## Mailvaganam Memorial Oration – 2015

2015 lecture was delivered by


## Professor K. Premaratne

Senior Professor of Physics,
Department of Physics, University of Peradeniya.


# Nanotechnology: Technology of the New Millennium

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### Summary:

In 1959, the late Great Physicist and Nobel Laureate, Richard Feynman said in an after-dinner speech delivered at an American Physical Society meeting that "There is plenty of room at the bottom". The speech was based on a comprehensive vision of controlling matter at the nanoscale, including controlling of individual atoms. He further said, "Why cannot we write the entire 24 volumes of the Encyclopedia on the head of a pin by manipulating individual atoms to make different words. Then, we should be able to read the script using an electron microscope". In justifying his proposition, he referred to the fascinating things that a biological cell can do. In his words: "A biological system can be exceedingly small. Many of the cells are very tiny, but they are very active; they manufacture various substances; they walk around; they wiggle and they do all kinds of marvelous things – all on a very small scale. Also, they store information. Consider the possibility that we too can make a thing very small so that it does what we want".

Today, many of his speculations have become realities! For example, we are able to control atoms individually using latest versions of Atomic Force Microscopy. In 1960, magnetic fluids called` ferrofluids` that consist of nano-sized magnetic particles( 1 nm – 100 nm), were developed. In early 1970's, the first quantum well was fabricated. Now, Quantum well Infrared Photodetector cameras(QUIPs) are in operation, especially for night vision purposes. Quantum well is a structure in which one of its three dimensions is reduced to nanoscale. Also, they are in wide use in diode lasers including red lasers for DVDs , laser pointers, etc. When two of the three dimensions are reduced to nanoscale the structure is called a quantum wire and if all dimensions are of nanoscale, they are called quantum dots. All these structures have numerous applications in nanotechnology.

Carbon-based nanostructures have a special place in nanotechnology. There are four different structures of carbon: Diamond, graphite, C60 (Fullerine) and carbon nanotubes(CNTs). Carbon nanotubes that were discovered in 1990s have unusual mechanical and thermal properties and unique electrical properties. The structure of a carbon nanotube resembles a graphite sheet that has been rolled up so as to form a cylinder. There is a wide range of applications of CNTs such as nanoelectronics, quantum wire interconnections, field emission devices, composites, chemical sensors, biosensors, detectors, etc.

On the other hand, quantum dots and quantum wires have many interesting properties. A metal quantum dot has properties that are very different from that of a bulk piece of the same metal. Even though a metal has a sea of electrons with overlapping electronic energy bands without a gap, when the size is gradually decreased to nano-level a band gap opens up and the gap increases as the particle diameter decreases. This leads to a change in light absorption of nanoparticles with size. In a porous structure consisting of nano particles the effective surface area is about thousand times larger than that of a thin film made out of the same material. In 1990, Gretzel was able to employ this property in dye-sensitized solar cells to improve their efficiency by about 7-fold. Also the resonance absorption of surface plasmons of metal nanoparticles, such as silver, has a wide range of applications in the medical field.

The important and fascinating properties of nanostructures, some of which are summarized above, lead to applications of Nanotechnology in a wide variety of fields such as energy, medicine, pharmaceutical industry, nanoelectronics, optoelectronics, cosmetics, sports, information technology and biotechnology, making it the ‘Technology of the New Millennium’.