INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NPTEL

NPTEL ONLINE CERTIFICATION COURSE

Biomedical Nanotechnology

Lec-01
Introduction to Nano

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Hello everyone, myself I am Dr. Gopinath, associate professor of biotechnology and also I joined the faculty in the center called nanotechnology. I welcome you all to this course on biomedical and nanotechnology. The first lecture of this course is introduction to nano.

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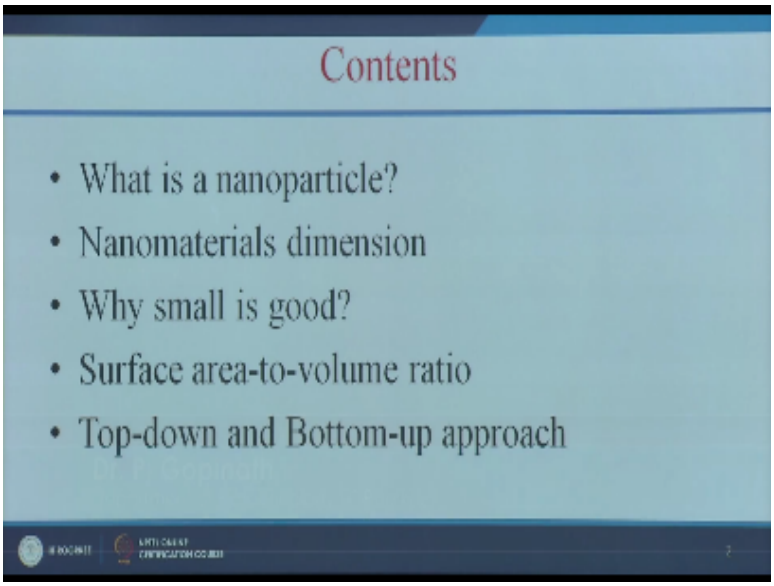

So in this course we will be learning what is the nano particle and how we can categorize this nano materials away into the dimensions. And why nano means good, why is small particle is good and we will also learn what is surface area to volume ration and what are the approaches like top-down approach and bottom-up approach to make the nano structures. And we will also get a idea overall idea about what are the biomedical applications of this nano materials.

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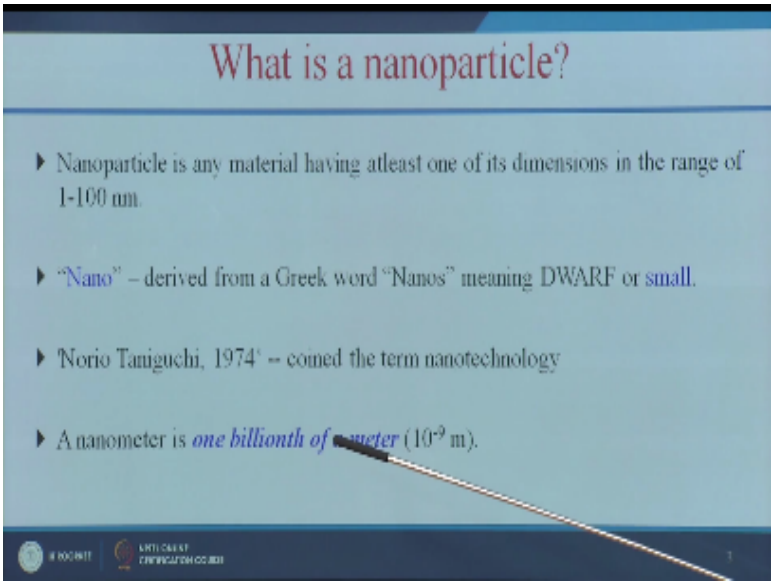

Let us see what is a nano particle, nano particle is any material having at least one if it's dimension at the range of 1-100 nanometer that is called as nano particle. So what is the meaning for the word nano, nano is a Greek word it means DWARF or small. So who coined the term nanotechnology, the term nanotechnology was coined by a scientist Norio Taniguchi in 1974. So what is a nanometer, a nanometer is one billionth of a meter that is 10^{-9}m. So to understand the nano scale let us have a comparison between macro, micro and nano scale.

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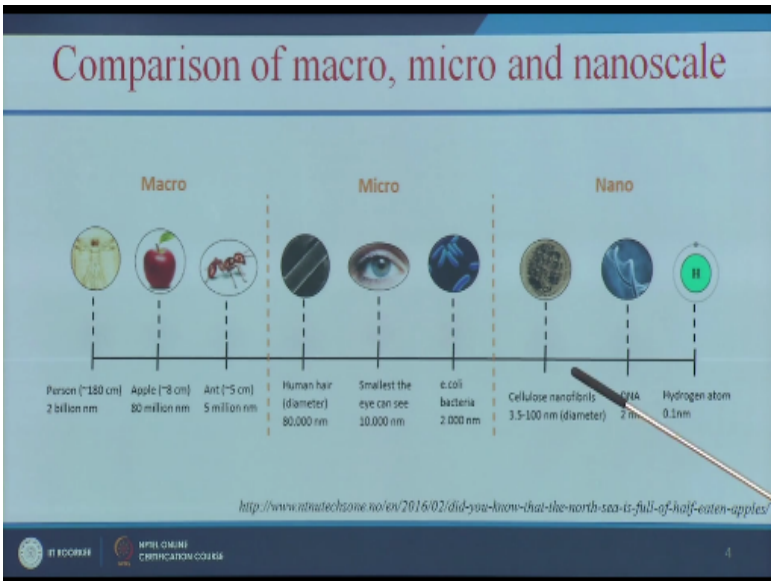

So let us see one example macro, so the average person of height is like 180cm which is equal to 2 billion nanometer, and apple which is size of 8cm it is equal to 80 million nanometer. An ant the size is 5cm, and it is equal to 5 million nanometer. So let us see the micro scale, here the approximate size of human hair is 80,000 nanometer and the smallest, the eye can see is only 10,000 nanometer.

And the normal e-coli bacteria, so the size of e-coli bacteria is in the range of 2 micrometer that is equal to 2000 nanometer. And the average size of mammalian cells range from 5 micrometer to it can go up to 100 micrometer. So let us see the nano scale when compared to macro and micro, so here you can see the diameter of DNA is only 2 nanometer and the cellulose nano fibrils which is in the plant cliff and everything. So it is in the range of 3.5 to 100 nanometer diameter.

And the size of hydrogen atom which is in the range of 0.1 nanometer approximately. So we got a idea about the scale between these macro, micro and nano, so let us have another simple example to understand what is nano.

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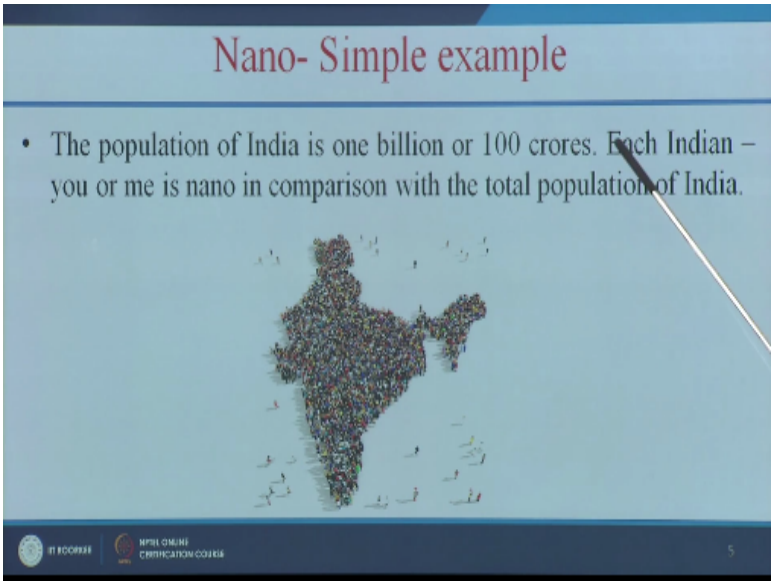

So we can see the population of India is 1 billion, so 1 billion is equal to 100 crores that is 10^9. So each Indian you or me is nano in comparison to the total population of India. So when you compare yourself with the total population of India like 100 crores you are nano.

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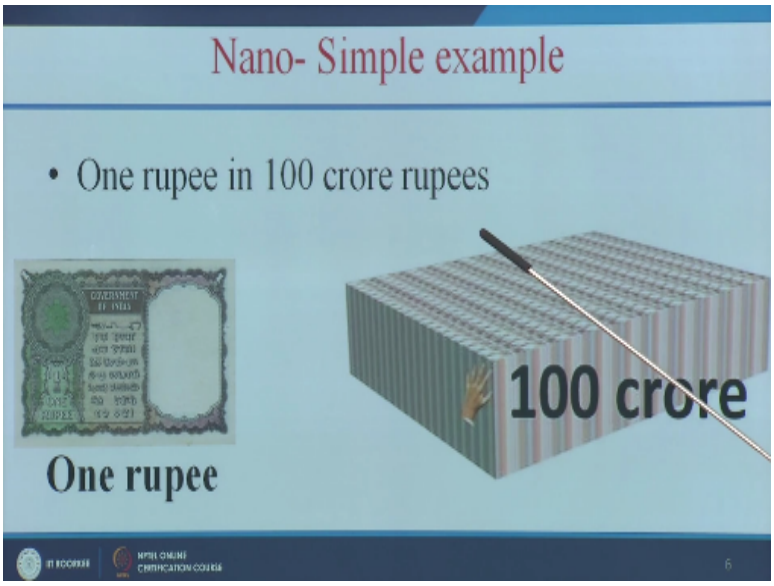

So let us see another example, another simple example if someone ask you what is nano, you can tell them it is equal to 1rupee in 100 crore rupees. So here the 1 rupee is nano, so this 1 rupee in 100 crores is a scale difference you can understand how small the nano is and materials with small dimension show new physical phenomena collectively called quantum method which I will discuss later in detail. So we can categorize this nano material according to the dimensions.

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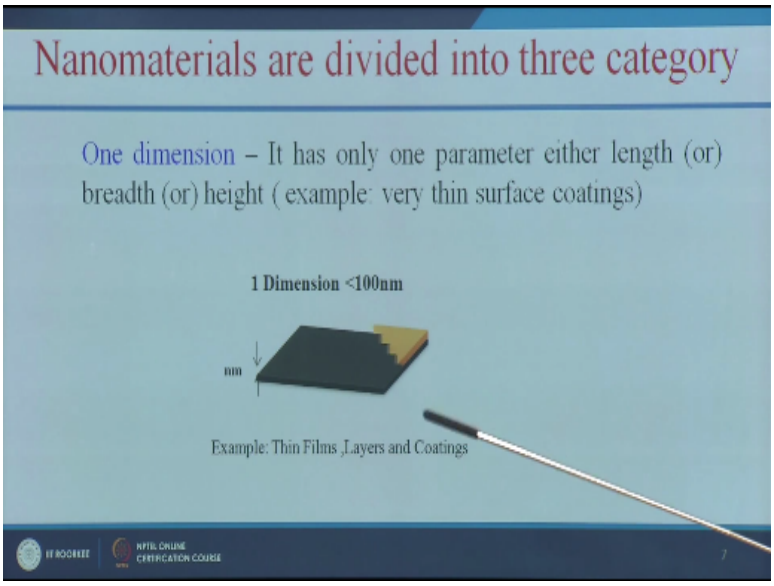

So here we can see the example, the first one is one dimensional nano material so here you can see here it has only one parameter either length or breath or height it is in the range of nano meter so we can see here this picture this orange color coating the coating is in the range of nano meter thickness so it is a one dimensional nano material so example for one dimensional nano materials contains layers and coatings.

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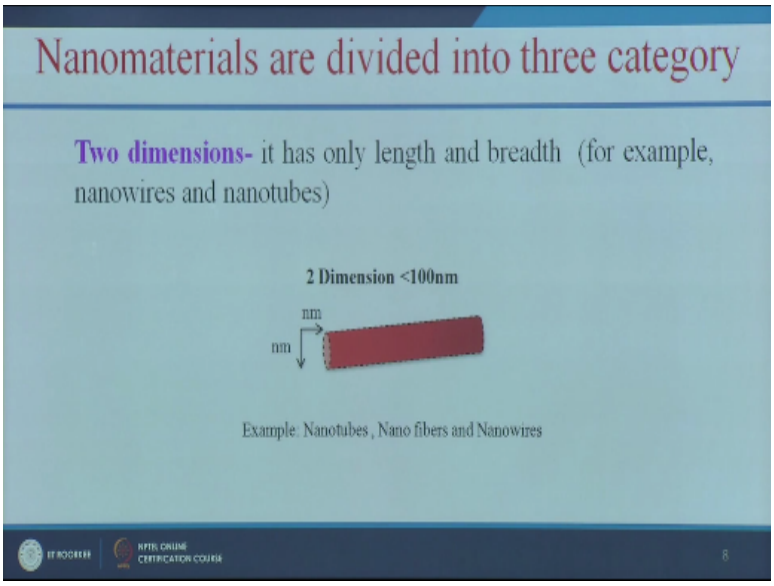

So next one is two dimensional nano material here you see here the length and breadth will be in the range of nano meter dimension the simple examples are nano tubes, nano fibers and nano wires, so here you can see here the length is also in the range of nano and also the breath is also in the range of nano meter in dimension.

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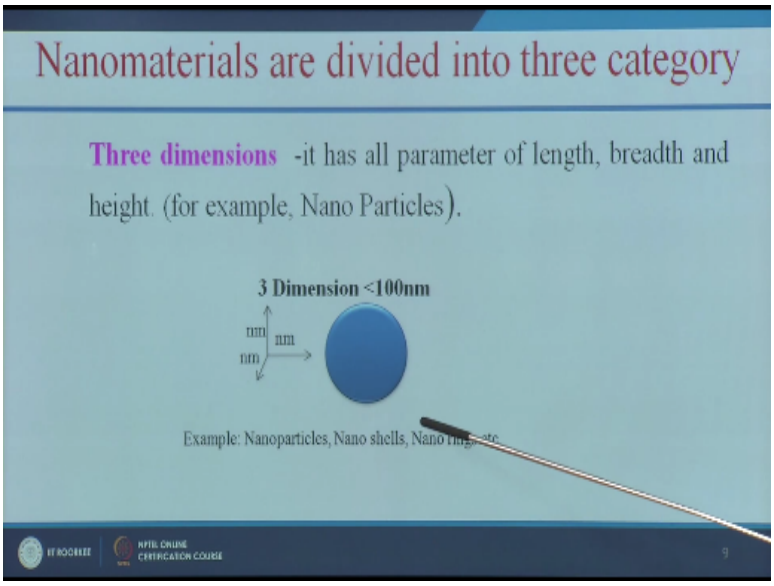

Third example is a three dimensional nano particle it as all the parameter length breath and height everything in the range of nano meter so example is nano particles, nano shells and nano rings I hope you understood what is a size nano and also how we can categories this nano particle according the dimension.

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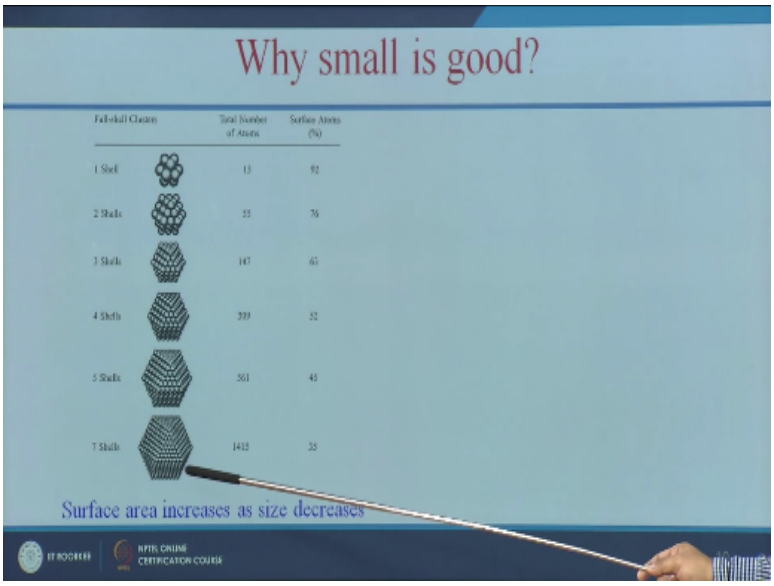

So why we need nano we already have macro micro what is the advantage of nano so here you see here the simple example the full shell cluster so here you are having like seven shells the seven shells comprisal of 1415 atoms so total number of atom is 1415 atoms but when you see the surface atom it is having only 35 surface atoms and the same seven shells if you make it like small practical like one shell so one shell the total number of atom is only 13 but if you see the surface atom it has 92 surface atoms.

So when the size goes down the surface area getting increased so what happens when the surface area getting increased so here you can see here the nano objects can perform very faster and it can be lighter than the bulk material and it can get in to small spaces for example if you are having a drug anti cancer therapy drug and if some of the anti cancer drugs cannot enter into the mammalian cell because of the size.

But if we have the nano size material that can easily enter into the few more location so it can easily get into small space due to it is small nano size and obviously it is cheaper than the bulk material and it is more energy efficient and it will show different kind of properties at a small scale when the size goes down it will express different kind of properties.

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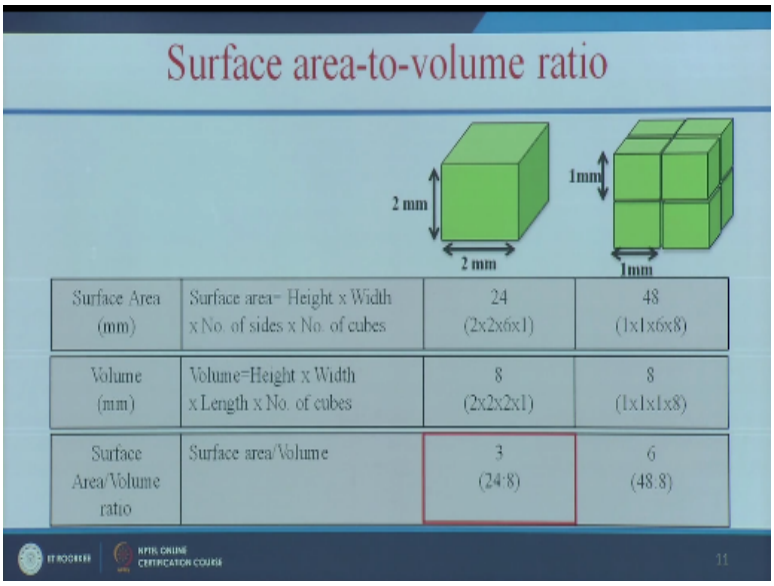

So let us see what is surface area to volume ratio whenever we talk about nano everybody says surface area to volume ratio getting increased so what is surface area to volume ratio we will take a simple example is a cube with 2mm size okay so the same cube we can cut into small pieces of size 1mm okay so when you have this cube so we can calculate the surface area for this cube so surface area formula is a height multiply by width multiply by number of size multiply by number of cubes so here you can calculate the surface for this 2mm cube will get a surface of 24 when you calculate.

When you calculate the surface area for 1mm cube you will get the surface area of 48 and let us calculate the volume formula is height multiply by width multiply by length and multiply by number of cubes so the volume is same for 2mm as well as 1mm volume is same it is 8 for both of the 2mm and 1mm so when you calculate the ratio between the surface area volume ratio between the 2mm as well 1mm you can see here the surface area volume ratio for 2mm is only 3 and surface rate volume ratio for 1mm cube is 6 so it is getting so it is increased okay.

So when the size surface area getting increased what are the properties we can achieve what are the normal property we can achieve we can see here so here we can see here.
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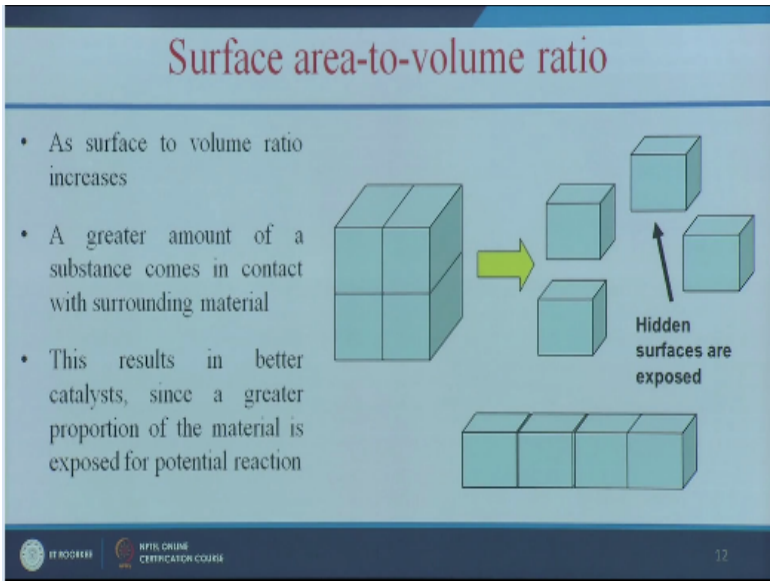

When the surface area to volume ratio increase what happen this a greater amount of substance come into contact with the surrounding material so here you can see here this cubes are open so the hidden surfaces are exposed when the hidden surface are exposed to the surrounding material or environment what happens it will show some remarkable properties, normal properties it can interact very efficiently with the surrounding material and it can have a very good catalytic activity.

So this is results in a better catalyst since the greater proportion of material is exposed for potential reaction so I will show you a simple experiment to demonstrate the surface area to volume virtue using a simple disprin tablet I can show you how this surface area to volume ratio play a important role so to understand the surface to volume ratio I will show you some simple experiment so I am going to use a tablet this tablet so this tablet is available in any medical shop it is only to 40 to 50ps per tablet.

So I am going to put that tablet as such so that will take at least 1 minute to resolve the complete tablet so again the same tablet I am going to crush into powder and going to put in the water I will take less than turn to dissolve in the water so we can understand is when the size goes down it can interact very efficiently the surrounding material and it can have a more catalytic activity so let us see the experiment from the disprin tablet I am just putting into the beaker which containing water.

So here you can see here the tablet is getting dissolve, so it almost taken 45 to 50 seconds for dissolving that complete tablets so the same tablet I am crushing into small powder okay. And putting in another beaker the powder of bit tablet so the moment I added it is dissolving immediately so it takes only 10 to 15 seconds to dissolve the complete tablet so that is why we can easily understand the surface at volume ratio when the size goes down it will have a more reactivity.

At mean that is it is interacting with the surface okay, hope you understood the concept of surface area volume ratio by this simple experiment the properties of materials can be different in the nanoscale.

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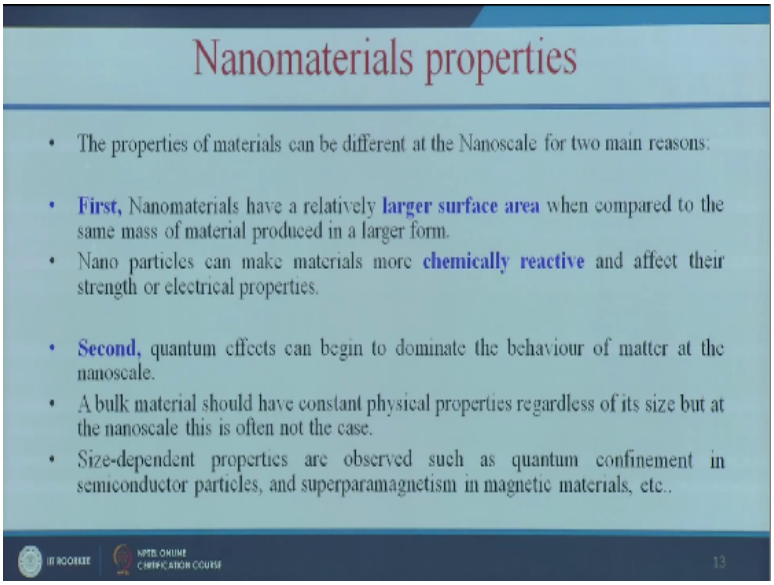

Because of two main reason the first main is it will have a relatively large surface area to volume ratio when compared to the bulk material and again it will be more chemically reactive so that affective strength or electrical properties so that is why the nano size material showing different kind of properties so the second reason is at the nanoscale the quantum effects will begin to dominate the behavior of matter so that is the one of this reason nano properties like nanoscale material show a different kind of properties.

So usually the bulk material will follow the constant physical properties regardless if size but nanoscale materials it is up or not the case okay so the nanoscale materials will show size

dependent properties for example quantum confinement in semiconductor particles or super paramagnetism in magnetic particles it ill happen in the when the material goes to the nanoscale.

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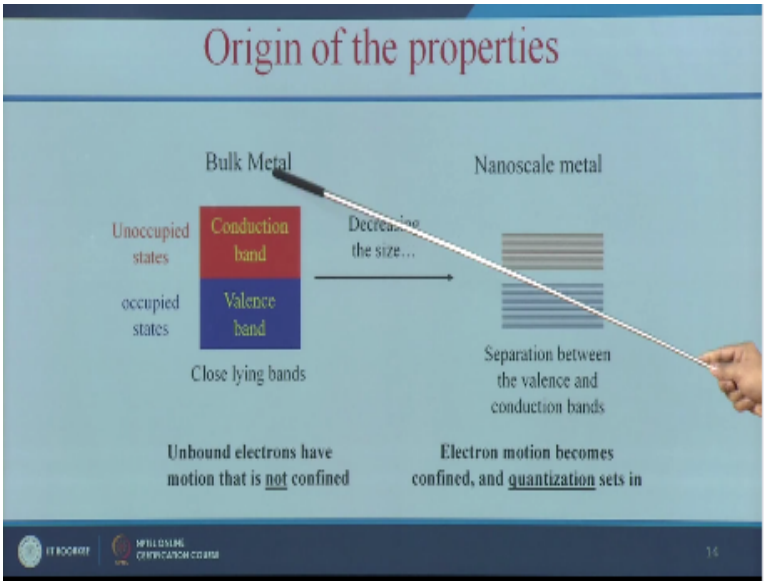

So let us see what is the origin of this properties, so here you can see here in bulk metal this conduction band and valence band are lying very close, so here unbound electrons have motion that is not confined in the case of bulk metal, in the case of when you decrease this bulk metal into Nano size what happens is, there will be a separation between the valence band and conduction band.

So when you separate this valence band and conduction band what happens is, the electron motion becomes confined and quantization's sets in.

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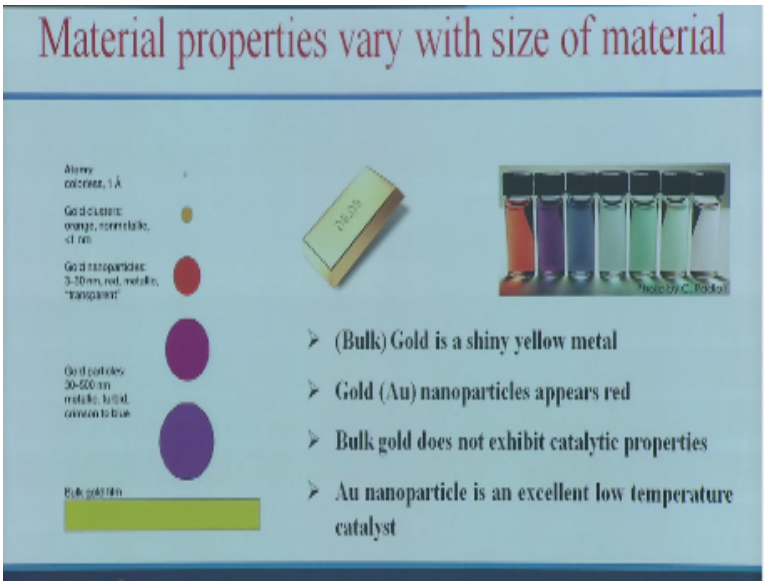

So let us have a one example to understand how the material properties is vary with the size of material, so we can see you can use a very good example gold, so gold you know gold is like a shiny yellow metal and which we use it for making ornaments and jewelries, so when you see this gold it is very inert material, when it is a bulk it is inert material. So when it goes to the Nano size you can see here.

The gold particles outside between 30 to 500 Nano meter it is metallic and it will have a turbid and the color will be between crimson to blue color, but the size goes down to 3-30 NM it will become red color particle okay and it will have the metallic property and it will be transparent again when the size goes down equal to Nano meter or less than that what happens is, you can see here it will be like orange color or it will be non metallic.

So from metallic it became non metallic and red color it became orange color in the gold cluster and when it goes down to atom level one Armstrong it became colorless, so this is a example of gold the same gold in different size and different shapes it is giving a different kind of color. The reason for the different color is surface plasma resonance so that will explain in the next lecture or subsequent lecture.

So here the bulk gold is a shiny metal so usually the gold Nano particles appear red in color as I told you the bulk gold do not have any catalytic property but when it goes to the Nano scale it will act like a excellent catalyst okay, so that is why we can understand this when the bulk material goes to Nano scale it is showing different kind of properties.

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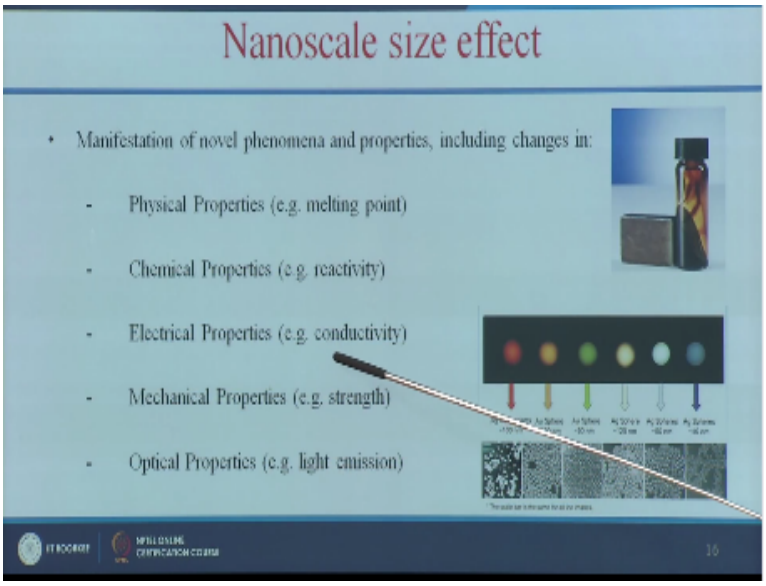

Other than that we can also see other properties such as melting point could be changed to physical properties and chemical properties as I told you it will have a enhanced reactivity so I told you already example how when the size goes down it will be exposed to the enamel and it will have more catalytic activity and again electrical properties somehow the material which is non conductor when it goes to Nano it can behave like a conductive material.

And mechanical properties so doing a making of Nano particles this Nano materials will have high strength and efficiency and optical properties I told you earlier it will have a different kind of optical properties it will have a different color light emissions so here you can see here as example so this silver spheres Nano spheres how 40 nm they showing in blue color and gold sphere of 50 nm showing green color.

And silver Nano prism it is showing a red color and gold sphere of same 100 nm is showing orange color, so depends on the size and depends on the shape it will show a different kind of optical properties and also again this example you can see here when the size of magnetic Nano particles goes down so it will have the very good magnetic properties.

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And again whether this Nano technology is new or not, so Nano technology is not new you can see here this beautiful paintings this paintings are not made by any color paints this paintings are made using different kind of metal nano particles of various size and various shapes so the thousand years ago Chinese have used gold nano particles to introduce red color in their ceramic porcelains, okay and here you can see the another example, in 1857 Faraday prepared gold colloids so that was stable almost for a century okay, it was being destroyed before during the world war II.

And here you can see the example so these are the gold nano particles of different size and different shape and under the transmitted light you can see it is showing a different colors and again the same nano particles when you see under the reflected light it is showing a different color, so let us see another example.

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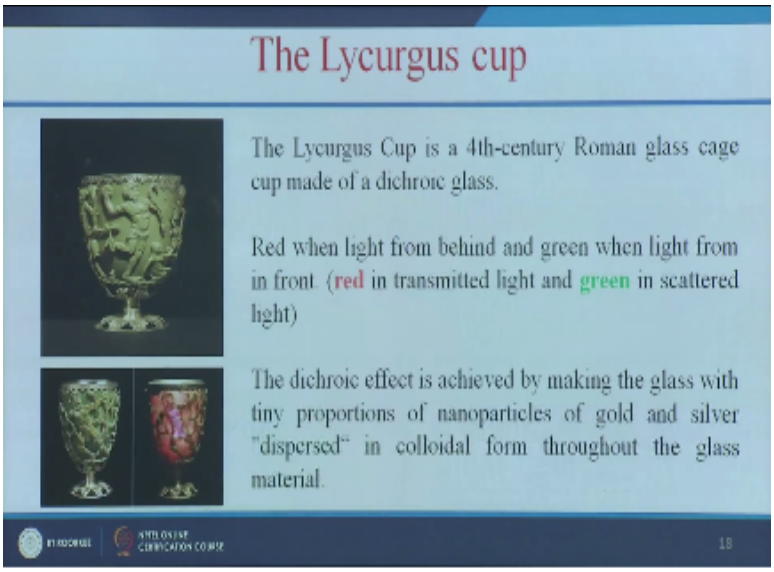

So this Lycurgus cup it is belongs to a fourth century so Roman glass cage made up of dichroic glass. So this will appear red color when light is from behind and it will appear green when light is from in front, and it will appear like a red in transmitted light and green in the scattered light so here you can see here it is changing the color of the cup is getting changed from red color so red color means transmitted light and green color is scattered light.

So this dichroic effect of this cup or glass is made by they added the tiny proportions of nano particles of gold and silver in the colloidal form and they coated throughout the glass cup so that is the reason it is giving a different kind of colors.

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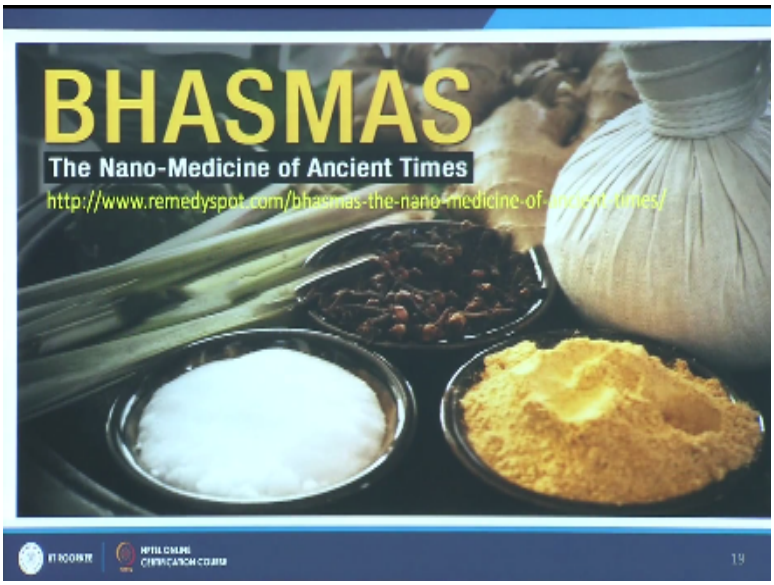

And again nano is not new to India also, so we had an ancient ayurvedic medicine like bhasmas so bhasmas also have lot of metal nano particles and till lot of researchers is going on how we can explore the applications of nano particles and bhasmas for various therapeutic applications.

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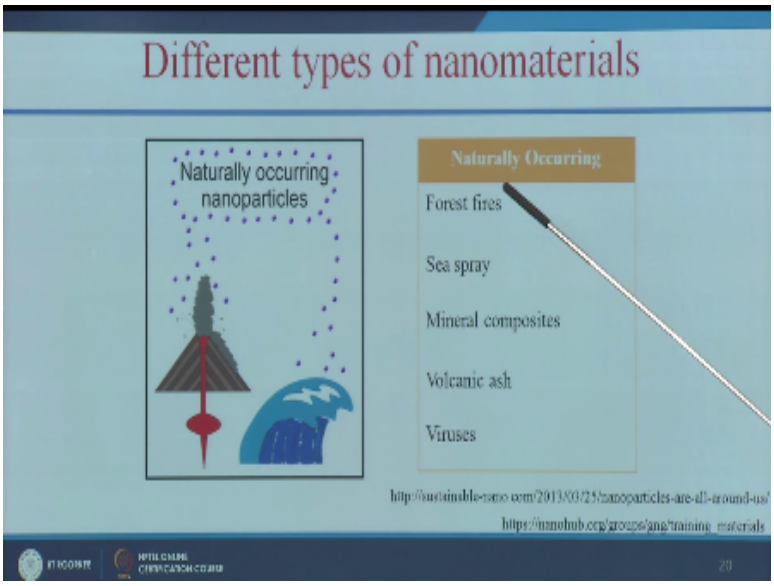

So what are the different types of nano particles so simple example the first one is naturally occurring nano particles so it can be due to forest fires or it can be volcanic ash or viruses so these are naturally occurring nano materials this materials are in the range of nano size.

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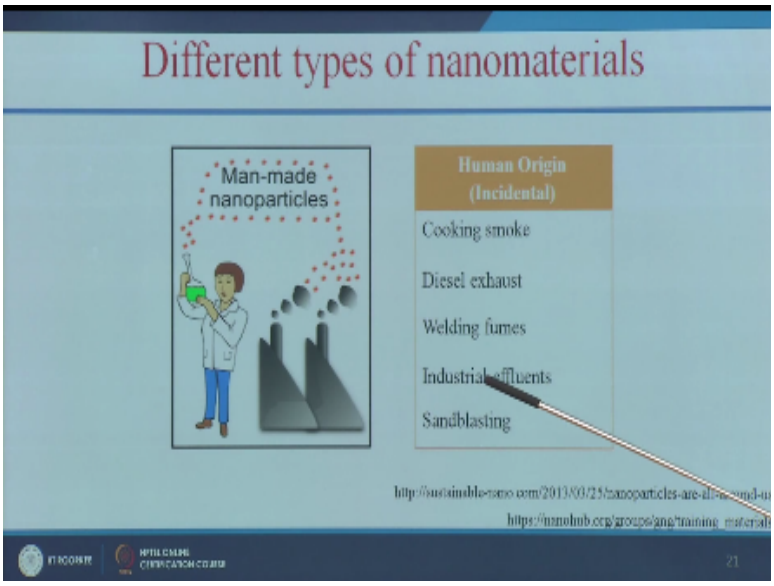

Again the next one is man-made nano particles it may be incidental or it may be engineered nano particle in the incidental nano particle cooking smoke and diesel exhaust these are the things it will have some kind of carbon nano materials.

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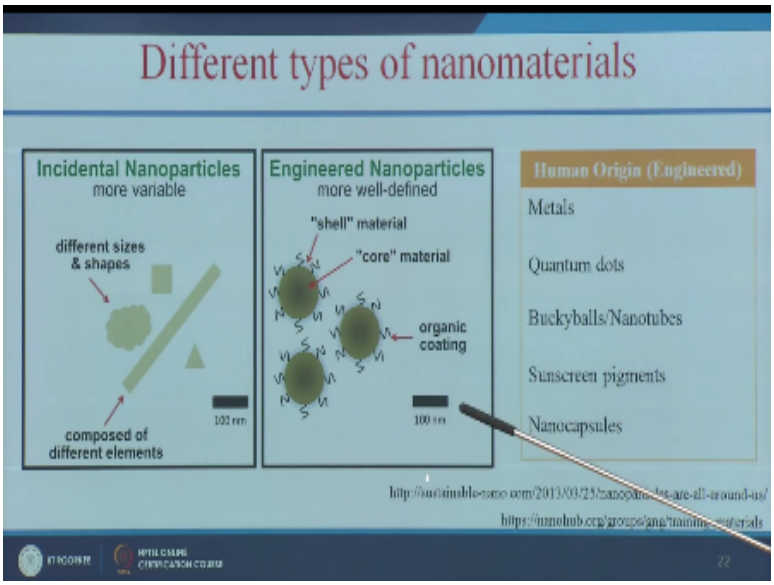

So what is the difference between in incidental nano particle and engineered nano particle, so engineered nano particle also human origin but we make in the lag so when you compared to the incidental nano particle which is more variable and you can see here different size and different shapes and when you make the nano particles in the lab you can have a control and well defined size and shape and also you can have the core and shell and also we have the organic coating and we can modify the and we can engineer the nano particle occurring to our need. So the examples are metal nano particle, quantum dots and nano capsules.

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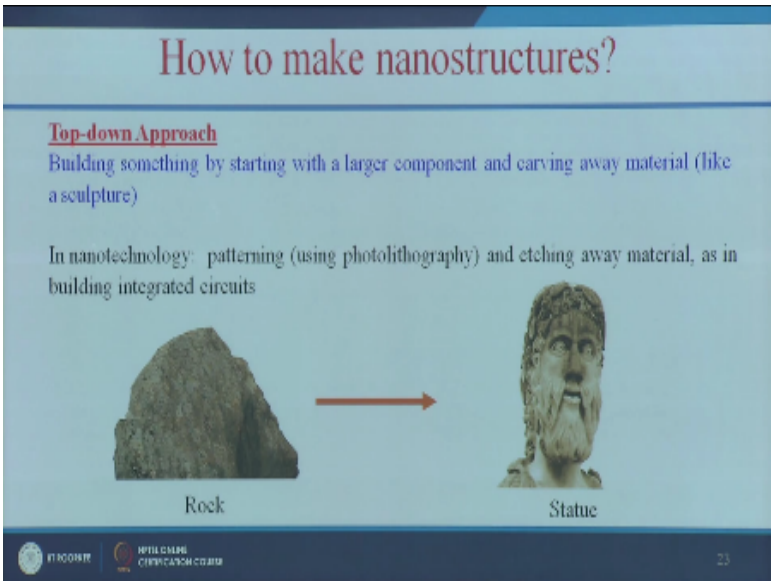

So how to make this nano structures, there are two main approaches one is top down approach and next one is bottom up approach. First we will see what is top down approach so top down approach is building something starting with the larger component and carving away material it is similar to making a sculpture from the rock.

So here your rock is a bulk material and you have carving out from the rock and you are making the statue, so this is your bulk material and this is your nano material your carving out the rock and making the nano material this is called as top down approach from bigger size you are making the nano size top to down approach, okay.

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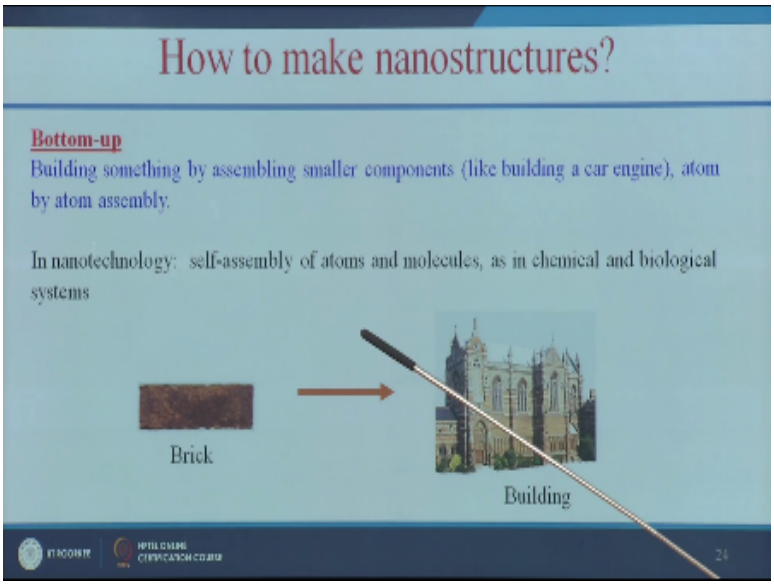

So next one is bottom up approach here the example is you are building something assembling smaller components so we are assembling the components and you are making a like a building a car engine or making a complete building, okay. So a simple example is like we will using the bricks and make the building, so here you will having like atoms and molecules atom by atom will assemble and form the nano particles so it is bottom up from atomic scale it became nano scale, so it is called as bottom up approach.

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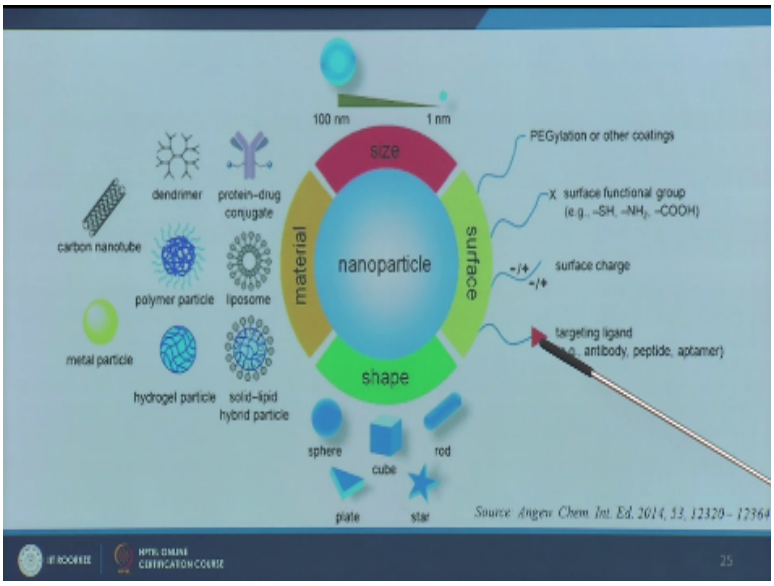

Son when you make this nano particle so we can make the nano particle of materials like inorganic or organic materials and it can be of hybrid of both inorganic as well as organic material and the size could be between 1 to 100 nano meter and again the shape also tuned between this rod or sphere or inner shapes and the surface can be functionalist with the polyethylene glycol that is the PE Gylation or other coatings and also we can have the surface charge it can be plus or it can be minus.

So when you have the positive charge nano particle it has high authentic for binding to the cell surface, cells and DNA have the negative charge okay. And we can also have a targeting ligand so we can add anti body or peptide so that it can specifically go on bin only to the decease cell not the normal cell.

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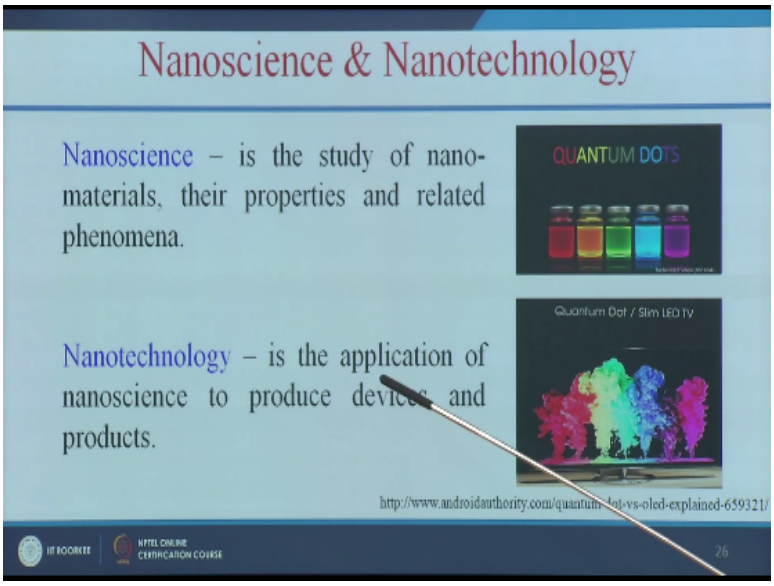

Let us see the different between the nanoscience and technology so here you can see nanoscience is the study of nano materials, and their properties related phenomena. The simple example is quantum dots the quantum dots are semi conducted nano crystals and it will have a different kind of flowers and properties with respect to size. So if we are using the quantum dots and we are studying the physical and chemical properties and everything that is nanoscience and we were using the quantum dots and making a slim LED TV that is called as nano technology. Ever using this application of nano science to produce devises and products.

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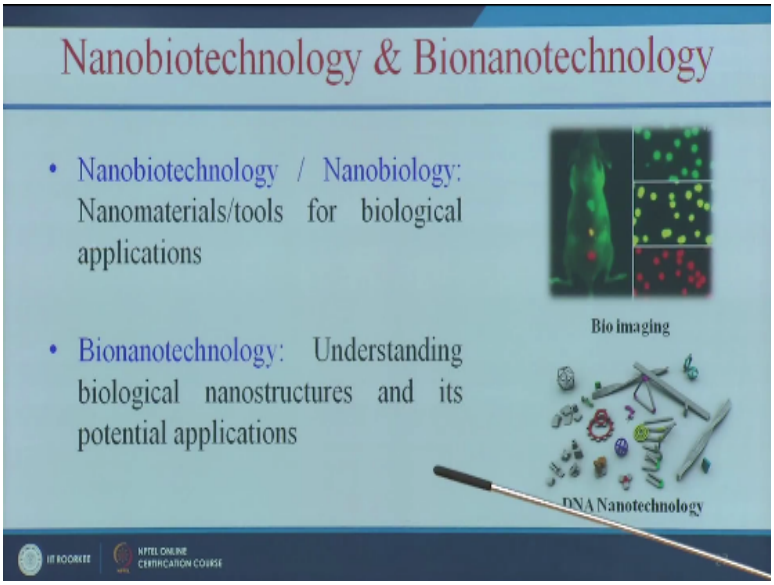

So let us also see what is the different between nano technology nano bio technology and bio nanotechnology so the minor difference between this nano bio technology and bio nano technology is so we will be nano bio technology will be using the nano materials or tools for biological application so we will be using like a nano particles for diagonal decease or imagine the decease so that will for rabbit diagnose of cancer or it can be rabbit diagnose of some other deceases.

So that means you are using the nano material or nano tools for biological application that is nano bio technology or nano biology and bio nano technology is understanding the bio logical nano structures and its potential applications for example we use the DNA we can use the DNA like a construction material instead of genetic material we can use like a construction martial we can make a nano cages and protean based ink so this can be useful for making like nano devises nano machines and also we can see the bacteria which have the flagella based on that we can make a small size nano robots that means you are taking the idea frump the biology to understand the biological nano structures and we are using it for various application. So this is called as bio nano technology.

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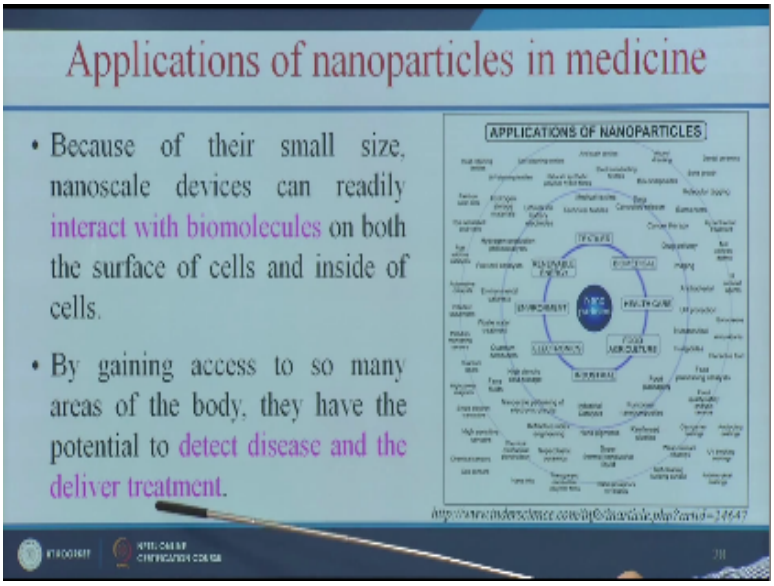

And this nano particles have wide applications in almost all the fields so in this course we will mainly focus on bio medical and health care so why we are using this nano particles for medicine application bio medical application because of the small size it can interact with the very good with the bio molecules and also it can easily enter in too many areas of the body and it can detect that this is in the early stage and it can deliver the theoretical molecule.

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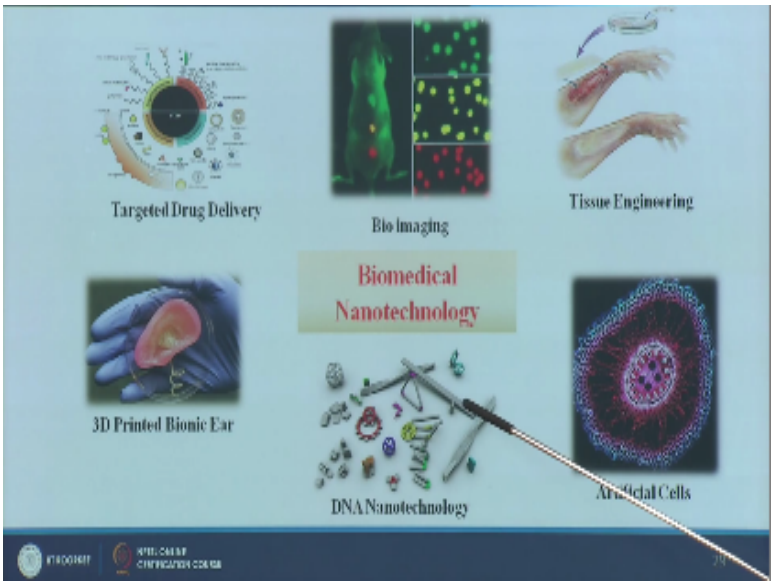

So let us see the bio medical applications of these nano materials one by one so the first application is we can use these nano materials for diagnosing various deceases and we can make some floors and nano particles which can easily reach to our location and it can use a floors and signal which can easily monitor. The next one is targeted drug delivery, so the main draw bag of the traditional cancer therapy is so we are not able to target only to the cancer cells it is able to kill the healthy cells also.

But when we use this nano particle it can specifically growth only to the cancer cell and kill the cancer cell so we can make a targeted drug delivery and again we can go for tissue engineering so in this tissue engineering so if you have the damages skin or damage organ we can grow that damage organ a scan in the lab and we can replace and the upcoming areas organ printing we can print any organs and we can go for the organ transformation.

So be this under clinical trends lot of research is going on this organ printing and we can also make the artificial cells in some of the cases we do not need the complete organ we can replace only the damaged cells or dysfunctional cells so that is called as artificial cells for example we want a make a artificial RBC I was think an b positive by using this artificial cells. And DNA narrow technologies are porting narrow technology this comes under bio narrow technology.

So here we can use this DNA and protein as a construction material and also I like a nano too to make nano machines or nano devises and which can useful for kind of bio diagonal therapeutics or which can also useful for understanding the various deceases. The bio medical nano

technology is the combination of nano bio technology as well as bio nano technology so ion the course we will be learning all the applications of this nano materials bio material application of nano materials in this sub sequent lectures.

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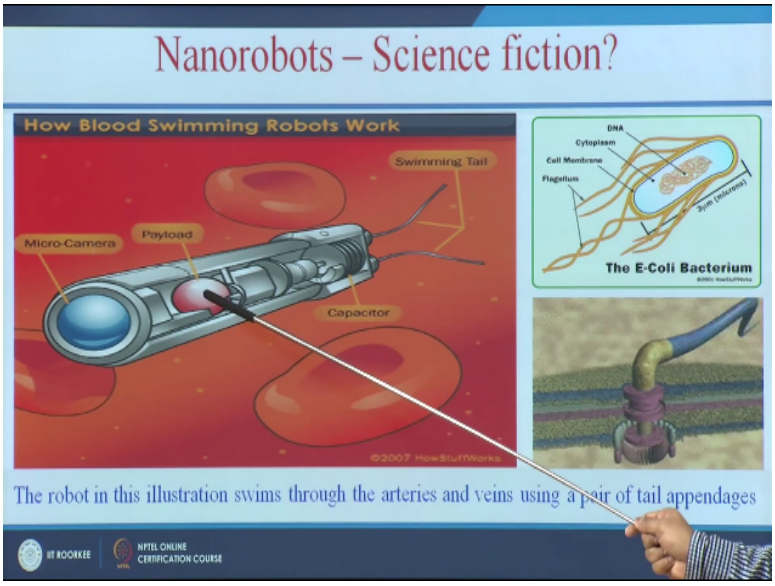

So before I control the lecture I will also so your another upcoming area called nano robots, so it may look like a science fictions but still lot of research is going on to make it reality so the nano robot typical nano robots will look like this scientist got the idea from bacteria you know bacteria move from one location to other location using the flagella. So based on that they made in small nano robots which have a tie like structure and it will have a micro camera so we can monitor whether it is going to the proper location or not and it will have the payload.

Payload is you are the apical molecule and it will have a capacitor it will have the energy to move from one location to another location and the swimming tail. So it will move from one location to another location to the arteries and brain using the tail like appendage and it can read the location and it can deliver the drug.

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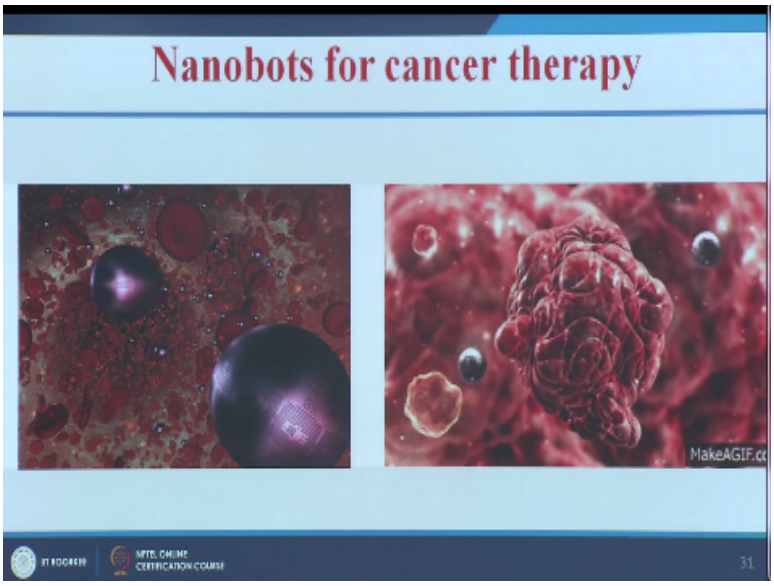

So this is how it will look like the connectional nano robots in short nano robots is called as nano boats, so in this picture you can see here the nano robots for cancer therapy. So this can swim in your blood steam an d it can reach the tumor location and once it reach the tumor location it can destroy the tumor cell and the cancer cells.

So this is the conception idea of nano robots for cancer therapy to other procedures are going on developing this kind of nano robots.

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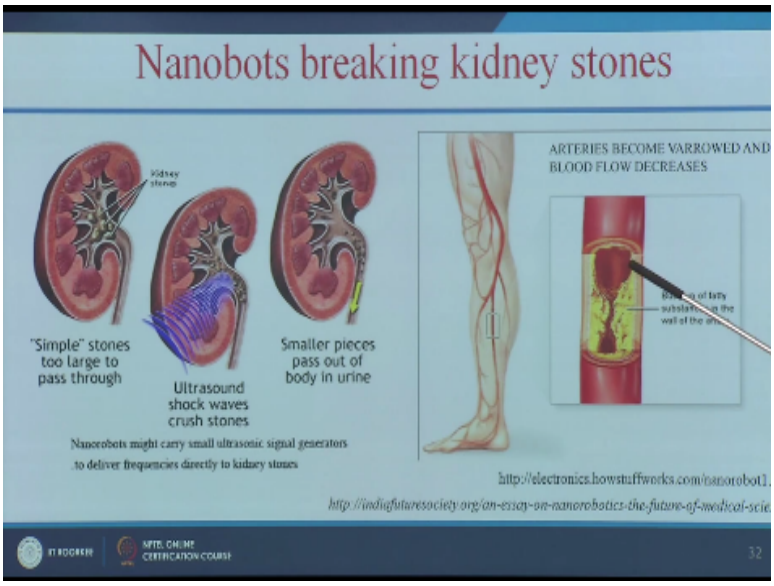

Not only for cancer therapy can we also use these nano robots for making I mean breaking the kidney stone. So nano robots it can carry a small ultra sonic signal generators okay, so it will deliver the frequency directly to the kidney stones. You can see here simple stones are very large to pass through so what happens is this nano robots can generate some shock waves it can break the stones and the small stones can easily pass through in the urine and it can be also useful for removing the fatty layers deposits on the where the arteries are blood veins so it can tin it bit also.

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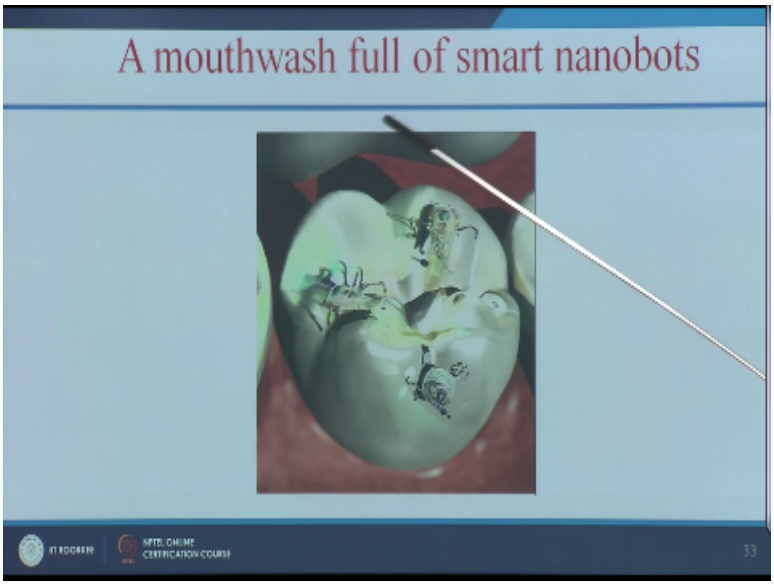

And nano robots not only for the bio medical applications it can also be f or the day to day applications for simple examples it is a mouth wash full of smart nanobots. So now we can nanobots which can clean your teeth. You might have seen a TV advertisement so me one will ask whether tooth paste have salt or not.

So I guess soon they will have advertisement whether your tooth paste have nanobots or not. So this nano is getting applications in your day to day life also not only in for bio medical applications in your day to day life it is entering slowly one by one. So in this course we will be learning all the bio medical applications.

We will be entraps in bio medical applications of nanobots how we can use for bio medical applications and diagnosed application as the summary of the first lecture so we learned in this lecture is we learnt what is the size of nano particles and how we can categorized the nano particles in dimension d1 and d2.

We have learnt why the nano particle is is good and better then the bulk material and how the material products are changed in respect to the size we learnt. We also learnt what the velocity of volume ratio is and then we got the idea of how we can use these nanobots in various bio medical applications.

I end my lecture here thank you for listening to this lecture I will see you in other interesting lecture.

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