DEPARTMENT OF PHYSICS AND NANOTECHNOLOGY
SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

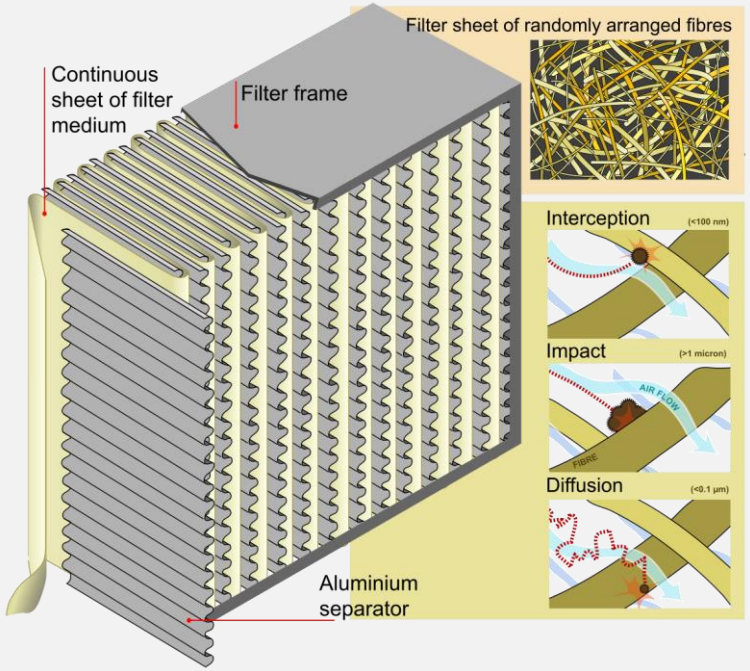
18NTO301T - APPLICATIONS OF NANOTECHNOLOGY
Module-I, Lecture-5

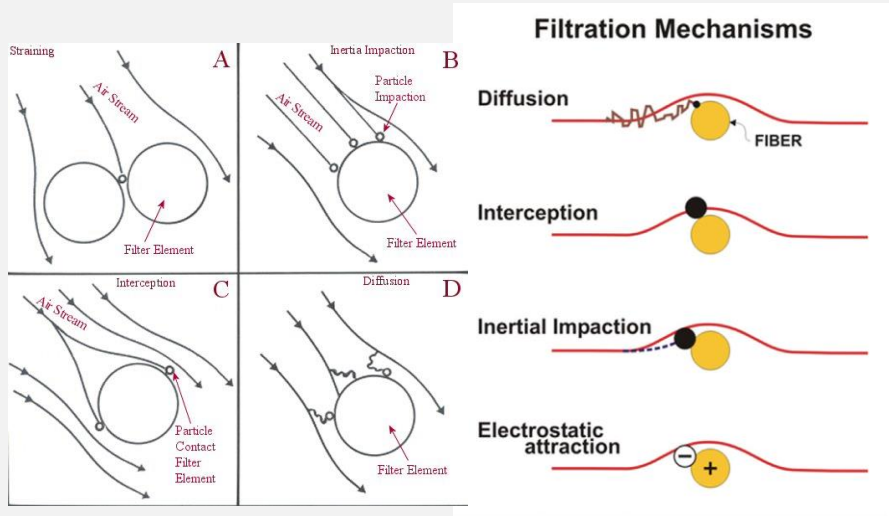
NANOTECHNOLOGY: ENVIRONMENTAL APPLICATIONS

Air Purification, Water Purification, Nano Monitoring, Nano Bioremediation, Soil Structure and Remediation

Air Purification:

- Nanotechnology is contributing towards indoor air quality on all of these fronts. Samsung Electronics has launched new nano e-HEPA (for electric high efficiency particulate arrest) filtration system.
- The system sifts the air to filter particles, eliminate undesirable odours and kill airborne health threats.
- It uses a metal dust filter that has been coated with 8 nm silver particles.
- The Kitasato Research Centre of Environmental Sciences in Japan found the nonfilter killed 99.7% of influenza viruses.
- Up to 98% of odours were eliminated, and another nonfilter eliminated all noxious VOC fumes from paint, varnishes and adhesivesives.
- Donaldson Filtration Systems uses ultra-web nanofibre media from a layer of nanofibres that encourage dust particles to rapidly accumulate on the filter surface building a thin, permeable dust-stopping filter cake.





[Guidance for Filtration and Air-Cleaning Systems to Protect Building Environments from Airborne Chemical, Biological]

- Donaldson Filtration Systems uses ultra-web nanofibre media from a layer of nanofibres that encourage dust particles to rapidly accumulate on the filter surface building a thin, permeable dust-stopping filter cake.

- Ultra-Web cleans the air better by filtering even submicron contaminants.

- This filter has an efficiency of 0.3 micron filtrate and eliminates larger particles by capturing them on the surface of the media, solving premature filter plugging and making contaminants easier to pulse off compared to depth-loading 80/20 blend or cellulose commodity media.

- Independent lab tests concluded that 80/20 and cellulose media have lower MERV efficiency ratings and are not suitable for capturing submicron particulate matter.

- ConsERV brand energy recovery ventilator products that are claimed by their manufacturer, Dais Analytic Corporation, to improve heating, ventilating and air conditioning systems in buildings, have been promoted as reducing the energy required to heat, cool and dehumidify, working best when outdoor weather is extreme and energy demand is highest, and bringing in the freshness of outdoors while controlling uncomfortable humidity and moisture that can lead to mold.

- Unlike other energy recovery products, ConsERV uses patented polymer membranes in a highly efficient and reliable solid state enthalpy exchange core that has no moving parts.

Nano Monitoring:

Nano Biosensors for Pesticide Detection:

- In agriculture, farmers use numerous pesticides to protect crops and seeds before and after harvesting.
- Pesticide is a term used in broad sense for organic toxic compounds used to control insects, bacteria, weeds, nematodes, rodents and other pests.
- The pesticide residues may enter into the food chain through air, water and soil.
- They affect ecosystems and cause several health problems to animals and humans.
- Pesticides can be carcinogenic and cytotoxic. They can produce bone marrow and nerve disorders, infertility, and immunological and respiratory diseases.
- Due to the large amounts of pesticides commonly used and their impact on health, prompt and accurate pesticide analysis is important
- Biomonitoring is a scientific technique for assessing the environment, including human exposures to natural and synthetic chemicals, based on sampling and analysis of an individual organism's tissues and fluids.

- The results of these measurements provide information about the amounts of natural and man-made chemicals that have entered and remained in the organisms and induce the corresponding effects.

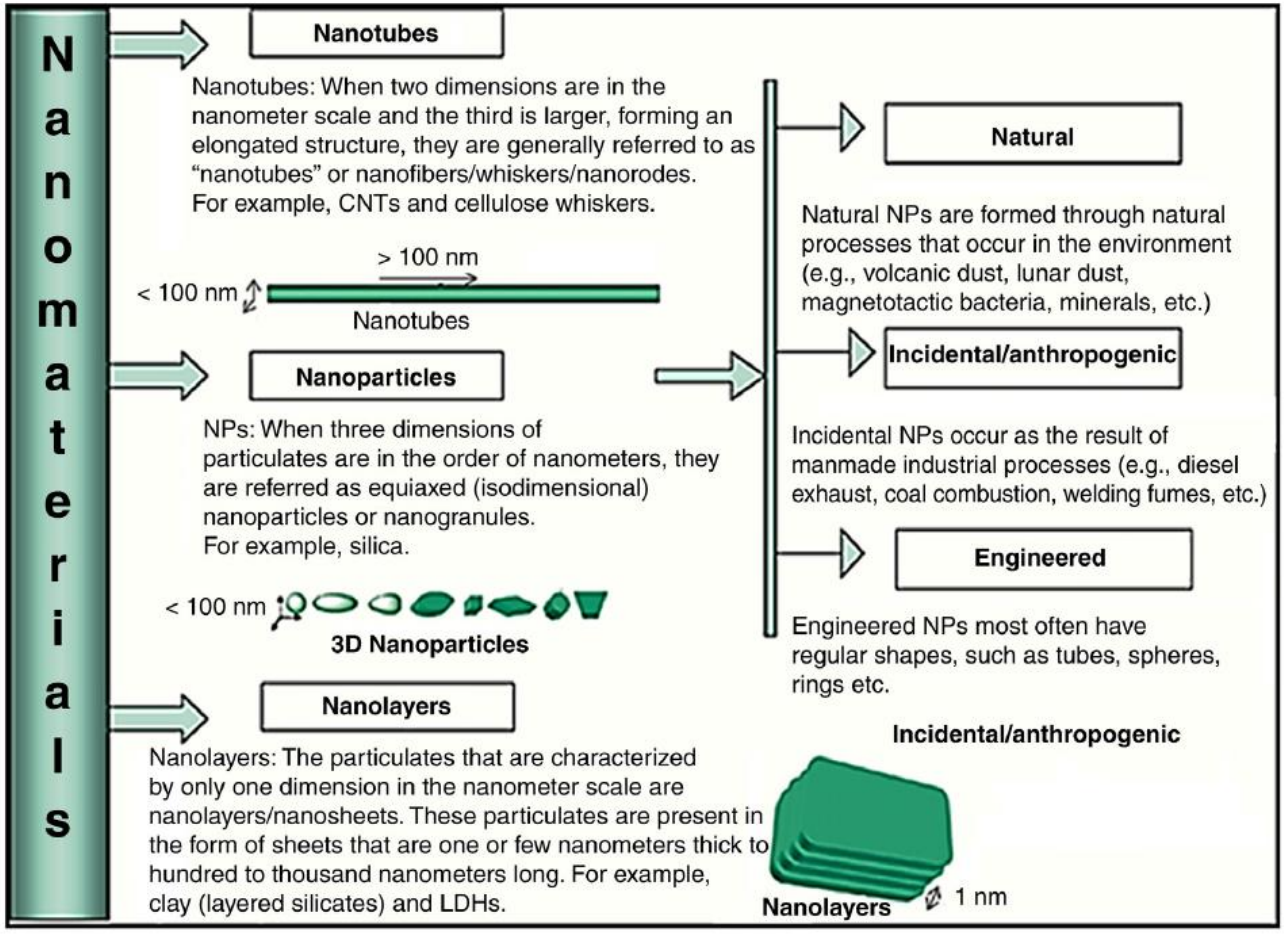
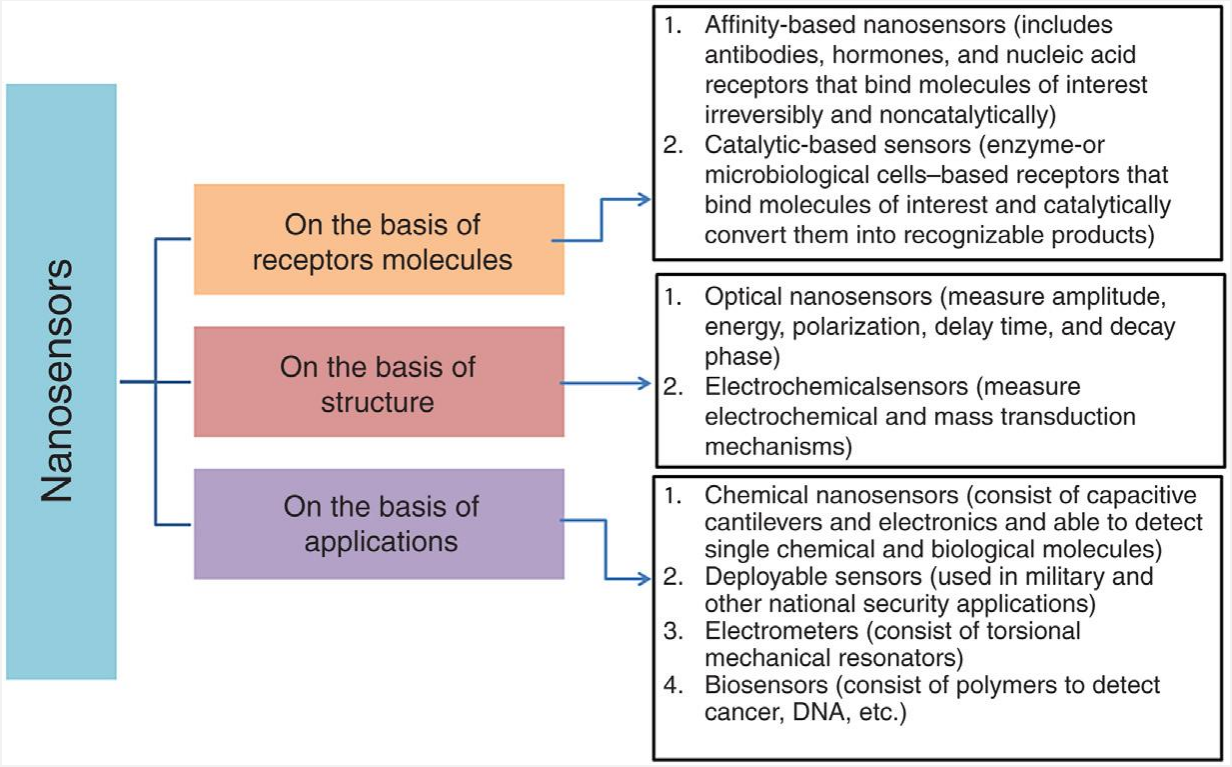


Figure 14.2. Schematic classification of nanomaterials. *CNTs*, Carbon nanotubes; *LDH*, layered double hydroxides; *NPs*, nanoparticles.

- Several studies have been undertaken to explore the inter- relationship between sensors and nanotechnology over the past several years.
- Researchers have put intensive efforts into designing nanomaterial-based biosensors that can offer high sensitivity and stability in terms of performance.
- The combination of nanotechnology with modern electrochemical techniques allows the introduction of powerful, reliable electrical devices for effective process and pollution control.

- Although the NPs in general play different roles in different electrochemical sensors, electroanalysis using a NP-modified electrode has several advantages:

1. effective catalysis
2. fast-mass transport
3. large effective sensor surface area, and
4. good control over electrode microenvironment



Nanosensors can be classified on the basis of receptors molecules, structure, and applications

The ideal sensor should possess the following characteristics :

1. specificity for the target species,
2. sensitivity to changes in target species concentrations,
3. fast response time,
4. extended lifetime of at least several months, and
5. small size (miniaturization) with the possibility of low-cost manufacture.

- The past several decades have given rise to significant advancements in nanotechnology, which were eventually transformed into fabrication of functional nanostructure-based biosensors.

- The so-designed devices have replaced the conventional technology-based sensing systems and offered not only improved sensitivity, but also selectivity and multiplexing capacity.

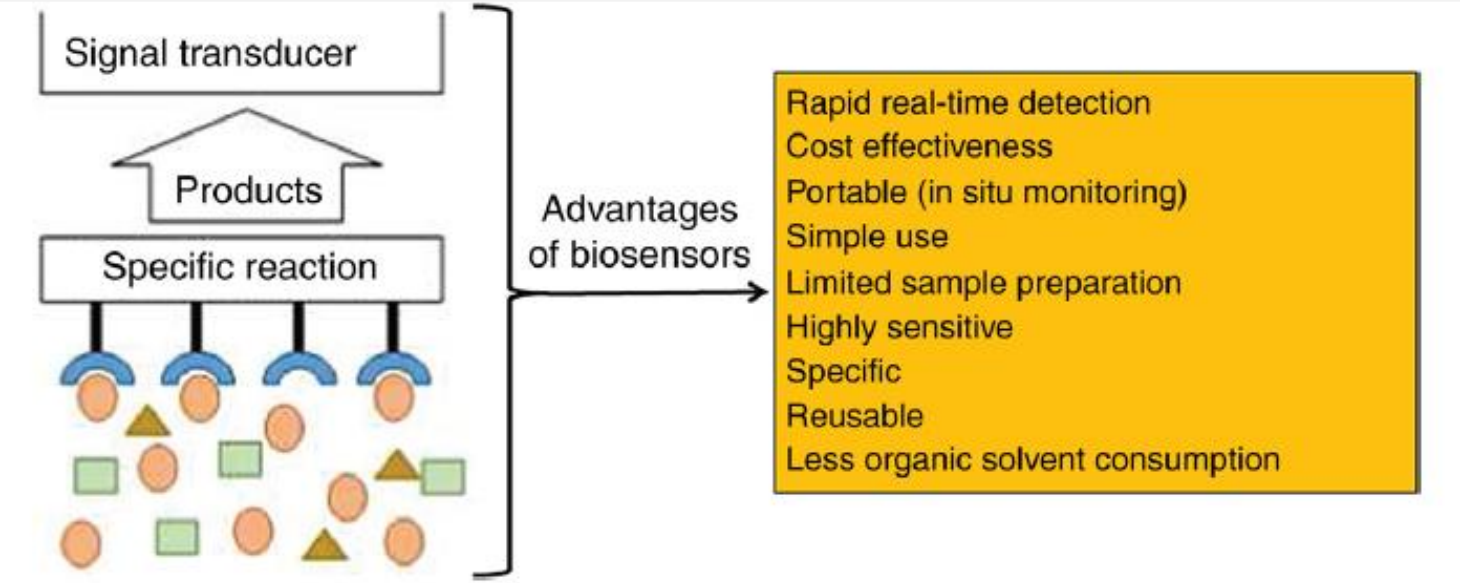


Figure 14.4. Schematic representation of the detection mechanisms of biosensors.

A Nano-biosensor based on the inhibition of cholinesterase activity is one of the most widely used in the determination of organophosphate pesticides, such as chlorpyrifos.

The analytical device that incorporates the enzyme is integrated into a physical-chemical signaling transducer or the transduction microsystem

- The bio-sensors varies from free biomolecules to those conjugated to a substrate such as NPs, nanowires, nanotubes and thin films.

- Interaction of the target with the biosensor can be measured either directly or indirectly by recording the changes in colour, fluorescence or electrical potential.

- In array technologies, multiple biomolecules are fixed to a substrate allowing multiple analytes to be measured simultaneously.

- A gold NP (30 nm)-based dipstick competitive immuno-assay with a sensitivity of 27 ng ml−1 was developed to detect organochlorine pesticide such as DDT.

- Gold NPs have the property of agglomeration associated with colour production, which was used for pesticide detection. Development of a colour signal aided easy visual detected when gold NP-labeled antibodies were bound to the pesticide residues.

Nano Biosensors for Plant Pathogen Detection

- Recently, several methods of microbial identification and typing are available for most plant pathogens. Methods based on traditional culture are time-consuming.

- Techniques based on biochemical profiles for identification are limited by the population of characterized strains in the databases.

- The specific serological techniques such as ELISA and indirect fluorescent antibody staining depend on the titre and specificity of the antibody either monoclonal or polyclonal.

- Currently, a novel microbial detection technology based on NPs is being developed. Silica-based NPs (60 nm) were filled with a fluorescent dye and conjugated to an antibody specific to a surface antigen of the microbe of interest

- Detection of a single bacterial cell was possible using this technique. This method has potential for the sensitive detection of plant pathogens. Recent advances in the development and application of biosensors for environmental analysis and monitoring are reviewed.

Nano Bioremediation

Pesticide Degradation:

- Treatment on pesticide-contaminated soil and water ranges from conventional methods such as incineration, phytoremediation and photochemical processes to innovative methods such as ultrasound-promoted remediation and other advanced oxidation processe).
- Degradation of bio-recalcitrant pollutants using NPs is another promising approach.
- Research studies showed that pesticides such as atrazine, molinate and chlorpyrifos are susceptible to degradation with nanosized zerovalent iron.
- Nanosized ZVI had a greater reactivity than granular ZVI, and their direct injection into the groundwater plume to minimize installation costs was suggested.
- Applications of ZVI structures and iron oxide NPs were found for the removal of humic material and toxins.
- However, little is known about the long-term performance of these nanoparticles/colloidal systems.

- The application of NPs such as biopolymer-stabilized FeS (200 nm) are in scavenging and degradation of lindane, a persistent organic pollutant found in drinking water as well as in food.

- The approaches for photocatalytic decomposition of pesticide residues using titania doped with Fe_2O_3 or other metals sprayed directly on crops or even incorporated into the pesticide formulation are promising (Sasson et al., 2007).

- Layer-by-layer surface (LbL) nano-engineering is a novel strategy for direct surface modification of colloidal entities, which utilizes sequential adsorption of oppositely charged polyelectrolytes to form a complex assembly via electrostatic interactions.

Soil Structure and Remediation

- Soil clays are sub-micrometric soil particles. Common clays are layered phyllosilicate materials, with a polymeric silicate base, which are nano dimensional in one plane.

- Advanced instrumentation such as transmission electron (TEM) and high-resolution transmission electron (HRTEM) microscopy showed that clays are composed of stacked tetrahedral and octahedral sheets

- Other inorganic nanomaterials such as the tubular aluminosilicate imogolite and its non-tubular precursor called protoimogolite are soil components. NPs such as iron and silica originate from natural weathering of bedrocks. Other naturally occurring NPs are iron oxides (2–5 nm length), as colloidal phases of ferrihydrite, associated with organic matter in river-borne material