Surface Engineering of Nanomaterials
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Lecture - 10
Applications of Surface Engineering towards Nanomaterials

Hello, today my lecture is depends upon the surface modification techniques which we are going to use for different types of nanomaterials. The thing is that in my last several lectures I have discussed about that why we are doing the surface engineering, what are the methods, how we are going to do the surface engineering. So, now, today I am going to discuss about the surface engineering of different types of nanomaterials for various applications. Though it is very difficult to cover up the whole modifications or maybe the whole area of the surface modifications of the nanoparticles in a stipulated time, but I will try to finish my lecture within this short period, so that I can give a glimpse of different types of nanoparticles modifications to you all.

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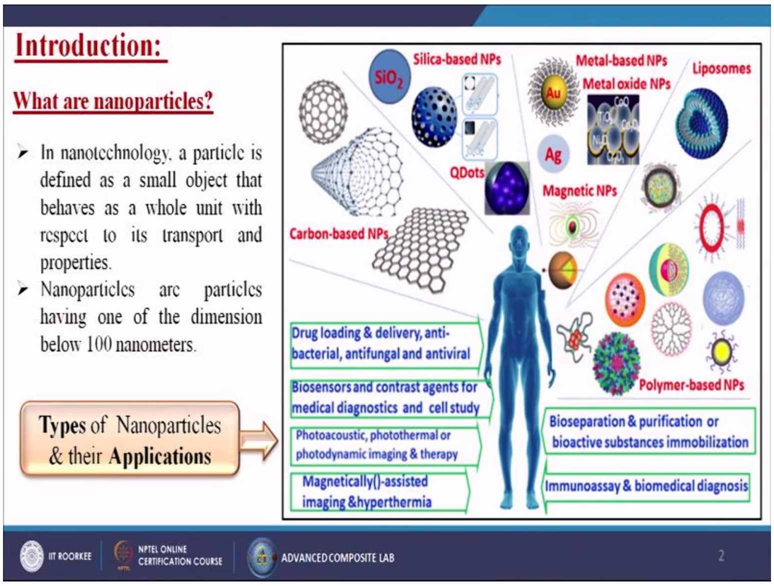

So, first in the introduction part we are going to discuss that what are the nanoparticles. So, as I told already, nowadays we are whatever the materials we are dealing in the environment or may be whatever the materials we are touching and all these things, these all are into the macro size. But when we are talking to the nano, nano is nothing but the 10 to the power minus 9 meter. So, when we are talking about the nano particles that should be below 100 nanometers, so that is the particle which will give you the better properties than the macro itself which will give you the better properties in terms of mechanical properties, thermal properties, chemical properties and thermo mechanical properties, and all other several electrical properties. So, these particles are the simply is that miniatures or may be the small creatures of that these macro materials or may be the macro elements.

What are the nanoparticles? In nanotechnology a particle is defined as a small object that behaves as a whole unit with respect to its transport and properties. So, here a small nano particle is acting as the head of the whole family or rather I can say that whole of the whole macro system. Nanoparticles are particles having one of the dimensions below 100 nanometers. So, right hand inside picture we are going to describe in details in the later subsequent slide, but here I am going to give you a glimpse that what are the nanoparticles or maybe rather what are the types of nanoparticles generally we are doing or maybe we are doing the research in recent days and their applications. So, from this particular figure you can understand that there are several applications of those particular nanoparticles.

If we are talking about the carbon based nanoparticles we are having the fullerene we are having carbon nanotubes and not only that we also know that there are several types of carbon nanotubes it is called single walled carbon nanotube, multi walled carbon nanotubes, double walled carbon nanotube depending upon the how much layer or maybe the thickness are inside the tube. Then we are having the 2-D dimensions shit which is known as the graphene or rather we can call it as a graphene oxide or maybe the reduced graphene oxide. Then we are having the silicon based nanoparticles SIO2, then quantum dots, then we are having that silver dot nano particles generally we are using these materials for the antibacterial applications, some solar cell applications. So, there are several types of things.

Liposomes, we are having some polymer based nanoparticles which we are going to use for the targeted drug delivery or maybe which we are going to use some advanced technology where the macro system cannot work or maybe consisting into that particular environment, but these nanoparticles can work fantabulously.

So, here first we are talking about that drug loading and delivery, antibacterial, antifungal, and antiviral applications where we are using this kind of nanoparticles; biosensors, contrast agents for medical diagnostics and self study; photoacoustic photo thermal or photo dynamic imaging and therapy; magnetically assisted imaging and hypothermia; bioseparations and purifications of bioactive substance and in mobilizations; immunoassay and biomedical diagnosis. But here I have listed a very few there are n number of applications where we can use this kind of nanoparticles.

Next slide we are going to discuss that where you are going to use or maybe rather we can say in this manner that why we are going to modify those nanoparticles. You see each and every time whatever the material we are discovering or maybe whatever the material we are getting that is having certain properties right, but still we are going to make newer material every time, we are making some newer composites, we are making some newer alloys or maybe the blends. So, the nature of the human being to is to try to develop the newer things every time. So, these nanoparticles whatever the nanoparticles we are preparing today, maybe tomorrow it will not give you the result up to that much level. To acquire those results we have to modify those nanoparticles, so that we can get the better result than today itself.

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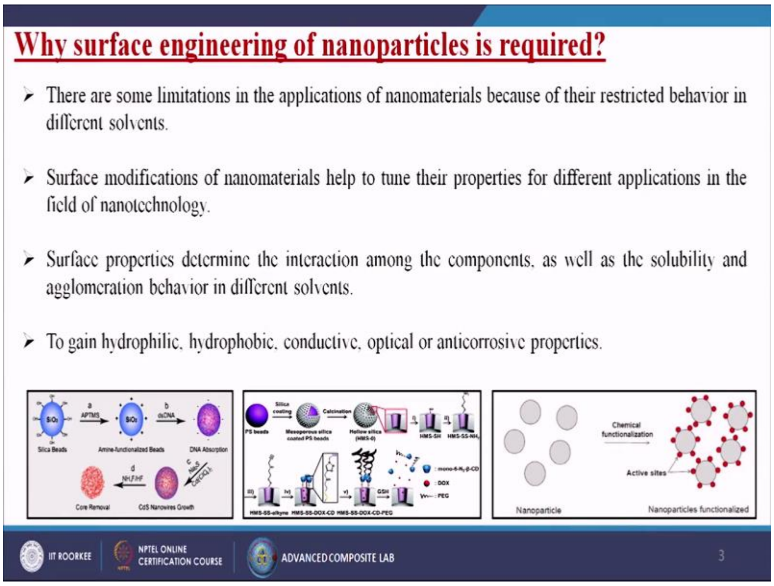

So, there are some limitations in the applications of nanomaterials because of their restricted behavior in the different solvents. Maybe today some nanoparticles is acting into, some or maybe we can make the solutions of the nanoparticles into some solvent, but tomorrow maybe that nanoparticle will fail into some newer solvent. So, for this we have to modify that nanoparticle or maybe we have to modify those solvents which can readily accept these nanoparticles easily. Surface modifications of nanomaterials help to tune their properties for different applications in the field of nanotechnology. Surface properties determine the interaction among the components as well as the solubility and agglomeration behavior in the different solvents. Nowadays when you are talking about the nanoscience, when we are talking about the nanotechnology; that means, we are trying to use certain kind of nanoparticles inside the matrix, right.

So, some people there are two school, generally one school they are calling it is the nanoparticle or maybe nanocomposites and another school they are calling it as a nanoreinforced composites, rather let us tell about the nanoreinforced composites because nanoparticles its very very tiny which we cannot see by our naked eyes, we have to see it by some kind of electron microscopy or maybe some kind of optical microscopy. So, whatever the material we are trying to prepare that material is having a base material and in that we are putting certain kind of nanoparticles over there, so that is why people are telling it as a nanoreinforced composites.

So, when you are talking about the nanoreinforced composites, so these composites are having certain limitations in terms of thermal properties, in terms of electrical properties, in terms of electrical properties or maybe the meccano chemical process or maybe the thermo chemical process. So, when we are talking about the agglomerations the biggest problem of using this kind of nanoparticles is called the agglomerations because these all are the very tiny particles when we are trying to put these materials into some matrix and we are trying to make certain kind of films or maybe certain kind of materials they are making certain kind of clusters, they are jolting each other, so that means the total nanoparticles they are making it groups they are creating a agglomerations in one side, the total matrix it is going to the another side. So, what is there? When we are trying to get certain kind of properties there will be some phase separations because nanoparticle is into the one side and the matrix is into the another side.

So, our main motto as a nanotechnologist, as a material scientist, our main motto is to make those nanoparticles that it should be homogeneously dispersed into the matrix, so that we can achieve the better result in terms of anything.

To gain hydrophilic, hydrophobic, conductive, optical or anticorrosive properties these all are the very few properties are listed over here, there are n number of properties by which by incorporating the nanoparticles we can improve those results. So, here there are certain example, like this that here we are going to make certain kind of core structure of silicon dioxide. So, first initially we are using the silicon dioxide material, then we are using the APTMS, what is APTMS? The full form of that I will come into the subsequent slide or maybe the later. So, here we are trying to make the outer surface of that particular material active, so that I can add certain kind of nanoparticles or maybe certain kind of other materials at the surface of that particular material, so that I can make it barrier layer or maybe the coating, so that that material will be active or maybe it will make certain kind of coatings, so that it will not affect by the environment.

Then in this particular case also we are using certain kind of polystyrene bits, here also we are trying to modify this one by silica generally these all kinds of materials we are trying to use for the biomedical applications. So, here we are using certain kind of nanoparticles, we are doing certain kind of chemical functionalisation, so that we are preparing certain kind of active sites just outer surface of that nanoparticle, so that, that active sites can easily absorb the other materials or maybe the other molecules, so that it will not be detached or maybe it will give you the better properties.

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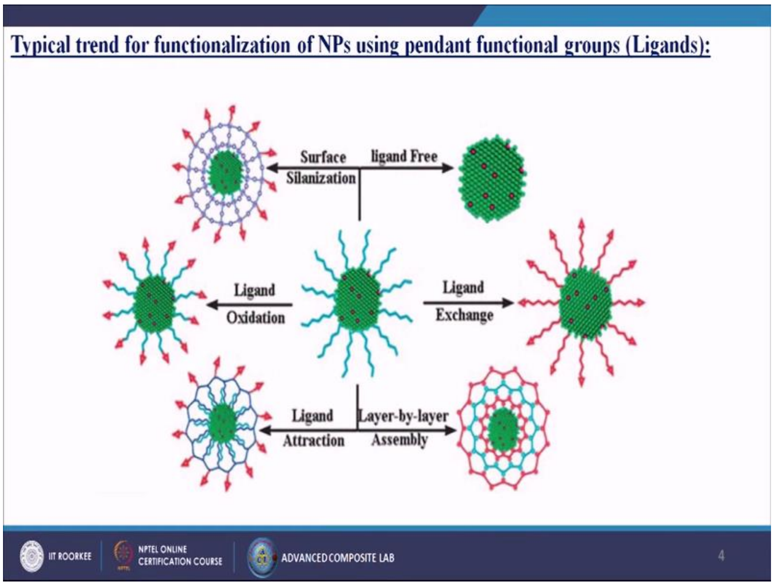

Here also some typical trained for functionalisation of nanoparticles using pendent functional groups. So, generally in a chemistry terms or may be the chemical engineering terms we are calling pendent functional groups as a Ligands . So, here we are trying to make the material. So, this was our initial material. So, we are trying to do some kind of surface modifications on top of that. So, layer by layer technique we are trying to modify those materials. Here in the right side you can see there is some ligand free; that means, the material whatever we have deposited onto that it has gone into the interstitial side, but there is no active site available over here. But when you are talking about these materials we are making so many layers active layers onto that particular material, so that, that material can make a protections against the environment or maybe it can work with some other materials easily because it depends upon the whatever the materials you are putting as a layer on top of that material.

In the next slide we are going to discuss that there are several applications where we are going to use this kind of surface modified nanomaterials.

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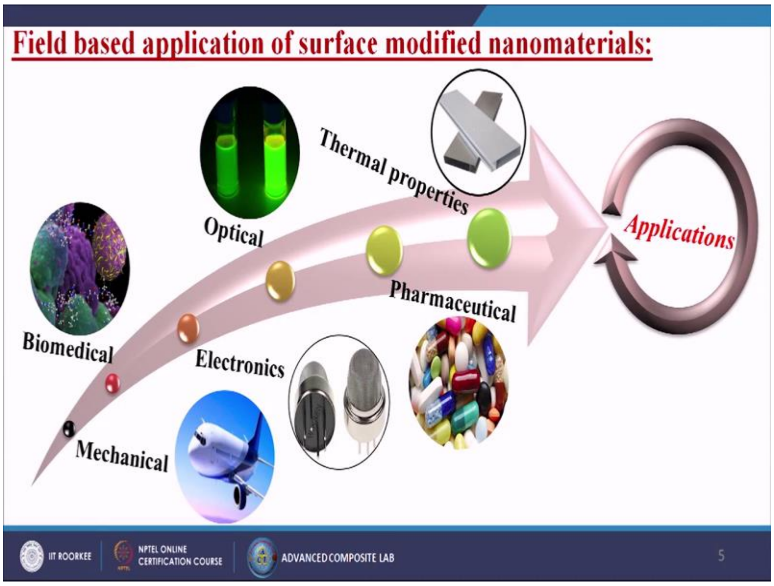

I have given so many examples till now. So, rather we are trying to modify these nanomaterials in terms of mechanical means for the aerospace applications or maybe those missile applications or maybe that rocket applications. So, in this particular case what we are trying to do? We are trying to modify that silicon carbide, nano alumina and then we are using those materials nanoparticles into some aluminum matrix, then we are making the outer surface of that any aeroplanes or maybe that automotive parts something like that. And nowadays we are using Kevlar Fiber it is a one kind of polymer which is the toughest till today. So, what about the polymer? We are going to use that polymer, we are trying to make the outer surface of that aeroplane body, so that it can easily within a half an hour from room temperature or maybe the from environment and temperature it can go up to the minus 50 or 60 degree centigrade when it is flying above 30000 feet or 45000 feet from the ground itself.

Next we are talking about the biomedical applications; we are talking about the targeted drug delivery, we are talking about the bone replacement, we are talking about the stained, we are talking about the nervous systems. So, there are n numbers of applications where we are trying to use these kinds of modified nanofillers. Then we are talking about the electronics, we are making certain kind of sensors, actuators materials which can easily detect, some kind of gaseous toxic gases or maybe some kind of mixed gases or maybe humidity of that particular area or maybe the environment and then we are talking about the optical, so these materials can be act as a some kind of florescent materials which can give you the better optical properties, then we are talking about the pharmaceuticals like drugs some kind of biomedical applications, then we are talking about the thermal properties that material can work in to the higher temperature side, but still it will not melt. So, these all are the several applications where we are using this kind of surface modified nanoparticles. Now I am trying to give you certain kind of examples that where we are going to use this kind of nanoparticles.

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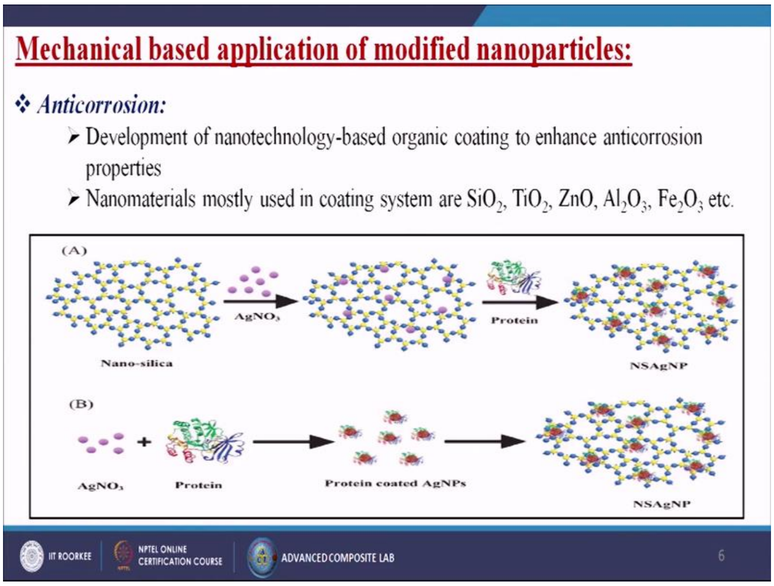

First one is called the mechanical based applications or modified nanoparticles. So, in this particular figure there are two methods by which we are trying to make the modifications of the nanoparticles, how fast is called the anticorrosion properties. So, you know that when you are making certain kind of material or main thinking or maybe the main motto is that how to save these materials from the environmental attack, from the moisture, from any kind of oxide formations or maybe the nitride formations or maybe the sulfite formations. So, when you are talking about the anticorrosion materials means what about the material I am going to prepare when I will keep that material into some environment open environment, it will not react with the environment, it will not react with the moisture, it will not react with the water, it will not react with any other chemical substances, so that its properties will remain same for a longer time.

So, development of nanotechnology best organic coatings to enhance anticorrosion properties, so what we can do? Either we can make a certain type of coatings on our prepared materials, so that it will not directly come into the contact with the environment or maybe we are trying to make certain kind of nanoparticles rather modified nanoparticles we can incorporate those nanoparticles into the matrix itself, so that when there will be some attack these nanoparticles will make a self barrier inside the material, so that it will not react with the environment itself.

So, here generally we are using two types of methods - one is called the nanosilica first we are putting the AgNO 3 silver nitrate over there, then this Ag is going inside the nanosilica particles like some kind of substitutional doping, then we are putting certain kind of protein over there then they are making a chain that means, that protein is giving a coating onto the silver nitrate. And in the second method before going to put that silver nitrate into the polymers or maybe the silica first we are trying to modify this silver nitrate with the protein molecules, then the protein coated AgNPs we are getting, then this one we are incorporating into the nanosilica. So, there are two methods, but ultimately our result will be same, but it depends upon the expense means what is the costly methods and how easily we can get these materials.

Next we are going to make certain kind of material which will be transparent and which will be wear resistant because in our first couple of lectures we have discussed several times regarding the wear, regarding the abrasions, so that is the one kind of inspiration that for why we are going to do the surface engineering of that particular nanoparticles.

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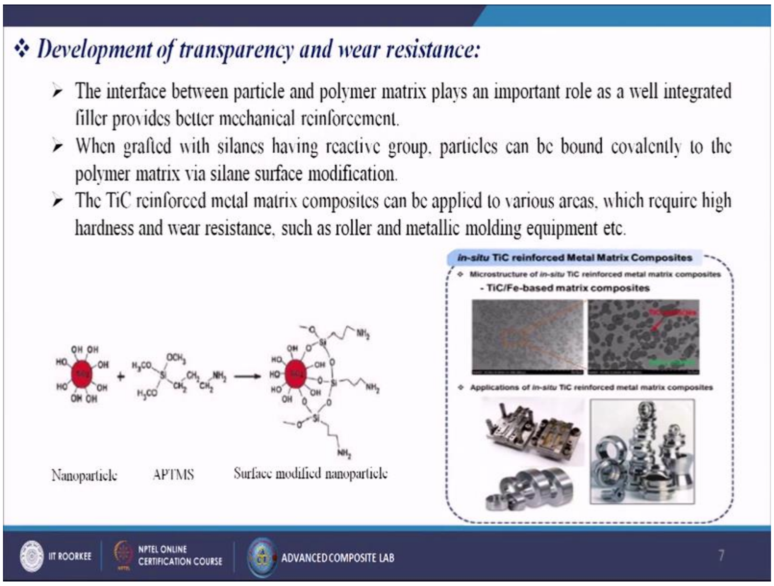

So, when we are talking about these kinds of materials the interface between particles and polymer matrix plays an important role as well integrated filler provides better mechanical reinforcement. The thing is that whatever the nanoparticles I am going to put inside the material if there will be a bonding in between those nanoparticles and the polymer matrix or maybe the metal matrix or maybe the rather any kind of matrix will be good. So, what will happen? While doing any kind of mechanical operations like, if you want to put certain kind of load, if you want to put certain kind of pressure or maybe you want to rub those materials simply that nanoparticle will not detach from the polymer matrix itself there will be certain kind of bonding. So, by doing these kinds of modifications on to the nanofiller, we can save those materials from the wear or maybe the abrasion.

Then when grafted with silancs having rated group particles can be bound covalently to the polymer matrix by silent surface modifications. So, from this particular case you can understand that we are having that nanoparticles then from outside we are making some kind of silent groups, so that that silent groups easily can attach with the polymer, so that there will be a quick bonding or maybe the strong bonding in between the nanoparticles and in between the polymers, so that it cannot be easily detachable. So, right hand side you can see certain kind of (Refer Time: 17:35) image that titanium carbide iron based metric composites, generally we are using this kind of materials for the some kind of automotive parts or maybe some kind of engine parts or maybe bearings or maybe some kind of mechanical fasteners like this.

Next we are going to use this kind of material for the biomedical applications. So, what are the requirements? Requirements for Solubilization and Bioconjugation of Nanoparticles:

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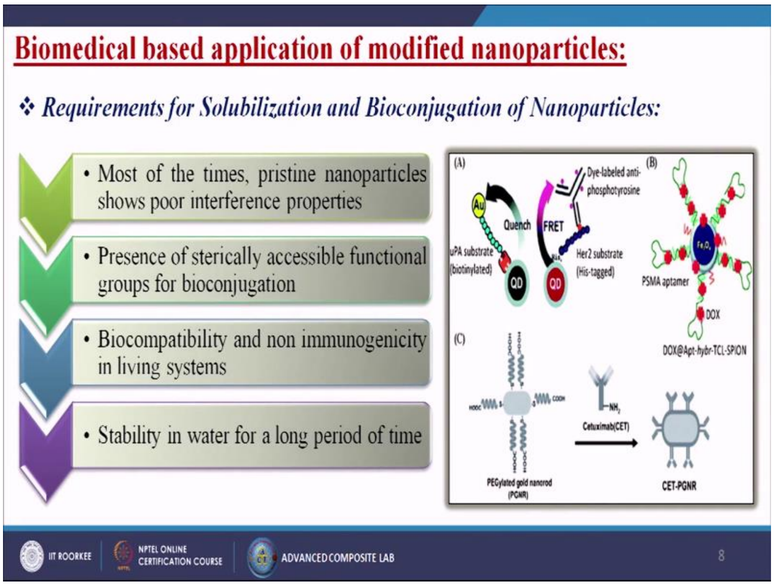

So, most of the times pristine nanoparticles shows poor interference properties, presence of spterically accessible functional groups for bioconjugations, biocompatibility and non immunogenicity in living systems, stability in water for a long period of time. The biggest problem for these nanoparticles while you are using these nanoparticles for the biomedical application is called the toxicity there are n number of nanoparticles are available there, but we cannot use all those nanoparticles for the biomedical applications because we do not know if we are going to use this kind of nanoparticles whether our body will accept those nanoparticles or not. So, before going to do this kind of research, before going to do this kind of application we have to go n number of research, n number of times we have to do that whether that body can accept these materials or not.

So, here we are using certain kind of quantum dots. So, quantum dots are generally made by certain kind of carbon materials or maybe the carbonaceous materials. So, first we have to take in care in our mind that these quantum dots well it is going inside the body maybe it can create certain kind of toxicity or maybe our body can react with these kind of materials, so that rather to cure ourselves we can put ourselves into some danger. So, when you are talking about this quantum dots we are putting certain kind of silver particles over there, but its luminescence property is going down. But rather when we are going to put certain kind of dye labeled anti phosphor tyrosine, so that time is quantum level or maybe the fluorescence property is getting increased.

So, we can use this kind of materials for the biomedical applications in that particular figure also we are using some kind of polyethylene, glycated gold nanorod. So, here we are using certain kind of amine group, so that now the final material will be CET-PGNR which can easily go inside the human body and it can do any kind of biomedical applications.

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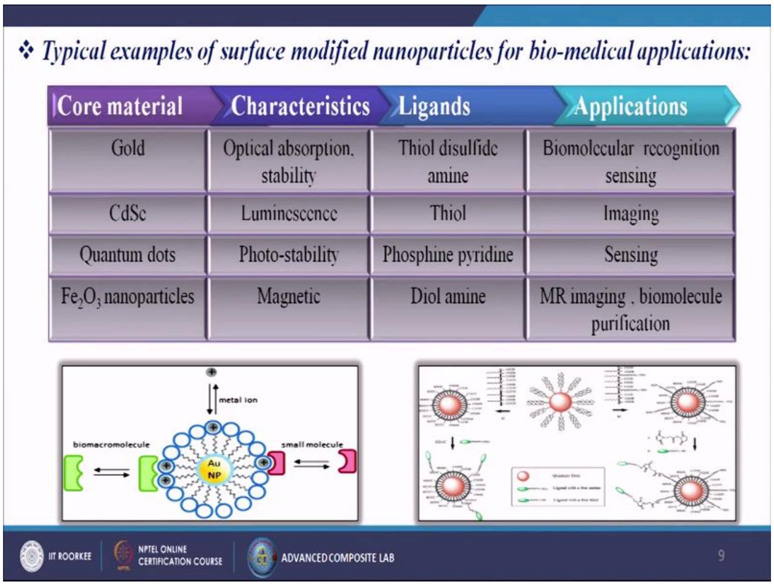

So, here we are trying to give certain kind of examples of surface modifying nanofillers or maybe the nanoparticles for biomedical applications. So, left hand side we are discussing about the core materials that what are the materials we are going to use as best material. So, here we are using gold Ag, then cadmium selenium, quantum dots, iron oxide nanoparticles. What are the characteristics? Gold can be used for the optical absorption stability CdSc can be used for the luminescence property; quantum dots can be photo stability and the iron oxide nanoparticles for the magnetic applications. But what are the ligands or maybe whatever the functional groups we are attaching with them it is called the thiol disulfide amine why we are going to use because the application will be biomolecular recognition sensing. So, directly we cannot use this gold for this particular purpose. So, we have to do some kind of modifications of these materials then only we can get this kind of applications over there. So, for CdSc we are using the modification by thiol then it can be used for the imaging purpose quantum dots can be used by sensing purpose where we are using certain kind of phosphine pyridine, iron oxide nanoparticles we are putting diol amine for a more imaging biomolecule purifications. So, here also so many examples we are giving regarding the biomedical applications or maybe the meccano chemical applications.

So, here we are using the gold nanoparticle then we are putting certain kind of bio macromolecules over there, then we are releasing some kind of metal ion, then again we are using certain kind of short molecules, thing is that it is like a recipe. So, here suppose

I am trying to add 4 to 5 materials if some materials is not good for then we have to take out that material and we have to put certain kind of substitute for that material to enhance the properties of that particular nanoparticle. So, it is depending upon our requirement, depending upon our choice we can modify that nanoparticles for several times for the several applications.

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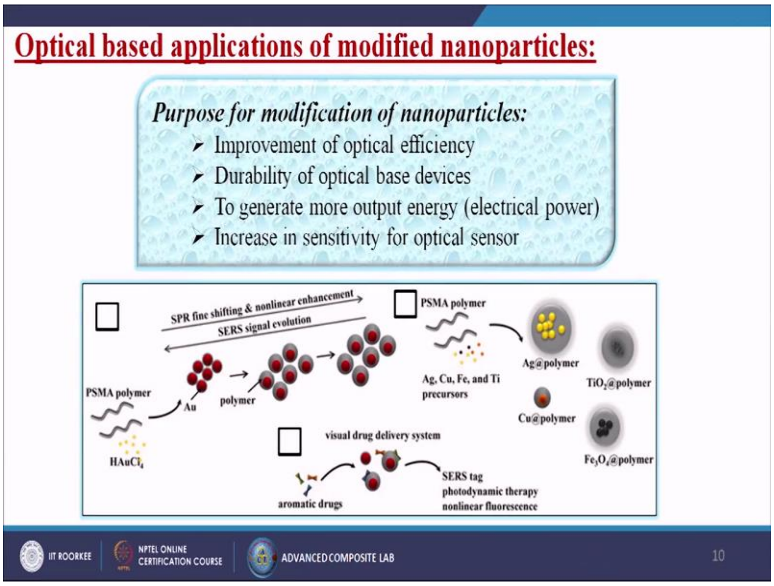

Next we are going to use this kind of nanoparticles for the optical based applications, what are the purpose? Improvement of optical efficiency, durability of optical based devices, to generate more output energy electrical power, increase in sensitivity for optical sensors. Nowadays you can heard about the solar cells people are using for the dye sensitized solar cells, peroxide solar cells, then people are using for the super capacitor materials, then flowable super capacitor materials. So, there is n number of applications people are doing on these kinds of semiconductor materials or maybe the solar cells by using these kinds of nanoparticles.

So, what we are doing? We are trying to modify those nanoparticles into the different way either we are wrapping that nanoparticles into some other materials or maybe we are doing the coating of that particular materials by some polymers then we are using those materials for the matrix, so that attachment will be good and ultimately the efficiency of that particular solar cell can be enhanced or maybe that super capacitor the charge distress capacity will be announced or maybe we can use those materials for the hydrogen storage systems, we can use those materials for some kind of electronic chips or maybe diodes or maybe any kind of materials.

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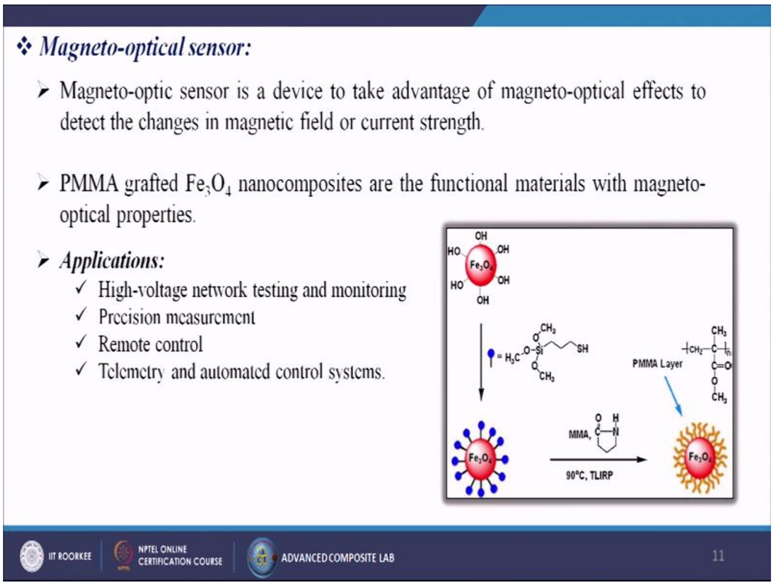

So, next we can use those materials for the magneto-optical sensor. So, magneto-optic sensor is a device to take advantage of magneto-optical effects to detect the change in magnetic field or current strength. Not only that by doing these kinds of modifications I am having some material which is insulated based I can make that material in a conductive based. So, simple I can add certain kind of conducting nanoparticles inside that material, so that inside it can make certain kind of chains or bonds, so that it can easily pass the current through it.

So, PMMA grafted polymer, poly, methyl methyl, acrylate grafted, ferric oxide, nanocomposites are the functional materials with magnetic optical properties. So, here you can see that PMMA it is a polymer, it does not have any magnetic properties over there and it is a biodegradable polymer generally these materials we are using for making our lance or maybe that specs or maybe any kind of biomedical implants. So, these materials we are giving a grafting on magnetite nanocomposites and it is giving super magnetic optical properties, what are the applications? High-voltage network testing and monitoring, precision measurement, remote control, telemetry and automated control system. So, this material can be used for any kind of sophisticated instruments, any kind of the properties of these materials is fantastic, its repeatability and a response is fantastic. So, these are not the different types of materials by which we are put, here this is the example. So, we are having the magnetite oxide - first in the outside we are removing this hydroxyl group then we are using these materials with some MMA and 90 degree centigrade with TLIRP then we are giving a coating of PMMA layer on to top of that, so that that material can be used for the magnet optical purposes.

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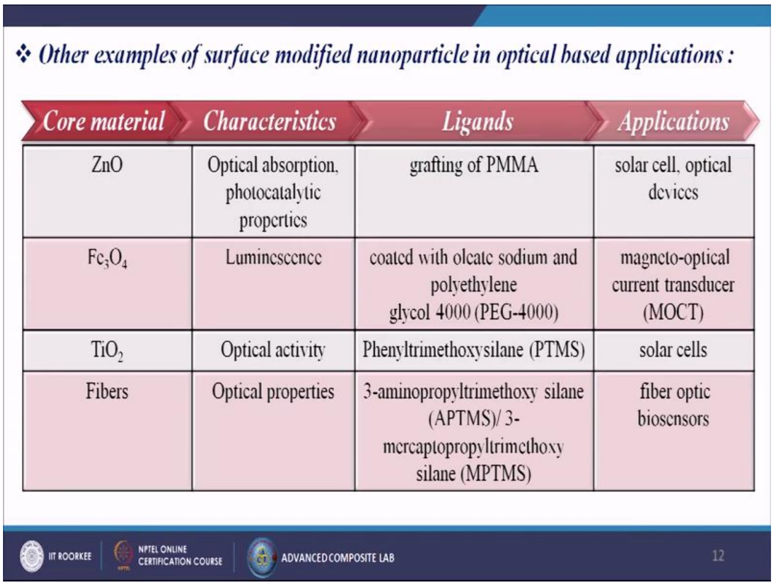

Core material	Characteristics	Ligands	Applications
ZnO	Optical absorption, photocatalytic properties	grafting of PMMA	solar cell, optical devices
Fe_3O_4	Luminescence	coated with oleate sodium and polyethylene glycol 4000 (PEG-4000)	magneto-optical current transducer (MOCT)
TiO_2	Optical activity	Phenyltrimethoxysilane (PTMS)	solar cells
Fibers	Optical properties	3-aminopropyltrimethoxy silane (APTMS)/ 3-mercaptopropyltrimethoxy silane (MPTMS)	fiber optic biosensors

Next other examples of surface modified nanoparticle in optical based applications are - we are using zinc oxide, we are using ferric oxide, we are using titanium dioxide, we are using certain kind of fibers means basically it is the fibers is either may be the natural fibers or may be any kind of polymer based fibers. So, here we are using those materials for optical absorption for maybe the photo catalytic properties, luminescence, optical activity, optical properties. What is the ligands we are going to use: Grafting of PMMA, coated with oleate sodium and polyethylene glycol 400 PEG, 4000 sorry its glycol 4000 that is known as the PEG 4000, then PTMS then APTMS 3 - aminopropyltrimethoxy silane or maybe 3 marcaptopropyltrimethoxy silane MPTMS.

So, these all are the different types of functional groups whatever we are trying to put onto our nanoparticles and then we are applications in solar cells then magneto-optical current transducers solar cells, then fiber optic biosensors. Here I have listed a very few only the four, but there are n number of materials, n number of ligands can be available by which you can modify those materials as per your choice, as per your requirements and you can use those modified nanoparticles for several applications.

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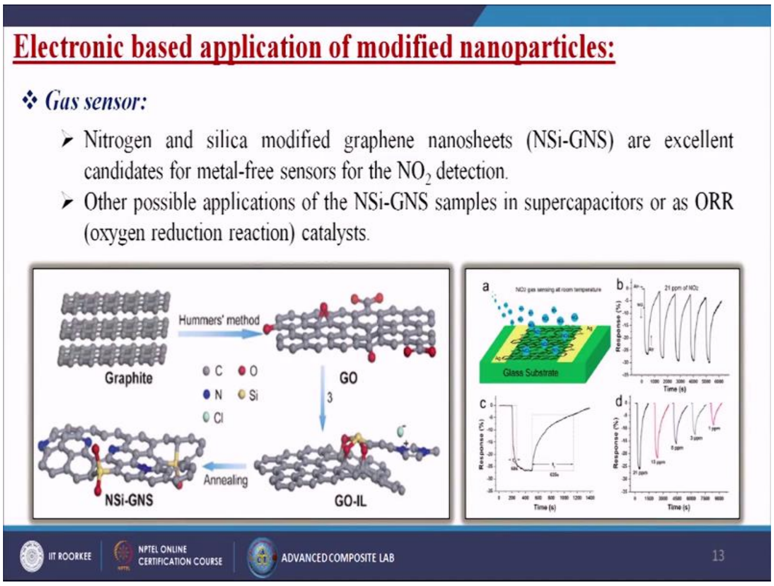

Next we are using this kind of materials for some gas sensors, some electronic based applications of the modified nanoparticles, gas sensors. So, I will give you a small example, few days back or maybe few years back you had certain kind of news that in naval that INS vikramaditya and INS is another one I forgot that name. So, those have got some attack some hydrogen attack inside it. So, when the crew went over there they trapped hydrogen gas over there, so one or two crew died. So, these all are the different phenomena.

So, basically when we are trying to do this kind of sensors, the basically when our submarines is going inside the sea water there are several types of creatures or maybe the animals who are exerting the carbon dioxide gas or maybe any kind of toxic gases. So, before reaching over there if from outside from the safe zone we can detect those gases trapped gases, then easily we can save our life’s we can save our crews. So, people are trying to use this kind of materials for the gas sensor applications basically for the toxic gases like carbon dioxide, nitrogen dioxide, N 2 nitrous oxide, then mixing up those gases. So, there are n numbers of gases which we can detect by applying this kind of modified nanoparticles. So, nitrogen and silica modified graphene nanosheets are excellent candidates for metal free sensors for the nitrogen dioxide detections.

Other possible applications of the NSi-GNS samples in super capacitor or as ORR oxygen reduction reaction catalyst it does not means that what about the nanoparticles we are modifying the applications is only one, that application are various that materials can be used for the several applications. We can use those materials for the sensor, we can use for this materials for the energy harvesting applications or maybe the energy storage applications, it depends upon that whether that material is capable enough to give that particular properties or not.

Next we are using some kind of metal oxide semiconductor field effect transistors generally for the electronic purpose we are using this - MOSFETs. So, as I told already we are using some kind of APTMS.

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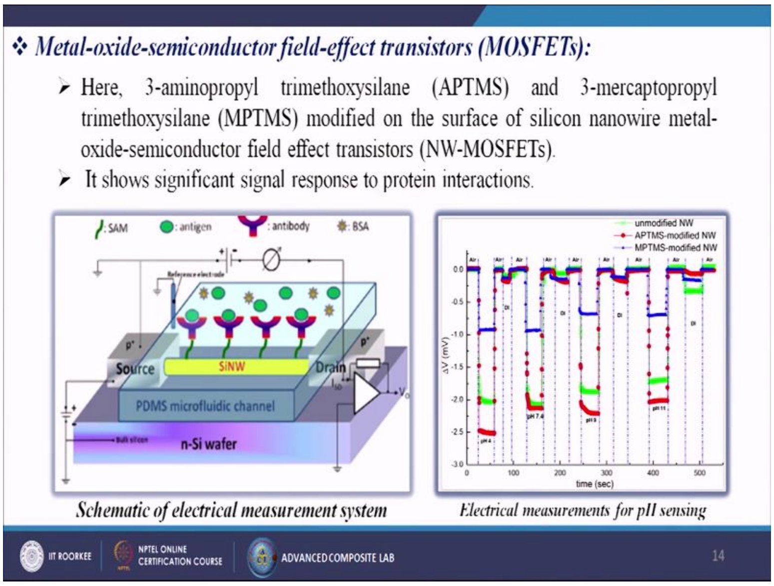

So, 3-aminopropyl trimethoxysilane and 3-mercaptopyl trimethoxyssilane MPTMS, these all are the two materials by which we can modify our nanoparticles. So, from the right hand side figure you can understand that the green color is giving the unmodified nanoparticles and then metal oxides nanowire metal oxides and then right color is giving the modified it by the APTMS and the blue color it is giving with the modified by MPTMS.

So, here we are trying to distinguish that which one is giving you the best results. So, and then what depending upon the properties, depending upon the characteristics we will choose the best one and the left hand side also you can see that how layer by layer techniques we are going to modify this kind of MOSFETs system. So, here we are having that silicon nanowire and we are trying to modify this silicon nanowire by APTMS and the MPTMS and right hand side it is showing the results; that means, the response curve of that particular sensor.

Next the other applications are these modified nanoparticles and future prospectus generally we can use this kind of modified nanofillers for the humidity sensor applications, where we can use these materials for making some thin film and by which we can detect the humidity percentage into any environment.

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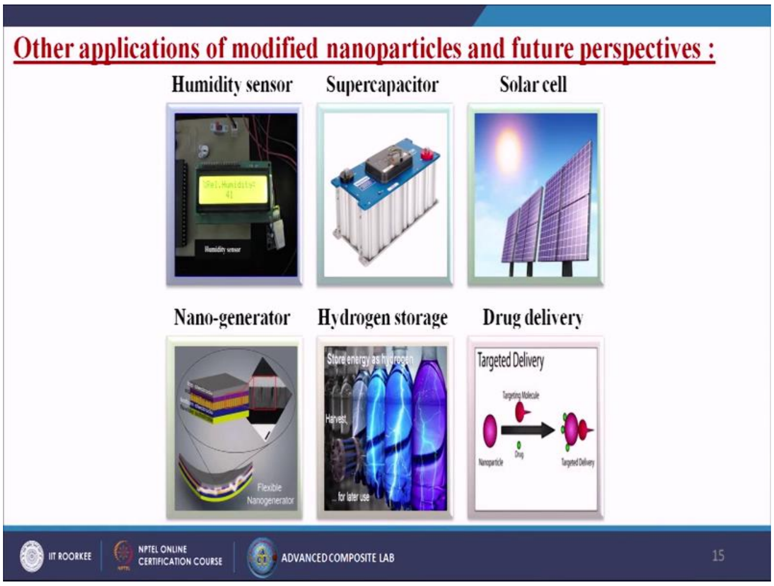

Then we can use this kind of material for the supercapacitor applications or maybe rather I can say it for the energy storage application. So, we can use this kind of materials for the lithium and battery which is nowadays a hot topic among the researchers, we can use certain kind of proton conductivity membrane, we can use these kind of materials for the lithium and battery, then we can use certain kind of solar cells people are using the peroxide materials, dye synthesized solar cells. So, there are n number of applications by which we can increase the efficiency of that particular solar cells, we can use the materials for the nanogenerator, it is nothing but it is a simple thing that by pressing it that it will give you the current. So, you can use certain kind of carbonaceous materials.

So, without having any piezoelectric crystal that is the beauty of this research is that without having any kind of piezoelectric crystals we can use.

So, for, worth mentioning that one of my scholar she now working on this and we have achieved some good results. Now these all are the topics by which actually we are working in our labs and we are getting some fantabulous results by using this kind of nanoparticles or maybe the modifier versions of these nanoparticles. We are working on some hydrogen storage, we are using that targeted drug delivery, so that directly I can use the medicine that which can directly go to that particular affected zone not it can go into some means good zone means where there is no disease, so that there will not be any side effect. So, from outside we can easily detect those materials. So, these all are the various topics nowadays whatever we are working in IIT, Roorkee in advanced composite lab. So, in summary I can tell you that nanomaterials and modified nanomaterials shows a promising technology in various applications.

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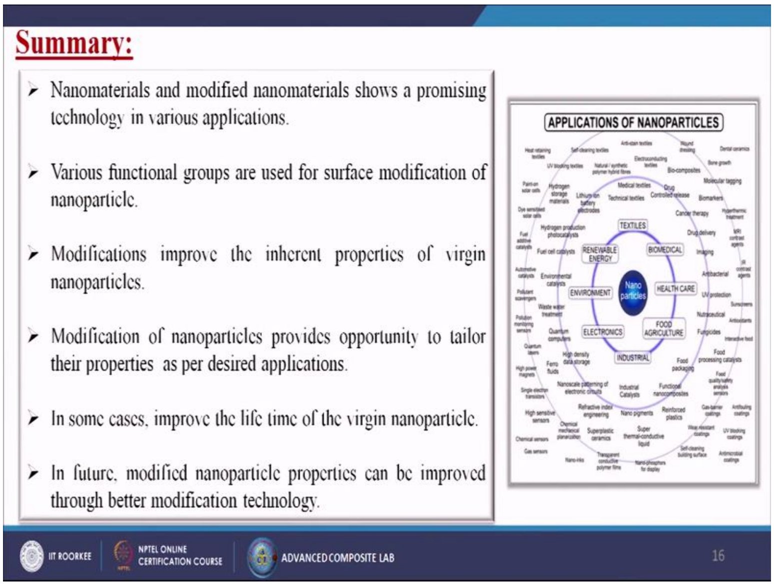

Various functional groups are used for surface modification of nanoparticles, modification improves the inherent properties of virgin nanoparticles, modification of nanoparticles provides opportunity to tailor their properties as per desired applications, in some cases improve the lifetime of virgin nanoparticle, in future modified nanoparticle properties can be improved through better modification technology.

So, through my all lecture I have said that it depend upon our requirement that which property we are going to need, then depending upon our need we have to modify those nanoparticles, we have to use those nanoparticles. Not only that, we can use those nanoparticles for several applications depending upon requirement whether I need the best electrical properties, whether I need the best mechanical properties, whether I need the best thermal properties or maybe the mixing of those properties and whether that material will be cheap or it will be expensive whether these will be lightweight or not and not only that it should be anti corrosives, it should be anti oxidant, it should not react with the our body or maybe the our skin or maybe the our blood.

So, there are n numbers of applications depending upon our requirement we can do these kinds of modifications of these nanoparticles and right hand side it is a small one that applications of the nanoparticles, you can see that in the blue side the middle one is called the nanoparticles it is surrounding by textiles biomedical, healthcare, food agriculture, industrial, electronics, environment, renewable energy, then these all are also divided into several parts like drug delivery imaging antibacterial, UV protection, food packaging, then high density data storage.

So, from this particular chart you can understand that they are on more than 100 applications has been listed over there, but still again I am telling these all applications are very very few because now our research area is expanding, our way of thinking is expanding we are trying to get newer more materials we are trying to modify our materials, we are trying to make our modern material more thin and less weight, we are trying to enhance our properties material properties. So, anywhere we can use this kind of nanoparticles, only that you have to see that whether these nanoparticles can be suited for that particular applications or not.

Thank you.