**Nano structured Materials-Synthesis, Properties, Self Assembly and Applications**

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**Module - 1**
**Lecture - 2**
**Introduction to Nanotechnology (Contd)**

Welcome back to this second lecture of the course on Nano structured materials-synthesis, Properties, self assembly and applications. So, in the first lecture, we introduced you to the basic fundamentals of nanoscience and nanotechnology. We gave you the definition of what are nanoparticles, basically any particle with dimensions of between one to hundred nanometers is the region, which normally is discussed as the regime of nanomaterials. Then we discussed what properties change as a function of the size, especially optical properties, catalytic properties, magnetic properties etcetera. Then we traced a bit of history like how the study of nanomaterials has developed over the years and how historically nanomaterials was known.

So, probably you have now some idea of what are nanomaterials. So, in continuation with the first lecture, today we are going to discuss some more aspects of nanotechnology mainly what the future holds for nanotechnology, so an introduction to that what are the applications in nanotechnology. So, this second lecture will be the concluding part of the module one of this course on a forty lectures of nanostructured materials.

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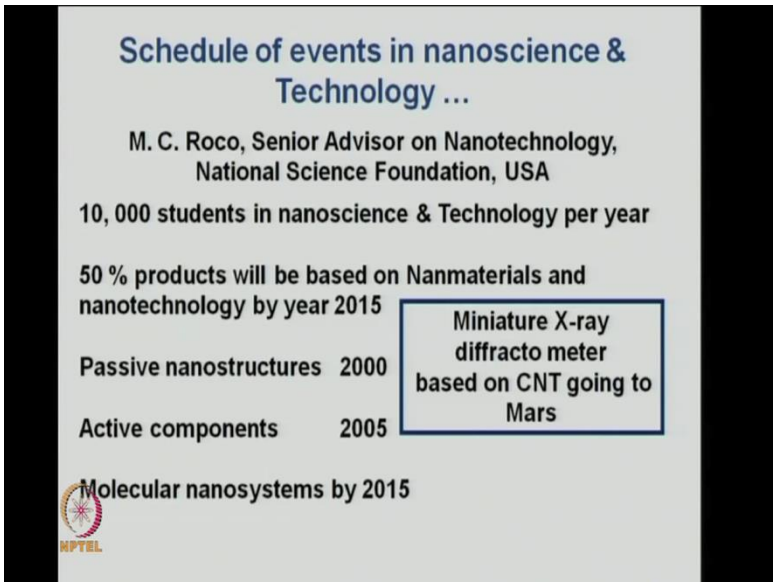


So, as the senior advisor on Nanotechnology of the National Science Foundation, in his lecture in 2005-2006 commented that we would be needing around 10,000 students in nanoscience and technology per year. And fifty percent of the products will be based on nanoscience and nanotechnology by the year 2015. Many devices are already being manufactured like passive nanostructures and active components, and even small components which are on X-ray diffracto meters or miniature X-ray diffractometers have already been made based on carbon nanotubes, which are on a space mission to Mars. There will be several molecular machines by the year 2015. This has been predicted by the senior advisor of Nanotechnology of the National Science Foundation.

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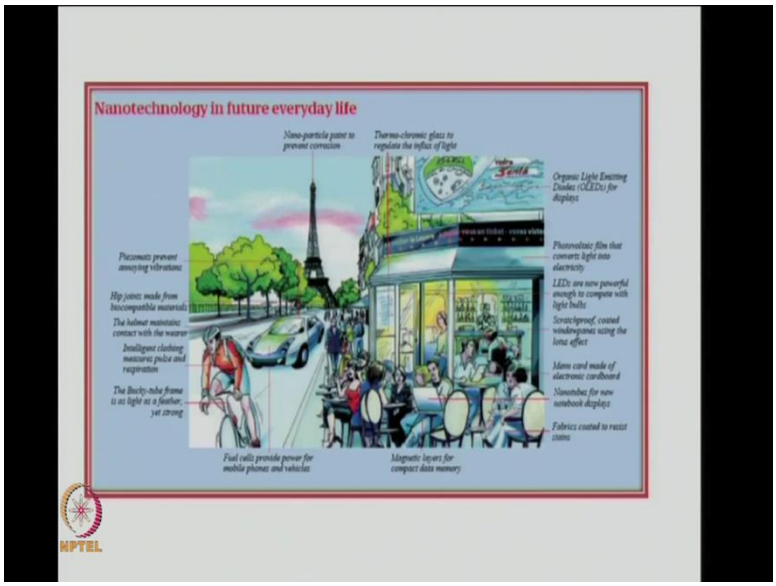


Now, we can see nanotechnology applications in future in everyday life. For example, you can see, there will be thermo-chromic glass to regulate the amount of light, which is going through a particular glass window. So, these can be coated with some nanomaterials which cut down certain wavelengths of light. Similarly, you will be having organic light emitting diodes for this place; you will be having a photovoltaic films that convert light into electricity; then LED's to have efficient light bulbs at very low cost based on many new nanomaterials. Then you can have glass coatings, which are scratch proof, and which have hydrophobic surfaces, they can be self-cleaning.

You can have vibration less surfaces like on vehicles; you can have helmets made of some nanomaterials, especially carbon nanofibers to make them very compact and light and at the same time mechanically tough. Then you can have intelligent clothing, which can at the same time for a sports person measure his pulse as well as his rate of respiration etcetera. You can have frames of vehicles made of carbon fibers which are very light. You can have fuel cells to provide the battery or the power to vehicles and that is a very important area of research for mobile phones, vehicle and the spacecraft industry. You can have very efficient storing devices - magnetic storing devices which can made of a nanomaterials. So, in everyday life, it is predicted that nanotechnology will be there in future, and we have all of us have to know little bit about nanoscience and nanotechnology to be able to use them in our daily lives.

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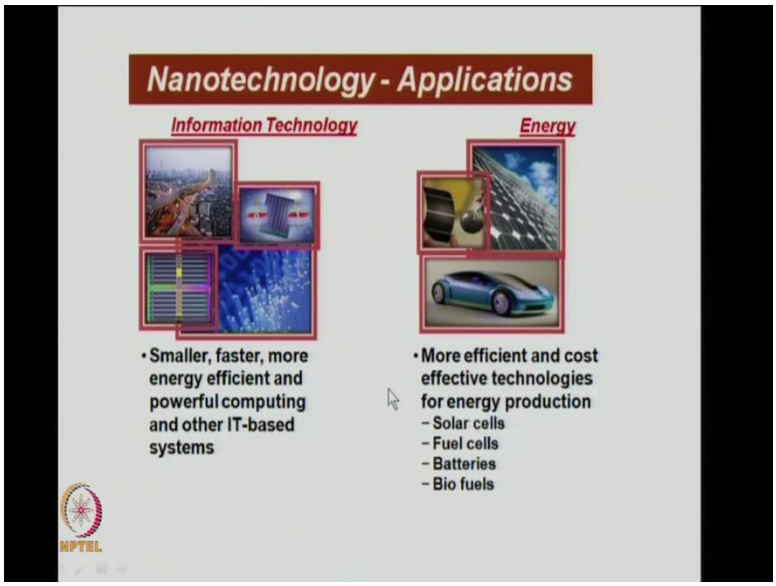


Continuing with applications, you will have applications of nanotechnology in information sciences like in the internet in IT based systems to have smaller, faster, more energy efficient computing systems .Then in energy to have low cost energy production design more efficient solar cells, and design more efficient fuel cells. So, the nanostructured materials which go into a fuel cell the like the electrodes and the electrolyte, how to engineer them with nanomaterials that is going to be a challenge. A batteries and biofuels, all these will contribute to the growing demand of energy in the future. As coal based and fossil fuel based fuel energy is going to be very difficult in the near future. So, we will have to depend on solar cells and other means of energy generation, especially renewable energy generation which can come from fuel cells and solar cells, etcetera.

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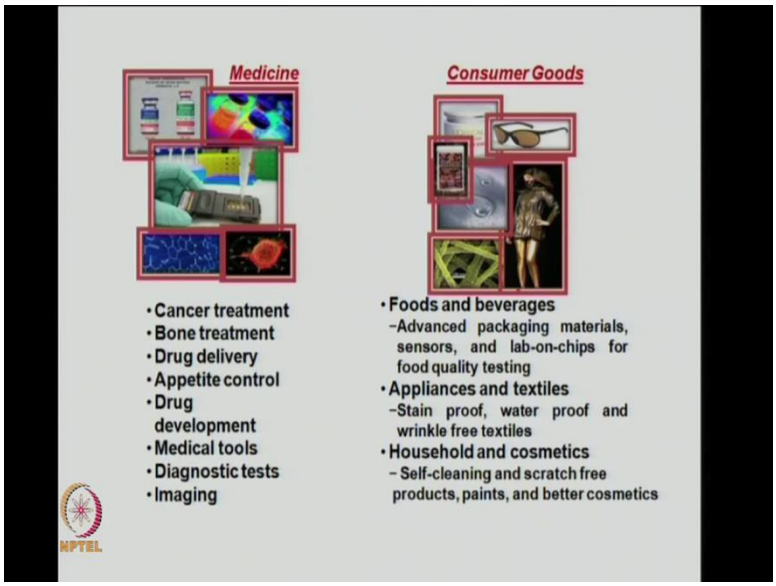


Now, you will certainly have lot of implications in the health industry in medicines using nanomaterials. People are trying to do drug delivery and drug targeting, people are trying to make artificial ligaments and bones using nanomaterials like calcium appetite etcetera. Various kinds of new drugs especially drugs with controlled release, so that can be are envision in the future, so that you can take one medicine in the morning and it will release the drug in definite doses at different time intervals. So, that you do not have to take the drug every six hours or every four hours.

A lot of interest or use of nanotechnology will be in diagnostic tests, where you can use nanomaterials or nanostructures to do biopsies and biosensing and they can be done in a very quick time on the patient bed sites, at home, so that you do not have to delay treatment. You have lot of work using a fluorescent quantum dots can be used in imaging devises, which will be used into diagnose tumor cells or cancer cells. These are all part of the health industry, where nanotechnology is going to play a very important role.

You are also going see lot of applications in consumer goods like in foods and beverages. Especially in packaging industry, since most of the biofilms or other films which are made can be shelf life of food can be enhanced if the proper packaging materials can be made based on some bio nanomaterials and certain work has already been demonstrated in this direction. Lot of work to generate sensors which can kind of analyze the quality of the food inside in packaged food are being thought about, so that

as the food quality deteriorates there may be a color change which you can observe from outside the packaged food which will tell you instead of looking at the expiry date. You can look at the change in the color of the sensor and decide whether to use that food material or not. So, a food quality testing and food packaging industry will rely heavily on nanomaterials and nanotechnology.

In smart appliances and smart textiles like stain proof textiles, water proof textiles, there is lot of work which has is already going on and there it has lot of prospects where nanotechnology will be used. Lot of self-cleaning products and scratch free products in windows and paints and many a UV protection cosmetics are already in the market, which use TIO 2 or other such nanomaterials, which protect you from ultraviolet radiation. So, there is lot of applications envisaged in the area of the medical industry and the consumer goods industry.

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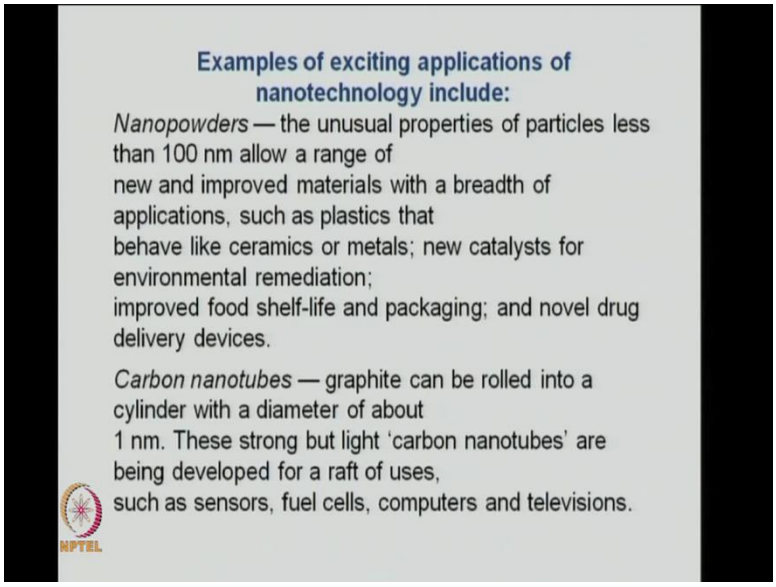


Some examples in details, we can discuss like synthesis of nanopowders of several ceramics or metals like new catalysts or particles which are embedded within films to enhance the shelf life of food as we discussed in packaging industry. Novel drug delivery devices where you have a some magnetic nanoparticles, iron oxide is being used for these kind of drug delivery systems, where the magnetic particle can be tagged to a drug and also moved around with the magnetic field. Carbon nanotubes which are basically graphite which is rolled into a cylinder you can think about carbon nanotubes like that.

These nanotubes are very strong, but light and they are being used for a variety of users, because of its mechanical, strength because of its conductivity. So, carbon nanotubes hold wide interest among a range of applications starting from sensors, to fuel cells, to computers, to heavy duty fibers which are of high strength and also as field emitters which can emit electrons under a certain voltage.

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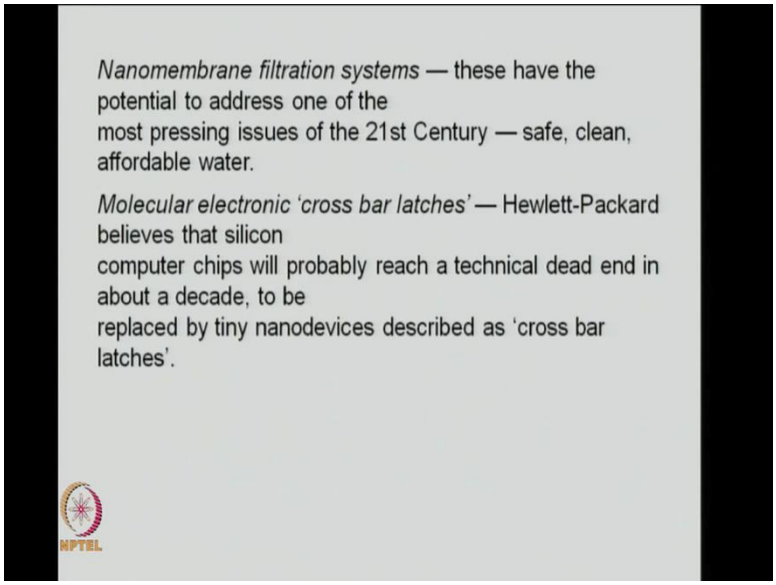


Then in nanomembrane filtration systems, because water purification remains to be a challenge for the world, and more and more we will need membranes, membrane based technologies to purify water. Lot of work in this area is going on to generate nanomaterials, which can remove toxins from water of different kind and generate these filtration systems. In nanoelectronics, people are expecting that the silicon based computer chips, which is reaching its peak or maximum that can be achieved using silicon chips is nearly come to its peak. So, we need to find out new devices and some examples of nanodevices based on what are called cross bar latches are being developed by Hewlett-Packard in the united states.

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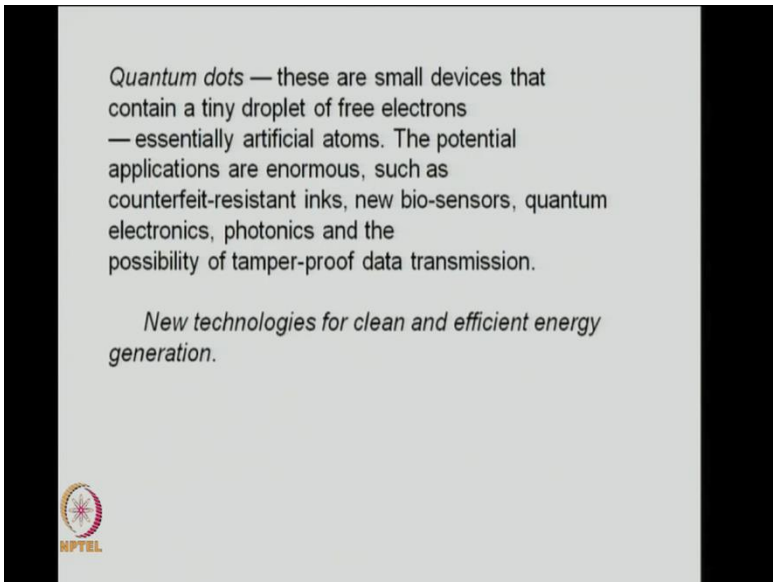


So, as you see the quantum dots could be used for several applications in biosensing quantum electronics, photonics, and clean and efficient energy generation.

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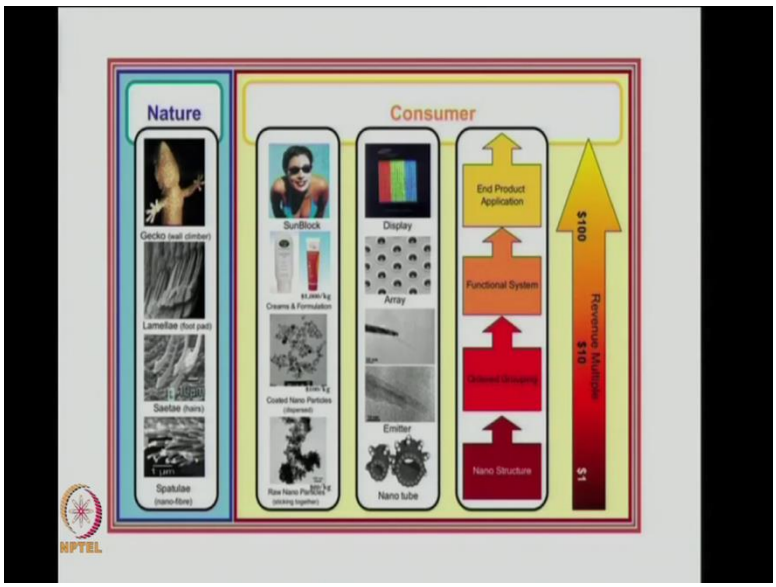


So, if we look around us, we will see manmade objects like consumer products based on nanomaterials and nanotechnology. For example, you have these sun block creams which are basically nanoparticles, some of them of T I O 2,and other nanomaterials which are already in the market which are being used as creams and lotions. They are based on nanoparticles. Similarly, your nanostructures are formed of carbon nanotubes or other

nanotubes or porous nanostructures arranged in a particular fashion, which interact with light to give you a displays, which you can use for several applications, and this is a subject or what is called nanophotonics.

And in nature also you can see from the nanostructures like fibrous structures in the Spatula-e to hairs and then to lamellae and finally to a fee, you can see from the starting particle to the end product. Similarly, in manmade objects, you can see the nanomaterials with which you start and the finished product, there is a lot of change as you go along this change. If you look at the from the economics point of view, you start with these nanostructures, they have may be some cost that as you turn towards the finished product, there is lot of engineering which goes manipulation which goes and the cost of the final product of course, becomes much higher. So, these are some of the consumer products, which are already there in the market.

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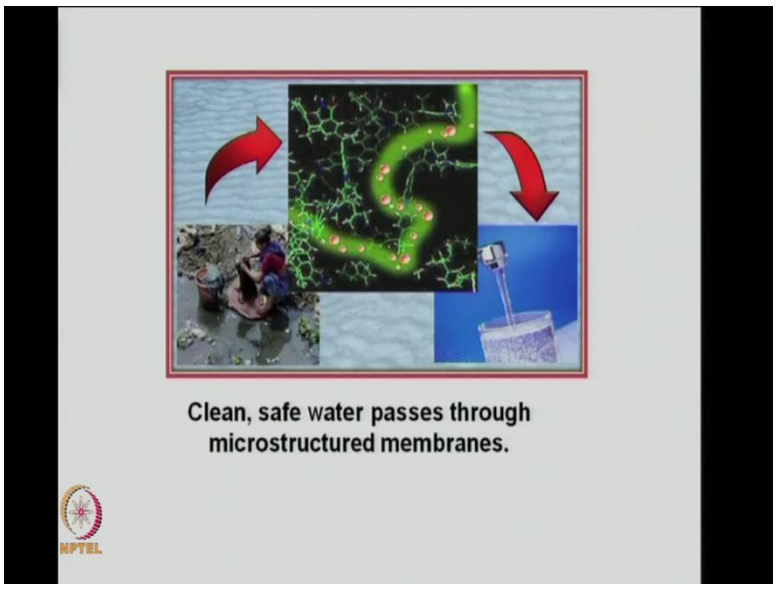


You can have other products like the purification of water - clean water, where you design membranes, which can remove metal ions from toxic water or can remove a biomolecules, and then can give you clean water. So, this is a very important area for the future to provide clean and safe water using membranes made of nanostructures.

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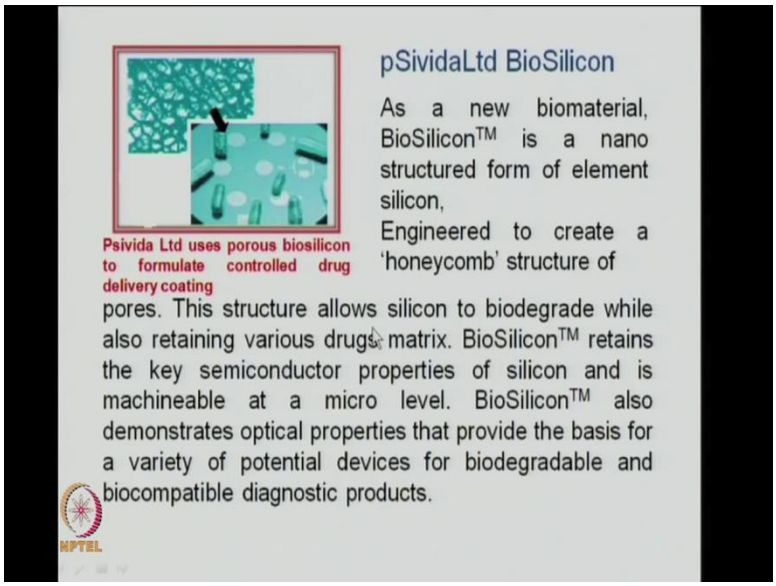


Then coming to some real products, which are in the market developed, based on nanomaterials. There is this product called BioSilicon. It is a biomaterial. It is a form of silicon, which are being made to have very porous structures, it has a honeycomb like structure, and it is being used for drug delivery coatings and it is biodegradable. So, BioSilicon is a product which is already in the market, and can also be used in biocompatible diagnostic products.

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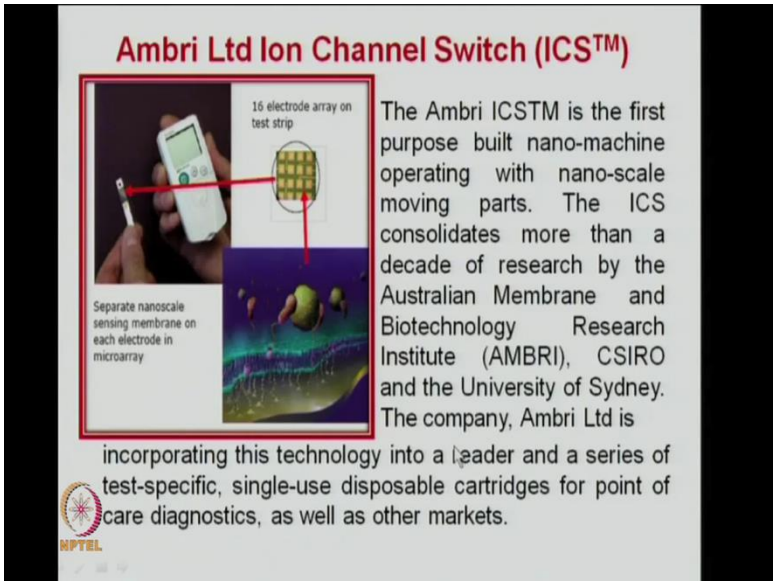

This is another product, which has been made by another company called the Ambri ICS TM. Here what it has, is it there are these cartridges which have these electrodes arrays on these strips, and these arrays act as a biosensors. So, if you add a drop of blood or urine, it can identify certain markers, which will you tell about an impending disease increase like if there is an increase in the blood sugar level or increase in some particular protein, which is normally enhanced before a cardiac arrest.

So, these kinds of biomarkers can be checked if you have the right biomolecules on this chip. So, it is basically a molecule on this electrode, which will be sensed when you put this cartridge inside this hand held gadget, and then what happens you can diagnose the level of that particular marker. Of course, you have to use a particular biomolecule to target or to sense a particular protein or amino acid or nucleic acid in the human body or any living body. So, these kinds of products which are single use disposable cartridges for diagnostics are already coming up in the market.

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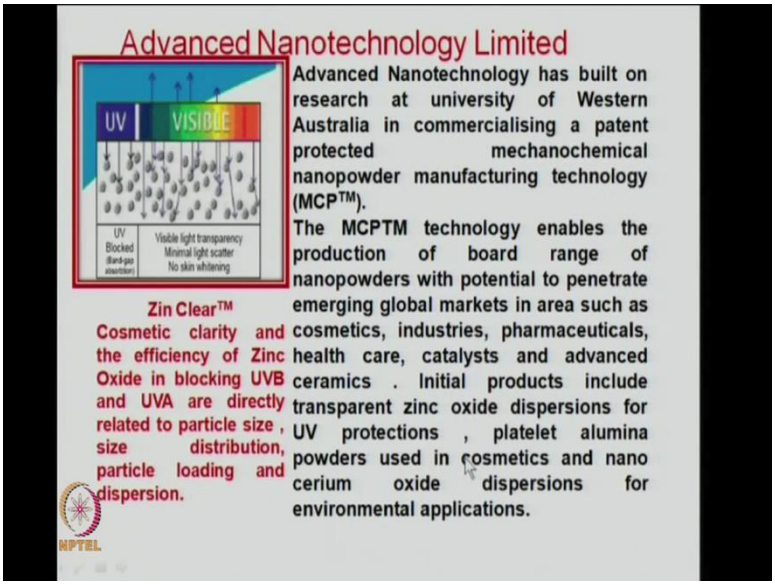


This another company which makes nanopowders. They make lot of nanopowders for like T I O 2, zinc oxide or cerium oxide for several products for health care, for catalysts and for environmental applications, and one application is shown here which is the UV blocker? So, if the UV radiation is blocked, whereas the visible light these particles are transparent and it will allow visible light to pass through with very less scattering of the

light. So, these kinds of nanomaterials are already in then being commercially sold in the market.

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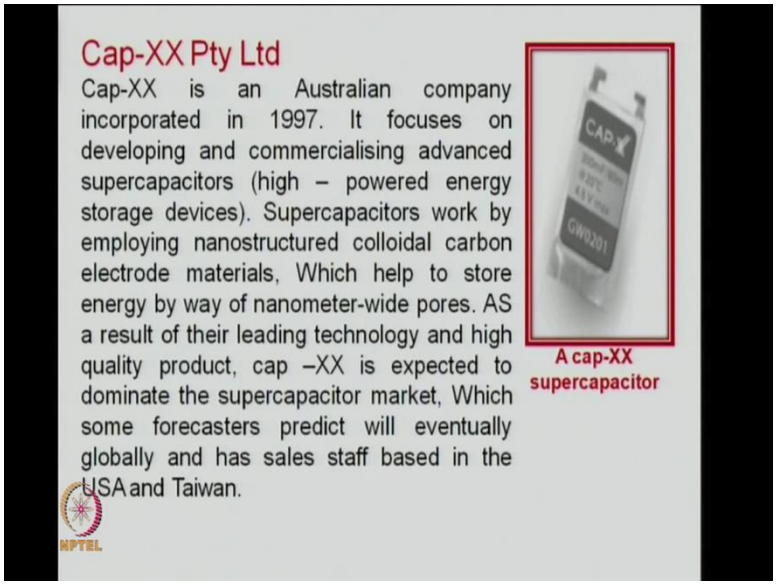


There is another application for which a company has come out with a product. This is a super capacitor; a super capacitor is something which is a can store very large amount of energy compared to a normal battery, a super capacitor can store much more energy. So, these are important materials, and these are important products, and they use carbon based nanomaterials, nanostructured materials. This is one of the products, which has been developed. Of course, other super capacitor based on other oxide materials are also being made and this is already in the market. This is another example of a product based on nanotechnology, which is in the market.

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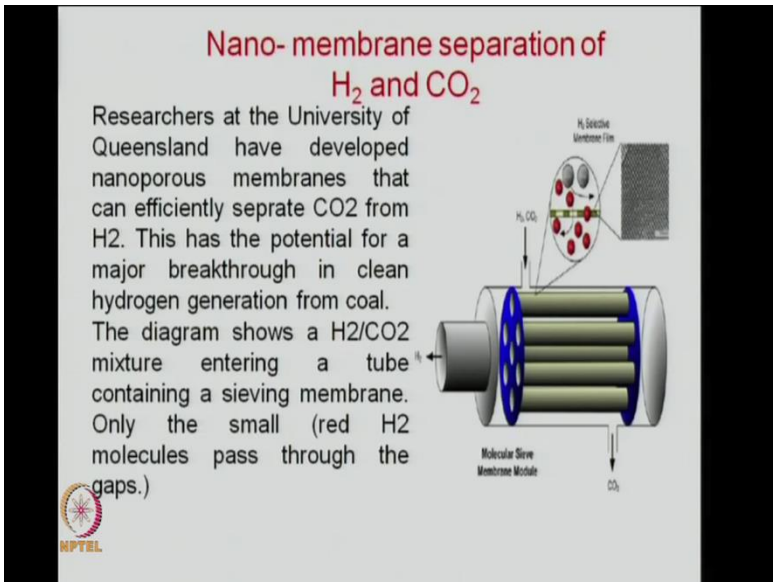


This is another example of how a nanotechnology can be of great use in fuel and energy considerations. For example, this is a membrane nanoporous membrane which has been developed which can separate carbon dioxide and hydrogen. So, you have these nanoporous membranes and because of the particular size or the pores, it can separate hydrogen from carbon dioxide. So, normally when you have a hydrocarbon or petroleum based industries, they produce these hydrocarbons, and from these hydrocarbons you get carbon dioxide and hydrogen which can be used in a application, but you have to separate the carbon dioxide and hydrogen. So, these kinds of membranes are very important and then if you can separate hydrogen from carbon dioxide and this hydrogen can be used as a fuel and can produce energy. So, this kind of application based on nanomembranes as is of tremendous interest.

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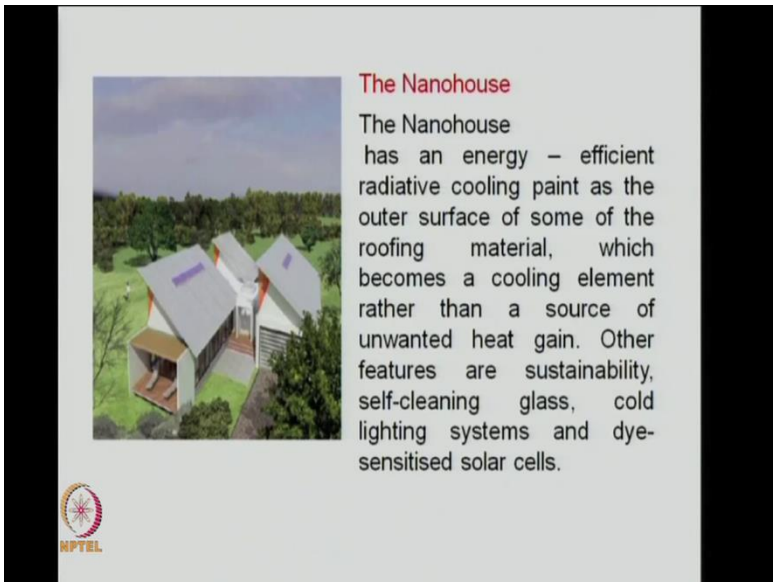


This is another idea of building a very energy efficient house. So, this has a coating on the roof of the house, normally the roofs get heated and for the heating of the house, the roofs are the most important structure. So, you need lot of air conditioning for cooling. Now if you have a efficient radiative paint on top of the roof then instead of heating it becomes a cooling element, and many nanostructured paints are being used or tiles have being used which can bring down, which have a radiative cooling affect rather than a heating effect. And that is one important application.

Of course, this kind of a model house which is called a nanohouse has other aspects like windows, which are which allows certain wavelengths of light to pass. In the sensors, which save which allow a different time, different amount of light to enter and self-lighting systems depending on what is a light intensity outside and inside, the sensors allow the lighting to turn on or turn off. And many many applications of solar cells like solar heating of the water, and solar electricity based on efficient solar cells together then this model house is the real futuristic house based on nanotechnology.

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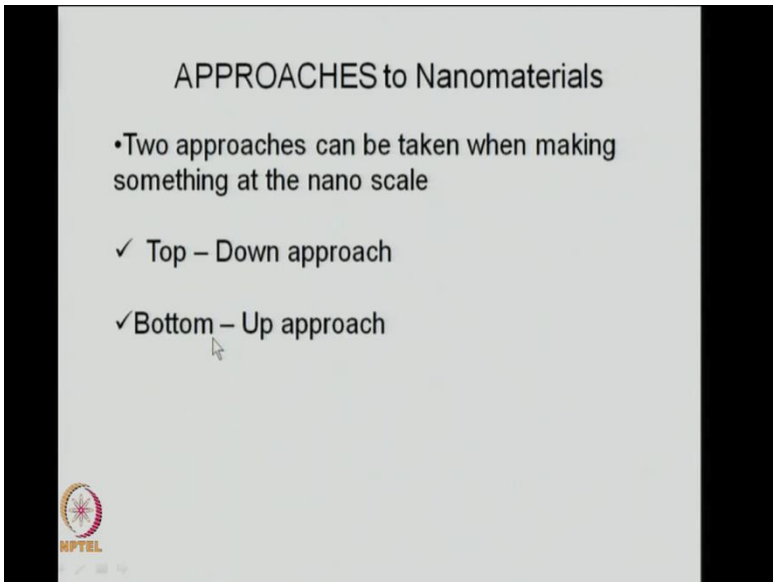


Now the finally, I come to what we are going to discuss in our next four-five lectures that is how the nanomaterials are to be synthesized. So far, we discussed about the we got you introduced to the subject of nanotechnology and why somebody should be interested in nanotechnology, the applications of nanotechnology and what the future holds for nanotechnology. But the most important thing is how will you make these nanomaterials and these nanostructures. So, two approaches are considered when trying to synthesize something at the nanoscale. One is the top-down approach and the other is the bottom-up approach.

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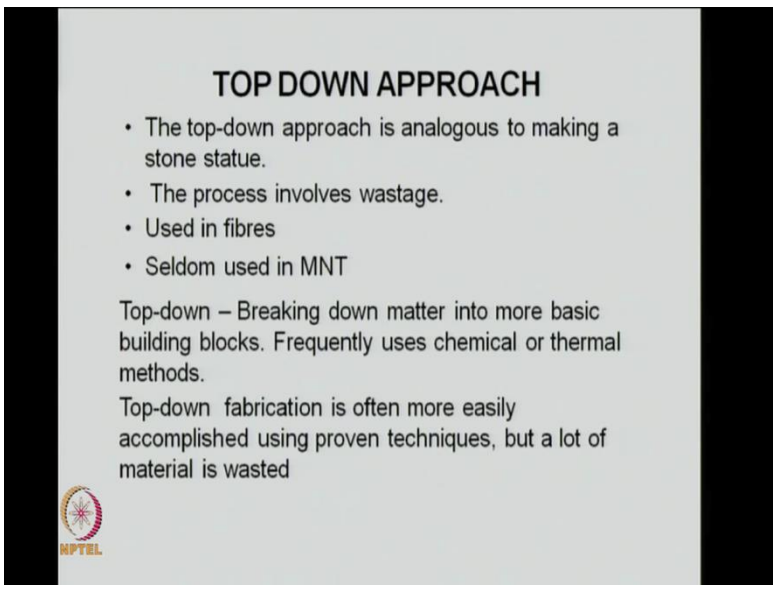

So, in the top-down approach, it is like you make a statue out of stone, you take a big rock like from the mountain and you start chiseling the rock; that means, cutting down the rock to a particular shape, which you have in front of you as a drawing. And you want to make curve out the statue out of the stone, so that means, you are removing the stone from the sides and making a particular shape within that rock. Now, this process involves lot of wastage, because you are throwing away lot of material, which is in the stone. So, hence this kind of a methodology will be seldom used in making a large-scale nanostructures in nanotechnology. So, breaking down matter into basic building blocks that is the top-down approach, and normally we try to avoid this when you have to use nanomaterials in very large-scale applications. However, top down fabrications is often easily achieved rather than the bottom-up approach, but the cost and is a kind of forbids us to use this in large scale applications, especially beyond product it is not going to produce lot of revenue.

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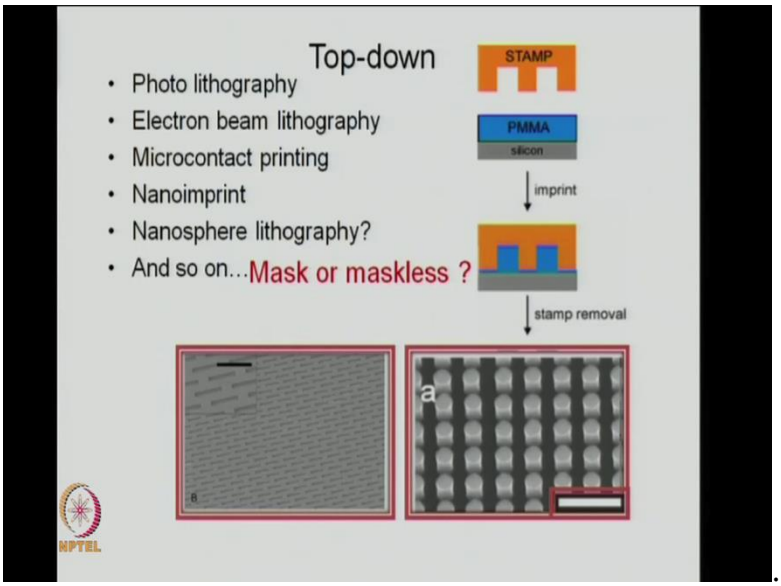


The methodologies which people have used for the top down processes people have used different kinds of lithography processes. The term lithography of course comes from lithos which is stone, so you are doing a kind of a structure a drawing from stone and that is why it is called lithography. And in top down processes, you can have different kinds of lithography. You can have photolithography; that means, your kind of removing atoms from the surface using light or you can have electron beam lithography, where you are using atoms and materials using electron beams. And then after you remove certain

atoms, you create a structure which can be called a stamp. And then you make an imprint of this stamp called a nanoimprint on another material which may be more flexible like a polymer. So, here you can see, you have a polymer called P MMA on a substrate silicon and you have a stamp, and you make an imprint. So, you can use masks or you can do maskless printing. So, there are many many techniques in the lithographic methodology, which one can do in this top-down approach.

So, you can see these are many structures which have been made by removing parts which are around them, and the removal of these parts around them, you have used basically by what we call either photolithography or electron beam lithography. We have used a mask, the mask was kept here, it can be called it can be kept here and so you remove only the places where the mask is not there, and it can be another way also, the other way. So, it is called sometimes, it is called positive etching or negative etching etcetera. But this is the basis of top-down approach, where you have a large object and you create small objects by removing parts of the body from that large object.

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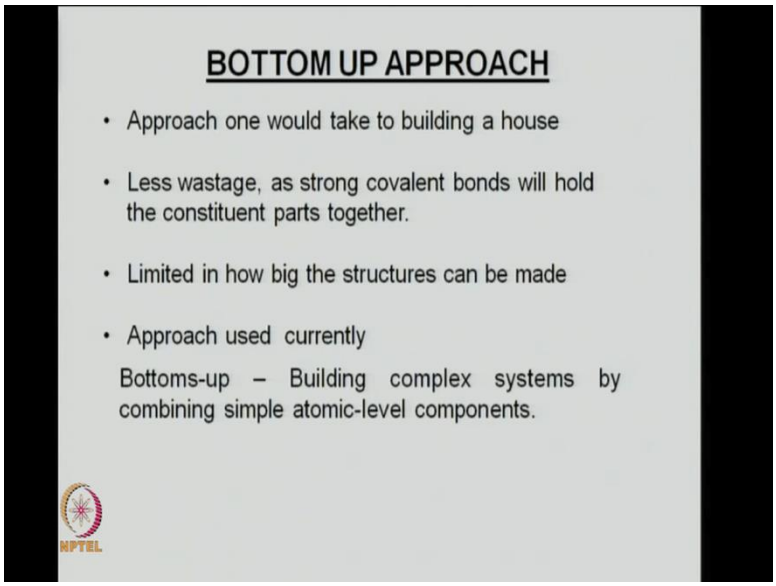


Now, in the bottom-up approach it is like building a house from bricks. So, you take a one brick and put another brick on top of it in a particular arrangement, and then you finally, get a house. So, in the bottom-up approach, you start with atoms and molecules, and then you build clusters or range of clusters, they can be twenty atoms big or two hundred atoms big or two thousand atoms big and but here you have to build from atoms

or molecules and then put them together. And here you will have very less wastage and you will have to study, how covalent bonds will be formed between these atoms or molecules. And the problem here is to build very large structures, because you are starting from atoms and molecules. So, how big the structures you can make in a controlled manner using these bottom-up approach that is the big challenge.

In nature always uses bottom-up approach. It always uses building molecules even the human beings starting from a single cell. So, it is possible to build very complex system from atoms and molecules. However, the technology that man has is yet very primitive compared to what nature has. So, it will take a long time before we can assemble a machine made of molecules, which nature makes everyday million times all around us. So, with that we come to the end of the lecture two, and the end of the module one of this introduction to nanotechnology.

In the next lectures, we will take up the each of these bottom-up approaches, the low temperature synthetic roots which are of different kinds and we will take them one at a time and study all the different types of methodologies used in the synthesis of nanomaterials using the chemical approach or the bottom-up approach in building nanostructures. That will be the next part of this course, and till then good-bye and see you later.

Thank you very much.