Unit-II
Nano-material and its Applications

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Semester –II
Core Course- V
Advances in Chemistry

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• Coarse Particle : <10 µm
• Fine Particles : <2.5 µm
• Ultra Fine Particle : ~ 0.1 µm (100 nm)

A nanometer is one millionth of a millimeter – approximately 100,000 times smaller than the diameter of a human hair.

• Nano Particle
• Diameter between 1nm -100 nm
• Size of protein : 1~20 nm ► Size compatible
• Nanoparticles have characteristic properties like Melting point, Boiling point, Band gap, Optical properties, Electrical properties, Magnetic Properties. Even Properties of materials changes with respect to size.

➢ In 1959 Richard Feynman gave a revolutionary lecture “there’s plenty of room at the bottom” - - which is initiation of Nanotechnology.
➢ Norio Taniguchi (University of Tokyo): First used the term “Nanotechnology” !
Why Nanoparticles Important....

- Electron are confined (Quantum effect);
- Large Surface to Volume Ratio of Atom;
- More disordered Dipole on Surface than in Bulk (Electric and Magnetic).

- Quantum dots (0-D): confined states, and no freely moving ones
- Nanowires (1-D): particles travel only along the wire direction
- Quantum wells (2-D): confines particles within a thin layer

There is no confinement effect in Bulk materials.
Refer to energy distribution.
Nano Technology in Biological World

Nano Medicine & Drugs

Chemical & Biological Sensor

Nano Therapy

Drugs delivery

In Vitro Diagnostics

cosmetics

Bio Engineering

BIOinspired Fabrication
- DNA/Protein Mediated Self Assembly

Nano robotics

Nano imaging

Biology...
Silver and Gold Nanoparticles

Unique Physical and optical property;
Localized Surface Plasmon Resonance [LSPR];
Fluorescence Resonance Energy transfer [FRET];
Surface Enhance Raman Scattering [SERS];
Non Linear optical Property;
Quantized Charging Effect.

Effect of particle size on gold nanoparticle dispersion color

Effect of aspect ratio on gold nanoparticle dispersion color

Optical Density (cm$^{-1}$) vs Wavelength (nm)
Cancer Treatment by hyperthermia using magnetic field.

Nanoparticles- Biomolecular Conjugation ....
Selected Application of nanomaterials

Nanomaterials having wide range of applications in the field of electronics, fuel cells, batteries, agriculture, food industry, and medicines, etc... It is evident that nanomaterials split their conventional counterparts because of their superior chemical, physical, and mechanical properties and of their exceptional formability.

Fuel cells

A fuel cell is an electrochemical energy conversion device that converts the chemical energy from fuel (on the anode side) and oxidant (on the cathode side) directly into electricity. The heart of fuel cell is the electrodes. The performance of a fuel cell electrode can be optimized in two ways; by improving the physical structure and by using more active electro catalyst. A good structure of electrode must provide ample surface area, provide maximum contact of catalyst, reactant gas and electrolyte, facilitate gas transport and provide good electronic conductance. In this fashion the structure should be able to minimize losses.
Microbial fuel cell

Microbial fuel cell is a device in which bacteria consume water-soluble waste such as sugar, starch and alcohols and produces electricity plus clean water. This technology will make it possible to generate electricity while treating domestic or industrial wastewater. Microbial fuel cell can turn different carbohydrates and complex substrates present in wastewaters into a source of electricity. The efficient electron transfer between the microorganism and the anode of the microbial fuel cell plays a major role in the performance of the fuel cell. The organic molecules present in the wastewater posses a certain amount of chemical energy, which is released when converting them to simpler molecules like CO2. The microbial fuel cell is thus a device that converts the chemical energy present in water-soluble waste into electrical energy by the catalytic reaction of microorganisms.

Carbon nanotubes

Carbon nanotubes (CNTs) have chemical stability, good mechanical properties and high surface area, making them ideal for the design of sensors and provide very high surface area due to its structural network. Since carbon nanotubes are also suitable supports for cell growth, electrodes of microbial fuel cells can be built using of CNT. Due to three-dimensional architectures and enlarged electrode surface area for the entry of growth medium, bacteria can grow and proliferate and get immobilized. Multi walled CNT scaffolds could offer self-supported structure with large surface area through which hydrogen producing bacteria (e.g., E. coli) can eventually grow and proliferate. Also CNTs and MWCNTs have been reported to be biocompatible for different eukaryotic cells. The efficient proliferation of hydrogen producing bacteria throughout an electron conducting scaffold of CNT can form the basis for the potential application as electrodes in MFCs leading to efficient performance.
Catalysis

Higher surface area available with the nanomaterial counterparts, nano-catalysts tend to have exceptional surface activity. For example, reaction rate at nano-aluminum can go so high, that it is utilized as a solid-fuel in rocket propulsion, whereas the bulk aluminum is widely used in utensils. Nano-aluminum becomes highly reactive and supplies the required thrust to send off pay loads in space. Similarly, catalysts assisting or retarding the reaction rates are dependent on the surface activity, and can very well be utilized in manipulating the rate-controlling step.

Phosphors for High-Definition TV

The resolution of a television, or a monitor, depends greatly on the size of the pixel. These pixels are essentially made of materials called "phosphors," which glow when struck by a stream of electrons inside the cathode ray tube (CRT). The resolution improves with a reduction in the size of the pixel, or the phosphors. Nanocrystalline zinc selenide, zinc sulfide, cadmium sulfide, and lead telluride synthesized by the sol-gel techniques are candidates for improving the resolution of monitors. The use of nanophosphors is envisioned to reduce the cost of these displays so as to render high-definition televisions (HDTVs) and personal computers affordable to be purchase.
Next-Generation Computer Chips

The microelectronics industry has been emphasizing miniaturization, whereby the circuits, such as transistors, resistors, and capacitors, are reduced in size. By achieving a significant reduction in their size, the microprocessors, which contain these components, can run much faster, thereby enabling computations at far greater speeds. However, there are several technological impediments to these advancements, including lack of the ultrafine precursors to manufacture these components; poor dissipation of tremendous amount of heat generated by these microprocessors due to faster speeds; short mean time to failures (poor reliability), etc.

Nanomaterials help the industry break these barriers down by providing the manufacturers with nanocrystalline starting materials, ultra-high purity materials, materials with better thermal conductivity, and longer-lasting, durable interconnections (connections between various components in the microprocessors).
Elimination of Pollutants
Nanomaterials possess extremely large grain boundaries relative to their grain size. Hence, they are very active in terms of their chemical, physical, and mechanical properties. Due to their enhanced chemical activity, nanomaterials can be used as catalysts to react with such noxious and toxic gases as carbon monoxide and nitrogen oxide in automobile catalytic converters and power generation equipment to prevent environmental pollution arising from burning gasoline and coal.

Sun-screen lotion
Prolonged UV exposure causes skin-burns and cancer. Sun-screen lotions containing nano-TiO$_2$ provide enhanced sun protection factor (SPF) while eliminating stickiness. The added advantage of nano skin blocks (ZnO and TiO$_2$) arises as they protect the skin by sitting onto it rather than penetrating into the skin. Thus they block UV radiation effectively for prolonged duration. Additionally, they are transparent, thus retain natural skin color while working better than conventional skin-lotions.

Sensors
Sensors rely on the highly active surface to initiate a response with minute change in the concentration of the species to be detected. Engineered monolayers (few Angstroms thick) on the sensor surface are exposed to the environment and the peculiar functionality (such as change in potential as the CO/anthrax level is detected) is utilized in sensing.