Nanostructures and Nano Materials Characterization and Properties

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Lecture - 27
Over View of Nano Structures and Nano Materials

In this lecture, we will learn about an over view of nano structures and nano materials. Because in the world of nano technology, it is very essential what that world comprises of that means nothing but nano materials and how do they can be blocked together to form certain pattern or sudden structure so that they can be utilized for an engineering applications?

So, we learn a lot much about science of materials at nano scale that is nano science of the nano materials followed by constructing them into certain structure or utilizing particular structure existing at that particular scale. Utilizing those concepts and building it for much higher life scale, bulk material or a component for actual or for real life applications. So, in this particular lecture, we will see overview of nano structures and nano materials.

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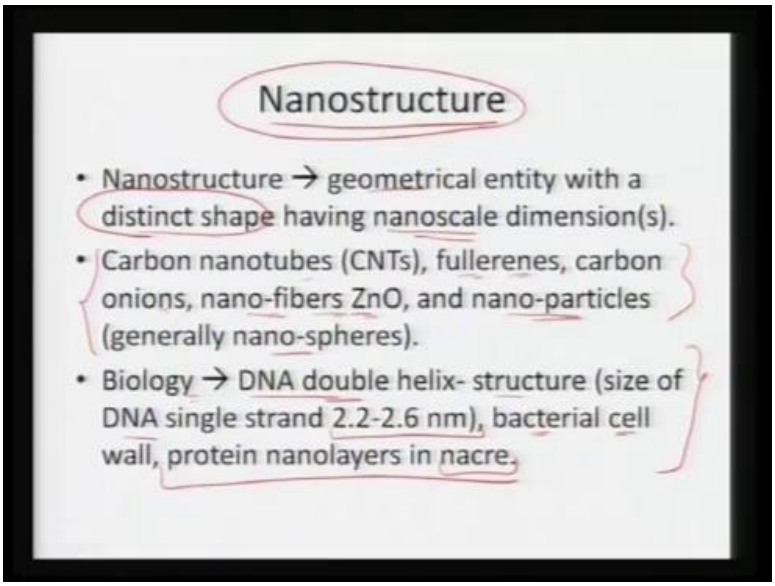

So, just to start with a nanostructure is nothing but a entity a geometrical entity with a distinct shape having nano scale dimensions. So, nano structure we are talking about certain entity certain pattern, which is a certain shape a certain size with the dimension at least one of the dimension on the nano meter scale. Certain example include carbon nano tubes fullerenes carbon onions nano fibers of zinc oxide, nano crystals of diamond certain nano particles of gold and many other.

So, there are many different types of material, they can be a tubular shape as on carbon nano tubes, they can be a ball shape or circle ball shape as in fullerene, carbon onions some sort of rings and the nano fibers zinc oxide. Nano particles, which again spherical again this nano structure a terminology is not really in new it has been existed as an biology, we have DNA, double helixtance. So, this structure it consists of DNA single, approximately 2, 2.2, 2.6 nanometers. It means that nano structure it has existed for long, it is just that we know we are able to see them, we are able to characterize them and at the same time we are able to tap it for certain engineering applications.

You know wall cell of bacterial cell couple of a nano meters, so again we can see the protein nano layers in micro is also two order of allow couple of nano meters. We can see that this nano structures have already existed in nature. The overall idea is to be able to engineer them, so we are build them by block and some engineer for certain useful applications and the size remain again in the nano meter. That nano meter scale can be constructed to follow micro structure, and the a real block scale to utilize the baser engineering components.

So, again we can see nano structure is nothing but an entity, it is geometrical entity, which has a certain shape associated with it, with dimensions atleast one length scale dimension in the nano meterogy. Certain examples includes carbon nano tubes, fullerenes, carbon onions zinc oxide a nano fibers a nano particles gold a many others as well. So, their certain distance shape associated with them and this nano structure in not really in new, it has already existed in nature like certain DNA double helix structure of protein nano layers in micro and even appetite crystals present in our bone. So, multiple number in which examples, which already have been existing in nature.

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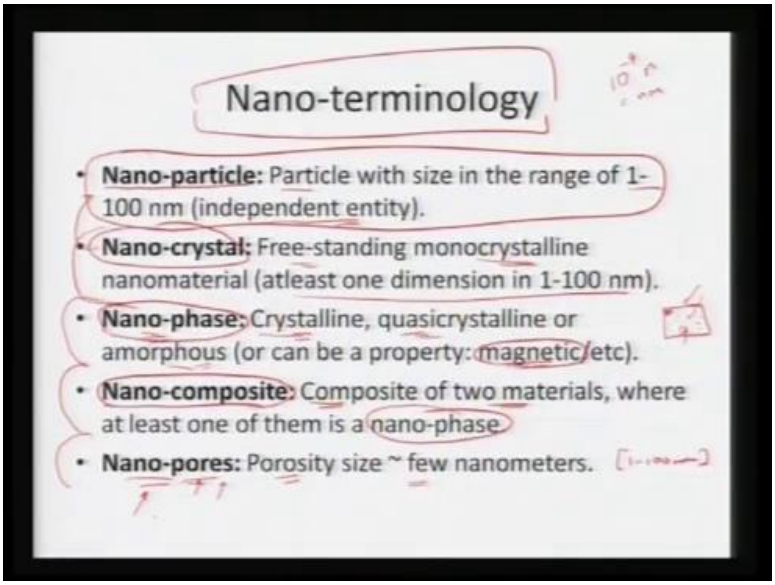

Before we know about a nano material it becomes essential to realize certain terms or certain terminology, which essentially nano materials. As we all know that nano is nothing but a prefix of 10 power minus 9. Once we associates the unit of lens to it becomes 10 power minus 9 meters. So, it is also called nano meter, but there should be entity which we learn about some something like nano particles. So, nano particle is nothing but particle which is size in range of 1 to 100 nanometers and it can as an independent entity, it can always algometric and form which it is in the individual entity is called nano particle, but it is capability of existing on its own.

So, nano particle is particle with the size is range of 1 to 100 nano meter about nano crystal, nano crystal is free standing mono crystalline nano materials and which has one dimension in the scale of 1 to 100 nanometer. So, we can see nano particle, so nano crystal can be a nano particle as well when we talk about nano phases nano phase can other crystalline quasi crystalline or amorphous. It is not only phase, it can associated with the property such as we can talk about magnetic or any particular domain magnetic domain.

So, we can always associates phase which as not only a structure like crystalline quasi crystalline or amorphous and it can also be a property such as magnetic to electric

domains which exist in a material. So, that is nano phase, so each material can have multiple number number of and if one of the phases has a unit of couple of nano meters 1 to 100 nano meters we can call a nano phase. It can again isolation of certain particles, which are either crystalline or quasi crystalline or amorphous when we call them nano phase, many come to nano composite nano composite, it is a composite of two or more materials.

We have at least one of the them is no nano phase, so once we talking about nano composite, at least one of the phases once nano. It means each that particular phase what we are talking about crystalline quasi crystalline or amorphous, it has certain properties associated with that. It is a existing in mixture of some other matrix or it can have two multiple nano phase materials. So, in that case, we call them nano composite then nano pores, it is the porosity which is the size couple of few nanometers 1 to 100 nanometers.

So, it not only phase or in free standing structure and a crystal, it can also have certain pores which have nano in size and these can also impact certain very nice properties. So, this will edit to the structural coolers which are ice as on pick up other, so we can see nano terminology, it can exist as nano particles. So, it is an independent unit entity which has size nano crystal, where we have a freestanding mono crystalline nano material with at least one dimension in the scale of 1 to nano meter and these nano faces.

It can be either a structure or a property associates with the particular entity that is existing that we call as nano phase a nano composite comprise any one of the nano phase been existing in a composite material. That can also be towards which as size a within 1 to 100 nano meter to then call him nano pores their certain nano terminology which as associated with the nano materials.

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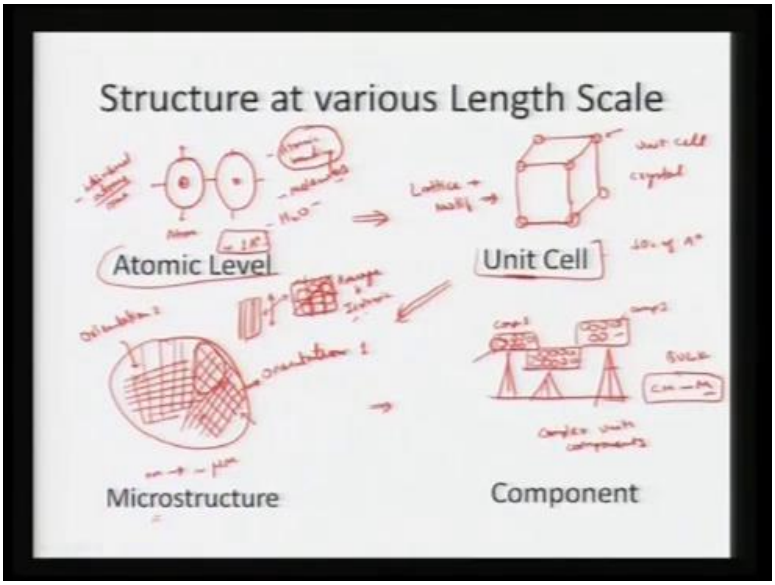

Now, call on to the structure, we can see the structure various length scale if he talking about individual item, so we know nucleus associated with that. That is electron clever on that and now the key at certain temperature, they keep vibrating the around the in the certain region. So, that is what we call at a atomic scale, we have a atom a many other certain items combine by certain bonds and then they can link to each other.

So, this we call either as atomic bonding or it can also be individual items, so we can see that either these are individual items or there are some kind of bonding which is occurring, which is existing between the truth to create. We can also certain molecules like an H2O, so we can see the other individual items of these can also be irons, which are existing. It can also has some bonding that particular scale and it can be a molecule such as H2O, so here we talking about couple of range of approximately 1 Armstrong or so that is nothing but the atomic levels, so around 1 Armstrong that is the level.

A scale which we are talking about, then once we come to unit cell know it comprises many more number of items so in this case know its start sum regularity. So, we can see a unit cell it comprises couple of items at different a at different a locations, so it is been defined the by either your lattice. Now, start comprising certain a certain basis to call it a crystal or unit cell so from lattice we had motive and then what we get is the simple

crystal and that crystal is define in terms of unit cell.

So, we have gone from atomic level which was couple of Armstrong to less than nanometer couple of nano meter as well. Then, we have come to unit cell where we are talking about couple of Armstrong as well, and it can again extend to couple of tens of Armstrong again. We can see from atomic level we are going to a unit cell level and now these many unit cells, once they are solidifying once we start solidifying a materials it can start or orienting in different directions. So, there multiple unit cells, which are oriented in different manner, so we gets certain nuclear sequence and it starts developing an orientation.

Then, you see a micro structure develop, so these not certain grains we can see, so this is orientation 1 and this is orientation 2, now we can see this unit cells the multiple number of unit sense know they combine and then they provide a structure. Now, a talking lens case in the order of couple of micro meters, so we have a gone from couple of Armstrong to be tense of Armstrong, and then know we have to a lens scale of micro structure something between when this particular micro structure. It can vary from couple of nanometers to couple of micrometers, once we talking about serial of couple of nanometers to working in the range of 10 power minus 9 meter.

That is nothing but structure of a nano structure and we observe that structure via see transmission electron microscopy scanning microscopy or very several methods, but now this micro structure. We call it micro structure, it can also be utilize for studying something at nano scale, it becomes a nano structure, but this nano structure. It is observation of that is structure; it is not really a existing nano structure contradict terms, so one thing is observing nano that is nanoscopy or sin. The nano material or a pattern that is called as nanostructure and it thing which is pattern regular pattern that is nano structure, but observing at that scale we call it nanoscopy, but the other term for using it is microscopy anything micro.

On a less, we observe them using microscopy, so we can see here from atomic level, we are not going to unit cell a level and from unit cell a level. Now, we have come to the micro structure, now this micro structure can be develop were certain patterns, and then

we can the developer certain component which we require for engineering applications. So, we can see this material will be now composed of multiple number of grains this can be micro grains or it can be nano grains, and then we can make it certain useful unit. So, we can developer more complex units or components by utilizing these particular materials.

Now, this one becomes a preoperative part of any particular components of we have component 1, component 2 and component 3 and there is the components dire engineering device or a particular structure. So, we can see we are going from atomic scale, we know items two levels of items or molecules which are existing. Then, these items they combine either in a regular fashion to form a crystal or they can again be a morphs. So, when the following crystalline structure, we can always identified the using certain unit cells know these go 10 to form something call micro structure, it can be nano structure or it can be micro structure.

We observe the using microscopy technique and also we have also particular material were engineered it, we can go and form much more complicate structure as a component, which is the bulk quantity. I am talking about couple of centimeter to meter scale or even both, so this is how the overall structure are lens scale is been distributed, so which is structure of way at various lens scale from automatic to again a tens of Armstrong.

Then, couple nanometer to couple of micrometer, and then going to centimeter or a meter scale that is how we can see structure of different lens scales. So, the importance of micro structure is the way the orientation of these particular a unit cells is occurring that gives rise to properties, which are either different. They are similar if you can align everything along one direction, we can have very different properties along this directions. We can vary properties we say at certain angle of this one if he tend to vary random orientation of all of these particular grains what we can get is the average along all the sides will be say the other.

We take any direction, the average will be same, so what we get is the isotropic property. It is no more an isotropic, it becomes isotropic in nature that over all deals with the microstructure and also get in isotropic property at bulk scale. We can utilize the

measure component which is the similar properties is in the all the directions that is the essential or that is the importance of learning about length scales.

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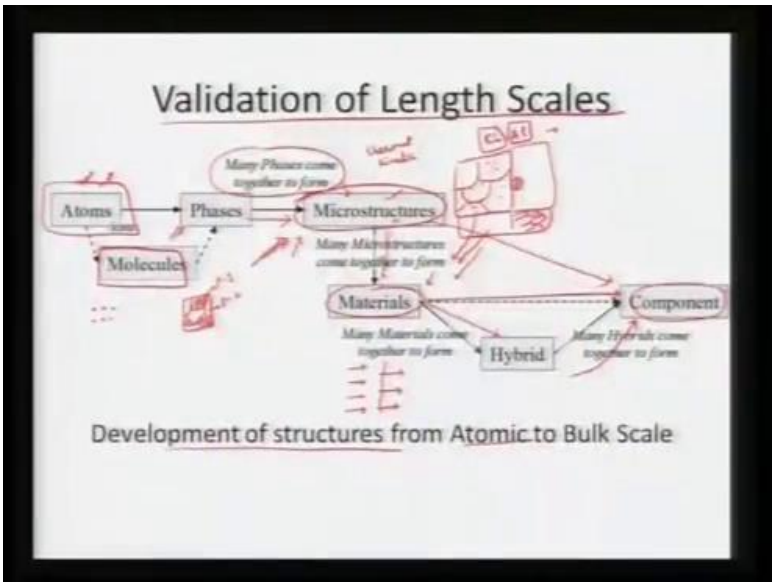

Either structure or property, so many phases they come together, and they tend to form micro structure. So, once we have items they go on to form certain molecules or even molecules are irons there tend to from certain phases, so we can see one phase second phase.

It can multiple number of phase because face 1 and then we can different face 1, this is face 1, this one is face 2. Now, these are following nothing but a microstructures many phases they come together to from the microstructures and of many of the microstructures, it can one type of microstructures second type of microstructures. Now, we can see many microstructures now they comprise the material, so we see a this case we have a face 1, face 2, so many faces gone from microstructures and this can one type of microstructures.

It can be stitched with many different of microstructures, it can also nano production, somewhere here it made a some bulks segregation somewhere. So, we can say it can develop a very complicated structure at micro micrometer lens scales and now these

gone to form material because we can have normally material 1. We can have one material we can have many more number of which can form bulk component or the bulk material. Also, we can have say combination of cu al the manner in which Cu and Al come together they can also form certain precipitates. So, we can see the precipitation generation as well in the structure, so in this case we can see many material, many microstructures they going to firm material.

Now, many materials they either form directly the component or we can also form something called hybrid, hybrids means we can multiple layer and multiple properties, which can come together to form a final component. So, again you can see this traverse of from atomic scale to a bulk scale, so we go from atomic molecule which gone to form phases this many multiple number of phases. They going to from microstructures, many microstructures their pertaining to certain materials and this material depends on how do we heat treat them and how do we process them? How do we apply certain environment? The properties come out very differently.

So, for even for steel, the way we temper them, the way heat treat them, the way process them, the way we do some mechanical treatment to the them, properties will come out very differently. So, we can have multiple number of materials, they can be either layered they form hybrids, they can be now gradient a promoted to form had a components which can be engineering for a certain engineering applications.

So, we can see how the complexity of component arises from the basic unit that is nothing but, the fundamental building blocks that is atom an atom it is unique identity and how it its pattern can be changed at micro structural level. So, same atom how it can be arranged in different manner to from different microstructures, so depending on thermal and kinetic profile of A, we can alter the microstructures of the materials. So, that is now is the main cause of affecting over all properties of the component and that is what we can see that by in co operating either nano materials or by incorporating nano structures.

By enduring the nanostructures, we can exactly out lay the requirements, which are required for the engineering design. Then, we can incorporate them to form certain

components, which are lighter, which are much more stiffer and much more efficient in terms of utilizations for the final applications. So, we can see development of structures from atomic to a bulk scale.

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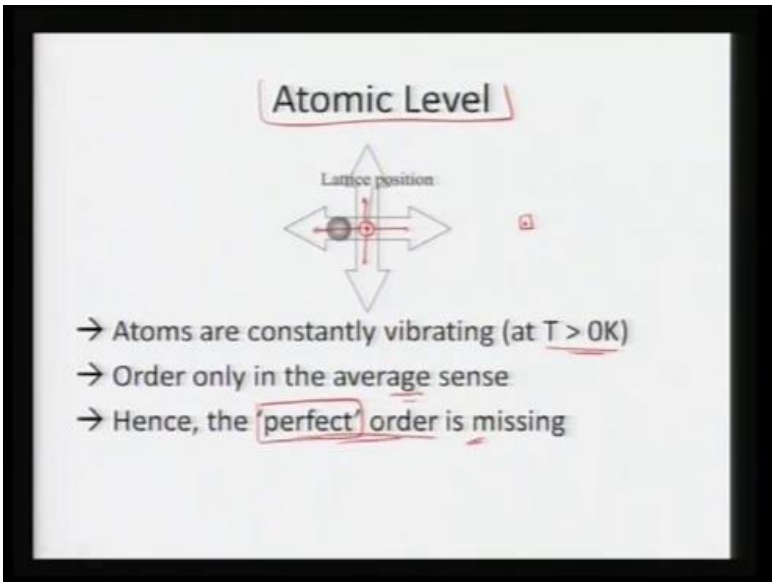

Coming to the atomic level, we can see that generally an atom will have a lattice point and now to start vibrating because of thousand fluctuations; it will have a mean position. So, atoms are constantly vibrating temperature which is greater than 0 Kelvin, so atoms is ideally should be here, but it is not trussing every were else.

So, we can see the order as only in the average sense and the perfect order, it means the item setting a exactly one point and nowhere else that is totally missing out at atomic level. So, we can see atoms are constantly moving at temperatures avoid 0 Kelvin because of vibrations and we get average sense of order. So, there is no perfect which is available at the at atomic level, but there has to be some anisotropy associated with this one, there is no order as such.

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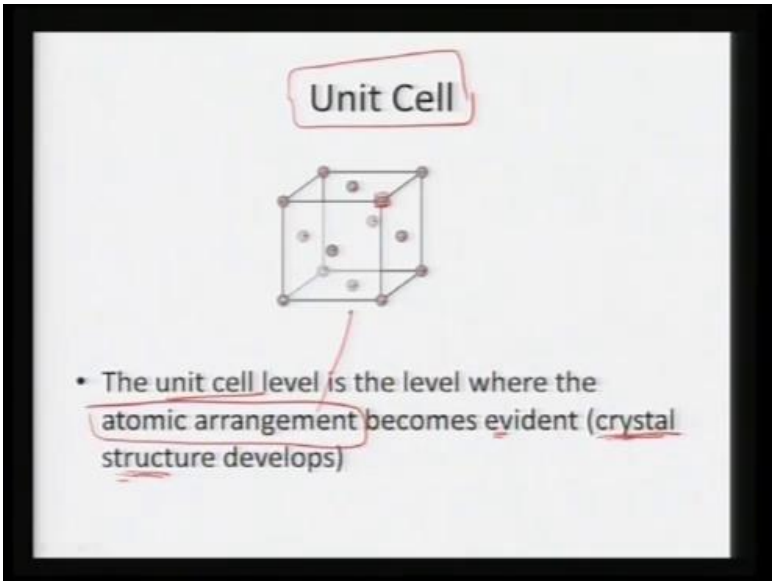

Now, coming to unit cell, so many atoms come together and they go on to from a repeating unit, which are units for a particular crystal. So, we can see in this particular we have a FCC unit cell, so we have faced a cubic lattice in which we have atom sitting out there, so unit cell is the level. We can now start the atomic arrangement, so because of certain a pattern, which we are able to associate the atoms, now it is much more evident and now there is something called as a structures.

Now, developing a crystal structure, so for unit cell we had no order as such at the level of unit cell, the start some order a where we can see the arrangement of atoms, which become localized to certain locations of the lattice point. In this case, it is a FCC lattice and that become evident at this particular unit scale a unit cell scale. So, in this case what we are saying? Yes, in the development of a crystal structure is being depended the unit cell.

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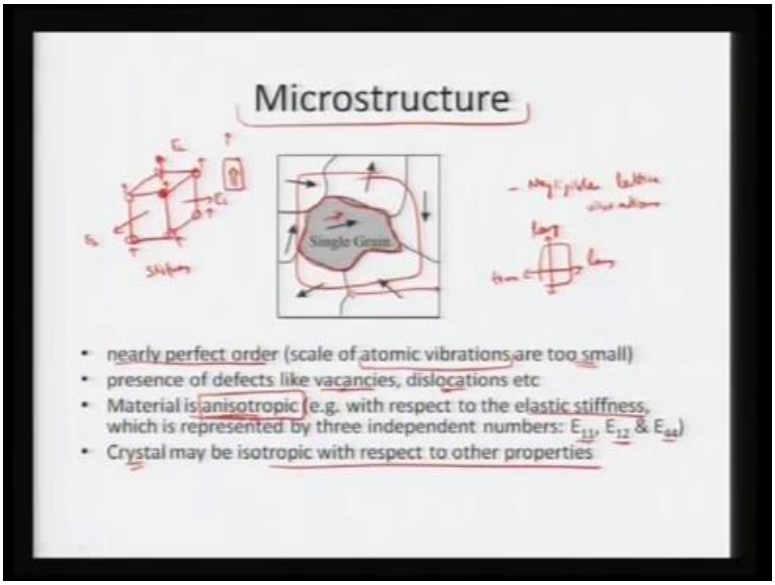

So, what happens? The next scale it is a microstructure, it is also called as nanostructure, so in this case what is happening in this case, now we have nearly perfect order why because the scale of atomic vibrations, which were existing in the even in unit cell, even in the atomic at the atomic level. It is now very negligible because now we can see that atomic vibrations are very small and complete to the length scale of one grain. So, once a talking about one grain the lattice vibrations are negligible, also we can see negligible lattice vibrations though there can presence of some defects such as vacancies a dislocations or trundle defect or short cut defect or many other A.

So, we can see that as they can vacancies these locations are imperfections which are available in a single grain, but what happens now? Materials now anisotropic with an a single grain because now we get at different properties a like elastic stiffness or e 1 1, e 1 2 e 4 4 is very different. So, it can happen that the material anisotropic because now we have different elastic module elastic stiffness along different plains a different perspective or vacancies that the materials becomes.

Now, anisotropic, it has certain directionality. So, it is might a much better properties say in this direction in longitudinal directions then in composition that of a transverse direction. We can see the material is now anisotropic at single grain level, so we can see

the most properties it might of the domains it made direction in terms of minority domains as well. We can see the property is varying for single grain the properties are much higher and lower certain directions that made the anisotropic, but for a single grain.

The crystal might be just isotropic with respect to some other properties; it might have domains in particular directions, but an in average a crystal. A crystal might have certain magnetic domains, which are align like this all align may be say in parallel to like this align all parallel directing upwards. So, it has certain magnetism along with directions, but the properties such as stiffness might be say then all the three directions. So, we can say e 1, e 2 and e 3 might be just similar are same in all the directions because these atoms are behaving in a similar manner.

So, they might have some domain magnetic domain for this direction a net domain a vertically up direction, it might have similar stiffness along all the three directions. Next, the material anisotropic with certain properties, but might remain anisotropic for other properties.

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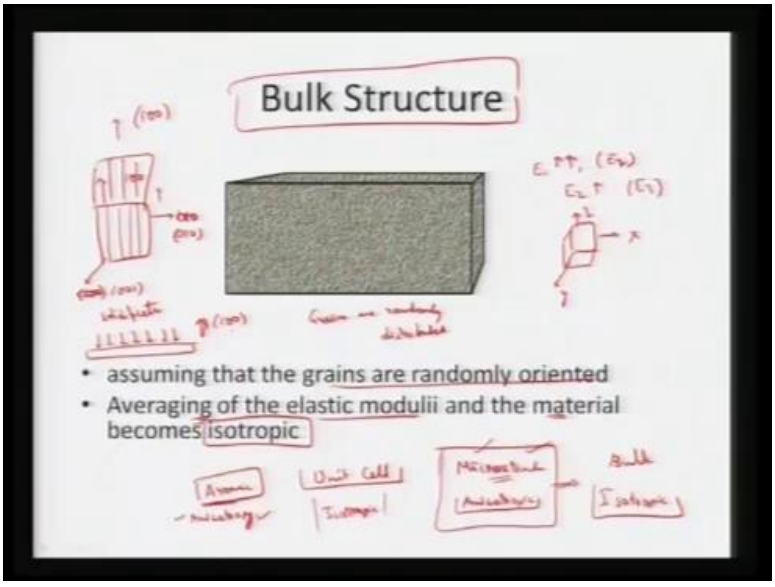

Now, coming to bulk structure, we can see such grains you can combine and they can

follow bulk structure. Assuming that the grains are randomly oriented, what we can though might have some disturbance or some difference in terms of in terms of elastic module say even was much greater that e 2 compared to e 2 and e 2 was higher than again say higher that e 3. So, it gets some directionality in terms of modules see that a x direction z direction and y direction, so may be e x was pretty high along one in direction. Now, it can what we can see the grains are now randomly distributed, so what happens that when common average that multiple number of grain there are millions and millions of grains are available on a particular bulk structure.

So, on average what can you get the elastic module, and the material in terms of other properties it becomes isotropic. So, that is the duty of this particular path, so we saw at atomic scale at level of unit cell scale micro structure. Then, a bulk we seen much more isotropic, we say isotropic property unit scale at micro structure isotropic and again a atomic perfect order that means again and isotropy. So, we can see automatic scale, we has some orientation, because of thermal fluctuation, so it was not showing a perfect order, so it means it has preference to certain direction makes it an isotropy.

At unit cell, it can have an isotropy, but it can also have isotropy once you consider certain property. So, it might it might eventually convert that that unit cell has certain isotropy at micro structure, we can see some orientation within a particular single grain. So, it might be an isotropy when coming when we have a random distribution a material again become isotropy. So, we can see up down of the isotropy associated because of the different lens scale and we can control much of the structure at this particular lens scale by once you are able to control the material, you can alter the properties of the bulk structure.

So, we should control something once we have a understanding, a nice understanding of how the structure is developing and how particular property associated with the orientation of the unit scale. We should able to control the micro structure all the merely domains getting aligned say along 1, 0, 0 direction and they are three equivalent 1, 0, 0 directions. So, we also need a directions to it if 1, 0, 0 getting aligned to a higher extent we can see 1, 0, 0, we can somehow align all those place together.

We can get an additive effect along this particular direction, so we can see it can be 1, 0, 0, this one can be 0, 0, 1, and this can be 0, 1, 0. So, if you want to get a additive property you might want to align the grains along this side by controlling the solidification or by applying apetexual film on which we can start growing the material of that particular directions. Now, what we can get is a net magnetic domain along this 1 0 0 direction and that thing can be controlled. So, we can align the material properties by controlling something at that scale and that will yield better engineering properties via applications of understanding the material like nano lens scale.

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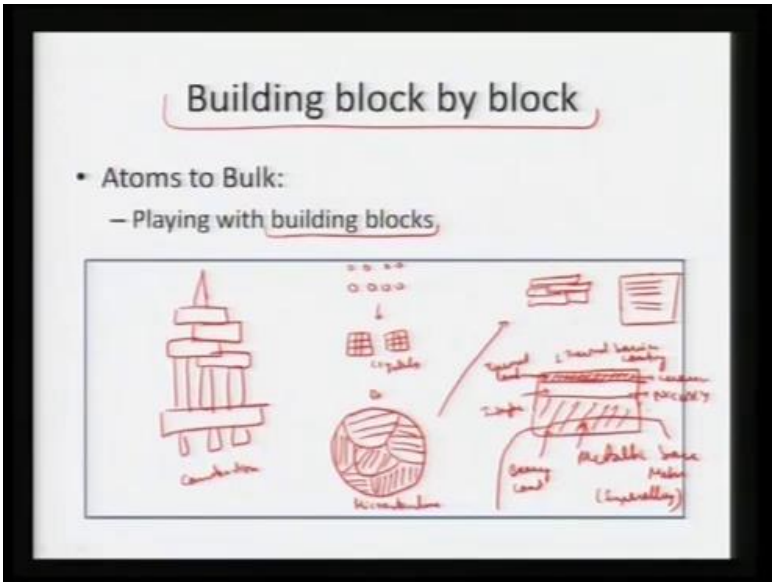

So, it is also like building block by block we must have played in our childhood with certain building blocks. So, we have certain block and then we go on to form in forming certain structures, and then for single building blocks we can keep building up until we get a complete structure and then. So, we started from a single blocks, now we are able to construct a entire component from it. So, we start with an atom we go on to lens scale of micro structure a unit cell first, so we choice a material which will align in a certain pattern, so we get now multiple number of unit cells or a crystal. Now, these crystals the way they grow, they can grow on from micro structure.

So, we can see certain alignment of on grain what you get now is the micro structure

once you are able to control the micro structure. We can have either the patterned layers we can patterned layers, we can have a gradient structure as well, so property will keep varying from top the bottom. So, in this case also see that utilize something thermal binary coatings, so if we can one material can sustain very high temperature that is nothing but, ceramic, so we can ceramic layer then we have bond layer. This is the base material, which is now taking the maximum load, this is nothing but the metallic base material it can be a super alloy. So, we can see that now this structure can take much more load at even higher temperatures cos.

Now, we have a barrier of thermal coating so what we can see that this the load barring component, so it is bearing the load this in one serves as an interface and this takes most of the thermal load. Now, this base materiel is protected from the environment even for oxidation or even for thermal load by this ceramic layer because ceramics can take very high loads. It has an interface to bind the ceramic layer with metal and this metal it can be super alloy, which I can take the entire load for running the turbinate at very high temperature. So, we can see that we can start from very small layers of atoms, we develop them in to crystals develop the micro structures build them to certain layers. It can be certain hybrids as well.

And now we can play with micro structure and then we can even develop something called gradient components. So, we can highly property different depth of the component or material, so that is how we can engineer by developing block by block of that particular entity as the structural or engineering marvel.

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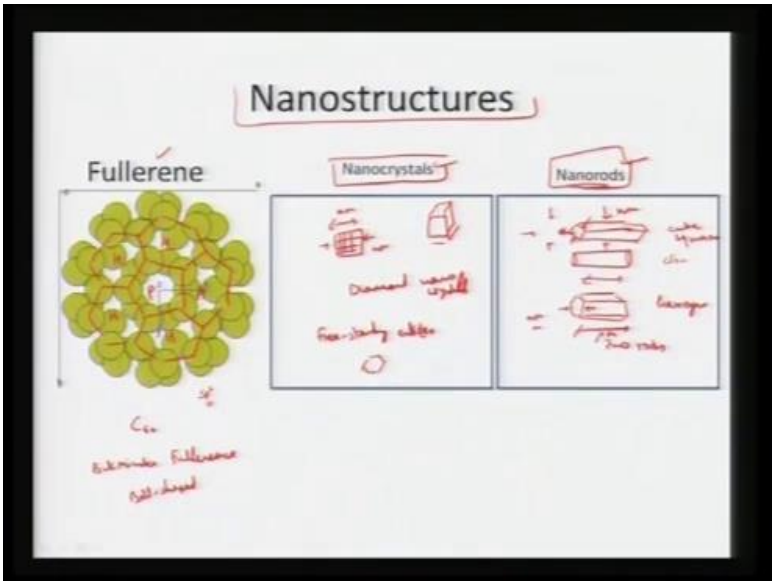

Again, coming to the nano structures, now well little about nano materials, so same the nano structures this is the nothing but patterned geometrical certain geometrical pattern associated with that. So, we can see in fullerene we have is also called c 60 molecule Si, it has multiple number of pentagons and hexagons to give it that shape.

So, it looks more like a soccer ball, so we can see here, it has certain hexagons, this is the hexagon, this is the pentagon. So, this gives it a more of a soccer ball shape it is also called buck minister fullerene buck minister fullerene. So, that is what we can see here it is the set of pentagons and hexagons that eventually go on to forming this structure. So, we can this hexagons now being supported by a pentagon that is utilized by that. Basically, it provides the turning to particular hexagons hexagon more like single layer this is more like they have a two type of a boding.

So, eventually form a fullerene or a ball shape structures and this is couples nano meter in size, we can also have something called nano crystals, so we can small small crystals, which of the order of couples nano meter, we can have say diamond nano crystals. This is the free standing entities free standing entities which can exist as the mono like crystalline unit, so we can see nano crystals couple of nano meters, any one off the lens scale. We can also see something nano rods the can have shape ant shapes, so the way

depending on a basic units, so tetragonal shape at may develop tetragonal shape so that can be associated unit cell.

So, unit cell is hexagonal in nature that show its at growing nano rods it is some unit it is rod shape its can be have cross section of circle and it can even but cross section of a hexagon it is the filled unites nothing but rods. So, we can again zinc oxide rods or this called other type of rod which can be circular in the cross check in the cross section type of even cube cross section of square cross section type of hexagonal cross section. This entities existing when this dimension is nothing but, in nano meter in scale, so we can see two nano rods.

It means two of the units vertical the length may couple of micrometers or more or less. Other two entities are in the lens of nano meters in nano crystals, we have entire dimensionality in nano meters nano rods. We can have dimensionality of nano meter how to all those dimension can be even longer and fullerene also we have all three directions in couple of nano meters.So, that is of fullerene nano crystals nano rods how we can the define them using this terminology nano crystals. These crystals, mono crystals which can exist in entirety and we can also nano rods dimension couple of micro meters along varies only nano meters case of directions.

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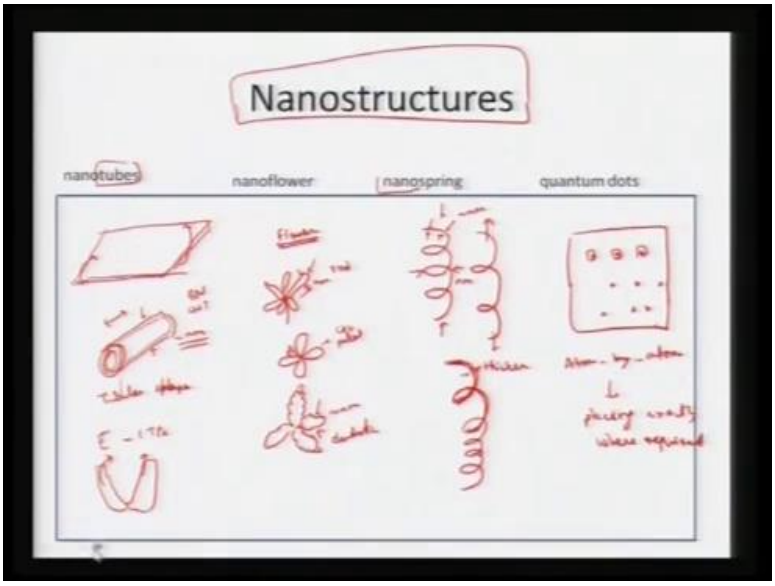

So, definition nanostructures some different type patterns, it can be nano tubes in which scale in this it is kind of a sheet once it is rolled to form an entity, which is the hollow tubular. It can see sudden thickness and that no room to found a certain tubular sheep it is no more rod some hollow structures am this diameter off particular tubes in order off nano meters while the land vary from couple of micro. So, we can see a single sheet once it is rolled join the ends, it can follow tubular structure made of carbon mutes carbon to have boron nitrites and then holes structures that is the terminology.

So, that is again important of nano structures, it can proved a in high, it was very high modules off order off around 1 tera Pascal very high bonding structures or facture strength. It can even bend without breakings; it was very large extent even without breaking we can see that we can bend very large extent bending the carbon tubes. So, we can tubes off nothing but hollow structure nano tubes when the diameter of this tubes couple of nano meters it as also something nano flow.

So, in case of nano flower point in from that, we can see many any different structures which can originate. So, it can form rod like structure so it can also dendrites structure, so it look more like a flower, so whether it is rods which is dimension of nano meters very fly flowery kind of a structure.

So, you can see many more, it can vary many more dendrites can originate. So, we can see appears more like flower dendrites so when this dendrites the thickness of nano meters so we can see that structure it also know that we can rod shapes may be d dendrites structure. It have every different circular or petal shape, it can see many different which can originate it nano structures, it can a nano spring like a case zinc oxide, we can always provide a certain do it, we can do it. This structure developer more like a we control the pitch we can control the turns we can control the rationality of them.

So, we can see this thickness also can be controlled, so we can make even thicker, so make even thicker or may be thinner then again. This dimension is non couple of nanometer and these are more legs breaks, so we can compressor them, we can expand them they can make thicker and even you can have much more calling of them. It can be

also be trained look more like the wire speed disturb in the telephone line, so these are the nothing but springs that have a nano dimension associated with them. So, this dimension the whole radio also be approximately nano meter for those nano springs, so coming to the quantum dots we can also layout certain heavy items using some proof tips, we can layout individual atoms in the location.

We have to form certain patterns, so this provide the flexibility of taking atoms it by atoms and placing it exactly where we want where required. So, you can take the individual atom take it up and then place it in particular chip. Now, you can make very nicely exactly where we put the atom and then you can make certain transistor registers capacitors on a small chip and there is how you can hen hence a density of this particular circuits and improve the performance of a computer.

So, we can see this there are multiple number of a structures it can be fullerene structures it can be nano rod structures and it can be nano tube structures nano flowers nano springs quantum dots. So, we can see such structures which emerge and it can right can we talking about certain structures which are solid we can also talk about structure of ports how we can organize the port in a particular pattern. Then, we can arrange it in different patterns so this is how we are defining in nano structures.

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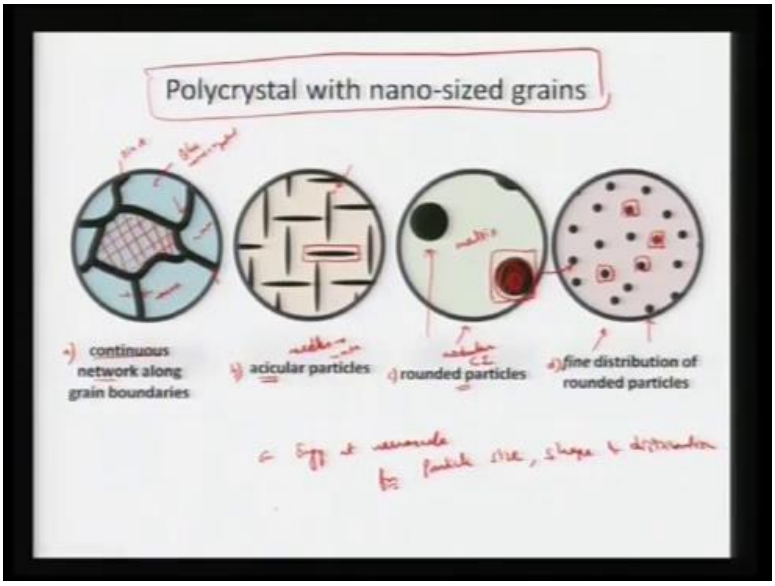

Going to the next level we can also arrange different pattern of those nano structures, so we can see a poly crystal with nano sized grains. So we can see how it when you have poly crystal, so either we can utilize the two faces in this have two faces one face is in the bigger one which is comprises with 60, 70 percent and more than 70 percent. So, in this case it is the blue and second case become black so you have black face, and you can have a blue face out here and one of the introductions can be nano in nature. Either we can make the second face black face nano and we can 6 percent out here and also what we can use in this blue matrix also nano crystal line.

So, we can make the size of this particular grain only couple of nano meters. so it is up we can play also and then control the structure the weight is generating to control the final property. In this, what is one more unique is that the black face continues network along the grain boundary. So, all the grain boundaries are now interest in the black face that is again one way you can dispose the face to you now face one in the second case. What we can do is, so in face one we can continues network and in case two what we can have we can have a acicular or middle chip of the second face. So, again we have the black face and the second face, but in this case we have need us, so need us also a dimension couple of nano meter and diameter.

The length can depending on the requirement or in the manner which micro structure is getting generated, now this structure you can very high stress concentration at its adjust or its tips so this structure may be form certain property might can be very hard. So, depending on the requirement we can you can utilize the properties, now we can see the third case we have the similar volume content, but now as sphere, so we have rounded article, so you avoid the tress concentration. Then, we can now have rounded articles disperse in a matrix, so either this material end of this line and even these rounded particles this can be made nano crystalline.

So, in this case we can now see that the stress concentration along the edges is not as much as it would have been in the needle shape. So, we can enhance the ductility of the material and this structure predominates the as in a forever. If you going to disperse this not used, we can have them has very fine distribution of this rounded articles, we consider as honor articles, then no more available in agglomerate.

Now, there are dispose throughout the matrix and the much more uniform fact, we can still go on we can still reduce the size of this particular a circular and rounded particles and you can make it much more final later on. So, you can see this again the way you can distribute the second best particles can a very pre dominated effect on the properties of the material and rounded particles may not get much in terms of it tends or yield stone. We can get much better utility when compare to that of a circular particle and once we enhance the distribution we can make the particles of more and more point.

We can also attain enhanced toughening enhance strengthening enhance ductility just because we will find many more number of these particular pacification. Those particles which can hinder the grain movement or they can provide as a obstacle to the movement of certain slipping phenomenon and they can enhance the whole strength also the toughness also be enhance by because of this smaller particles. So, we can see the poly crystal with nano sized grains can also have variety of properties depending on the distribution and the size of the second face particle as well as depends on the content of the matrix as well.

So, you see that engineering at nano scale is a function of particle size, shape and distribution if the particle is setting at the grains boundary if it is brutal little make the entire structure highly brittle. If it is available as a circular particle, it may induce stress concentration again it might be that much go to absorb as a module, it can be derived to much more enhance utility. If we can further improve the distribution, we can hen hence the fracture toughness it increase the strength of the material while maintaining the or increase in the utility of the material. So, that is what overall deal with the distribution of nano size entities in a particular matrix.

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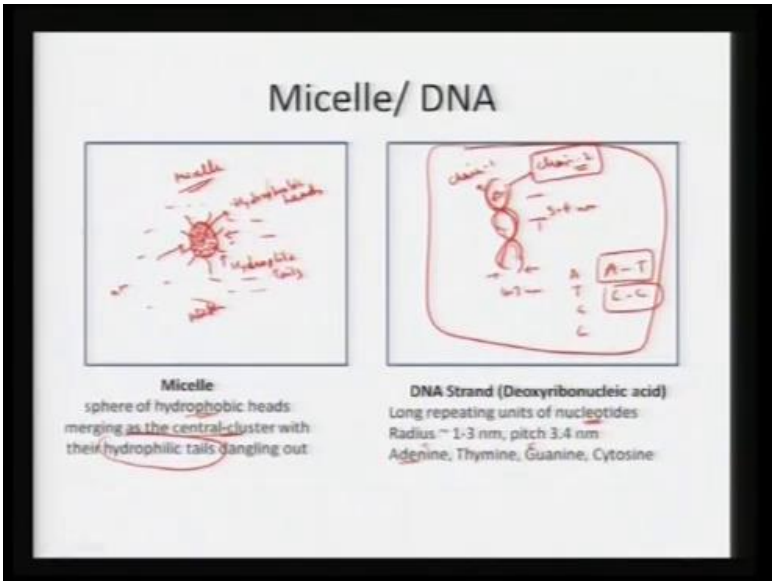

Again, certain structure has already existed in nature like in case of micelle we can have a sphere of hydrophobic head. We can see the heads which are coming of coming in join together as a plaster, and then it tails which are hydrophilic in nature. They are in the we can have water; we can see this a hydrophilic tails, and it is the they are clustering in together hydrophobic heads. Rather, they are some, may be a water we can invert a micelle structure which is existing, so this is central cluster is nothing but the hydrophobic head where is a tails are hydrophilic which are dangling out this particle global structure.

This structure can again in the nano meter and diameter, so that is what it gives right to a nano structure and also we know that the DNA stands the double helix type of a trends of DNA, it also a nano dimensionally, it is a long repeating unit of nuclear types it is a radios of an all 1, 2, 3 nano meter. It is a pitch of around couple of 3.4 nanometers and in this case we also know we have four nucleic acids which are adenine thymine guanine and cytosine and this always go and combine eighty and g c it combined with the number of nano size dimension. So, these are kind of contrary, so we are total of three dimensions.

So, we have what we can see the number of nano size dimension and number of bulk

dimension at to three so if any entity which as nano and all the three direction. So, we have small small fine crystals which have the length bright as well as height or if as particle its diameter of their fear everything in nano in nature. So, the certain example nano crystal of diamond nano crystal of gold or even quantum law which these are individual items, which have been placed together and these are called nano entities and the bulk dimension. It means anything which is much more than 100 nanometer and one of the dimension that is 0, so it appears more like a nano spear and nano crystal if we have nano dimension only in two direction.

In case of ward or wards, so we have the diameter approximately couple of nanometer where as the length can be very two couple of much more than nano meter. So, example of nano wires nano roads nano tubes example of carbon nano tubes zinc oxide rods or so on. So, in this case we have the bulk dimension it means a length has certain visuality to it is bulk, so we can the length can be full of microns that the result we have one dimensionally it in bulk there is two other that is the height and the width of a it is nano in nature. Then, we can have something called nano layers and nano films in this case we only have the thickness with the dimension the length and the width both are much more than nano meter it is thickness which is the dimension of couple of nanometer.

These forms nano layers and nano films certain example we have xl layer of silicon germanium silicon subscribe. So, once we talk about films these are nothing but nano layers and nano films which is the dimensionally in the nano radium of oven.

So, bulk dimension will be two because they coated on a very large surface as I was say this monitor or this particular may be. So, we can have two lines which have quite bit much more than hundred meter where the thickness part of couple of nano meter, so it comes under the category of nano layers. Then, we have a third category. And not all the dimension is in the order of nano meter range.

So, then we have dimensionally 0 where as all the three direction they are width height and thickness all are much more than hundred nanometer, so they come bulk scale example is bulk similar crystal of silicon. So, we can see how the dimension is very, so nano dimension when it is three this is called nano particle dimensionality are two.

That is called nano wire, nano rod, nano tube and nano dimensionality is one we call them as nano films nano layers and the dimensionality is 0. It is nothing nano unit, it is nothing but, a bulk entity that is how we can see how you can classify this all these structures. So, one dimension is we call it as nano layer two dimension are in nano call then nano wires nano rods and nano tubes, and all the three are nano we call then nano particles or nano crystals.

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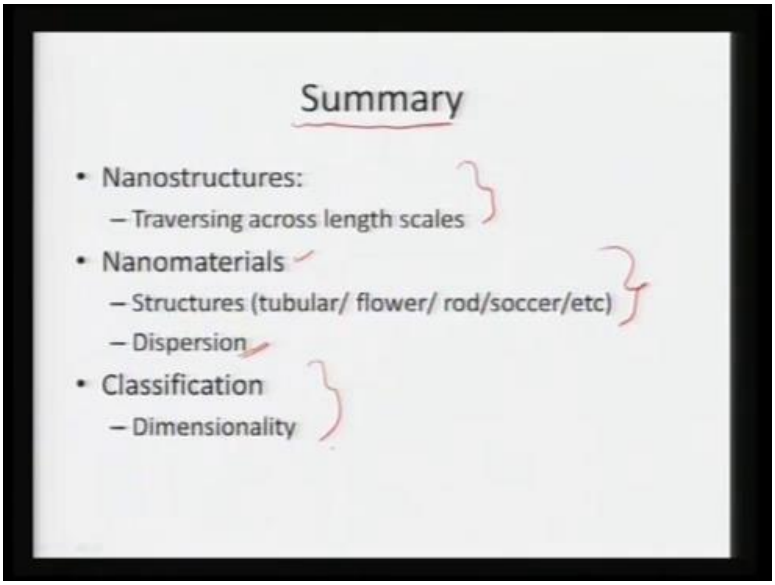

So, in summary once we talk about nanostructures we have traversing across the length scales. So, we can see what is nano materials it defined how the structure is developing. It can be tubular flower rod soccer extra when you identify what is happening at the nano structures how we defined the nano material and evolve them different length scales and how the dispersion is. Besides the all very show in the properties like if the second faces on the grain boundaries it present as a circular face, it present as a a circular face if the dispersion is occurring how properties can very drastically.

Now, come to the dimensionality it defining the nano structures, it can be one dimension two dimension three dimension are may not have any dimension along the nanometer length scale ones it is three dimension we call it nano quantum dot. We call them as nano structures, once it is nano dimension it is two direction, we call it nano rods, nano fibers,

when it has only one dimension in nano lens scale. We call it in films or lamellas, once it is no dimension along in nano, we call it bulk structures nano entity in that. So, I hope this one comprises the overall overview of nano material and nano structures and that is what it is the overall game of the particular lecture.

Thank you.