monoxide or biological molecules.

Further, an integrated sensor circuit research work was done by scientists at the Lawrence Berkeley Laboratory of the U.S. Department of Energy and the University of California at Berkeley. An integrated sensor circuit is based on nanowire arrays and combines light sensors with electronics made from different crystalline materials.

Being virtually one-dimensional and having well defined atomic composition, a nanowire is an ideal shape to be used as a light detector. Sensor downgrading to the nanoscale has shown that it drastically enhances their sensitivity in a variety of materials and applications. However, electronics must be integrated on the same chip to make this a practical application but the two devices would normally be made from different materials, presenting fundamental difficulties.

fundamental difficulties.

At Berkeley, nanowires were used for both sensors and transistors and were grown, either on a roller for contact printing or on a substrate that could be slid away. This has the benefit of 'combing' the nanowires into one direction and aligning them for uniform performance.

Cadmium selenide nanowires, which offer the best photo sensor performance, were used as visible-light sensors while germanium core/silicon shell nanowires comprised the electronic component, amplifying the light-response current produced by the photo sensors by five orders of magnitude. The two materials were positioned at precise locations on the receiver substrate. The device pattern was on a photo resist layer coated on the substrate, which was removed by acetone. Metal electrodes were deposited and each circuit represented a pixel when used for imaging. With small variations, successful photo response was shown in 80% of the resulting circuits and improvements are thought readily achievable with optimized device fabrication and nanowire synthesis. "This work presents a route towards the utilization of nanowire materials for integrated sensors."

There is also an increasing demand for low-cost gas sensors that can discriminate between low concentrations of analytes. Nanotechnology offers the promise of improved gas sensors with low-power consumption, and fast response time which will enable portability for a wide range of applications. It is well documented that nanostructured materials such as nanotubes and nanowires are suitable for sensing a number of different gases.

In most cases, these sensors were subject to cross interference by other analytes. The arranying of nanostructured gas sensing materials which are combined with advanced numerical methods such as pattern recognition have the potential to filter out some of these interferences. Thus, the development of a more analytic specific sensor is highly desirable. The above given are just a few of the potential uses of carbon nanotubes.

If I compare different technologies that came into being on several occasions into buses, earlier there were two buses in the world. Those were nuclear physics and quantum physics. Most countries got onto those buses and automatically achieved development drastically. Nanotechnology is the third bus; therefore we have a chance to get onto that. Not only the science sector but also the private sector is interested in this new field. Therefore, the government needs to take plethora to drive Sri Lankan academic and research work on that field.

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