Characterization of Nanomaterials

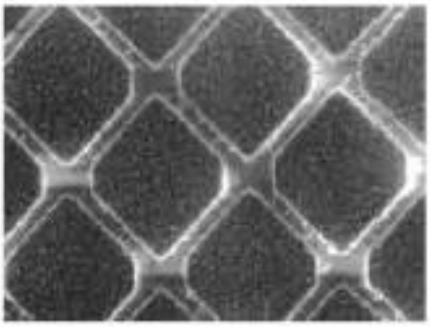
Nanotechnology is a field of applied science focused on the fabrication, Synthesis, characterization and application of materials and devices on the nanoscale.
Two main approaches are used in nanotechnology. They are
1) Bottom up approach where materials & devices are built up atom-by-atom
2) Top down where they are synthesized or constructed by removing existing material from larger entities An important aspect of nanotechnology is the increase in the ratio of surface area to volume in nanoscale materials. Materials when reduced to nanoscale show different properties in comparison to the bulk material.

1) Introduction:

Nanotechnology is a field of applied science focused on the fabrication, Synthesis, Characterization and application of materials & devices on a nanoscale. Nanomaterials are those which have structured components with at least one dimension less than 100nm.Nano technology is a technology in biology. Physics, chemistry and other scientific fields and involves the manipulation of material in nanoscale.

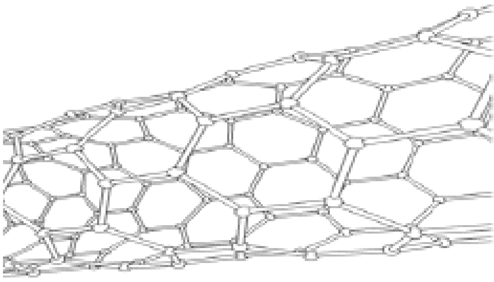
2) Types of nanomaterials

One-dimensional nanomaterials, such as thin films and engineered surfaces, have been developed and used in electronic device manufacture, chemistry and engineering. In the silicon integratedcircuit industry many devices rely on thin films for their operation, and control of film thicknesses approaching the atomic level is seen. Monolayers are also routinely made and used in chemistry. The formation and properties of these layers are reasonably well understood. Advances are being made in the control of the composition and smoothness of surfaces, and the growth of films.



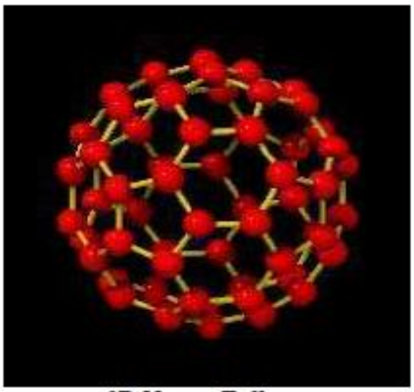
1D Nano

Two dimensional nanomaterials such as tubes and wires have generated considerable interest among the scientific community. Research is going on to study their novel electrical and mechanical properties. Carbon nanotubes cylinders made of carbon atoms. Their diameter is of few nanometers. Their physical properties like strength, resilience and ductility make them versatile in their applications.



2D Nano – carbon Nanotubes

3 dimensional Fullerenes (C60)-can be used as miniature 'ball bearings' to lubricate surfaces, drug delivery vehicles and in electronic circuits.



3D Nano - Fullerene

If semiconductor particles are made small enough, quantum effects come into play, which limit the energies at which electrons and holes can exist in the particles. As energy is related to wavelength (or colour), this means that the optical properties of the particle can be finely tuned depending on its size. Thus, particles can be made to emit or absorb specific wavelengths (colours) of light, merely by controlling their size.

3) Tools Used for characterizing nanomaterials

The various techniques used for studying the characteristics of nanomaterials are:

• UV- Vis Spectrophotometer

• X-ray diffraction

• Transmission Electron Microscope

• Scanning Electron Microscope

Nanotechnology, is a major frontier area of Science and technology to produce materials of nanometer scale. Nanoscience and nanotechnology refer to the control and manipulation of matter at nanometer dimension. The observation of material in the nanoscale can be done using electron, photons, scanning probes, ions, atoms etc. A wide range of technique is available in each of these areas and a systematic application of several tools leads to a complete understanding of the system. Observation is a key to making of new discoveries. It may be done with a probe which may consist of photons, electrons, neutrons, atoms, ions etc. For nanomaterials, the probing light or particle has varying frequency (gamma rays, IR rays). The resulting information can be processed to yield images or spectra which reveal the size, geometric, structural, chemical or physical details of the material.

UV-Visible Spectroscopy:

Ultraviolet and Visible spectroscopy investigates electronic transitions within the molecule or within specific chromophores. UV/Vis give some indication of the multiplicity and arrangement of certain functional groups (Chromophores).

X-ray diffraction

The most effective way of observing the atomic structure of crystals is through the study of diffraction effects, which occur when a beam of x-rays is passed through a crystal. X-ray diffraction is scattering of x-rays by periodic arrangement of atoms forming lattice or crystals. The phenomenon of x-ray diffraction was first discovered and experiments carried out under diffraction by Max Von Laue in 1912.

Scanning Electron Microscope

In light microscopy, a specimen is viewed through a series of lenses that magnify the visible-light image. However, the scanning electron microscope (SEM) does not actually view a true image of the specimen, but rather produces an electronic map of the specimen that is displayed on a cathode ray tube (CRT). The SEM has a secondary electron detector. The signal produced by the secondary electrons is detected and sent to a CRT image. The scan rate for the electron beam can be increased so that a virtual 3-D image of the specimen can be viewed. The image can also be captured by standard photography.

Transmission Electron Microscopy

One of the typical characters of nanophase materials is the small particle size. The direct imaging of nanoparticles is only possible using TEM and Scanning probe Microscopy.

TEM is unique because it can provide a real space image on the atom distribution in the nanocrystal and on its surface.

TEM is a versatile tool that provides:

1) Atomic resolution lattice image.

2) Chemical information at a spatial resolution of 1nm.

With finely focused e- probe, the structural characteristics of a single nanoparticle can fully characterized.

A TEM consist of

1. Illumination system
2. Specimen stage
3. Objective lens system

4. Magnification system
5. Data recording system
6. Chemical analysis system

4) <u>Applications</u>

The areas that nanotechnology promises to affect are:

• Pharmacy: It is possible to create biomolecules that carry out "Pharmacy in a cell" that could release cancer fighting nanoparticles in response to a distress signal from an afflicted cell.

• Therapeutic Drugs: It is possible to synthesize solid state medicine by producing in nanosize. The high surface area of these small particles allows them to dissolve in bloodstream where larger particles cannot.

• Tissue Engineering: Nanotechnology can help to reproduce or to repair damaged tissue.

• Chemistry and environment: Chemical catalysis and filtration techniques are two prominent examples where nanotechnology already plays a role. The synthesis provides novel materials with tailored features and chemical properties.

• Automobile industry: The performance of the automotive coating can be enhanced with nanoproducts that are scratch resistant, water & acid resistant. Nanotyres are more reliable, withreduced wear and tear and are less prone to skidding. Nano battery has twice the storage capacity compared to normal batteries.,

• Energy: The most advanced nanotechnology projects related to energy are storage, conversion, manufacturing improvements by reducing materials and process rates, energy saving e.g. by better thermal insulation, and enhanced renewable energy sources.

• Environmentally friendly energy systems : An example for an environmentally friendly form of energy is the use of fuel cells powered by hydrogen, which is ideally produced by renewable energies.

• Electronics: Novel Semiconductor devices, opto electronic devices, displays, nanologic, Quantum computers are some of the advances in the field of electronics.

5) Risks associated with nanotechnology

Potential risks of nanotechnology can broadly be grouped into three areas:

• the risk to health and environment from nanoparticles and nanomaterials;

• the risk posed by molecular manufacturing

• societal risks.

Since nanoparticles are very different from their bulk counterparts, their adverse effects cannot be derived from the known toxicity of the macro-sized material. This poses significant issues for addressing the health and environmental impact of free nanoparticles.

Nanoparticles in the atmosphere may be inhaled, swallowed, absorbed through skin which can cause danger to life. It is still not known for sure e if nanoparticles could have undesirable effects on the environment.