Nanostructures and Nanomaterials: Characterization and Properties

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Lecture - 8
Introduction to Nanomaterials (CI)

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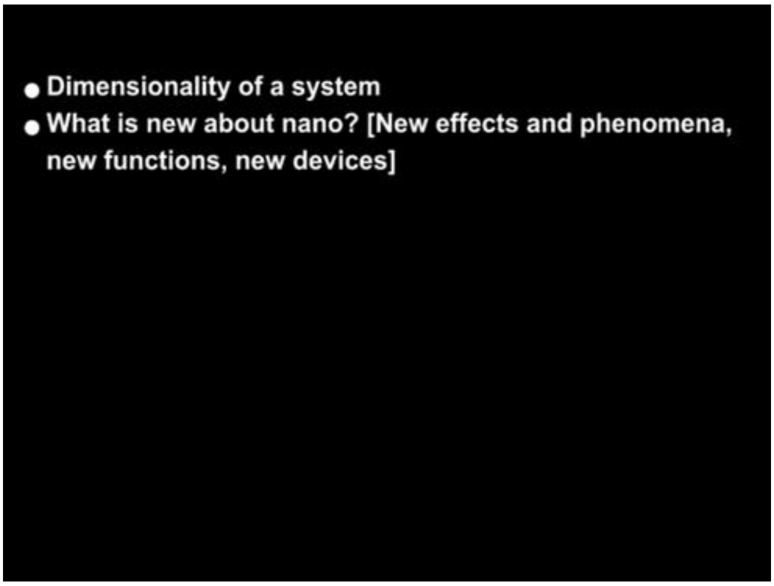

Now, we have classified nano crystals and nanostructures and nanomaterials based on dimension one fundamental.

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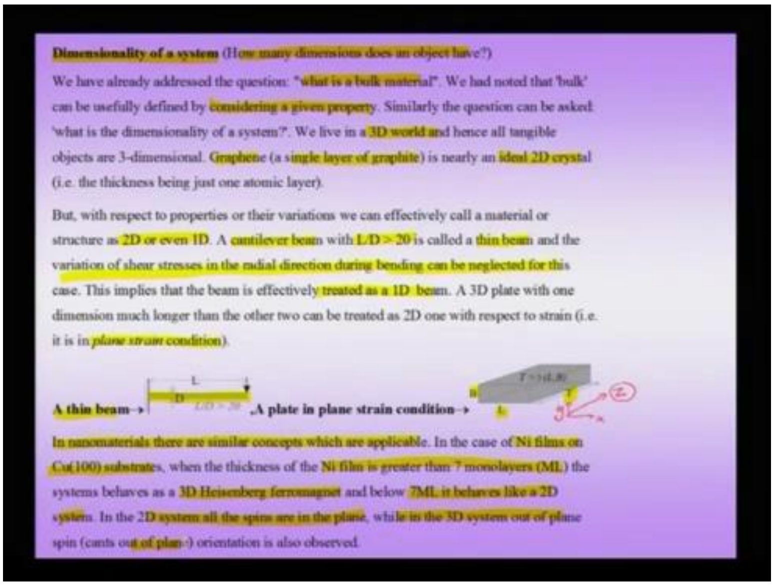

Another question which we have to ask ourselves is that what the dimensionality of a system is. In other words, how many dimensions does an object have, now this question obviously is a practical question, it is a question related to the physics of the dimension. This is in other words very closely related to question which we had asked before what is the bulk material and clearly we have noted that the bulk material could be defined based on a particular property that we are taking into consideration. Similarly, we can ask ourselves a question that even though we live in the 3 D world that means that the dimension world we live in this 3 D.

Hence, any tangible object is going to be three dimensional, but in terms of the physics or in terms of the effects, we see can there be some other dimensions to a given kind of a structure or given some kind of a physical property. For instance, suppose I take graphite which is almost a single layer of graphite is almost as close to an ideal two dimensional crystal that we can think of. So, this is just an atomic layer and therefore, I would like to treat this system as a two dimensional system rather than three dimensional system even though we know that this object has an embedding in three dimensions.

Similarly, suppose I look at other derivatives like carbon nano tube, which can be thought of a folded version of graphite this also can be thought of a curved two dimensional space. This would be a cylindrical two dimensional space a florian molecule can be thought of as what is called an s 2 space or an spherical two dimensional space.

Therefore, it is even though we live in the three dimensional world with respect to the given property or a structure. We have to talk about other dimensions which could be lower than a three dimensional world which could be two dimensions or as we shall see sometime even one dimension.

Now, let us take a very classic example a cantilever beam a cantilever beam typically which has a very long aspect ratio which has an l by d greater than 20, which is sometime call the oiler beam is a thin beam. The variation shear stress is in the radial direction during bending can be neglected for this case and sometimes in for many concentrations this beam can be treated as a one dimensional beam. So, do you think that I am talking about this drawn here, so it is an extremely long beam with very little thickness, very little as compatible length of the beam, L by d is greater than 20.

Now, it simplifies my overall calculations when I talk about this beam as a one dimensional beam, rather than considering it as a complete three dimensional system. Similarly, let us take an another example for instance a plate shown here, which has an height b length l the thickness t. Suppose, my thickness is very large as compared to the length of the breadth or in I can even pick one of the two dimensions like length and see the thickness is very large. Then, such a plate can actually be solved the questions for such a plate and we solved in two dimensions and the condition under which it solved it is called two dimensional plane string condition.

That means a strain in the third dimension can be treated as the 0 because whatever I am loading and I am applying on this body as I mean it has a no three dimensional condition, it is not along with its constant along the third dimension. I can treat this body like a two dimension body and solve my equations assuming the third dimensional strain in what instance I was about to call the z direction. The direction of the depth as my z direction because I can call this is my y direction and this is my x direction. So, if it is very large in z dimension, then I can treat this problem effectively as a two dimensional problem, very thin bodies like almost like a thin lamina.

We actually treated like even what is known as plain stress condition in which the stress in the third direction can be neglected. So, the message from these two examples of graphite and the examples of these two kind of what you may call as thin beam plate is that in terms of structures and in terms of properties effective equations. I need to solve and i may want to consider a lower dimensional body, which actually is very meaningful in terms of the physics. I am going to study in nano materials, again these I can extend these concepts, which I have learnt and such concepts are similar concepts also applicable.

A nice example for this would be in case of nickel films, which have grown on copper of 1 0 0 substrates, I am taking a specific example to illustrate a point, but the concept obviously as much more general application and very often this treating. This high dimensional system as a lower dimensional system can save a lot of my time in terms of computations and can save lot of time in terms of understanding the physics. It is worthwhile to treat them in the appropriate dimension, now in case of nickel film on copper substrate and we know that nickel is ferromagnetic material and while copper is not.

Now, this copper 1 0 0 is a single crystal on which I am growing a nickel film, when I am growing film layer by layer and I notice that if my film thickness is greater than about seven mono layers, the system behaves like a 3 d Heisenberg ferromagnet. The details of all ferromagnetic we will discuss later, but now we are worried about one important concept which will become as I go along and if I am below seven mono layers the system behaves like a 2 d system. Then, how I am differentiating 2 d system versus 3 d system in 2 d system all the spins are in plain and in 3 d system all the spins are out of plane. Typically in this system where spins, which cant out of the plane, therefore let me take the system and draw a schematic here.

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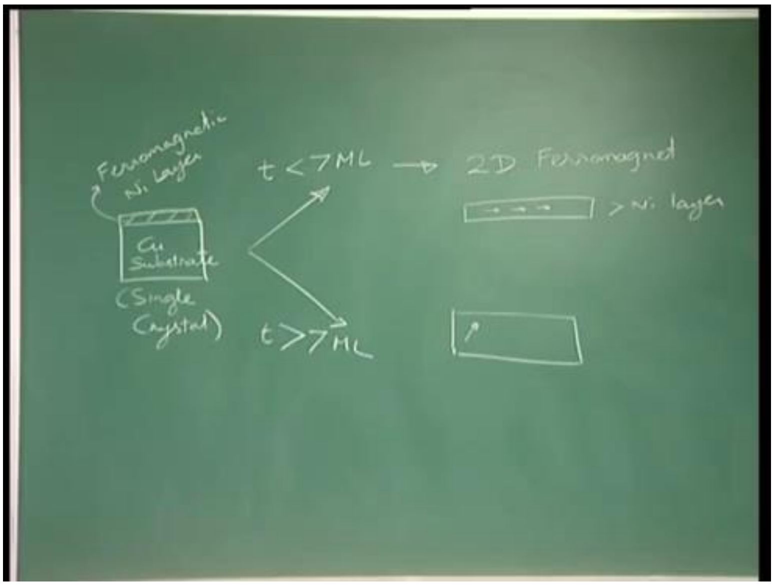

So, I have my copper substrate and this is now a single crystal and on top of it I am drawing my ferromagnetic nickel layer I have two cases, thickness less than seven mono layers and thickness greater than seven mono layers. So, I am talking about number of mono layers of nickel on copper substrate nickel being ferromagnetic for the case of the seven mono layers or less than seven mono layers, it behaves like a 2 D ferro magnet. Here, suppose I have to draw schematic of the layer, I would notice that all the spins schematically I am showing here, all the spins are in plane. Suppose, I am talking about thicker film, then I would notice that some of the spins what actually cant out of the plain for spins, there is a 3 D component of a system.

Effectively, these system can treated like a 2 D system and these system will have to talk be about 3 D system, therefore we clearly see that with respect to the physical property of spin alignment and also the spin orientation. We can have a lower dimensional system or higher dimensional system based on a specific geometry and based on specific property and considering and you would notice that in nonmaterial. Since we are going down to low dimensions very often that we can actually treat system in a lower dimensional manner keeping fully in view that actually the system is three dimensional.

We live in a three dimensional world and when we talking about reduce dimensionality is either is respect to us structure like the graphite or it is with respect to like ferro or a property like ferromagnetic spin alignment. So, we have to keep this in mind while we treating systems and solving equations which are important.

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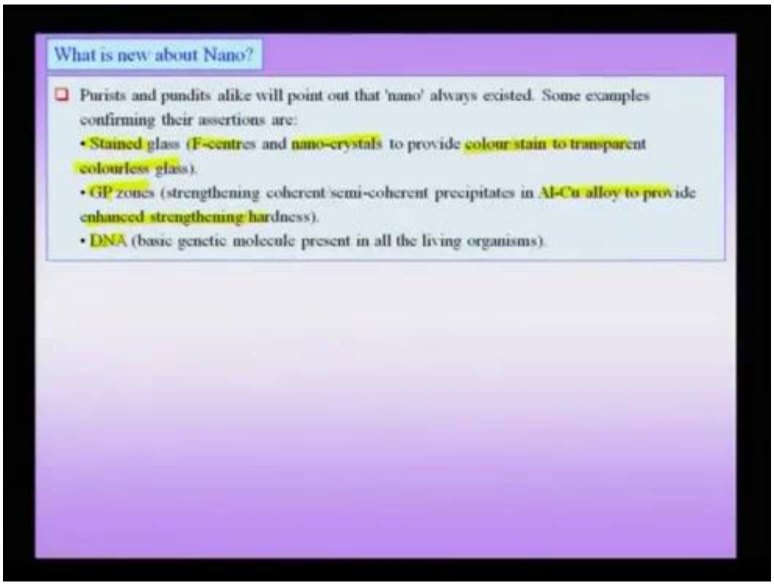

Now, one important question which comes to the mind and which we have often ask for the people researches people and working their nano material and nano structures is that what is new about nano? If you go back in history you would notice that in stain glass the f centers and nano crystals is what provide the color was staying in the transparent colorless glass and in stain glass has been found in very ancient churches. If you look at material science for more than 100 years the g p zones have been which are typically coherent and they can grow they can semi coherent in to the form of theta double prime precipitates in aluminum copper system.

They have been providing strength and hardness that means more than 100 years we are been dealing with g p zones and systems which are now giving us hardness though they exact structure of g p zones. The details came out where actually discovered only after the transmission electron micro scope came to be being, we all know that we are made up of genetic material which is DNA.

We already said that DNA itself is a nano structure, therefore if somebody were tolike question that when nano materials always in existence the answer has to be there were all there for a long time the nature is among with them. In fact, when you take your candle and collect the suit on the top suppose I flame a candle and collect suit on the top, then I would find many of the nano structures which have been discovered in the last thirty years actually formed in a common suit. Therefore, in some sense nano materials and nano structures always existed, but then what is new about nano that is a question which we will come to our mind and we will try to answer this question in the coming slides.

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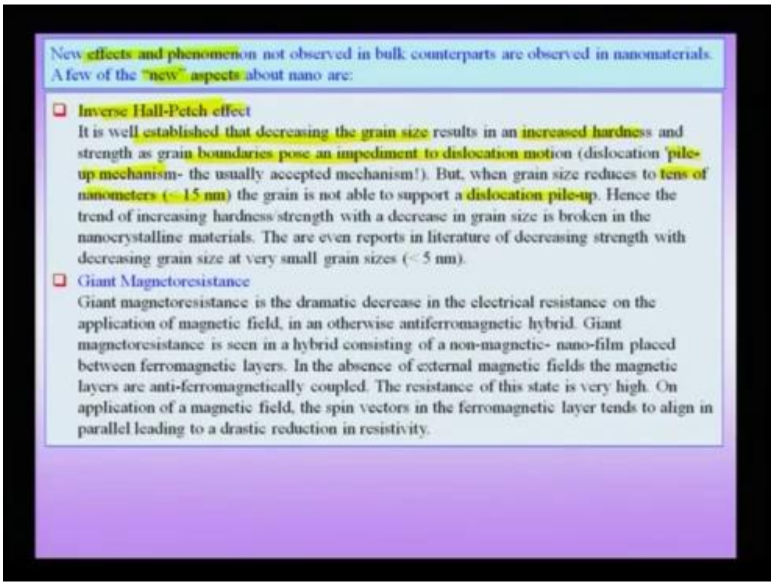

The problem lies in a fact that very many new effects which have been discovered of the advent of intense study of area of nano science. These effects we are not known to the science before the advent of what you might call research into nano materials and nano structures before the advent of nano technology. We will take up a few of these effects which we can call absolutely new about nano and here we are talking about effects and phenomena which have perhaps no bulk counter parts. In other words, they are never not observed in the bulk materials is very specific to nano structures and nano materials, so we will take a few of these the details of these.

We will obviously consider with respect to the whenever we go to the relevant topic and we will discuss some of these in detail. For instance, when we are talking about hall page effect, when we are dealing with mechanical behavior we will talk about hall page effect and when we are talking about for instance magnetism in detail, we take a magneto resistance at this stage. It is important just to note that in spite of the field of nano in some sense existing in for ages, in fact you can use ancient, they are new things which have come up of late. Therefore, it warrants a separate place in our study and in scheme of things for us to study nano materials and nano structures as a separate branch varying specific attention to some of these aspects.

Of course, we are only listing a few of these kind of effects here and further many more effects we will consider in relevant topics. So, let us start with the inverse hall page relation is well established as start wish that are decreasing the grain size. The hardness and strength of material increases this is primarily comes under the fact that the green boundaries pose an impediment to the motion of dislocations. One of the classic models in this case is the dislocation is file up mechanism which suppose to lead to the inverse hall page relationship. There are still issues to be resolved regarding the origin the mechanism how the inverse hall page relationship comes about, but we will not go the details.

Now, we will just assume the hall page relationship is coming because of the impediment post by green boundaries to the motion of dislocations. So, these locations which are weakening the crystal and if there are impediments to its motion then we are going to get an increased strength, but this hall page relationship on one hand in very large grain size material has been questioned. It does not our region of interesting very small grain sizes when we are talking about tens of nano meters typically are less than about 15 nano meters.

It is been observed that the green itself cannot support a dislocation pilot and it is seen that the hall page relationship actually breaks down in very specific experiments. Of course, many of these experiments still need a confirmation of larger spectrum of materials. There have been reports that not only that traditional hall page behavior break down, but they can actually be something known as the inverse hall page relationship, so in the hall page relationship.

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Typically, we observed that if I am plotting one by root t same as with respect to the that means the decreasing grain size i, we would notice that decreasing grain size to right, I would notice that there is a straight line. This is my some kind of strength of parameter which could be for instance stress and yield strength, now when we go to very small grain sizes and here say for instance I am talking about this is an order of about 15 nano meters or less there are three possibilities which come about. Either I can continue the harden the way it is, but typically what is absorbed is the hardening rate actually comes down, but in very some very specific case, people have actually that the hardening may even come down without possibilities.

The hardening becomes constant with respect to grain size, so it is very clear that when we go to small sizes the hall page relationship breaks down the grain is too small to support to pileup. Even if you are not talking about pileup mechanism this is the experimental result and you have to take the way it is and notice that the hardening rate changes with respect to grain size d is my average grain size. Of course, it may the rate of hardening becomes constant that means it becomes invariant of the grain size, but in very specific cases you may actually absorb the inverse hall page relationship. So, the inverse hall page relationship obviously is not absorbed in large grain sizes and therefore, it has no bulk counterpart it is only observed in very small grain size materials and the inverse hall page.

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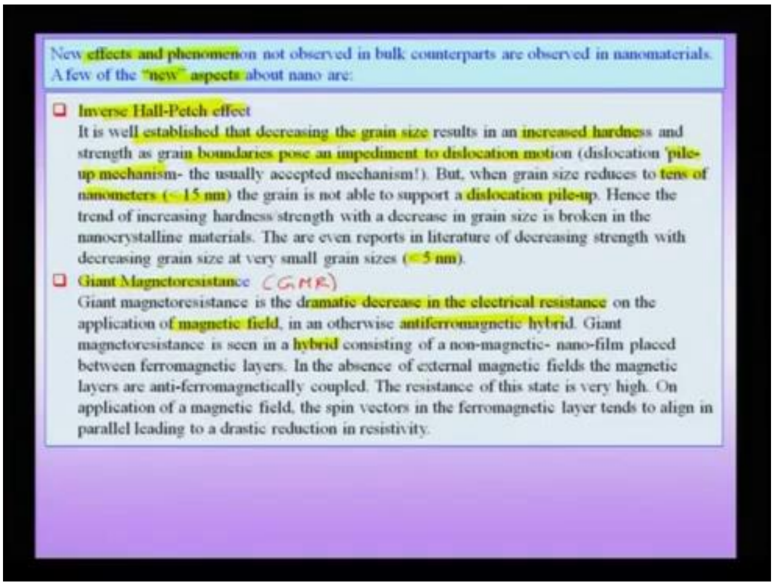

Typically, takes in at a grain size of about in the range of what five nanometers, so it is very clear that I am going to very small grain sizes now I am talking about nano structured material. That means material is bulk, but the grain size is in nano scale the mechanism of deformation can change the mechanism of deformation or the mechanism of strengthening can change and since this mechanism is changing. You would absorb that deep the traditional relationship like a hall page relationship which is valid in the large grain size regime is no longer valid in the smaller grain size regime.

It is depending on what we might call experimental details the kind of material the kind of material what you might call the starting materials conditions etcetera. You may even absorb what is known as an inverse hall page relationship which has no bulk counterpart. The second example we consider is from the world of magnetism and we take up an effect known as giant magneto resistance typically the acronym used for this, again like the previous example there is no bulk counterpart to this.

It is actually found in hybrid nano scale in normal magneto resistance we observe that in presence of a magnetic field the resistance increases while the absence of magnetic field the resistance is in lower state in giant magneto resistance. This magneto resistive effect takes a new higher order all together which could reach 80 percent or more because in normal magneto resistance the value is magneto resistance is of about 5 percent.

Here, we having a much higher enhancement in the electrical resistance and this happens in the presence of a magnetic field. So, here we make what is known as an anti ferro magnetic coupled hybrid, in another words I take two materials and in the I will just take one example now and details of which we will talk later.

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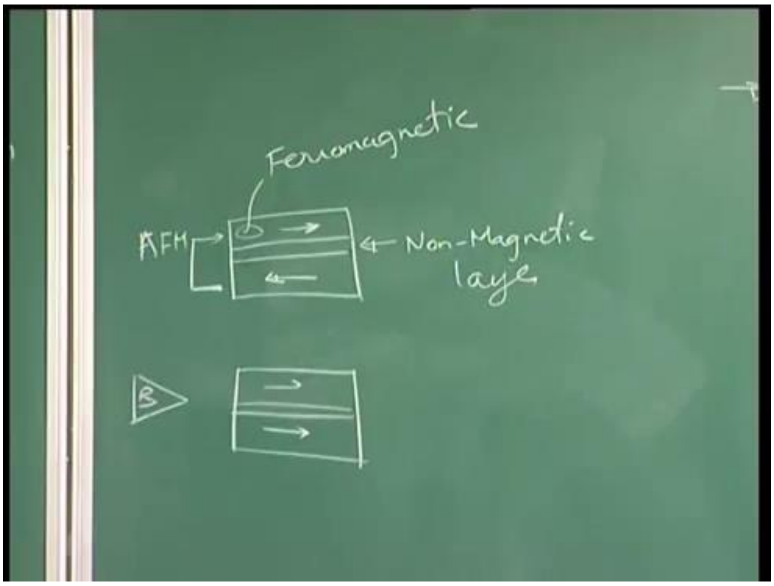

So, I make an hybrid of three layers and this is known magnetic layer and these are ferro anti ferro magnetically coupled ferro magnetic layers. So, the coupling between the two is anti ferro magnetic, but these layers by themselves are ferromagnetic. So, in the presence in the absence of a magnetic field, the spins in one layer is pointing opposite to the spins to other layer and this is now my high resistance state and the resistance is coming from spin dependent electrons capital. Now, what happens suppose I switch on the magnetic field in the presence of magnetic field like b, what I get here this is a state in which my spins are ferro magnetically coupled this is my magnetic layer.

This is another magnetic layer in between these is a nonmagnetic layer and you would the thickness of the middle layer is less than what is known as the spin diffusion length. If they get ferro magnetically coupled, then I get a low resistance state the difference between the resistances of the low resistance state in which happens in the case of with the magnetic field. These are the high resistance state which is in the absence of a magnetic field when this two ferro magnetic layers are anti ferro magnetically coupled is very large. This is the effect of giant magneto resistance, now obviously it is very clear that the thickness of this layers and the thickness of these layers are very small.

This layer's thickness and internal spacing layer thickness very important because this has to be the spin diffusion length of the material and that the mode of scattering here which is giving rise to electron resistance. I pointed out is actually spin dependent scattering and this spin dependent scattering which is giving rise to the resistance in a material. Of course, I am ignoring here scattering from the interfaces there could also be scattering from this interface and scattering from this interface. We should add on resistance which is present, but we are looking the difference in resistance between the ferro magnetically coupled layers and the anti ferro magnetically coupled layers, then it is basically the spin dependent scattering.

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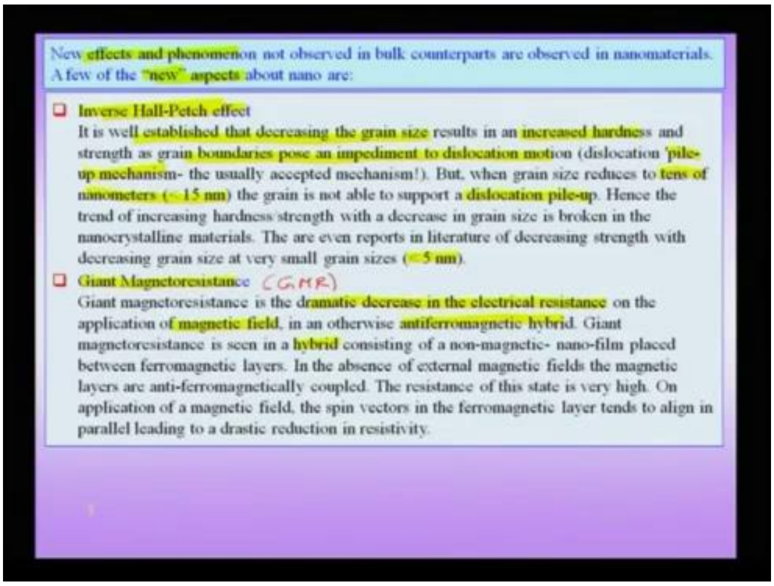

Now, this particular configuration actually has important applications in reading heads etc and this can also used for deduction of magnetic field which are very small. Therefore, clearly there is no classical analog to this because here we are made a sandwich structure or more precisely hybrid which is the whole mechanism of which operates because of the nano scale in which the spacing layer is present. The anti ferro magnetic coupling between the ferro magnetic layers and therefore, there is no classical analog or the bulk analog to this. Therefore, when we are talking about giant magneto resistance, absolutely new phenomena which is present in what is called present at the nano scale.

They are close cousins of this which are close present like tunnel magneto resistance and some of the other things we will consider very soon. So, it is clear that when we are going to nano scale, there are new things which we are observed extremely fascinating new things which have no bulk counter points. Therefore, it definitely makes us worthwhile to study what you might call nano materials nano structures from a completely new prospective and try to understand some effects which are coming there.

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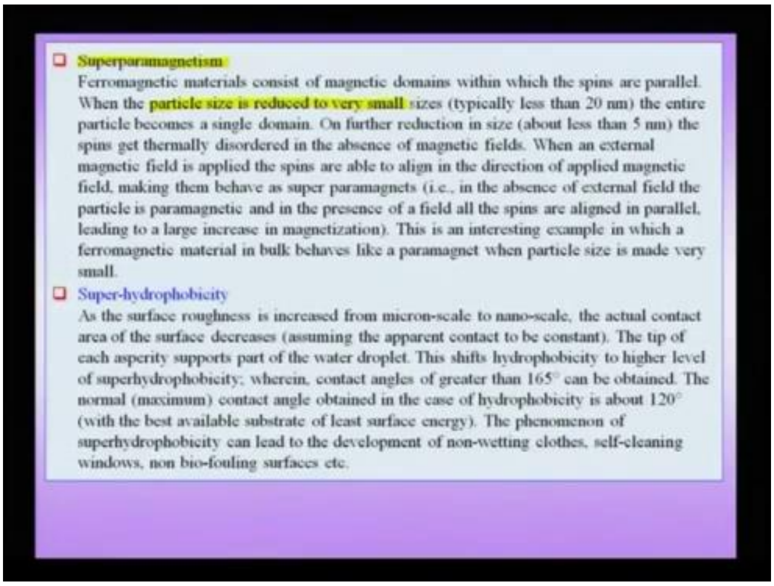

Once other effects, which we can talk about now is super para magnetism, it is very well known that when you heat up the ferro magnetic material about the Curie temperature it becomes paramagnetic. If I apply external fields to paramagnetic material, then there is a tendency for alignment of the spins in the paramagnetic material, but it is constantly fighting against with thermal disordering. Suppose, I take a molecule like oxygen which is paramagnetic the typical susceptibility is very small, that means it has the susceptibility in the order of 10 power minus 6.

That means the alignment in the process of magnetic field is very small the reason the alignment is very small is because this oxygen is not ferro magnetic. Now, there is an alternate way of producing what you might call paramagnetic material as I pointed out like that it some starting with an ferro magnetic material. There are two ways of producing a paramagnetic material from a ferro magnetic material one is as I pointed out is actually heating the material above the mercury temperature. An alternate method is to actually reduce the particle size to very small sizes, so let me right down summarize the ways I produce I can produce is actually my para magnetic material.

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So, there are materials like for instance I can write example of oxygen which are always paramagnetic and we are not talking about these substances. Here, we are actually talking about materials like iron which are actually ferromagnetic, but which can be made in to paramagnetic state by heating or by reducing the particle size. In some sense, both heating and reducing the particle size as usual c is equivalent when you when it comes to the essential physics, what is happening here and we will see how it leads to the phenomena of super para magnetism.

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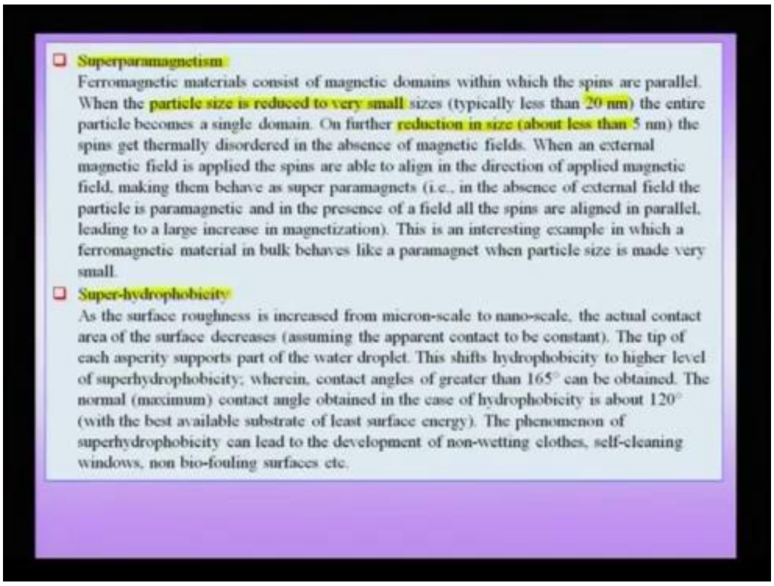

You reduce the particle size to very small sizes typically say less than about 20 nano meters the entire particle becomes single domain we know that we already have seen bulk magnetic material it is actually split into multiple domains. Now, when it goes when he particle size goes to less than 20 nano meters, now this is single crystal I would know that the entire particle becomes because the domain wall thickness is too large the particle size is too small. Therefore, it cannot support any domain walls within the particle and the entire particle becomes a single domain.

Now, at this state this material is still ferromagnetic even though it is a single domain, but suppose I reduce its size even further and take it to the size order of 5 nano meters. Now, I am assuming a pure iron particle there are no oxide layers covering it, then the particle size is so small that the inherent tendency for all the spins to align within the particle is becomes small.

I simply do not have enough number of atoms in the material to give me my effective spin alignment. Therefore, the tendency for alignment is becomes a smaller and smaller as I reduce my particle size and about a critical size of about 5 nanometer what happens is that the temperature becomes the temperature which is time to disorder this alignment spins wins over. Therefore, I get into a paramagnetic state now this is a paramagnet and obviously as I pointed out this is the reduction of particle size is very similar to heating the material because overall because actually disordering the temperature.

This is actually fighting against the ordering effect of inherent ferromagnetic spins and of course when we are talking about ferromagnetic alignment I mean the spins are aligned parallel in the same direction. Now, since the particle size is too small and the thermal disordering is have taken over this material becomes paramagnetic, but such a material is very much different from paramagnetic material. For instance oxygen which has no inherent tendency for alignment of spins since this material is paramagnetic is inherently ferromagnetic which becomes paramagnetic. If I apply even a small field just below the critical size at which it becomes paramagnetic, so below the critical size at which it becomes paramagnetic even a small magnetic field will tend into align the magnet.

We remove the field again it gets into a paramagnetic state in other words such a material shaving a tendency to align all its spins even in the presence of a week field. In other words, this is unlike the oxygen case in which very high fields are required to even to get a partial alignment of the spins here the spins are automatically orient themselves. Therefore, you get very high enhancement in what we might call paramagnetic susceptibility such material therefore, is called super paramagnet and this is purely coming from the effect which is size reduction effect.

So, by reducing size I have made the material which is normally for a magnetic into paramagnetic material this paramagnetic material in the presence of a field tends to align all the magnetic movements. Therefore, which has a very high susceptibility and such a material would not have any hysteresis, therefore I have a very interesting effect again related to magnetism coming from this particle size reduction. Let me move onto the next example which is from a totally different physical property coming from totally different from physical property. This is the area of super hydrophobicity all of you must have observed when you take a lotus leaf for instance. You put water on lotus leaf tends to bleed up very similar to what bleeding may happen if you put a water drop on a glass.

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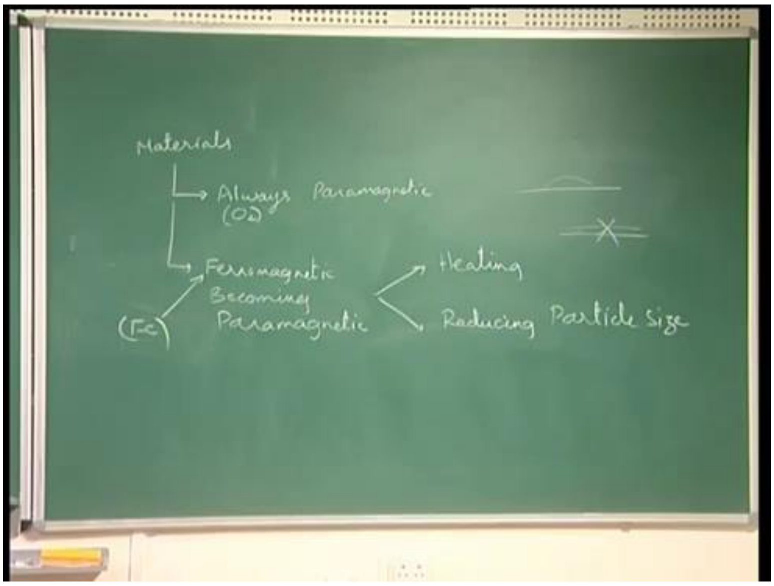

So, if you notice that if you put a water droplet on glass it will tend to bleed up rather then become a smooth layer on top this is not what happens with water it tends to bleed up and you would notice that if you put water on wax. For instance, this is the similar effect you would observe, therefore such materials do not tend to be wetted by water there is a reason why the lotus leaf should not wetted by water because. If water will were to wet the lotus leaf the lotus leaf would sink and therefore this is not a desirable property for the life of a lotus leaf.

So, the important point which comes about when we study the lotus leaf is a fact that it is not just hydrophobic what hydrophobic meaning it repels water, but it is actually is a super hydrophobic. The difference between hydrophobicity and super hydrophobicity can be understood by measuring the contact angle, so my contact angle if understand.

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So, I put a droplet and I measure the contact angle and this is my contact angle that the droplet makes measure the contact angle, and see what a contact angle is. I will observe that for normal hydrophobicity I can get a maximum of 120 degree contact angle even 120 degree possible only when I have the best available substrate with this surface energy. That means such a substrate this is not wanted to be wetted by water, I am not best, I can go low energy substrate is about 120 degrees, I cannot get hydrophobicity greater than 120 degrees.

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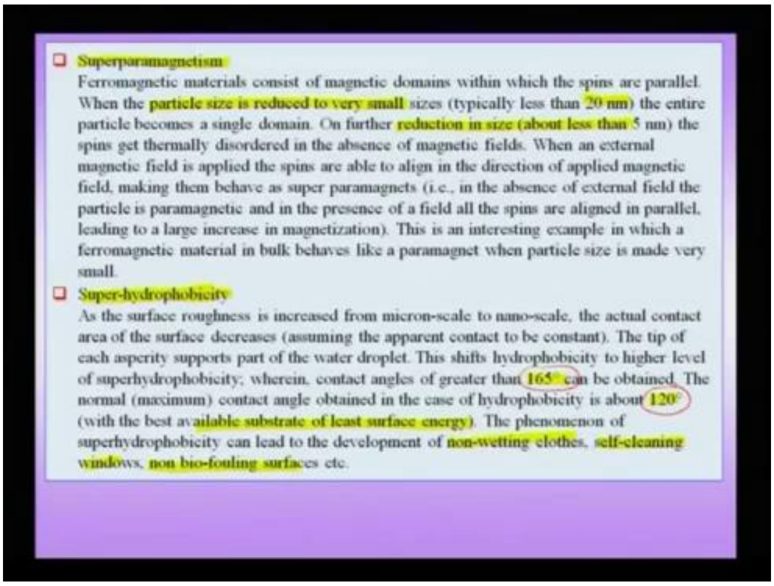

In the case of lotus leaf you can observe actually you can get a 165 degrees, this is what defines a property of super hydrophobicity is that to super ability repel water suspicious substrate does not want to wetted by a water. The question arises how many able to go from a value of 120 degree which is possible purely by low surface energy which is coming from chemical character of the surface to something like 165 degree. Here, something more is in what obviously cannot be just chemical nature of surface because that can wanted to give a degree what is this, which can give 165 degree take up as very soon, but this phenomena is absolutely coming because of structures of scale.

Therefore, not only structures of scale consider this beautiful example hierarchical structure let us talk about hierarchical structure exited the important example is when hierarchical architecture actually give us a super hydrophobicity. Now, we will assume that super hydrophobicity and this is coming from hierarchical structure where in you have not just low surface energy, but in certain structural contribution which is giving that structural contribution. From learning from super hydrophobicity, we can actually make non wetting clothes is very important practical applications. We can make self-cleaning windows non bioholing surfaces, typically you might have notice that ships have barnacle sticking to them.

Therefore, you might some kind of pain, but the problem of these kinds of pains sometimes very environment non friendly that are very bad for the environment and therefore, you don’t want might be among these kinds of chemicals. Suppose, I have a hydrophobic surface then there is chance sticks to it, now suppose I am talking about an application the chemicals transporting in a utensil. Then, I would want to empty the entire utensil later on with the cell without any chemical being left is serve two purposes. Of course, when I am going to refill the utensil, I do not have clean to prior to refilling second thing my gain is 100 percent in other word all the chemicals.

I have transferred easily into whatever the application for which actually now in a commercial products the people are actually manufacturing the inner surfaces of these phases. These have an architecture very similar to what we have learnt from the lotus leaf. These are hydrophobic and super hydrophobic surfaces and there is a very interesting application when it comes to using to phenomenon of super hydrophobicity in some sense. These are called by bio metric material or bio non stick material where we are learning from nature actually engineer our surfaces to have what we might call low wetting capability.

Typically, surfaces in macro scale are either hydrophobic or leo phobic either they repel water or they repel oil, but in nano scale it is there is certain surface which have been near and both leo phobic and hydrophobic. There is very interesting possibility we go to the nano scale material one of the example which of course, may not be very surprising a new is a concept of super surface activity. Now, we know that small sizes for a given volume of material the surface energy or a surface area is going to increase. Later on, during the lectures we will actual make a calculation to see that for a give a volume. Suppose, I reduce my particle size how much my surface area I am going to create, so the phenomenon I am talking about here.

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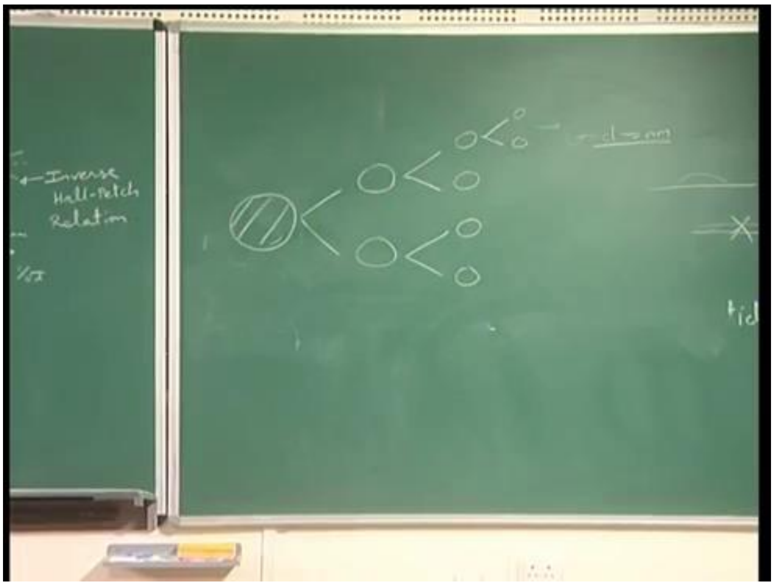

Keeping the volume of a particle constant consider a volume then split this particle into two particles and further I may want to split this particle into two particle and carry on this chain for the when I go on doing at point of time. My particle size will become nano size and this will become nano meters, therefore, I am keeping the volume of a particle constant, but I am keeping on dividing the particle. It is a visualization this may not be the way actually a the nano particles may be actually manufactured, but the essential concept dealing this here is for a given volume of a material. My surface area is increasing drastically, this increase surface area, of course means that I have a large amount of high interface energy present in the material.

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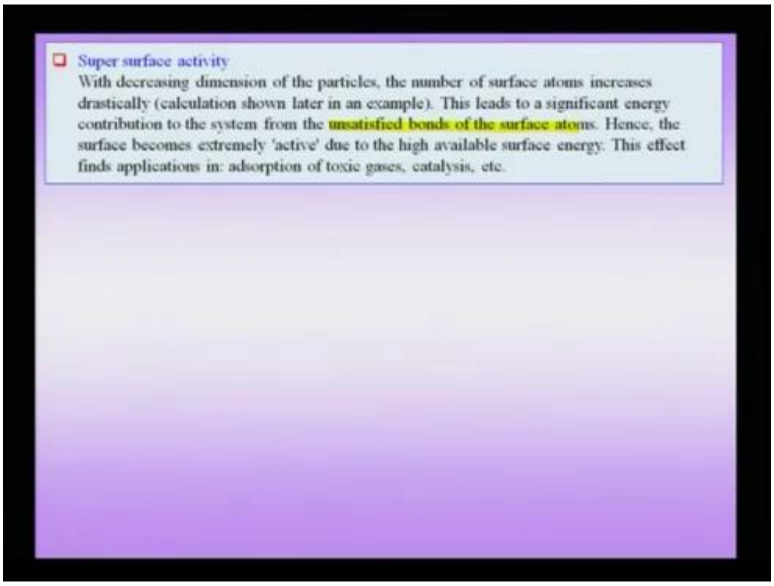

Interface energy is a surface energy because the surface actually is a region of unsatisfied bonds the bulk of the material.

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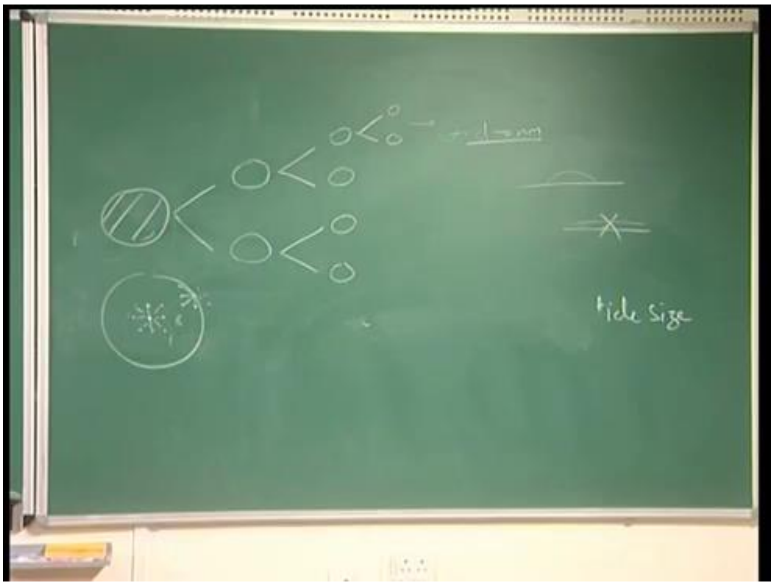

Suppose, I have to talk about bonding inside the material taking a particle like this I am just going a pure schematic this is bonded all the sides. So, for the region this could be bonded for some sense nearest and next nearest neighbors to fallen, so many of these neighbors 1, 2, 3, 4, 5, 6, 7, 8 of these for suppose the atoms are sitting on these surface actually bonded only to a few of them. Therefore, they are some unsatisfied bonds which cause the material energy and this is of course we know the origin of surface energy, which also the concept of surface tension.

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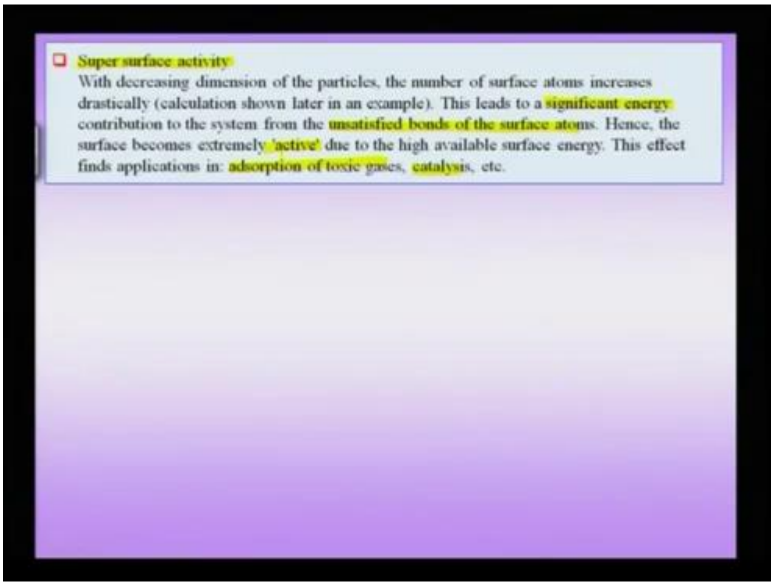

Now, since the surface area is increasing drastically there is a significant amount of energy stored on surface available at the surface, and therefore and the surface will come extremely active this highly active surface can be used. Actually, we have quite some time for distance in absorption of toxic gases in catalysis etc, so this is we all know that activated charcoal can be used as an absorption media of gases. Furthermore in when we are talking about for in sense application trying to slow hydrogen in the solid state for in sense and transport application. This kind of application using a surface area helps in actually first of all breaking up the hydrogen in to h which can further diffused into the material and then stored in interior of the material.

Therefore, the super surface activity is natural consequence of the presence of large amount of surface area for a given volume of material. We will return this topic very frequently how this interior surface area is some sense important in some sense what may call the expectations we have the nano material. This we should know that as we said new phenomenon and when we are talking about nano materials.

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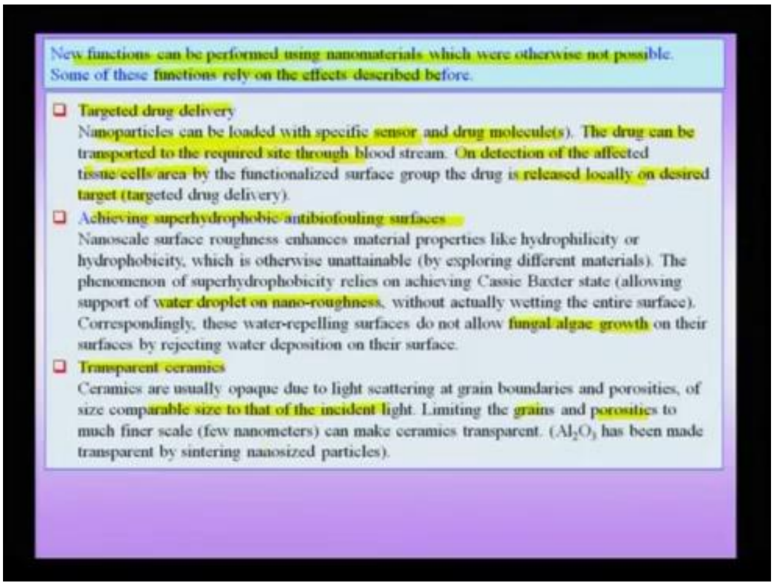

We should note that new functions can be performed using nano materials, which otherwise could not be possible. So, we are asking questions what is new about nano why would if somebody comes to tell you that nano is always existed we have to conquer with him and we also point out. Then, there is new function and there is a new phenomenon and there is a new applications and new devices which otherwise has no classical counterpart. Some of these functions relay on the effects which we have be described before we take a few examples to illustrate what we might call the power of nano material.

The nano technology which has come from the use of nano materials first of this targeted drug delivery nano particles can be loaded with the specific sense and for in sense of drug molecule. This is now we might call us nano particle the drug can be transported to the required side to the bulk stream. If you are talking about magnetic material an external magnetic field can be assisted to bring this particle which has been now loaded with sensor, but also the drug loaded molecule to very close to the tissue. This has been affected on deduction of the affected tissue cells and area by the functional surface group the drug is released locally to the desired target. Now, they are three components to this whole process, but let us first look at the benefits are doing, so when you are doing at targeted drug delivery obviously you do not have to over saturate the system the entire body with a lot of drugs.

So, you save on the amount of the drug delivery you may end up of side effects put into the general effects if this drug is put into the handle systems and you can avoid side effects by making the drug only go to the specific location. Here, you want drug to be delivered the amount of as drugs that can be selling and the amount of drug, which can be used and further you may want to give only a very specific amount of drug and as a sensor material that is the drug may not be required throughout. It may be required during specific times and only when the drug is required we can actually the drug.

Therefore, we make it sites specific quantities specific and also time specific, so this is possible by using what we call smart nano material particle where in the nanoparticle has been functionalized. We will talk a little more about functionalization soon and the nano particle is what you might call empowered with the sensor and also with the treatment drug molecule. Now, this is a beautiful example and already a lot of field trials are going on to use this transacted drug delivery and in the future we are going to find the more drugs that are going to be delivery in a very specific site specific manner.

We go to have more and more of targeted drug delivery what you might call helpful for both curing of the drug disease and also in wording the side effects come from saturating the system with lot of destruct. So, this is actually a very beautiful application of nano materials in the field of medicine and as a pointed out that two levels at which this sites specificity could be obtained, one is the particle itself sensing as a specific area, the second before that we can actually take this particle to the specific area by for since we use a one external magnetic field if the particle is meant magnetic.

So, nano particle is now becoming a smart device by itself it is now not only meant for empower of the sensor, but also empowered with the treatment method, we have already seen this example of achieving the super of hydro-phobic surfaces. We can actually get anti bio forming surfaces and we will soon see when we talk a little more detail that is a super hydrophobicity actually comes from certain kind of the roughness which is now in the nano scale. This can be used for making coating switcher which repel or do not allow the growth of fungus and algae, so this is a nice another applications and this functions will not be able will not achieve this functions by user conventional coatings and surfaces. Therefore, we have to rely on nano structure or nano structures on the surface another interesting application is the emergence of transparence ceramics.

Typically, if you take a ceramic like aluminum you notice that it is optic aluminum for instance can become optec because the fact that there are porosities in defects in the poly crystalline alumina which include the gain boundaries and these gain boundaries. The porosities have a length scale which is comparable to the wave length of the incident light. Therefore, scattering of light arising from these defects which is can be gain boundaries porosity within a material which is making this material optec if by suitable processing. We will see soon what kind of suitable processing we can take up we can actually reduce the defects in a material.

That happens when you actually produce a few nano meters during sites ceramic we can actually get what is known as a transparent ceramic. So, again we have to rely on nano material or nano technology for the making this transparent ceramics and a typical as you can see typical alumina sample is actually opaque. Now, what are uses of these transparent ceramics, we will see very soon that how these transparent ceramics can perform roles which otherwise not possible with conventional lenses made out of glasses.

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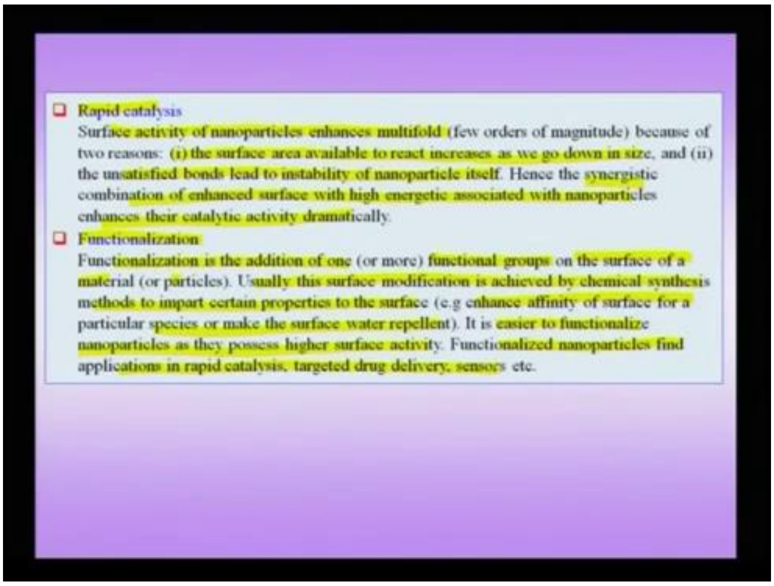

We already pointed out that the increases surface area also means that we are going to get an high amount of what might to call an ability for a material to perform like a catalyst. The starting example is the case of gold the gold in its macro scale does not have any catalytic role. Typically, but suppose I am talking about the gold in nanoscale and if i am specifically concerned say gold in nano scale embedded process in a if two or three kind of a substrate than you would notice that gold in other wise does not show any catalytic property turns into good catalyst. It actually gets and actually get lot of specificity in the kind of process that can be controlled with this can be catalyst if reduces nano scale.

So, surface activity of nano particle is enhanced many fold and sometimes few orders magnitude. This is because of the increase surface area of available to react and say go down in size which is what we have noted when your time divide a particle into smaller and smaller sizes. The unsatisfied bonds leads to instable nano particles itself sense synergetic effects of combination of enhance surface of high energy associated of nano particles enhance that catalytic activity drastically. Therefore, with if I have catalyst which is performing certain role in the bulk state if I now make it in the nano scale.

Then, definitely have chance of increasing catalytic, but a few orders of magnetic and this straitening pointed out. There are case where the normal material or the bulk material is not does not show catalytic activity, but when reduces nano scale in the case of gold for the instance, it assumes the catalytic role that to very important catalytic role. We already have seen an example of how functionalization is very important this is we saw in the case of what we meant called taking nano particle functionalizing with surface with that and attaching for instances of drug molecule fictionalization is the addition of one or more functional groups on the surface of material or particle in this current context.

Usually, this surface modification is achieved by chemical synthesize method it is imports certain properties surface. For example, we can enhance of surface for particular for specious to make the surface. It is easier to functionalizing nano particles as a process high surface activity functionalize nano particles and application in rapid catalyst targeted of delivery in sense of etc. Therefore, fictionalization is much more of what we have called feasible because of the presence of this highly act surfaces.

Now, I can not only load my part nano particle with one kind of functional molecule, but I can use multiple functional molecule, which can perform the multiple roles. Therefore, I may have actually achieved multiple task in a single with a single nano particle, so what kind of devices as say which using the some are of the effect process that we have seen just now that what we are going concern next.

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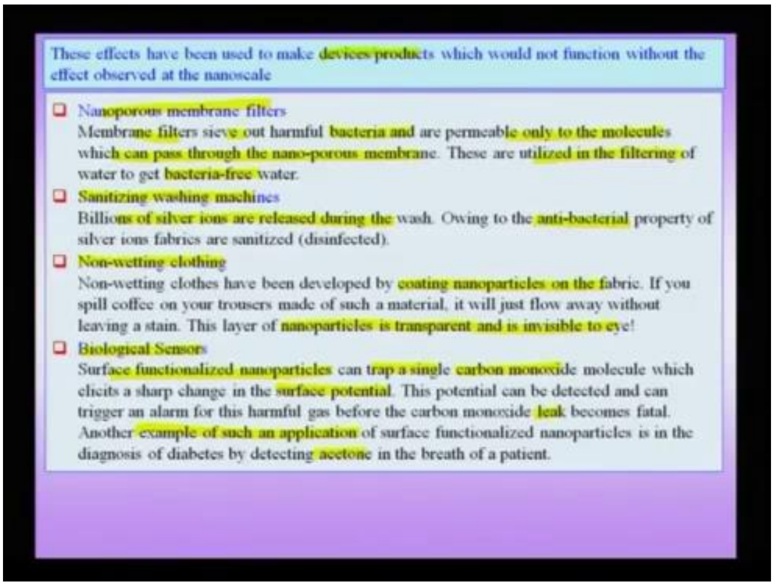

Huge variety of devices and products are already in the markets many more on the way and as we can see that there are filling area materials can not solved our problem one example is nanoparticle. Our memory in filters already seen that an example how to make nano for us material which is an hybrid of matter and air and matter and vacuum and as such membrane filters for bacteria and for us membranes. We want to see particularly how bacteria pass through membranes and I can actually make membranes which is thus dual role of keeping out bacteria going important molecule pass through and these are been in utilize in filter.

What do we mean call the process that we have seen just its now that is what we going to consider next huge variety of devices products are already in the market many more on the way. As u can see that they are what do we mean they are filling into what areas conventional materials cannot solve our problems one is nonporous membrane filters, we have already seen that an example of how we are going to get nonporous material. It is an hybrid of matter and air or a matter and vacuum and such membrane filters can see how harmful bacteria. From here, only two molecules which can pass through the nano porous membrane, in other words I mean what particularly harmful species like bacteria, but not other molecules to pass through these membrane.

I can actually make an membrane thus this dual role of keeping out bacteria and allowing the important molecules to pass through and this have been utilizing actually filtering water to get bacteria a free water. Another nice example is production of sanitizing washing machine, so here washing or washing process is as a dual role and this in fact has this kind of sanitization washing machine usually available in the market. I think more than 1 company is producing such kind of a sanitization washing machine and in this basically during the wash two things are happening, of course we are getting lot of dirt.

Additionally, we can also having an antibacterial effect which is coming from the washing this is achieved by actually having the silver nano particles in their interior surface of the wash of washing machine. This silver nano particles least pilings of silver ions in the wash till per ions have an antibacterial property, which kills the bacteria present in the fabrics. Therefore, now I have a fabric which is not only clean off that, but also clean off bacteria, so this a nice commercial product which is now available in the market wherein well known principles for intensive toxicity of silver ions to bacteria and defect.

That large surface area provided by nano particle can actually help sore lease of silver ions have been put together to produce something very useful and common which can be find on every house. We already seen the example of knitting clothing and we always not knitting clotting because we do not functions in dividing the core we do not want that skills to get into that code which could be harmful for that coat or in come into contact with this skin. The beautiful thing about this that these nano particles which are embedded in these kind of fabric or transparent any useful to guide therefore, they donor alter the look or the texture or the fabric which is basically done by the coating nanoparticles the fabric and even in a common application for this.

Suppose, I was in coffee on to the also made of session material then they of coffee will not penetrate through the cloth flow way and the before this has applications from very specific to application wherein you want the coat to be resistant. It is another kind of very harmful chemicals to very common applications where anyhow want to scolding coffee into a skin. We already seen a nano scale sensor, but the general area of sensors and especially biological sensors nanoscale materials are making serious in roads.

Now, the amount of the material I need to actually make a sensor and number two the amount of material which can be detected by the sensor is very small. Therefore, I can now deduct those concentrations of for instance a very harmful molecule like carbon monoxide though carbon monoxide by itself is not a toxic material, but actually deprived a human system of oxygen. In fact, it prevent bonds with a hemoglobin and therefore, you may get carboxy-hemoglobin instead of ox hemoglobin. Therefore, your blood could be deprived over oxygen which is bad for us suppose I want to deduct carbon monoxide in their atmosphere.

I can use surface nanoparticles which can now have a sensitivity which is much higher than that if I use some conventional deduct or and if this were connected to a complete device. The change in the potential surface potential of the nano particle can be deducted this can be a set of alarm and this alarm can alarm can tell us that the carbon monoxide levels in the atmosphere is as exceeded what you might call a leak which is now can be fatal. Therefore, I can avoid an evacuation procedure or a kind of embroider procedure can be deducted another such example of a important deduction would be acetone in the breath of a patient.

Suppose I see there is a acetone then this could be aa assign of an in pending diabetics and this can be early deduction in a patient. Therefore, I can take lot of preventive accurate measures which actually helps us to before the disease spreads to all extend variant it can no long effectively. So, the area of sensors holds lot of promises where it comes to deduction of gases molecule solution. This typically can be harmful or can be assign for kind for certain kind of diseases or in living being stalked about this little bit that how we can make transparent ceramics.

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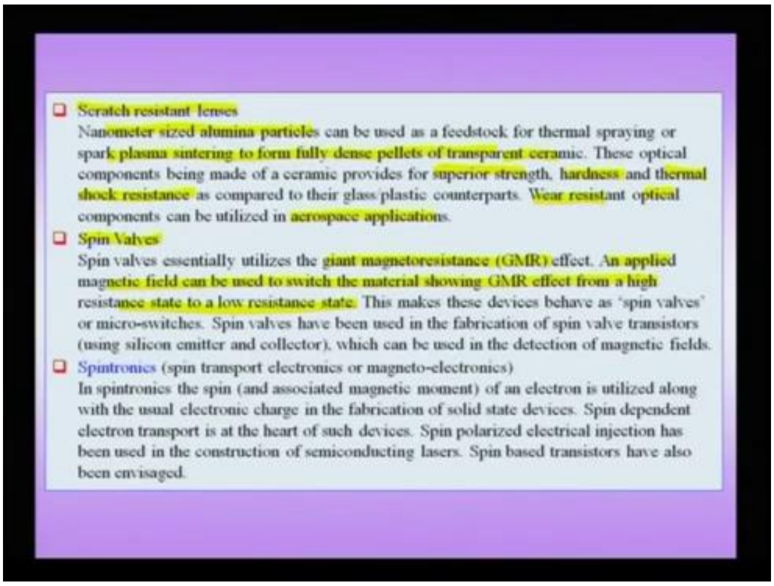

This transparent ceramic can actually put to fantastic views by making scratches, so most I am talking about an aerospace, where in I need lengths which of course you know that in aerospace application. I am talking about space cannot be there is a scratching lengths cannot be easily replaced. Then, I need a kind of length which is where optically transparent and additionally as good hardness and fractalness is so that any kind imperfect outer space during the application cannot destroy and normal glasses easily fracture. Therefore, making a lengths out of normal glass is not a very good idea it comes to outer space applications. Now, we can actually produces transparent aluminums ceramic lenses which is produce by plasma fully dense fell it.

This transparent can use to make a lengths which have superior strength high hardness and good commercials appreciate is also very important outer space if my lenses is in the sun sight or facing the other make a difference could be large. Therefore, I have additional this helps in making a good kind of lens for outer space applications, so in some scratches lenses or in a perfect lens which I would like to co operate in an optical system especially for good applications. Another example is just an extension of the phenomena encounter the phenomena joint magnet to the system.

Using this a set of monetarism, an applied magnetic field using this to switch the material game or effect high resistance to a low resistance, this is what we just seen this very effect of shown also means that the device behaves like a spin ball another words.

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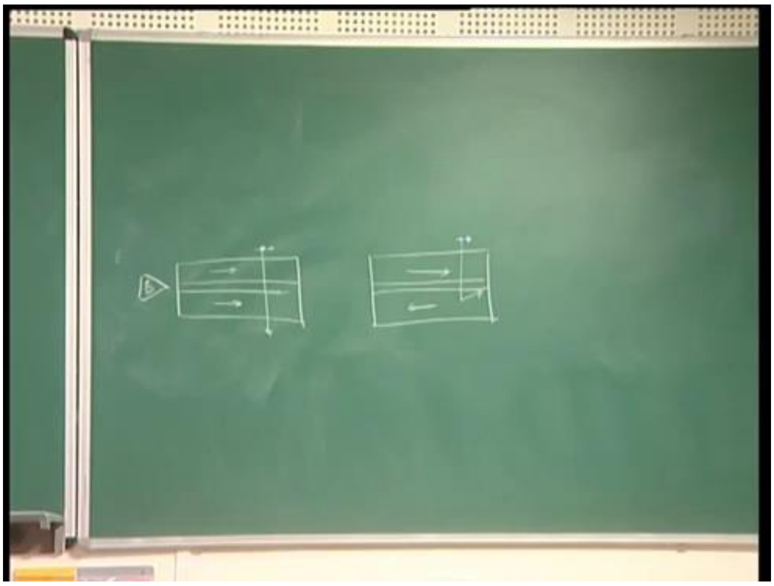

If I have a material multilayer joint monitorial system and i am talking about state where in the two layers of bottom layer ferro magnetically covered. Then, if I have electron spins with this kind of a spin electron, this will pass through suppose I switch on the magnetic field then get into a state which we are drawn before where in my spins are anti ferro magnetically coupled. This is in the presence of magnetic field b and this is in the absence of the field b and this is the state electron will tends to scatter from the second layer which is now opposite spin compared to the spin.

Therefore, I can actively control now and the spin which passes through I can switch on here switch off the passage of the electronic by using the I have the spin dependent scattering. This is done by switching on and switching of the magnetic field, therefore this is effectively spin, certain kinds to go through.

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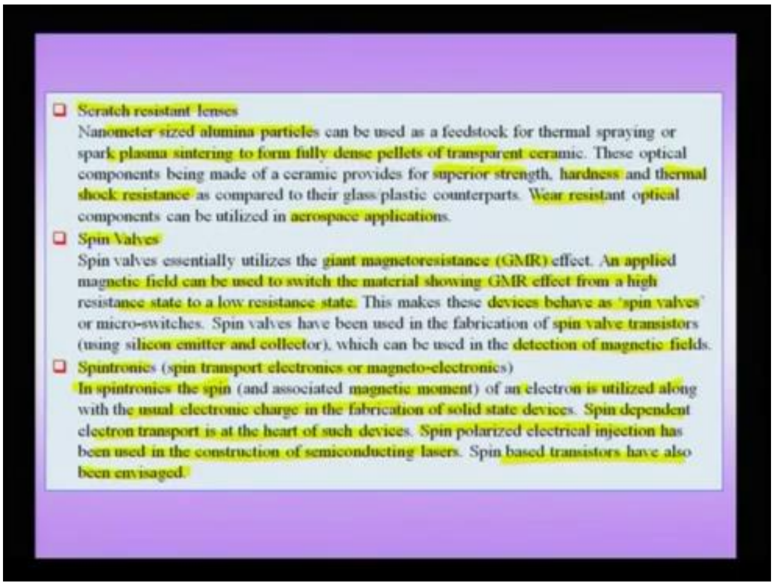

Therefore, now I can use for instance in making what is known as spin valve transistors where in Silicon is used as this can also be used as an enough magnetic fields especially of low magnitude. Therefore, I can I have joint, this can be actually treated like a effectively a spin valve and this spin valve can be used to make nice devices like magnetic field directly. This whole concept of spin valve and joint magnetic part entire area which can be called spintronics, spin transport electronics of magneto electronics now playing with charge of the electron.

Of course, when I am talking about associated magnetic moment which comes from the angle in this, we use the electronics spin of the electron utilize along with the usual chart electron is always in charge in the fabrication of devices spin electron transport. That means now I am controlling my passage of electron lying on the property of spin of course construction of semiconducting these is already formed applications.

Here, use to make a layer which is semi conducting layers spin base transistors also be in the same previous application. Therefore, nano materials and nano structures we see that we not only deal with the charge of an electron. We can actually control the spin of an electron we can make devices specifically deal with the spin of an electron and therefore, we can have an entire new field, which is come up the field of spin electrons.

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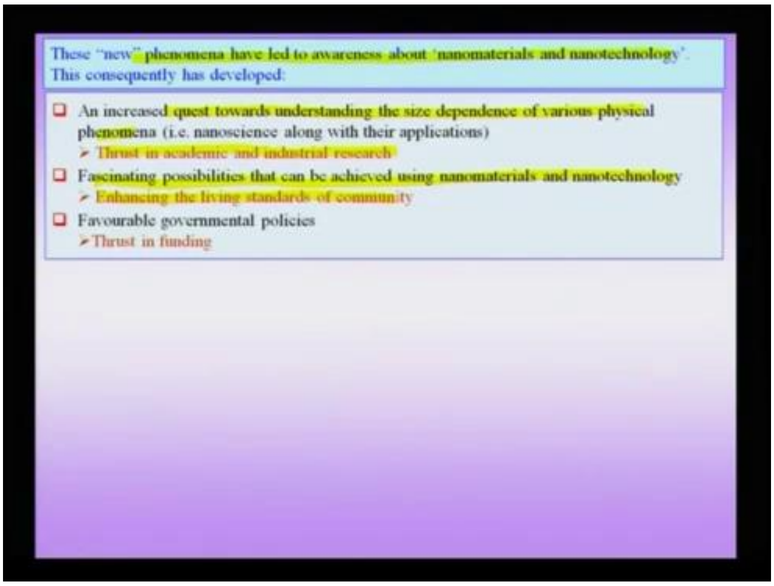

So, there is an overall benefits to these effects and all we will just half of these to actually come, what you might called as an application from policy.