Novel Technologies for Food Processing and Shelf Life Extension

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Lecture – 39
Food Nanotechnology

Another important and upcoming subject in food technology i.e. food nanotechnology will be studied.

Nanotechnology

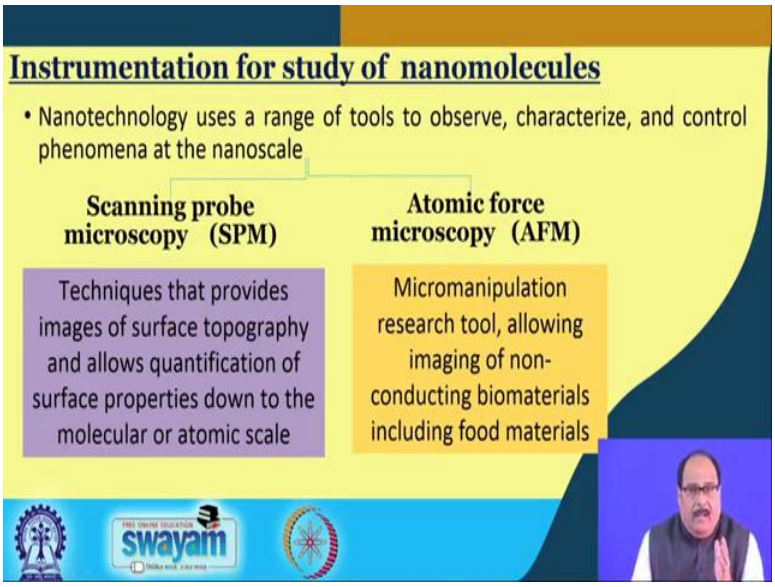
According to the British Standards Institution (BSI), nanotechnology is defined as "design, characterization, production and application of structures, devices and systems by controlling shape and size at the nanoscale".

- Most promising scientific fields of research in decades.
- Manipulation of materials at macromolecular, molecular & atomic scales.
- Properties and functionalities of nanoscale molecules & atoms differ significantly.
- Nanoscale size range is where one or more dimensions are of the order of 100 nm or less.

Building strategies in nanotechnology

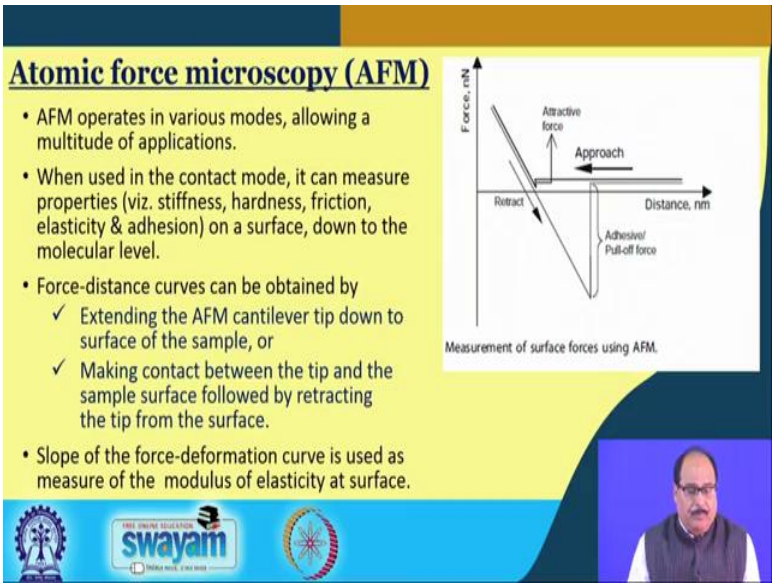
They include top down approach or bottom up approach. Top down approach involves that nano-level structures are generated by breaking up materials through milling, nanolithography or precision engineering. In the bottom up approach, nanostructures are built from individual self-assembling atoms or molecules.

The bottom up strategy of nanotechnology is used for the development of remarkably strong materials with precisely controlled structures and properties. They are also used for development of high surface area particles and materials that encapsulate active compounds. The strategies can be used for the development of smart coatings that are self-cleaning or can change colour depending upon environmental conditions.



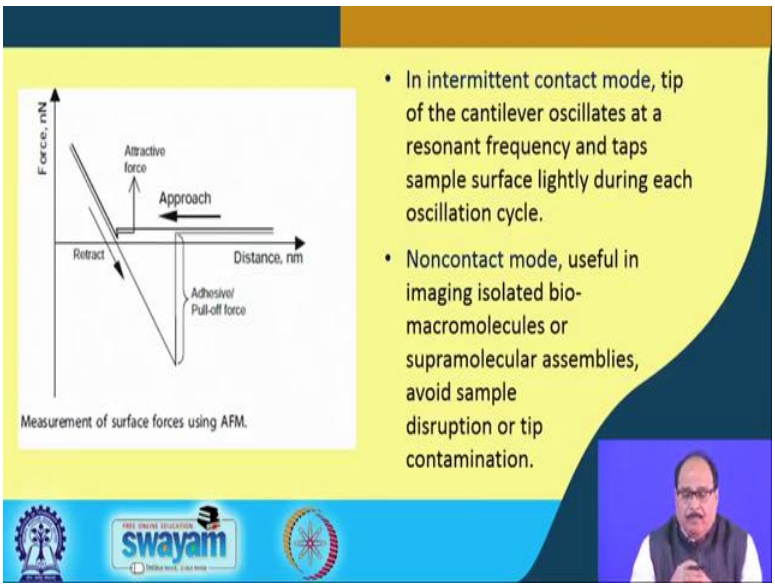
Instrumentation for study of nanomolecules

The use of this nanotechnology, has been made possible after the suitable instrumentations were developed to study the characteristics of the material at nano-scale. The instruments used for characterization include scanning probe microscopy or atomic force microscopy. In SPM, techniques that provide images of surface topography and allows quantification of surface properties down to the molecular or atomic level. The atomic force microscopy is the micromanipulation research tool, which allows amazing of non-conducting biomaterials including food materials.



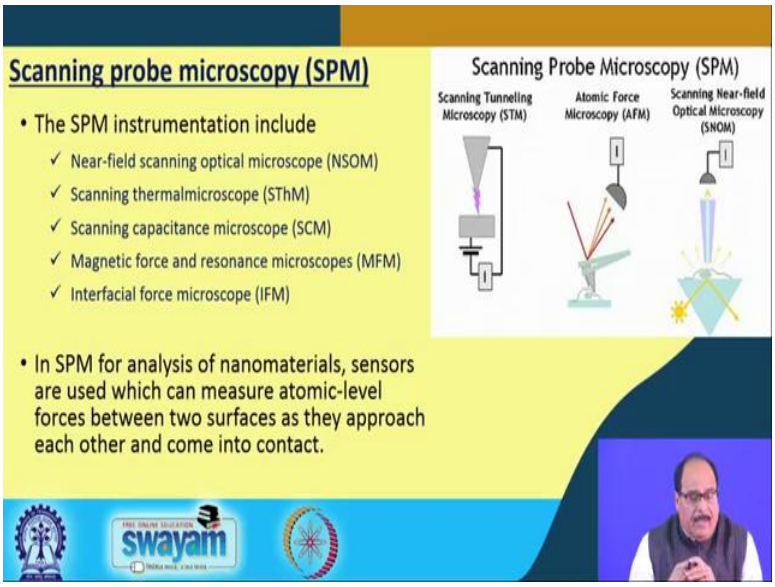
Atomic force microscopy (AFM)

- AFM operates in various modes, allowing a multitude of applications.
- When used in the contact mode, it can measure properties (viz. stiffness, hardness, friction, elasticity & adhesion) on a surface, down to the molecular level.
- Force-distance curves can be obtained by
  - ✓ Extending the AFM cantilever tip down to surface of the sample, or
  - ✓ Making contact between the tip and the sample surface followed by retracting the tip from the surface.
- Slope of the force-deformation curve is used as measure of the modulus of elasticity at surface.



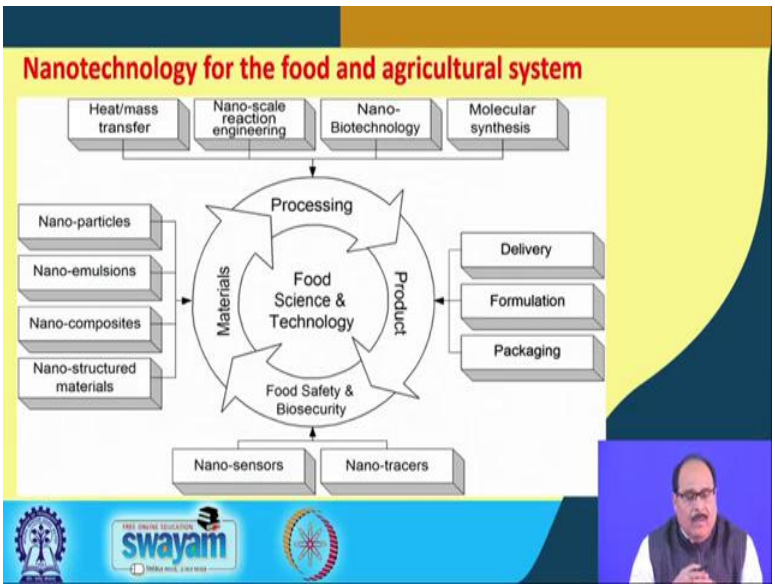
The slope of the force deformation curve is used as measure of the modulus of elasticity at surface.

- In intermittent contact mode, tip of the cantilever oscillates at a resonant frequency and taps sample surface lightly during each oscillation cycle.
- Non-contact mode, useful in imaging isolated bio-macromolecules or supramolecular assemblies, avoid sample disruption or tip contamination.



Scanning probe microscopy (SPM)

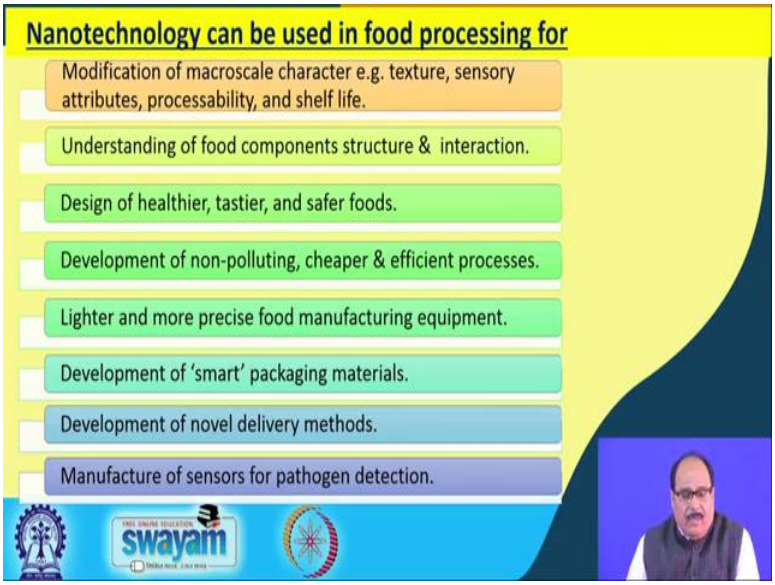
- The SPM instrumentation include
  - ✓ Near-field scanning optical microscope (NSOM)
  - ✓ Scanning thermalmicroscope (SThM)
  - ✓ Scanning capacitance microscope (SCM)
  - ✓ Magnetic force and resonance microscopes (MFM)
  - ✓ Interfacial force microscope (IFM)
- In SPM for analysis of nanomaterials, sensors are used which can measure atomic-level forces between two surfaces as they approach each other and come into contact.



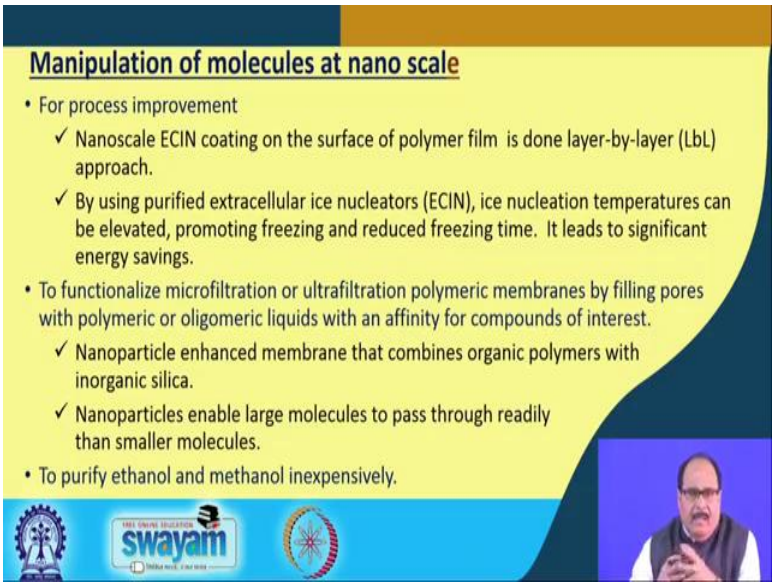
Nanotechnology for the food and agricultural system

It can be used to improve the processing methodologies or processes like heat and mass transfer, nanoscale reaction engineering, nanobiotechnology and molecular synthesis. It can be used to develop the products in food process, product manufacturing development in the delivery of the targeted nutrition, formulation, and packaging.

The nanotechnology can be used for the development of materials like nano particles, nano emulsions, nano composites, nano structured materials which has wide ranging scope in food processing industry. This has a very good application in the analysis of food safety and biosecurity like nano sensors or nano tracers that can be used to detect pathogen, to detect toxins in present in food etc.



Nanotechnology can be used in food processing for modification of macroscale characteristics of materials like texture, sensory attributes, processability, and shelf life. It can be used for understanding the food components structure and their interactions, for design of healthier, tastier and safer foods. It can be used for the development of non-polluting, cheaper and efficient processes. Nanotechnology can be used for development of lighter and more precise food manufacturing equipment, smart packaging materials, novel delivery methods, and for the manufacture of sensors for pathogen detections.



Manipulation of molecules at nano scale

- For process improvement

✓ Nanoscale ECIN coating on the surface of polymer film is done layer-by-layer (LbL) approach.

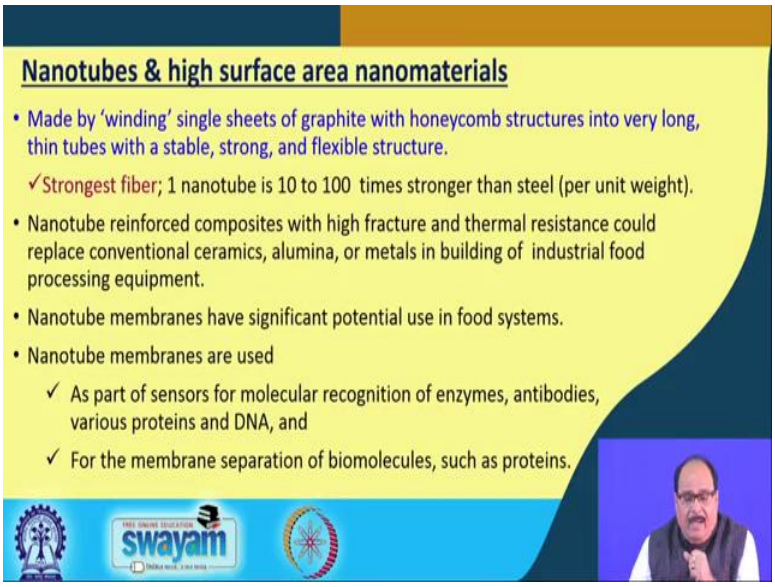
✓ By using purified extracellular ice nucleators (ECIN), ice nucleation temperatures can be elevated, promoting freezing and reduced freezing time. It leads to significant energy savings.

- To functionalize microfiltration or ultrafiltration polymeric membranes by filling pores with polymeric or oligomeric liquids with an affinity for compounds of interest.

✓ Nanoparticle enhanced membrane that combines organic polymers with inorganic silica.

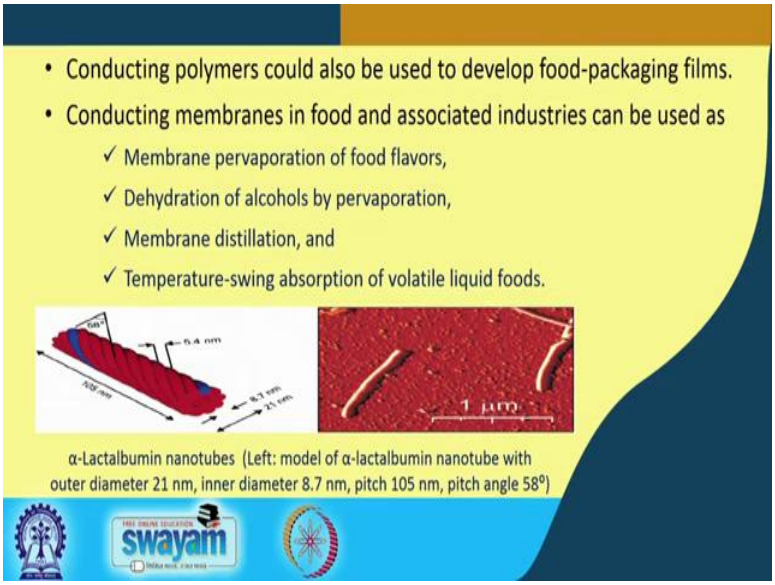
✓ Nanoparticles enable large molecules to pass through readily than smaller molecules.

- To purify ethanol and methanol inexpensively.



Nanotubes & high surface area nanomaterials

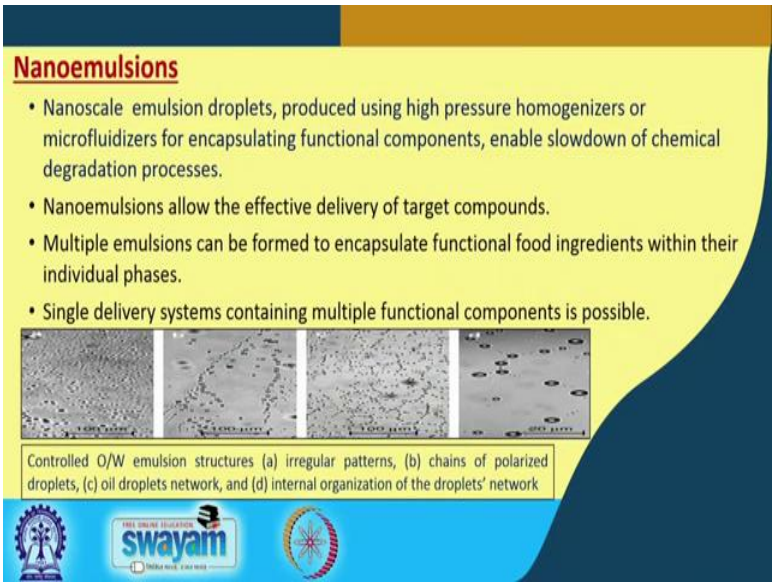
Nanotubes and high surface area nano materials are made by winding single sheets of graphite with honeycomb structures into very long thin tubes with stable, strong and flexible structure. Nano tubes are the strongest fibre. In fact, 1 nano tube is 10 to 100 times stronger than steel (per unit weight). Nanotube reinforced composites with high fracture and thermal resistance could replace conventional ceramics, alumina or metals in building of industrial food processing equipment. Nanotube membranes have significant potential used in food systems. Nanotube membranes are used as a part of sensors for molecular recognition of enzymes, antibodies, various proteins and DNA. They are also used for the membrane separation of biomolecules like proteins etc.



Conducting polymers could also be used to develop food-packaging films. Conducting membranes in food and associated industries can be used as membrane pervaporation of food flavours, dehydration of alcohol by pervaporation, membrane distillation, and temperature-swing absorption of volatile liquid foods.

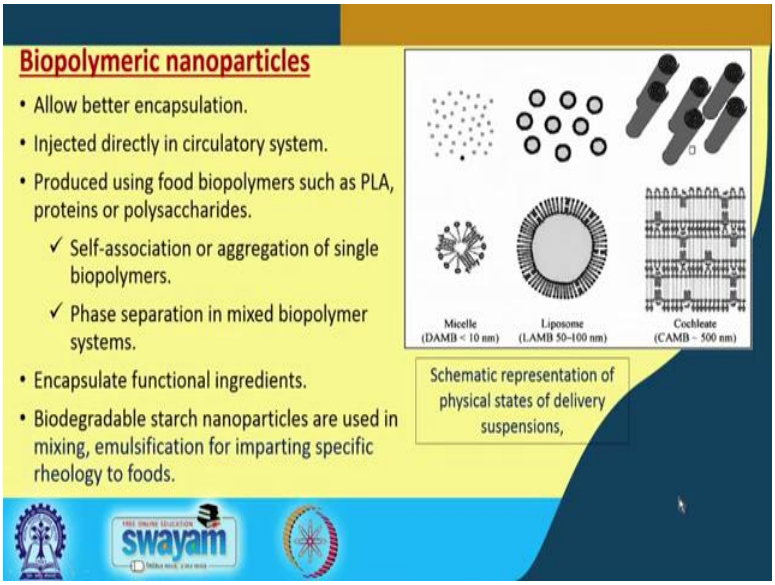
Nanodelivery systems

Nano delivery systems is one of the very interesting application of nanotechnology in food processing. It is the development of novel systems to deliver functional ingredients to the targeted release sites. Precise control of properties and functionalities of the bioactives can be found at the molecular level, by nanometre sized association colloids, surfactant micelles, vesicles, bilayers, reverse micelles, liquid crystals and at the nano-level. This of course, has both advantages and disadvantages. The advantages include, it can be formed spontaneously, is thermodynamically favourable, and provides a transparent solution. However, it requires large quantities of substrate. There are still some problems related to flavour, cost and legality at the process.



Nanoemulsions

- Nanoscale emulsion droplets, produced using high pressure homogenizers or microfluidizers for encapsulating functional components, enable slowdown of chemical degradation processes.
- Nanoemulsions allow the effective delivery of target compounds.
- Multiple emulsions can be formed to encapsulate functional food ingredients within their individual phases.
- Single delivery systems containing multiple functional components is possible.



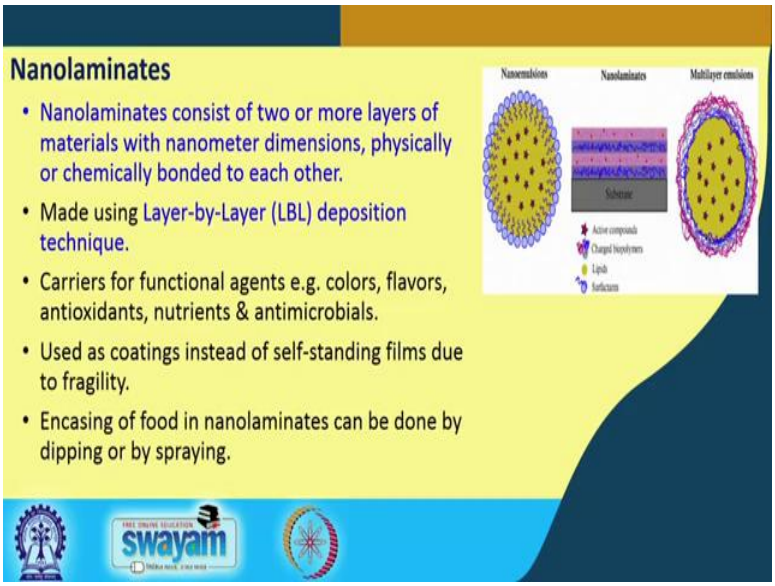
Biopolymeric nanoparticles

- Allow better encapsulation.
- Injected directly in circulatory system.
- Produced using food biopolymers such as PLA, proteins or polysaccharides.
- ✓ Self-association or aggregation of single biopolymers.
- ✓ Phase separation in mixed biopolymer systems.
- Encapsulate functional ingredients.
- Biodegradable starch nanoparticles are used in mixing, emulsification for imparting specific rheology to foods.

Nanocomposites

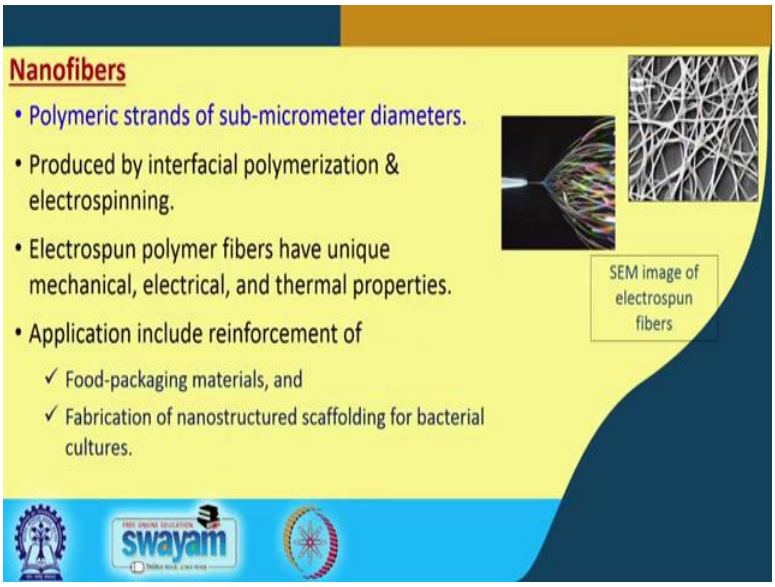
- Nanocomposites made from nanoscale structures have unique morphology, strength and good barrier properties. They can be used to
  - ✓ Enhance mechanical strength,
  - ✓ Improve conductivity,
  - ✓ Incorporate and efficiently deliver active substances into into biological systems.
- Barrier properties of nanocomposites, obtained from natural materials, are useful for food packaging applications for enhanced shelf life of foods such as processed meats, cheese, confectionery, cereals, or boil-in the-bag foods.

- Packaging material made of potato starch & $CaCO_3$ has good thermal insulation properties, are lightweight and biodegradable.
- Can replace polystyrene used for fast food.



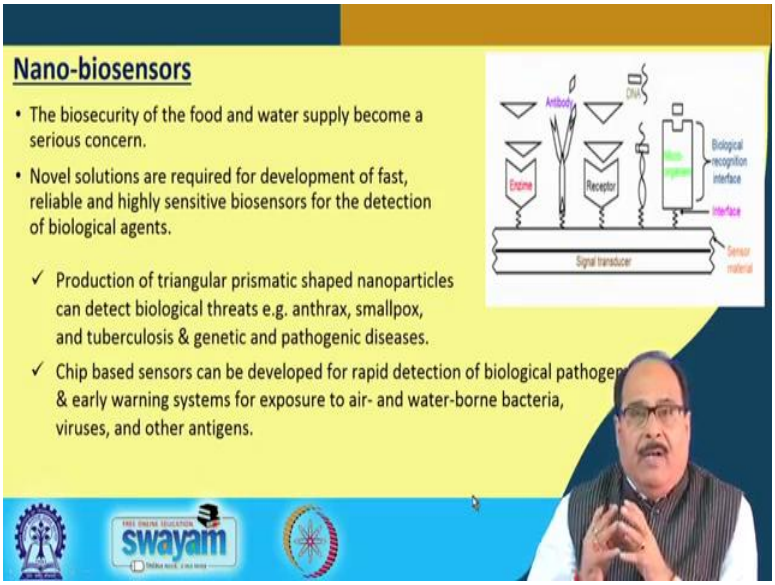
Nanolaminates

- Nanolaminates consist of two or more layers of materials with nanometer dimensions, physically or chemically bonded to each other.
- Made using Layer-by-Layer (LBL) deposition technique.
- Carriers for functional agents e.g. colors, flavors, antioxidants, nutrients & antimicrobials.
- Used as coatings instead of self-standing films due to fragility.
- Encasing of food in nanolaminates can be done by dipping or by spraying.



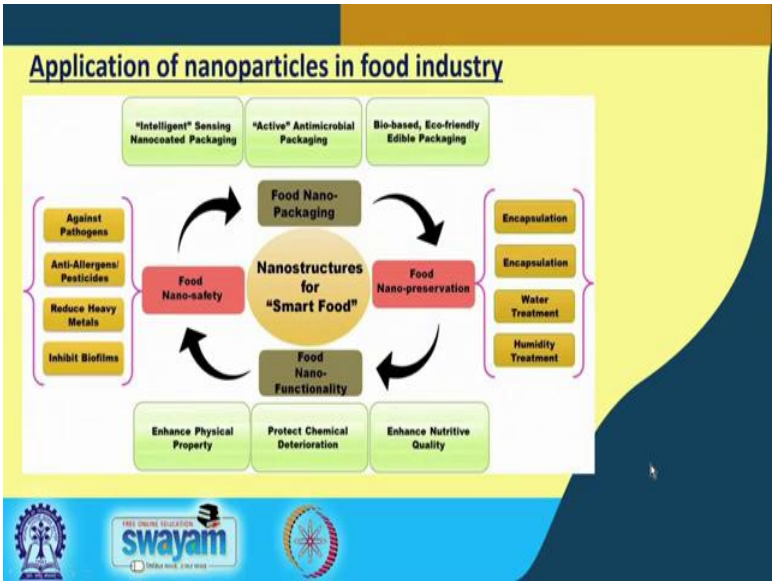
Nanofibers

- Polymeric strands of sub-micrometer diameters.
- Produced by interfacial polymerization & electrospinning.
- Electrospun polymer fibers have unique mechanical, electrical, and thermal properties.
- Application include reinforcement of
    - ✓ Food-packaging materials, and
    - ✓ Fabrication of nanostructured scaffolding for bacterial cultures.



Nano-biosensors

- The biosecurity of the food and water supply become a serious concern.
- Novel solutions are required for development of fast, reliable and highly sensitive biosensors for the detection of biological agents.
- Production of triangular prismatic shaped nanoparticles can detect biological threats e.g. anthrax, smallpox, and tuberculosis & genetic and pathogenic diseases.
- Chip based sensors can be developed for rapid detection of biological pathogens & early warning systems for exposure to air- and water-borne bacteria, viruses, and other antigens.



Application of nanoparticles in food industry

The application of nanoparticles in the food industries is discussed; it can be used for food nano-packaging, food nano-safety, food nano-functionalities or food nano-preservation and food nano-preservation. For micro encapsule, i.e. the wall materials having desirable release properties, desirable disintegrating rupture properties of desirable strength, desirable solubility, etc. all these can be prepared using this food nano-technology. In areas of treatment of water, humidity treatment of the storage environment etc. this nanotechnology has a lot of potential.

In food nano-packaging like intelligent sensing or nano coated packaging, active antimicrobial packaging, these nanomaterials can be coated on the interior of the

packaging material. They improve the interaction between the surface of the food as well as the interior of the packaging material or they manipulate the environment that may result into the enhanced shelf life. So, this bio based eco-friendly edible packaging can be developed using nano technology approach.

As far as the food nano safety is concerned that is the nano materials can be developed which are active against pathogens, they are anti-allergens or pesticides, they reduce heavy metals, they can inhibit biofilms etc. Even this nanoparticles improve the food functionality like enhance physical properties, protect chemical deterioration of the food and enhance nutritive quality of the food materials. So, this has a very wide ranging application in food industry.

Before it is made successful, there are certain challenges to overcome. For example, the prospect of commercializing these nano applications in food sector will depend upon their cost-effectiveness. But if the cost-effective nanotechnology methods are developed, it can found wide use in the food processing industries. If the improvement in the functional characteristics and other quality attributes of the food is more than the cost involved, obviously industry would like to use it.

But at present, in most of the countries there are not much regulations related to the application of nanomaterials or nanotechnology in food processing. So, before this technology is made versatile and commonly accepted by the food processing industries,

significant changes in the current food regulations and legislations might be required in several countries, particularly the safety related concerns.

They are very effective, they improve the functionality and other properties of the material, but their safety, how they interact with other components in the body system in the food system, whether safe for consumption, etc. need to be established; that is another challenging issue.

Another factor is the significant contributions for improvement and extension of shelf life of the material. So, if the use of nano technology results in more extension of shelf life then the industry will be tempted to use it. But the significant results or data are required to be generated in this direction.

If this nanotechnology is properly conducted it might result in thorough improvement of food and agriculture systems and the consumers will obviously, be benefited from the advances in nano technology contributing to the improved safety and nutrition value of the foods.

However, more developments of not only the process technology, but also suitable equipment, suitable infrastructural facilities to prepare or to form the nanomaterials and other things are needed.