Lec 31: Introduction to Nanoparticles

Hello everybody, welcome to this massive open online course on solid fluid operation. As we are discussing about the conventional part of that particles in our earlier lectures, there we are talking about what are the different characteristics even flow and drag coefficients, even the frictional resistances and also how that solid particles can be separated by different mechanisms that we have discussed till now. And today onward in the successive three lectures, we will try to know something about that out of that conventional particle size, it is regarding as nanoparticles. So here in this case, we will try to know about something, nanoparticles and how that nanoparticles can be defined and what are the conventional size of that nanoparticles and where those nanoparticles can be applied and also what are the, methods by which that nanoparticles can be produced or made or synthesized. So in this lecture, it will include that, , definition of the nanoparticles, properties of nanoparticles and what are the application of that nanoparticles and how are nanoparticles will be made. As that smaller particles size, nowadays a very trend because you will see that these nanoparticles, that means very fine particles that will behave differently than their bulk, , counterparts.

As particle becomes smaller, you will see that their surface area will increase and this increase of surface area will give the different benefits of mass transfer or, you know, production of different chemicals and also other physical and chemical processes and their process will be intensified based on this, , larger surface area. Now what are those, different behaviors of that nanoparticles will show. You will see that there will be an increase in electrical and thermal conductivity, lowered melting points, stronger magnetism, unique optical properties of the particles, even other properties of that materials will be, , increased if you reduce the size of the particles from the conventional size to the nano-sized particles. Now whenever we are talking about that nanoparticles, of course that power of 10 will be, , matters.

So in that case, if we are considering that different size range of that particles from the 10 to the power minus 2 to, , 10 to the power minus 7, then we can have different types of, you can say that materials, even different examples in our daily life that we can see there that their size range of that particle will be, , within a power of that, , 10. Like if we consider that, , 10 to the power minus 2 meters, 2 10 to the power minus 3 meter, there you will see that it will be maybe that 1 centimeter or 10 millimeter to 1000 micrometer within range, you will see that whatever suppose dal, suppose moshutdal we are using that particle size of that moshutdal is around 4 millimeter. Whereas if we talk about that plant cell, its size is 100 micrometer. And also human hair, you will see that the size of the human hair is 10 to 50 micrometer. So it is also the range of that 10 to the power minus 4 meter, that means 0.

1 millimeter or you can say 100 micrometer. Even 10 to the power minus 4 to 10 to the power minus 5 within this range, you will see that some, , particles will be like here red blood cell, their size is 2 to 5 micrometer. Even if we measure that lipo-zome in our, , that cell, you will see that its size will be 50 to 1000 nanometer. That means the size range

within that range of, , 10 to the power minus 6 meter or you can say 1 micrometer to, , 1000 nanometer. Then if we go even smaller of this size of 1000 nanometer, you will see that it will be like, , 10 to the power minus 7 meter in range or you can say 0.

1 micrometer or 100 nanometer or 1000s almost from there. So in that case, you will see that that dendrimer that is neuron you can say that the size is 1 to 10 nanometer in size. So these are the different examples of, , particles where that you can get within a range of 10 to the power minus 2 to 10 to the power minus 7 meter in range. So all those actually particles whatever we are assessing that will be also within a range of, , 10 to the power something that means your power of 10 does matter and this because of this the matter of this, , size range from this, , 10 to the power minus 2 to 10 to the power minus 7 in range even smaller you can say. Based on that, , size of these particles derivation of these materials based on the size that is come from very ancient period.

So according to that period that we can say that some will be, , that conventional particle size based on that that is age and up to that, , nano material or nano particle frames that actually defined based on that development of that material characteristics based on their size. So if we are talking about that 10 to the power 5, , BC that means at that time that nanoparticles or, , nanomaterials about that it was actually dark. So at that time only stone and wood that they were working but at the age comes you will see that gradually that, , size of the materials coming gradually lower to lower and accordingly the different applications at different ages are there. Here sometimes it is your bronze age, it is 3000 BC then iron age, you will see that cement age where, , this age 0, steel age then you can say polymer composites that is developed in 1990 that is after BC and then you will see that, you will see that nanomaterials or nanoparticles that is derived from 2000 stone or even till now it is being, , developed in different way or synthesized and also their application nowadays. So we can see that there will be a change of that, , material development from the ancient age to the present age based on its application in terms of their size of the materials.

And also if we are talking about that nanoparticles or nanosize range of the material, then there will be certain, , range of that material which can be regarded as a nanomaterial. So how that nano terms has come and how that nanomaterials can be defined there. So if you are talking about that nano, you will see that it will be actually recognized as the dimensions between 1 nanometer to 1000 nanometer, where 1000 nanometer means 1 micrometer. So below that 1 micrometer we can say that here it will be that nanometer range. So 1 nanometer to 1000 nanometer within this, , range of this dimension it will be regarded as nano.

This nano terms basically came from that Greek word that is nanos, which means that dwarf are extremely small and it can be used as a prefix for any unit to mean a millionth of that unit. Here in this case, we can say that this nanometer is applied for the length here within that, , range of that 1 nanometer to 1000 nanometer. So 1 nanometer is extremely small, we can say that is in length corresponding to 1 billionth of 1 meter or 1 millionth of 1 millimeter or you can say 1000th of that 1 micrometer like this. So these are basically that nano and then definition you will see that this definition of this nanoparticles comes based on that different material characteristics even in which fields that is being applied and also it can be defined based on that structure of that material. So the definition of nanoparticles differ depending upon the materials, fields and also application concerned.

The particles in the 3 digit range of nanometer from 1 nanometer to 1 micrometer could be called as nanoparticles and also you will see that particles smaller than 10 to 20 nanometer where the physical properties of the solid material themselves would drastically change and because of the change of that physical property, nowadays these nanoparticles are being applied for various applications for deriving in our domestic usable materials there and also in industry they are actually using for various processes to get that intensified way of that yield of that process. In many cases, you will see that the particles from 1 to 100 nanometer are generally called as nanoparticles there, sometimes regarded as the particles smaller than those called conventionally submicron particles. So it is concretely less than the wavelength of visible light, its lower limit is about 400 nanometer as a measure which need to be treated differently from the submicron particles. Now different organizations they have given different definitions for these nanoparticles or nanomaterials. In 2008, the International Organization for Standardization that is ISO defined a nanoparticle as a discrete nano object where all three Cartesian dimensions are less than 100 nanometer.

So the ISO standard similarly defined two-dimensional nanobjects, the nanodiscs and nanoplates and also one-dimensional nanobjects that is called nanofibers and nanotubes. So here as per this ISO, the definition of that nanoparticles is basically the particle size which will be within a range of less than 100 nanometer. And also as per this ISO, they told that nanoparticles dimension will be as two-dimension and three-dimension like this. So two-dimensional nanobjects will be like this like nanodisc and nanoplates whereas the one-dimensional nanobjects it will be nanofibers and nanotubes. Here in this picture it is shown that nanodisc, nanotube, silver nanoparticles, silver nanoplates and also nanofiber, it is shown in the slide there.

So how those actually look like that you can see here. So another definition which will be more technical as per Commission of European Union. In 2011, the Commission endorsed a more technical but wider ranging definition of this nanoparticle. According to that Commission of European Union, a natural incidental of manufactured material containing particles in an unbound state or as an aggregate or you can say as an agglomerate and where for 50% or more of the particles in the number size distribution, one or more external dimensions is in the size range of 1 nanometer to 100 nanometer. So this is the statement that they have given for the definition of nanoparticles in 2011.

So here also it is defined that the resize range will be 1 nanometer to 100 nanometer. So the lower limit of 1 nanometer is used here because atomic bond lengths are reached at 0.1

nanometer. So 1 nanometer is actually used as for that reference length of its definition to up to 100 nanometer. And there are different types of nanoparticles will be there as per this slide here shown here.

So several different types of nanoparticles are shown here. Some will be based on size, shape and material properties and some will be based on organic and inorganic compound based. Some will be based on carbon, ceramic, semiconducting or polymeric substance based. Some will be either it is soft or hard particles based on that these nanoparticles are being classified. Now based on size, shape and material properties we are having that you will see that one dimensional, two dimensional and three dimensional even zero dimensional nanoparticle also.

Like zero dimensional nanoparticles like you will see that Q dots even it is called fullerenes and gold nanoparticles. And one dimensional nanoparticles like here you will see that carbon or metallic nanotubes, gold nanowires, polymeric nanofibers, metal nanorods like this. And two dimensional nanoparticles like carbon coated nanoplates, graphene sheets even you will see that layered nanomaterials there. And three dimensional nanoparticles, bulk nanomaterials, polycrystals, even liposome those are actually three dimensional nanoparticles. And based on that organic and inorganic type we are having inorganic type like gold nanoparticle, quantum dots like this.

Iron oxides nanoparticles like lenthanite, iron, even also you will see that organic based like dendrimers and also micelles, liposome, even ferritin also there. So these are the different types of nanoparticles which is classified based on that organic and inorganic compound. Based on carbon, ceramic, semiconducting or polymeric substances, these nanoparticles can be classified also like carbon nanotubes and fullerenes there. So these are called nanoparticles of type ceramic or carbon types and also hard or soft particles like titanium, silica particles and also fullerenes are that is called hard particles that is nano size particles. And soft nanoparticles are like liposome, even vesicles and also nanodroplets etc.

Basic shapes of the nanoparticles are like zero dimensional, one dimensional, two dimensional and three dimensional. Zero dimensional likes the quantum dots, fullerenes and gold nanoparticles. One dimensional like gold nanodots, carbon nanotubes and nanowires. Two dimensional like silver nanoplates, graphene sheets and bilayer graphene and three dimensional liposome and polycrystalline materials, even dendrimer like this. So these are basic shapes of nanoparticles are there.

Some examples of nanoparticles and their related phenomena is given in this table. This is taken from that Hasuka Vaitl books that is nanoparticle technology. In this case you will see that this nanoparticle based on its size, you will see that different type of nanoparticles based on their metal type, inorganic, organic or bio or pharmaceutical or aerosol type that different types of nanoparticles and based on the size also it is given in the table there. So go through this table once then you would be able to understand that within a certain range of that dimension what are the different example of that you know nanoparticles that can be obtained here. Now then we have to discuss about that what are the different features of nanoparticles, what are the different properties of that nanoparticles there.

Now with the decreasing particle size that is coming to nano size, the solid particles generally tend to show different properties from the bulk material and even the physical properties like morphological structure, even thermal properties, even electromagnetic properties, surface area properties, mechanical properties, even optical properties those will be changing as particle size decreases. And also you will see that some particles will be having some activation enhancement of that particle at its surface like particles as they are micronized, they are affected by behavior of atoms or the molecules themselves and show different properties from those of the bulk. The change of that bonding state of that atoms or the molecules will be there. Even you will see that if its size will be reduced then on the surface this activation energy will be changed based on this surface area increment. So in this case you will see that if we consider a cube of 1 centimeter and if it is divided into a cube of 1 micrometer you will see that particle number will increase to 10 to the power 12 and being divided into 1 of 10 nanometer then it amount will be up to 10 to the power 18.

So in that case huge number of nanoparticles will be there and each particles will give you its surface area. So one big size particles if it is converted to 10 to the power 18 number of nanoparticles there you will see that surface area will be increased. So the atoms or the molecules at the surface are more active than those inside the solid particles because of easy bonding with the contracting materials and causes various changes in particle properties. So in this case we can enhance the activation of this particle surface by decreasing its size to up to nano range and because of that changing its nanoparticles the size as the micronization of that solid particles in that case the specific surface area will be increased generally in reversal proportion to the particle size. If you increase the particle size surface area will reduce whereas if you decrease the particle size surface area will increase.

So when the particle of 1 centimeter is micronized to 1 meter and 10 nanometer you will see that the specific surface becomes 10,000 times and million times respectively here 1 micrometer. And in this case as the increase in the specific surface area directly influences such properties such as the solution and reaction rates of the particles. So as we increase the surface area you will see that the activation energy for that reaction will be increased by that catalyst surfaces. Now another properties like morphological or structural properties. What is that morphology? It is basically a form of nanomaterials that is compressing its shape, size and structure and it is important for materials for exploiting their properties.

Some materials will be amorphous in nature that will usually adopt a spherical shape or nanospheres and anisotropic microcrystalline whiskers that will correspond to their particular crystal shape. For example there are nanospheres that are spherical, nanorefies you can say, nanoboxes, nanoclusters, nanotubes like that. These are the example of that nanomaterials or nanoparticles. In that case you will see that optical filters and biosensors that are actually that are using that optical properties of that gold nanoparticles and it requires anisotropy of the particle shape as larger shapes produce greater plasmon losses. So in that case nanoparticles will give you that better optical properties based on conventional sizes.

And also the morphological characteristics will be different like some will be flatness, some will be sphericity and also aspect ratio. In that case these are the parameters based on which you can assess that morphological structure. The shape is attained during that growth through a self-assembling process that is detected by the interplay of size and molecular interactions. And high aspect ratio, the nanoparticles include nanotubes. I think we have discussed that aspect ratio in the beginning of this course that what is the different characteristics of the materials there.

There one terms we have discussed that circularity, aspect ratio and also sphericity all those things. So this high aspect ratio nanoparticles include nanotubes and nanowires with various shapes such as helix, zig-zag belts or perhaps nanowires we can say with diameter that wires that will vary with length. And small aspect ratio now morphologies include spherical, oval, cubic, prism, helical or pillar. In that case collections of many particles exist as powder, suspension or colloids. So these are the different parameters based on which you can assess that morphology of that nanoparticles.

For that certain equipments are available to measure those aspect ratio, sphericity, flatness, even surface area, even other surface characteristics. Here in the picture it is shown different morphologies of nanomaterials. They are graphene sheets in A and also you will see silver nanoparticles in B, in C silver nanowires, in D gold nanorods, gold nanoparticles, nickel oxide nanoparticles and also copper oxide nanoparticles here in the picture. So here in this case I want to acknowledge that this has been taken from this metal nanomaterials, immune effects and implications of that physicochemical what is on sensitization in this paper. It is published in journal of immuno-toxicology there.

So thanks and I am grateful for them to use this their picture in this academic teaching. And also thermal properties, there is another important properties of the nanoparticles. The melting point of the material decreases from that of the bulk material because they tend to be able to move easier at the lower temperature. You will see that some gold nanoparticles, their melting point, basically that 100, 3036 Kelvin as a bulk, but it starts to decrease remarkably below the particle size of about 20 nanometer and drastically below 10 nanometer and also then becomes more than 500 lower than that of the gold bulk around 2 nanometer. So as the size of that particles decreases this the melting point will be lowered.

The reduction of that melting point basically of that ultrafine particles is regarded as one of the unique feature of the nanoparticles related to it that aggregation and grain growth of that nanoparticles or improvement of sintering performance of ceramic materials. So there is a you can say that linear relationship between that ratio of melting point of nanoparticles to that of bulk materials and a reciprocal number of a particle diameter. Also another property of nanoparticle it is called electromagnetic properties. Here you will see that this electromagnetic properties play a great role for that improvement of the product performance when these particles will comes to reduce its size. And the dielectric constant of suppose lead telecom trioxide tends to increase considerably as the particles become smaller than about 20 nanometer and also the minimum particle size to keep the ferroelectric property critical size differs depending on the kind and composition of the materials.

So it varies from 7 nanometer for lead telecom trioxide to 317 nanometer for barium and lead telecom compounds there. Also you will see that the you will see that Curie point defined as the point changing from ferroelectric material to the paraelectric phases of PVTI O3 reduces drastically with the decreasing particle size below 20 to 30 nanometer. And also the optical properties of that nano size particles will be changed as the size of the particles becomes in several nanometers range. They absorb the light with a specific wavelength as the plasmon absorption as stated by Kurukawa and Hosua in 1996 from their experimental observation. And this is caused by plasma oscillation of the electrons as they stated and are transmitted light with different color that would be depending on the kind of metal and particle size that is obtained.

So as per this Kobayashi 2004 experimental observation they have stated this the change of this specific wavelength as the plasmon absorption there this is because of that the plasma oscillation of the electrons and the transmitted light with a different color that will depend on kind of metals and particle size. So in case of gold nanoparticles it is reported that the maximum light absorption wavelength will be 525 nanometer for the particles of 50 nanometer but it is enlarged by about 50 nanometer for 45 nanometer particles. Then another property it is called the mechanical properties you will see that hardness of the crystalline materials it will increase with decreasing crystalline size and the mechanical strength of that material you will see that increases by reducing its size. Also you can say that not only in the micro it may be that the mechanical strength will be increases up to its nano size range also. So basically that mechanical strength we can say that it will be increased if you reduce the size and also you will see that contact angle that will be increased as the size of that particles will increase.

The contact angles of all liquid metals will decrease at less than 40 nanometer and a remarkable decrease of that contact angles is observed when particle radius is less than 10 nanometer. So here so contact angle is basically a function of then particle size. So contact angle will be increased if particle size increase and contact angle will reduce if the particle size is coming less. So this contact angle will give you that whether that wettability characteristics of the particles or not. Sol below 90 degree of that contact angle it will give you that hydrophobic nature of that materials even above 90 degree of this contact angle it will give you that hydrophilic nature of the material.

And also one of the important point here to know about that characteristics of the nanomaterials which will give you that more surface area as the size you if you reduce it. So whenever you are getting that nano size particles there will be specific surface area increased. So that specific surface area can be calculated by this equation number 4 here S will be equal to 6 by rho L.

Here the Equation

$$S = \frac{6}{\rho l}$$

What is that rho is the density of that material and L is the length of that size of cubical size of the material. Suppose this the surface area of is divided cube as shown in the figure here one big cube is there where volume is 1 into 1 into 1 centimeter cube means here all side of this cube will be is equal to 1 centimeter.

So if you are having this cube that is the its surface area of this divided cube will be given 6 into L square and the number of divided cube is given as 1 by L cube. Therefore the total surface area of all divided cubes can be expressed as 1 by L cube into 6L square. Thus we can say that 6 by L here we are having this total surface area. So here specific surface here then it will be coming as 6 by L divided by rho that means per unit mass. So considering that a dense cube of 1 centimeter on a side is divided into cubes then L centimeter on a side then you are having that surface area specific surface area as that 6 by rho L and composite structure of that nanoparticles the equation of nanoparticles increases with increase in the surface energy of the particle by the nano sized effect.

You see that all particles will have a certain surface energy based on the surface area. So per unit surface area what will be the surface energy if you reduce the size of the particles your size will reduce means your surface area will increase. So in that case more surface energy of the particles can be obtained. So in that case more surface area will be released more surface energy will be released by that nanoparticle. And also classification of that composite structure of nanoparticles as we classify that nanoparticle which form that composite structure.

So in that case the composite structure using nanoparticles in that case type of composite structure will be there based on which we can have different types of materials like some will be core shell some will be internal dispersion some will be hollow shape some will be porous. So in that case if we have that composite structure formed from agglomeration of nanoparticles in that case you can have the shape like this or structure like core shell internal dispersion even hollow porous even some will be coating that based on that surface modification and also agglomeration. And the composite structure body fabricated from the nanoparticles based on which you can get that composite structure like nano dense body, nanoporous body, nano thin film like this. And different composite structure as shown in the picture here some will be core shell like A this is core shell and then here B is called that internal dispersion and C is basically that agglomeration D is basically what this nanoparticle coating and E is hollow shape hollow type and also F is basically porous type of structure and G is bulk body that is from nano grains you can say and H is basically porous body from nano grains and also I that is nano thin film. So these are the composite structure of that nanomaterials which will contribute to that formation of this structure.

Now we have to know some application of that nanoparticles where that nanoparticles to be applied. After knowing that different characteristics and also that synthesis of that nanoparticles then you have to apply that nanoparticle somewhere that will be useful. So here we have not actually discussed about that synthesis of that nanoparticles. In the next lecture we will try to discuss about that nanoparticle synthesis but here we will first try to know some applications where that nanoparticles can be used. Now you will see that based on that their intrinsic properties of the structure that is created from that nanoparticles even the effects of nanoparticles based on their structure and also type of materials we can apply this nanoparticles in different emerging technologies.

Like here some applications will be in the cosmetics and sunscreens lotion development there. And also like that in cosmetics and sunscreens you will see the conventional ultraviolet protection sunscreen that lacks long term stability during uses if you are using that nanoparticles. Even the sunscreen including nanoparticles such as titanium dioxide even it will provide that numerous advantages in that case if you use that nanoparticles. Here you will see that some lipsticks that uses iron oxide nanoparticles as a pigment and also for protection of that UV that titanium oxide and zinc oxide nanoparticles are being used in that lotion or other that cosmetics there. Because they are transparent to visible light as well as absorb and reflect that UV rays when that titanium oxide or zinc oxide has to be added to that cosmetics.

In electronics area you are in the electronics industry they are using this nanoparticles like use of nanoparticles in the display technology for computer monitors or televisions for large size and also high brightness displays in your mobile also. For example nanocrystalline, lead, telluride, cadmium sulphide, zinc selenide and sulphide are used in the light emitting diodes of modern displays those are that nanocrystalline particles are there or materials are there. Also you will see that batteries sometimes made from nanocrystalline nickel and metal hydrides and due to their large surface area which will require less resurging and last longer so this nanocrystalline nickel and metal hydrides are being used. And the increase in electrical conductivity of nanoparticles are used to detect like gases like carbon dioxide, nitrogen dioxide, ammonia in a gaseous mixer. So to sense those nitrogen dioxide or other gases based on that conductivity properties of that particles these nanoparticles are being used for detecting all those gaseous components from the gas mixer.

Nowadays it is coming that nanocatalyst particles there where high surface area will be there that will offer you that high catalytic activity. Due to their extremely large surface area to the volume ratio the nanoparticles function as efficient catalyst in the production of various chemicals like use of platinum nanoparticles in the automobile catalytic converters. As they reduce the amount of platinum required due to very high surface area of the nanoparticles and also reduce the cost significantly and improving their performance. Also these nanoparticles can be applied in medicine here nanotechnology has improved that medical field by use of nanoparticles in drug delivery. The drug can be delivered to the specific cells by using nanoparticles.

Here you will see that in the traditional treatments such as an artificial implants and organ transplants can be replaced by tissue engineering. One such example is the growth of bones carbon nanotube. This called that scaffolds nanotube scaffolds carbon nanotube scaffolds there. So in this case this bones carbon nanotube scaffolds when it will be use that that bones can be growth by this scaffolds. And for instance you will see that iron oxide even gamma type iron oxide that super magnetic iron oxide nanoparticles are the main nanoparticles that is used for site specific drug delivery.

And also the particles versus small that can pass can pass through that cell membrane and deliver agents like DNA and protein into the particular cells. In food industry you will see that the improvement in production processing protection and packaging of food that is achieved by incorporating this nanotechnology. For example a nanocomposite coating in a food packaging process can directly introduce the antimicrobial substances on the coated field surfaces. So these are the applications and also in construction industry also they are trying to implement that nanotechnology just how to enhance that process by making them quicker or inexpensive and safer. For example when nanosilica is mixed with the normal concrete the nanoparticles can improve its mechanical properties and also improvements in durability.

Also you will see that in paint you will see that to itself healing abilities and corrosion resistance and insulation that can be obtained by adding some nanoparticles to the paints. Also that nanoparticles can be used for sterilizing or anti fouling properties and catalyze powerful chemical reaction that break down that biolite or it is called that some organic compounds which are more volatile in nature and some organic compounds that is as that pollutants you can say. So that titanium dioxide nanoparticles can be used for that separating those unwanted compounds in the mixture or in wastewater you will see that sometimes nowadays nanoparticles are being used for absorb that some trace elements by that nanoparticles. And also the killing that microorganism by nanoparticles there is a specific property of the nanoparticles to kill that microorganism. So there see this titanium dioxide or other nanoparticles are being used there.

Also in environmental remediation that I said that there will be unique physical and chemical properties of that nanoparticles that can be used in environmental remediation to enhance that performance of renewable energy sector as well as some removal of some hazardous or poisonous element from the waste materials. The nanoparticles are used to treat the surface water by disinfection, purification and desalination. Also nanofiltration now it is coming which is recent membrane development that is for membrane filtration techniques for water purification widely used in food and dairy industries also. You will see that the major use of nanoparticles are to treat that municipal and industrial waste water as well as the sludge production. For the extensive research for improvement of that that is production of oil by this nanoparticles sometimes enhanced oil recovery that oil can be recovered by this applying that nanoparticles there.

Also you will see that some hydrophobic property of that some nanoparticles has led to self-cleaning solar cells there in energy sector. You will see that high thermal conductivity and heat absorption capacity of certain nanoparticles that can be used to coat boilers or solar concentrators to improve their thermal efficiency. So these are some examples in renewable energy sectors. Also to produce that biosensor that nanoparticles nowadays are extensively used because of that nanoparticles has some optical and electronic properties. So in that case these properties will make them suitable for biosensor application.

The noble metals like gold, silver, platinum nanoparticles those show actually special physicochemical features which make them the most popular components of nanoparticle based biosensors. And in this case the role of that nanoparticles in electrochemical biosensors is to improve that sensitivity and signal detection. Also you will see that some nanoparticles like silver nanoparticles they have some ability to detect proteins which is used actually nowadays for cancer detection. Also those particles can be used for detecting glucose, DNA, even dopamine, ascorbic acid, even some other biological molecules. So that is why these nanoparticles are nowadays extensively used for the development of biosensors to detect different microorganism whether it is in the cell or not or some other chemical compounds.

Is there any proteins, what is the amount of proteins are there to detect that and also what is the DNA, RNA, all those things that some biological molecules that will be detecting based on which this treatment is being done by assessing those things. And in this case that nanoparticle has that capability to improve that sensitivity and signal detection where that devices or biosensors are being used where that nanoparticles will be used. Next we are talking about that nanoparticles what are the physical properties, chemical properties, even how that nanoparticles being defined and then where that nanoparticles can be applied. And now if you have that wide application of the nanoparticle then you have to produce that nanoparticles, you have to synthesize that, you have to make that nanoparticles and what are the techniques or what is the procedure to synthesize that nanoparticles.

That means how can you make that nanoparticles. So that nanoparticles can be synthesized or can be made by two approaches. One is called that top-down approach another is called bottom-up approach. That means top-down, when in physical method another is called chemical method. Here in this slide it is shown that top-down and bottom-up. What is the top-down methods? You will see that in the top-down methods or it is called physical method.

In this case some bulk material is physically broken down to a smaller molecules. So that is called top-down. That means bulk size materials to be broken into a smaller size particles. So this is done basically by physically or some physical method. Some equipment would be used to breaking that bigger size particles into nano size.

It is also called that is dry production method. Some common methods are like milling method, laser ablation method, spark ablation method. Another it is called bottom-up that means chemical method. In this case you will see that some molecules that is from chemical, some atoms will be nucleating into a sized materials. It is called that nanoparticles.

That means here nucleating atomic size materials into the nanoparticles. It depends on the material which is being generated. So it is also called wet production method. Some common methods like RKV's method is called citrate reduction method, gas phase synthesis, co-polymer synthesis and also microbial synthesis.

There are several methods there. So we are having that method of two approaches. One is called top-down and another is called bottom-up. That is called physical method and chemical method. So by these two methods we can synthesize the nanoparticles. So up to this test that how to synthesize that nanoparticles. In the next lecture we will try to learn about that physical method and then successive lecture we will also try to learn about that chemical method by which you can synthesize nanoparticles.

There it will be described in details and there are also some example and step by step methods will be discussed how to synthesize that nanoparticles. So in this lecture we have learned what is nanoparticles, how it is defined and what are the application of the nanoparticles and what is the basic method by which you can synthesize that nanoparticles. So thank you for giving your attention. In the next lecture we will try to discuss more about the synthesis of nanoparticles by physical method. Thank you.