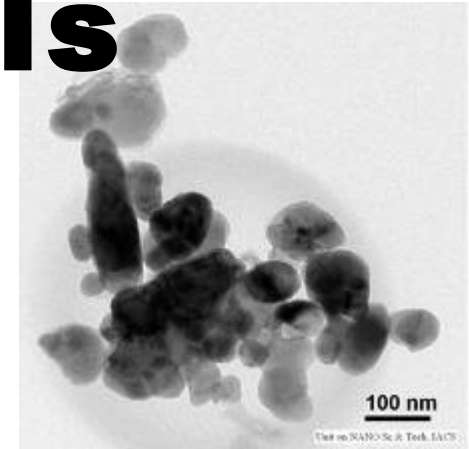


Nanomaterials

- Top-down Science
- Bottom-up Science



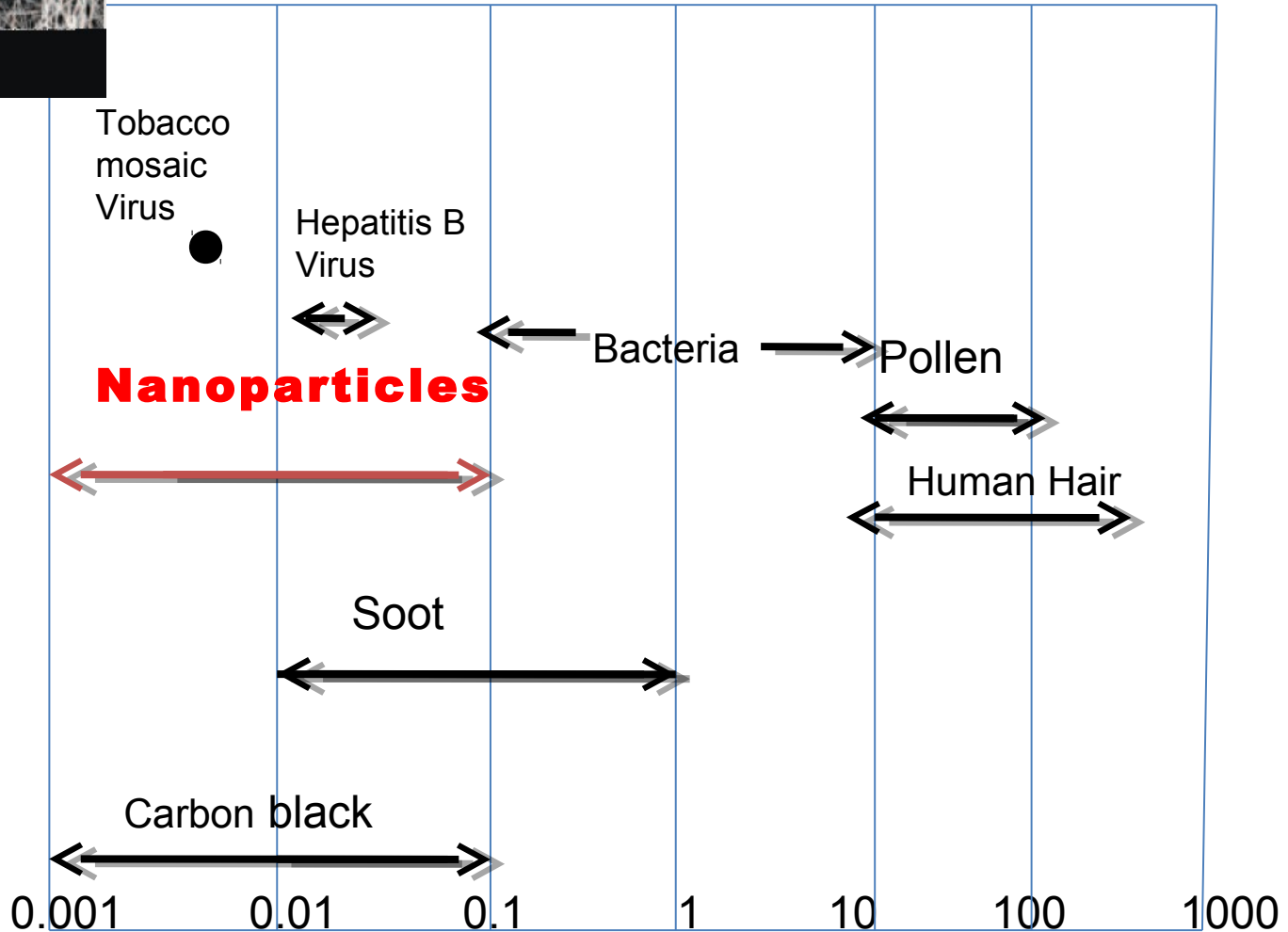
What are nanomaterials?

Nanomaterials are materials are materials possessing grain sizes on the order of a billionth of a meter (10⁻⁹ M)

nanomaterial research literally exploded in mid -1980's

Typical size of small particles

Particle size μm



- Conventional material have grain size anywhere from 100 μm to 1mm and more
- Particles with size between 1-100 nm are normally regarded as Nanomaterials
- The average size of an atom is in the order of 1-2 Angstroms in radius.
- 1 nanometer =10 Angstroms
- 1 nm there may be 3-5 atoms

- Two principal factors cause the properties of nanomaterials to differ significantly from Bulk materials:
 - Increased relative surface area
 - Quantum effects.

These factors can change or enhance properties such as reactivity, strength and electrical characteristics.

Surface Effects

- As a particle decreases in size, a greater proportion of atoms are found at the surface compared to those inside. For example, a particle of
- Size-30 nm-> 5% of its atoms on its surface
- Size-10 nm->20% of its atoms on its surface
- Size-3 nm-> 50% of its atoms on its surface
- **Nanoparticles are more reactive than large particles (Catalyst)**

Quantum Effects

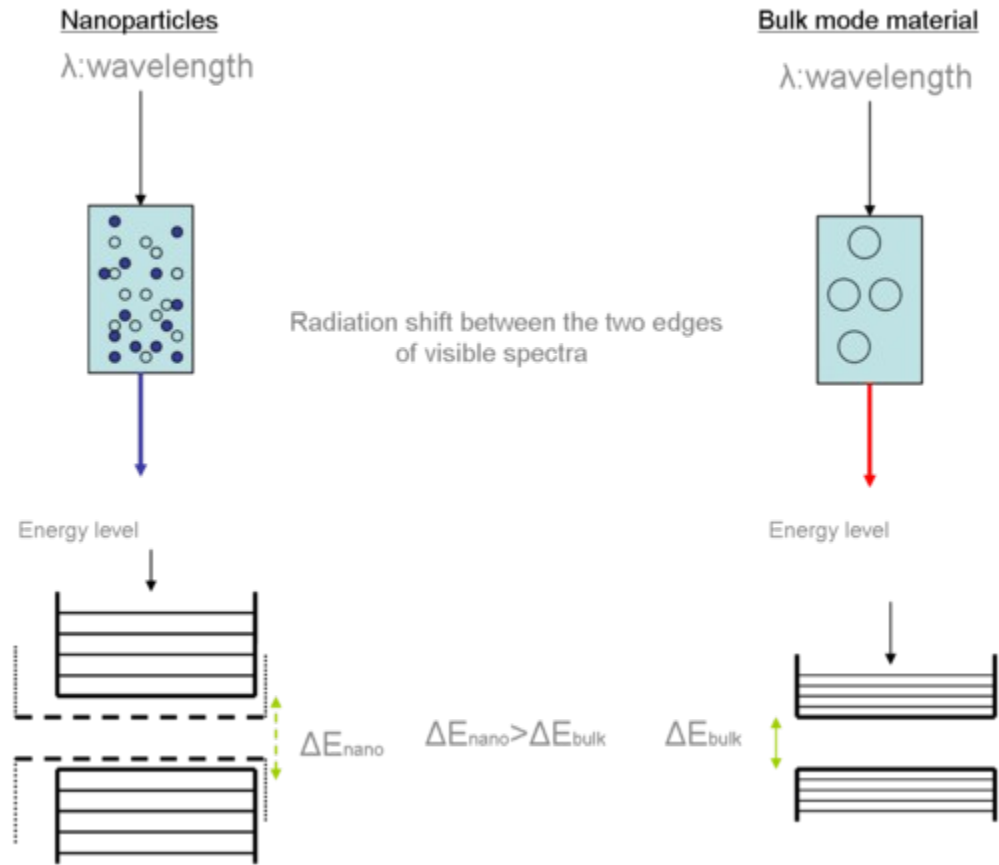
Quantum confinement

The quantum confinement effect can be observed once the diameter of the particle is of the same magnitude as the wavelength of the electron [Wave function](#).

Quantum confinement is responsible for the increase of energy difference between energy states and band gap. A phenomenon tightly related with the optical and electronic properties of the materials.

When materials are this small, their electronic and optical properties deviate substantially from those of bulk materials. (GOLD)





Classification of Nanomaterials

- **Nanomaterials as those which have structured components with atleast one dimension less than 100nm.**
- **One dimension in nanoscale (Other two dimensions are extended)**

Thin films

Surface Coatings

Computer chips

- **Two dimensions in nanoscale (Other one dimension is extended)**

Nanowires

Nanotubes

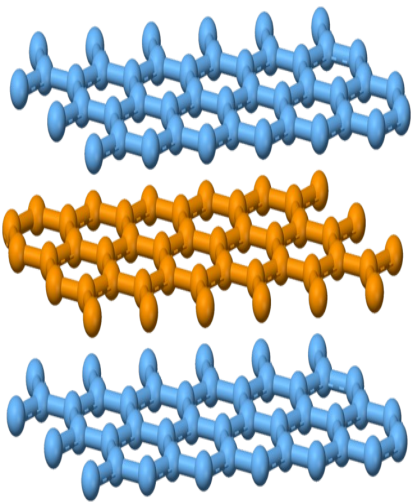
- **Three dimensions in nanoscale**

Nanoparticles

Precipitates

Colloids

Quantum dots (tiny particles of semiconductor material)



Graphite

It is also a crystalline form of carbon.

STRUCTURE OF GRAPHITE

In graphite each carbon atom is covalently bonded to three carbon atoms to give trigonal geometry. Bond angle in graphite is 120° . Each carbon atom in graphite is sp^2 hybridized. Three out of four valence electrons of each carbon atom are used in bond formation with three other carbon atoms while the fourth electron is free to move in the structure of graphite.

Basic trigonal units unite together to give basic hexagonal ring. In hexagonal ring C-C bond length is 1.42 \AA . In graphite these rings form flat layers. These layers are arranged in parallel, one above the other. These layers are 3.35 \AA apart and are held together by weak van der Waals forces only. These layers can slide over one another. Thus it is very soft. Fourth electron of each carbon atom forms delocalized p-bonds which spread uniformly over all carbon atoms. Due to this reason graphite conducts electricity parallel to the plane of its plane.

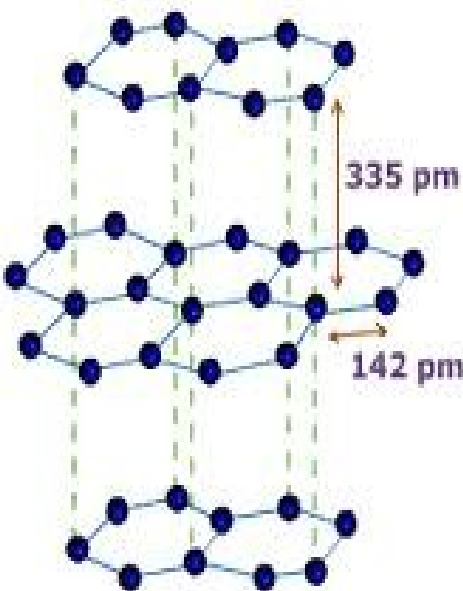
Uses

Solid lubricants

Moderator in nuclear reactors

Electrodes

Pencil lead

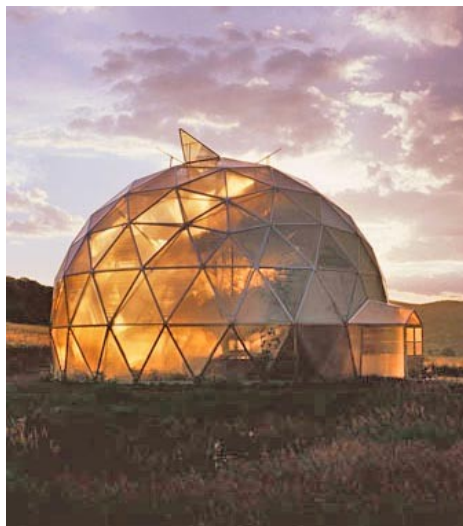
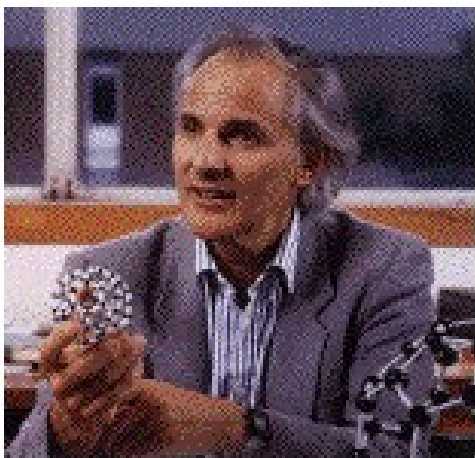


Fullerenes

The 1996 Nobel Prize for Chemistry has been won by Harold W. Kroto, Robert F. Curl and Richard E. Smalley for their discovery in 1985 of a new allotrope of carbon, in which the atoms are arranged in closed shells. The new form was found to have the structure of a truncated icosahedron, and was named Buckminster fullerene, after the architect Buckminster Fuller who designed geodesic domes in the 1960's. In 1990 physicists W. Krätschmer and D.R. Huffman for the first time produced isolable quantities of C₆₀ by causing an arc between two graphite rods to burn in a helium atmosphere and extracting the carbon condensate.

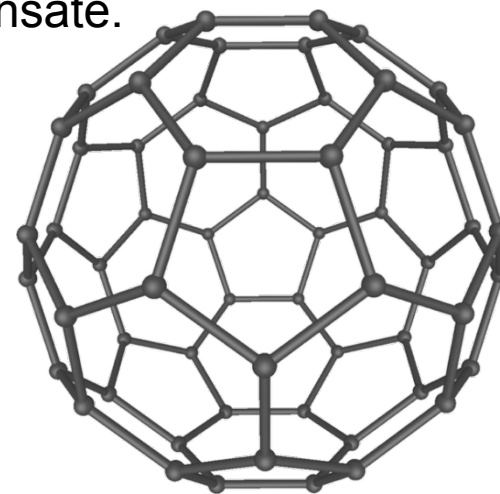


Professor Sir Harold W. Kroto



Geodesic dome

C₆₀



Football like structure
20 hexagones
12 pentagones

Applications-

The fullerenes have synthetic pharmaceutical and industrial applications.

Degenerative diseases and ordinary aging processes are caused by intracellular

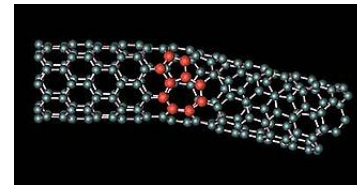
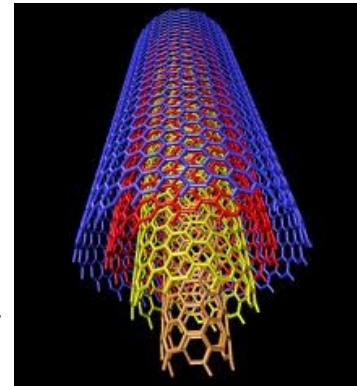
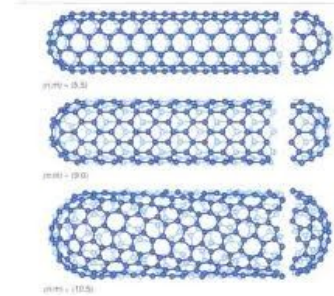
Oxygen free radicals with unpaired electrons. C60 fullerenes can react with radicals

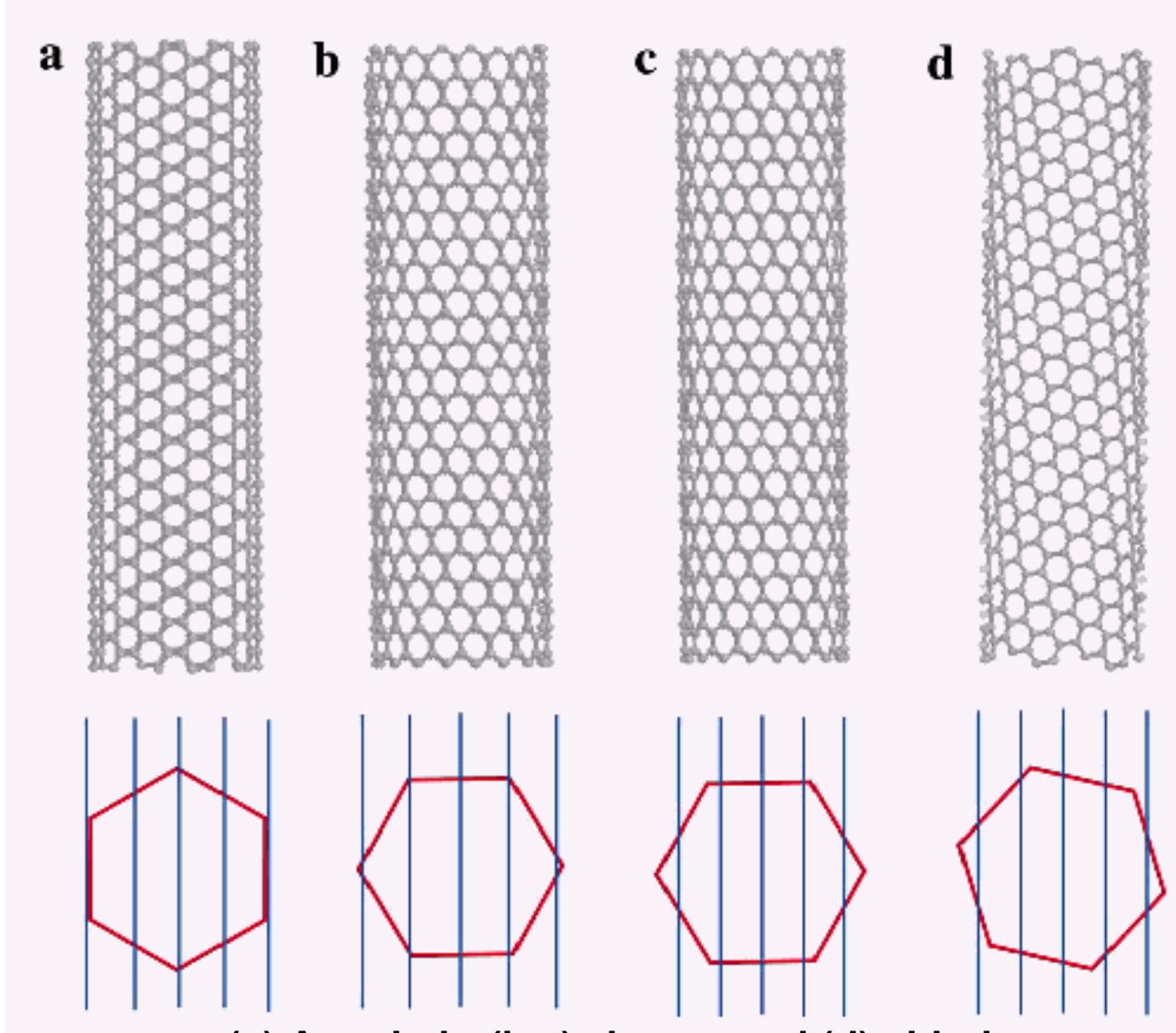
Thus halting the process of aging. It act as good MRI contrast agent. They can also

Be used in light emitting diodes in different electronic equipments and computing devices

Carbon nanotubes (CNTs) are [allotropes of carbon](#) with a cylindrical nanostructure. Nanotubes have been constructed with length-to-diameter ratio of up to 132,000,000:1, significantly larger than for any other material.

These cylindrical [carbon molecules](#) have unusual properties, which are valuable for nanotechnology, [electronics](#), [optics](#) and other fields of [materials science](#) and technology. In particular, owing to their extraordinary [thermal conductivity](#) and mechanical and [electrical](#) properties, carbon nanotubes may find applications as additives to various structural materials. 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](#). Nanotubes are categorized as [single-walled nanotubes](#) (SWNTs) and [multi-walled nanotubes](#) (MWNTs). Individual nanotubes naturally align themselves into "ropes" held together by [van der Waals forces](#).





(a) Armchair, (b,c) zig-zag and (d) chiral tube; (a) metallic, (b) small gap semiconductor, and (c,d) semiconductor.

Properties and Applications:-

The nanotubes are extremely strong and stiff and relatively ductile. For single walled nanotubes tensile strengths range between 50 and 200 Gpa more than carbon fibres. This is strongest known material. Elastic modulus values are of the order of one tera pascal with fracture strains between 5% to 20%. They have very low densities. Because of these properties carbon nano tube has been termed as ultimate fibre. It has been regarded as 100 times stronger Than steel at the same time six times lighter (weight wise). They find Applications in filling material in composite material.

They can act as either conductors or semiconductors depending on their chirality so they find their applications in molecular electronics and Computers they are used as ultra sensitive electrochemical sensors. They are used in batteries and fuel cells.

Field emission results from the tunnelling of electrons from a metal tip into Vacuum under application of strong electric field. Small diameter and high aspect ratio

(lower loading of CNTs is needed compare to other conductive additives to achieve same electrical conductivity .CNTs are very favourable for field emission.)

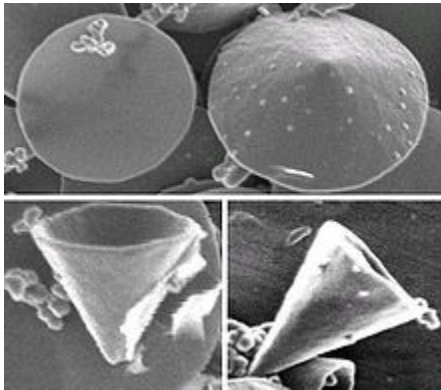
Even for moderate voltages a strong electric field develops at free end of supported CNTs because of their sharpness.

The large surface area and high absorbency of CNTs make them ideal candidates for use in air gas and water filtration

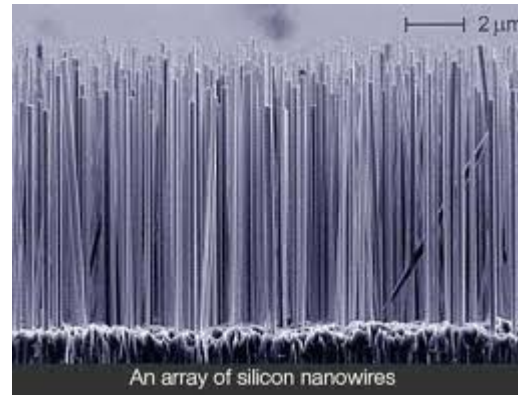
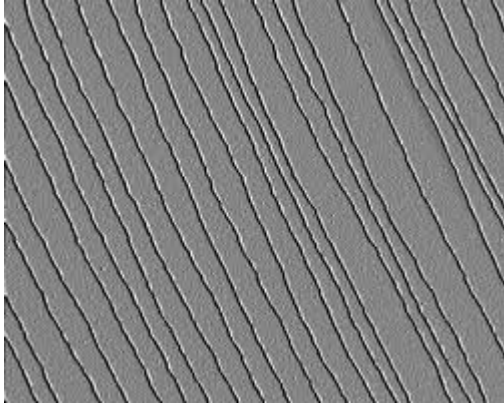
Carbon nanocones



The open carbon cone can be modeled as a wrapped **graphene** sheet. In order to have strain-free, seamless wrapping, a sector has to be cut out of the sheet. That sector should have an angle of $n \times 60^\circ$, where $n = 1, \dots, 5$. The nanocones are produced by carbon condensation on a Graphite substrates and pyrolysis of heavy oil. The essence of the method is heating the graphite surface with intensive short laser pulse, which evaporates some number of atoms from role as the cut and glue procedure. On the graphene sheet, and other atoms rearrange into the conical surface described above. There is also one special class of nanocones, called **nanohorns** with exact five defects. These structures with good electron emission properties are easy to get and stable enough. Nano horns show metallic behaviour.



Nanowires



A **nanowire** is a nanostructure, with the diameter of the order of a nanometer (10^{-9} meters). Alternatively, nanowires can be defined as structures that have a thickness or diameter constrained to tens of **nanometers** or less and an unconstrained length. At these scales, quantum mechanical effects are important — which coined the term "**quantum wires**". Many different types of nanowires exist, including metallic (e.g., **Ni**, **Pt**, **Au**), semiconducting (e.g., **Si**, **InP**, **GaN**, etc.), and insulating (e.g., **SiO₂**, **TiO₂**). **Molecular nanowires** are composed of repeating molecular units either organic (e.g. **DNA**) or inorganic (e.g. $\text{Mo}_6\text{S}_9\text{I}_x$). The nanowires could be used, in the near future, to link tiny **components** into extremely small **circuits**. using **nanotechnology**, such components could be created out of **chemical compounds**.

Typical nanowires exhibit aspect ratios (length-to-width ratio) of 1000 or more. As such they are often referred to as one-dimensional (1-D) materials. Nanowires have many interesting properties that are not seen in bulk or 3-D materials. This is because electrons in nanowires are quantum confined laterally and thus occupy energy levels that are different from the traditional continuum of energy levels or bands found in bulk materials.

Nano wires are synthesized in laboratory from elements.

There are many applications where nanowires may become important in electronic, opto-electronic and nanoelectromechanical devices, as additives in advanced composites, for metallic interconnects in nanoscale quantum devices, as field-emitters and as leads for biomolecular nanosensors.

Haeckelites

If we try to bend graphene sheet it will straighten up. A new hypothetical type of graphene sheet which admits pentagons heptagons and hexagons. It has been proposed, noting that the no. of heptagons and pentagons should be same, in order to compensate for the negative curvature of the heptagons and positive curvature of pentagon. These arrangements are now called **haeckelites** in honour of **Emst Haeckel** a German zoologist who produced a beautiful drawing of radiolaria, (Organism) in which heptagonal hexagonal and pentagonal rings are observed. Carbon haekalite structures are metallic. It is possible to roll up the haekelite sheets to form nanotubes which will be conductors independent of diameter and chirality.

Methods of preparation of CNT

Arc Method

Laser Method

Chemical vapour Deposition

Ball Milling

Laser Method

In 1996 CNT were first synthesized using a dual pulsed laser and achieved yields of 70% wt. Samples were prepared by laser vaporization of graphite's rods with a 50:50 catalyst mixtures of cobalt and nickel at 1200°C in flowing argon followed by heat treatment in vacuum at 1000 °C to remove the C60 and other fullerenes . The initial Laser vaporization pulse was followed by second pulse to vaporizes the target more uniformly .The use of two successive laser pulses minimizes the amount of carbon deposited as soot. Second pulse breaks up the larger particles ablated by first one and feeds them into the growing nano tube structure. The material produced by this method appears as a mat of ropes 10-20nm in diameter and up to 10 micro meter or more in length.

- **Chemical vapor deposition method**

This Method is useful in production of CNTs on large scale . Both MWCNTs and SWCNTs are obtained by this method . The Method involved decomposing a hydrocarbon gas such as methane acetylene ethylene at temperature of about 1100oc ,in presence of metal nano particle catalyst mostly Ni Co Fe supported on MgO or Al₂O₃ . Carbon atoms produced by decomposition are condensed on cooler surface containing metal catalyst . The size of the metal nano particle determine the diameter of the nano tube with open ends. It is continuous process used as industrial scale.

CONCLUSION

one needs to remember the words of Richard Feynman: "... there is plenty of room at the bottom". This statement was made in 1959, and its meaning reflects the (possible) significance of the molecular – scale devices. In his lecture at the California Institute of Technology, Feynman proposed the new ideas to be realized on the molecular size level – the information on the nanoscale, miniaturized and quantum computers, and the extensively advertised concept of nano - robots. And what do we see at the present time? On the one hand, there is a popularized idea of nano – robots, which will appear to build any thing in no time and without any cost; but there are no ideas (even in the theoretical aspect) how these systems should look like. There are many enthusiasts of this approach but they lack the practical techniques which are needed to convert their dreams into the scientific and technical reality. On the other hand, there are some types of the nanostructures (the quantum dots, semiconducting hetero structures and the carbon nanostructures described above) which are investigated enough, and some of them have commercial applications . The most important thing we need to do now is to develop the present technologies in accordance with the present state of the science and with the requirements of the mankind. The highly advertised nanorobots would be just a little part of the wonders of future engineering. Both the development and use of the novel technologies are in our hands; our duty is to manage them in the worthy way.