Nano Structured Materials-Synthesis, Properties, Self Assembly and Applications

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Module - 3
Lecture - 26
Core Shell Nanostructure – III

Welcome to this course of nanostructured materials synthesis, properties, self assembly and applications. Today we are going through lecture number twelve of module three, and this is the third lecture of the series of core shell nanostructures, and today we will do some applications of core shell nanostructures.

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So, there are many types of applications of core shell nanostructures depending on what the core is and what the shell is. For example, you can have a magnetic core and a non magnetic shell or a ferromagnetic core or a anti ferromagnetic shell or diamagnetic core and a magnetic shell this is with magnetism.

Similarly, you can have a optical materials as core covered with the shell with the different optical property like a different band gap and you can have core shell materials which can carry drugs to be used for drug delivery. So, core shell nanostructures have applications in a wide variety of technologies which are going to be useful in coming years to a large extent.

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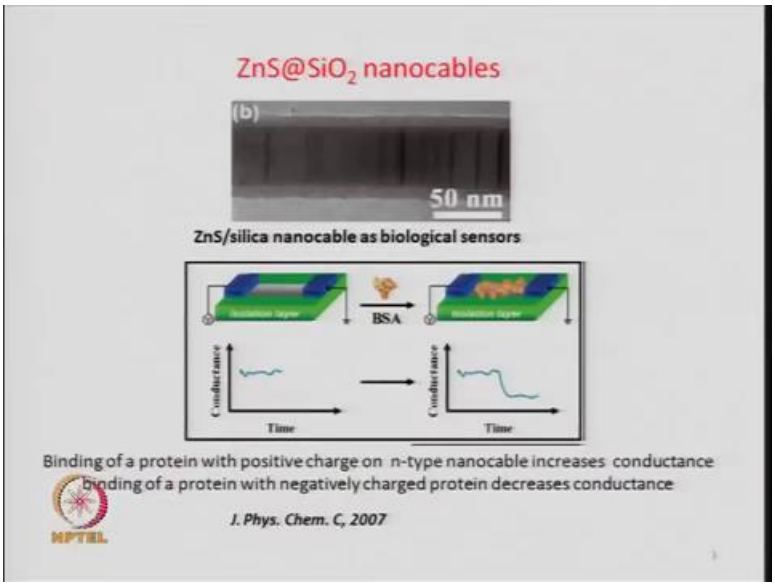

So, the first example that we can discuss is a zinc sulfide core on with the shell of silica and the core shell structure is not spherical, but it is in the form of a thick wire or we can call them nano cables. So, inside this dark part is the core material we are calling which is zinc sulphide and on top of that, you have silica and this combination of zinc sulphide and silica core shell nanostructures can be used as sensors for finding out a particular biological molecule. So, these nano cables can be used as biological sensors, so here kind of a device is shown, where you have the core shell nanostructure on top like this.

There are two electrodes and you can measure the voltage across this, now when there is a molecule like the protein molecule here it is a molecule BSA. Now, this BSA molecule if it is on top of this nano cable, where the surface is of silica, so if this is having a some charge, then the nano cable with silica on the shell normally has a negative charge.

So, a protein which has a positive charge will sit on it easily because this shell has got a negative charge that is the property of silica surfaces. Since, the protein has a positive charge, this protein here is bovine serum albumin that is from the blood of is a protein from the blood of the bovine like cow and this protein has a positive charge and hence will be a stabilize on the surface of the nano cable. Now, when that happens then the conductance changes, so here you see before the protein was attached to the nano cable the conductance is somewhere here and it remains more or less constant with time.

However, when the protein is on top of the silica surface of this nano cable, then the conductance falls so this signal of the drop in conductance will give you a sense of the biological molecule. So, such nano cables can be used to sense biological molecules here a particular case where the charge of the biomolecule is of importance because that is bringing about a change in the conductance. So, what one is measuring is the conductance and this fall in conductance can be quantified and accordingly you can tell how much of the protein is sitting on the surface, so this is an example of a core shell structure as a biological sensor.

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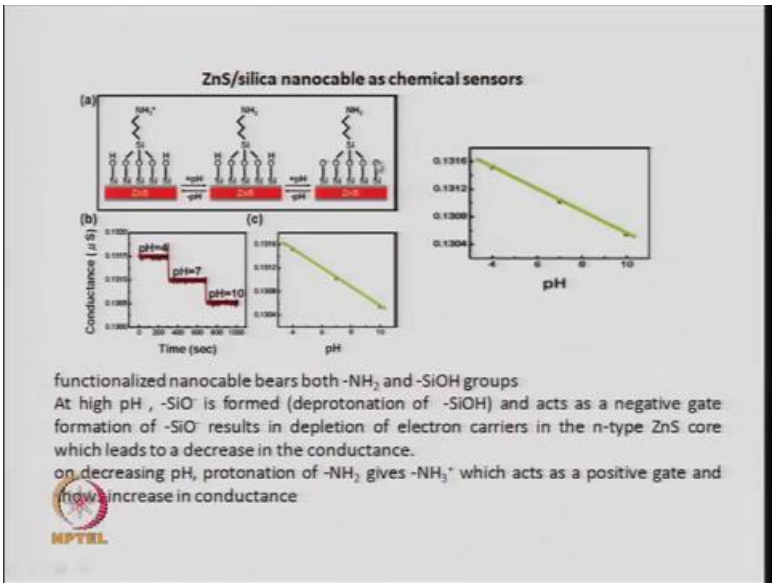

Now, this is another example of zinc sulphate silica nano cable as a chemical sensor, so you have this zinc sulfide core on top, you have this silica surface its silicon and oxygen bonds and on top of this, you have a functionalised molecule with an ammonium iron. So, here it is protonated amine and at a different pH when you raise the pH, this proton will be lost and it will become simple NH 2 group. You have got these kind of OH groups at some of this silanol groups which are in the OH form in the hydroxylated form.

Now, if you increase further pH, so you increase a pH and you have this amine group instead of the protonated group at further high pH even this protons from the OH groups will be lost. So, in the first step these protons will be lost in the second step at higher pH the OH protons will be lost and that you can see in the conductance. So, when you are

having this configuration, the conductance is somewhere some 0.13 micro cements at around pH 4 and it is more or less constant.

When you increase to pH 7, then this proton has been lost and the conductance falls and then it continues like that till again you change the pH to higher pH. Now, you are at pH ten the conductance falls further because even the OH groups have been the protons have gone away. So, you can plot as a function of pH a variation in the conductance depending on the studies, so functionalised nano cables. So, you have functionalised this core shell structure of zinc sulfide and silica and you have these kind of Si O minus groups at higher pH and NH 2 groups are having NH 3 plus.

So, this kind of variation in pH is controlling the conductance and it is behaving like a gate, so this is well known in devices semiconducting devices where one controls the current flow through a particular voltage which is called the gate voltage. Here, you are doing this by varying the pH of the system, you can make the system act like a gate here, it is acting like a positive gate on decreasing pH and a negative gate on increasing pH. That means when you increase pH the conductance is decreasing that means charge carriers are less and when you decrease pH, there are more charge carriers.

So, the conductance goes off so this is another example of a nano cable, a core shell nano cable, which is acting as a sensor and here it is a chemical sensor because it is identifying the variation in the concentration of protons it is a chemical object. In the previous example, there was a biological molecule, which was being sensed by the core shell nano cable and then it was a biological sensor, here it is acting as a chemical sensor.

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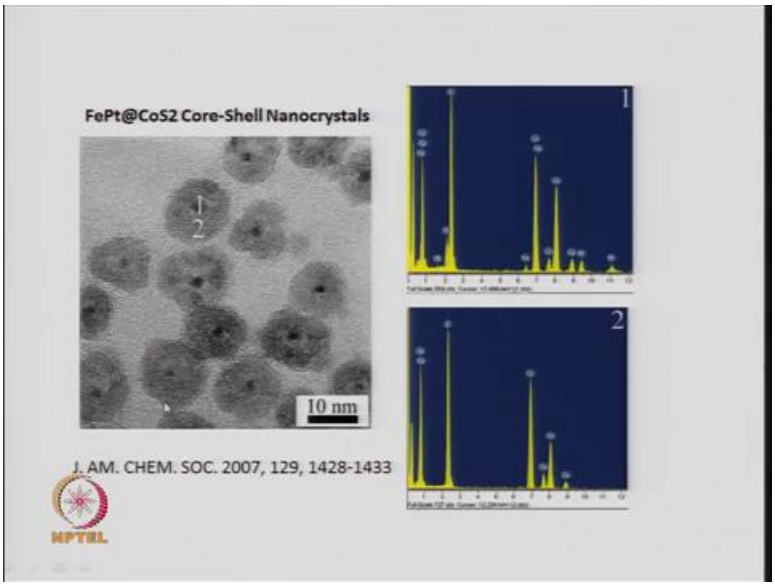

Now, this is another example of core shell structure, where now it is an alloy particle forms the core. So, this is a transmission electron micrograph of a core shell structure and these are like spears and the dark spear small spear at the centre is basically the iron platinum alloy and the lighter a coating or the shell is made up of cobalt disulphide. These are spherical core shell nanostructures and if you take the edacs centre of the sphere that is point one you will get an edacs, which will show you iron platinum and cobalt all three and the copper comes from the grid.

If you take the edacs analysis from the shell, then the point two if your electron beam is going through point two, then you will only see those metals or those elements which are present in the shell. Here, you can find sulphur, which because it is their sulphur is there and you will see cobalt because cobalt sulphide is there, but will not see any iron or platinum because they are in the core.

So, iron and platinum is missing here, whereas all the elements you can see here because when you pass the beam through one it goes through the shell into the core and you will see all the elements which are present in the core as well as the shell.

So, these are edacs analysis normally done in a transmission electron micrograph, transmission electron microscope by choosing the electron beam to fall on specific positions in the core shell structures and that is how you identify that your core is made of iron platinum and your shell has got cobalt disulfide.

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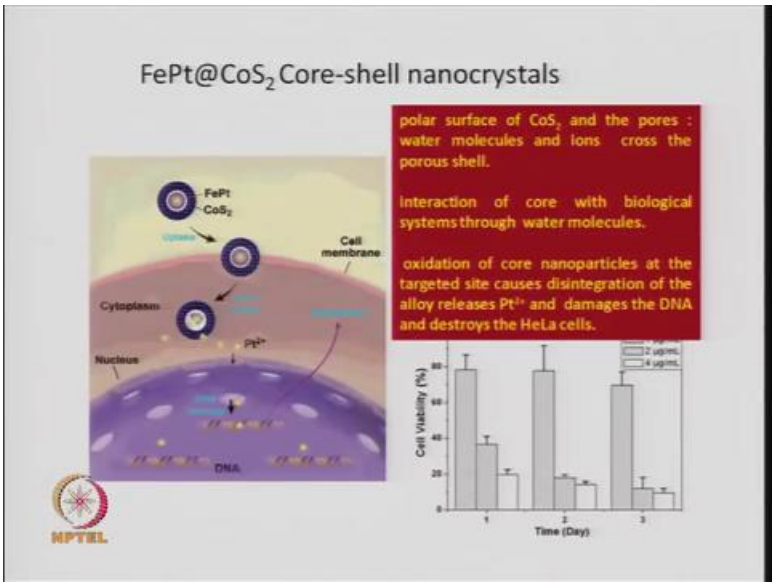

Now, why do you make such a material for some application and what is the application here in mind, that the cobalt sulfide which is on the outside the shell. It has got a polar surface and is also pores because the way you make the shell using Kirkendall effect, you generate pores structure for the cobalt disulfide shell. So, there are pores in this shell and from these pores when this core shell is in a solution, it can interact with biological molecules in the solution. Then, what happens is oxidation of the core material because whatever is there in the outside, if you oxidize the iron platinum, then the platinum is released.

So, when the platinum is released it can go out of the shell and interact with the biological specimens and typically attacks the DNA and will damage the hela cells, which is a particular cell line. That can be seen in this plot that the cell viability percentage, it goes down with time and this can be seen using different concentrations.

So, basically you are making platinum ions interact with the DNA by controlling the shell structure such that platinum is released only it comes when it gets oxidized and then it will be released and then it can act with the DNA and destroy the DNA of the hela cell. So, this is a kind of targeted drug delivery because the oxidation of the core nanoparticles at the targeted side occurs.

Then, only the platinum is released and the platinum then destroys the cancerous cells, which are present ant that is kind of an example of using a core shell structure at a

specific side. So, you are having a targeted drug delivery you are targeting a particular type of cell and you are delivering the drug, in this case platinum ions at the site where you wanted to be...

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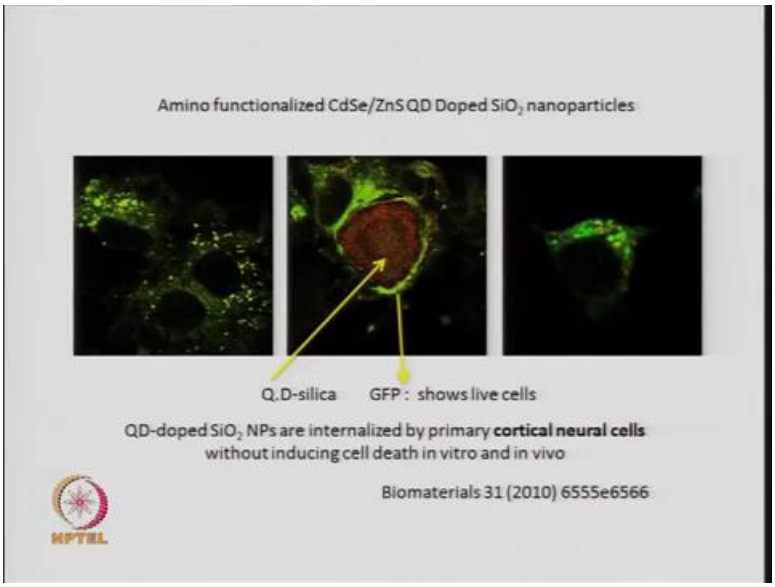

Now, this is another example of core shell nanostructure, where the core is made of a cadmium selenide zinc sulfide quantum dots. So, this mixture of cadmium selenide zinc sulfide quantum dots, very small nano particles act as the core and you have on top silica nanoparticles. Now, what happens when you put them in a solution along with green fluorescent protein, now the red mark for the red point are places were the quantum dot silica core shell nanostructures are there, so here also you can see that spots.

So, in a particular solution these are pictures taken in a confocal fluorescence imaging microscope, where you are having this core shell particles of quantum dots and silica and you can see along with green fluorescent protein and the cells are basically neural cell. These are some cortical neural cells and you can see that the red particle, which are the quantum dots with the shell. They are the red ones and the green ones are the g f or the green fluorescent protein and the property of the green fluorescent protein is it will be seen only where there are live cells.

So, if these are all live cells and these are the core shell particles and this is from another part of the cell of the solution, where as cell is present and you can see that the quantum dot with the shell is internalized. That means it goes inside the cell and the cell is alive

because you can still see the green fluorescent protein on the edge. That shows that without inducing cell death the quantum dot silica core shell structure can be internalized. So, this is an example of using core shell structure to image and later on after imaging, you can try to deliver drug and see whether it goes into the cell.

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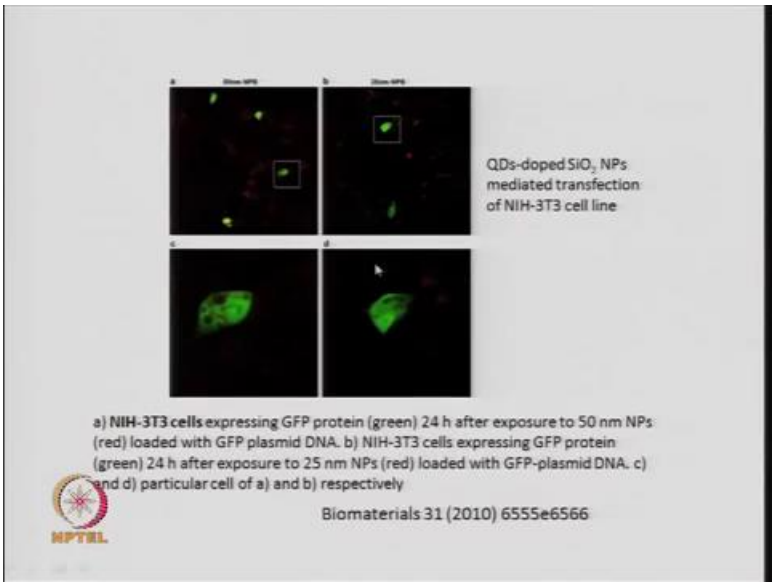

Now, this is another example of another type of cell, these are called NIH 3T3 cells and here also you can see that the GFP protein are showing up, that means the cells are still alive. So, these are typical regions from these places, this is a zoomed image of these parts, so this belongs to this part and this belongs to this part. So, these quantum dots with silica are mediated, they mediate transfection of this cell line and the cells are alive because the green fluorescent protein can be seen, they are expressing it. So, this is enough evidence that you can use these particles for imaging and also for drug delivery if required.

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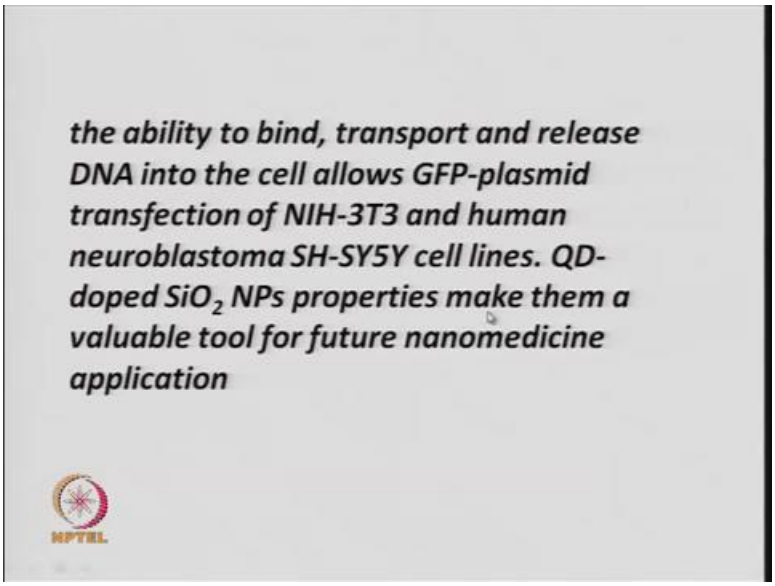

So, the last two examples that we showed, shows the ability to bind transport and release DNA into the cell and which allows the GFP the green fluorescent protein plasmid to be transfected and human neuroblastoma cell lines. So, NIH 3T3 and human neuroblastoma cell lines were used and the thus the quantum dots silica core structure allows them to be of value for nano medicine applications. That means we can use these core shell structures and take drugs and visualise where the drug is going without killing the cells. So, these two examples to show the viabilities of this core shell structures to be used up in drug delivery and in nano medicine in general.

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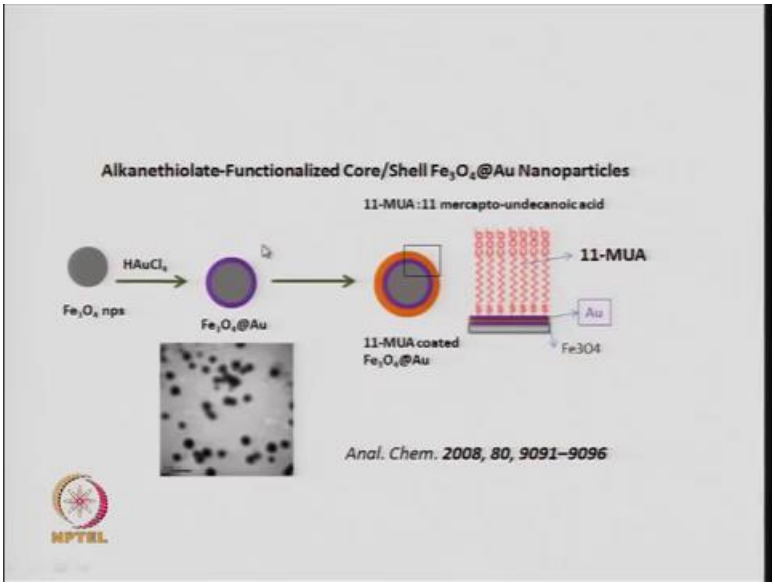

Now, this is another example of a core shell structure were we have used a alkanethiolate functionalized core shell structure, where the core is made of iron oxide Fe 3 O 4 and it is coated with gold. So, you have this iron oxide inside and outside you have a gold coating, the purple ring that you see is the gold coating and on top it is functionalized this red colour is functionalization by this alkanethiolate.

Now, the thiol part, it will be towards the gold surface, so this can be seen better in this diagram. So, how do you make this first is that you first make iron oxide nanoparticles with standard procedures. Once you get these spherical iron oxide nanoparticles, then you use auric chloride that is the starting material for making gold particles or gold surfaces. So, on iron oxide nanoparticles, you put this auric chloride and you get this iron oxide core shell structure with the shell of gold.

Then, on top of that here you use mercapto undecanoic acid which we call 11 MUA to form the functionalization on top of the gold. So, the thiol part will be of this or the mercapto part which is the thiol part will link to the gold surface, this purple surface and the red part is the long chain. So, it can be shown this part if you see or the one two three layers is the basically the iron oxide and the gold on top the purple.

On top is this chain of the mercapto undecanoic acid, the eleventh carbon chain at the end, you will have the carboxylate group and so these negative ions will be on the surface. This is the TEM image of this iron oxide, you can see at the centre the dark spot is iron oxide and this is covered with the gold particles. So, on top of that then you add this 11 mercapto undecanoic acid to get this core shell structure which is functionalized with this long chain acid. Now, what is the use of this kind of a core shell structure, so you have modified a core shell structure with the particular functionalization and what is the application?

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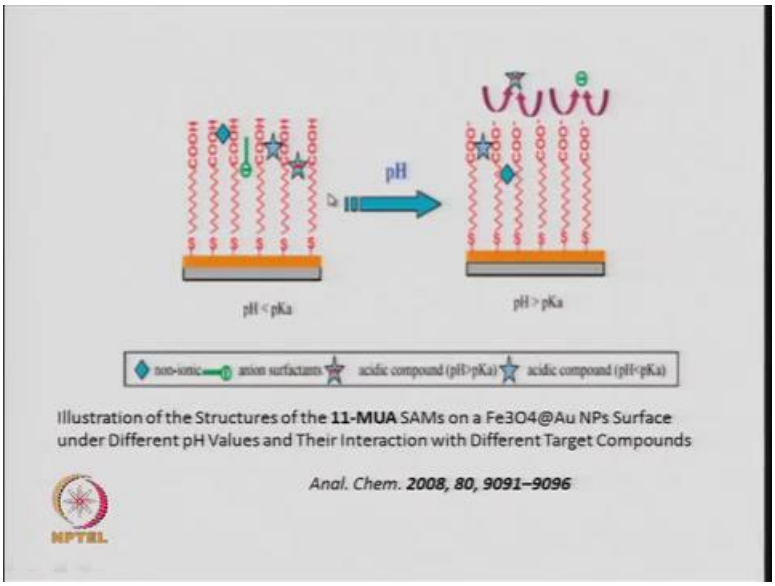

The application is this that at certain pH, which is suppose less then pKa, you will have all the protons they are not hydrolyzed. So, you have all the protons they are not protonated it is an acid with the OH group and at a pH which is larger than the pKa value, you will get these anions because the protons have been lost. So, this will be able to pick up certain molecules, which this will not be able to pick up because this is negatively charged, it will not be stable with negative or anionic species. So, if you choose four type of these species say non ionic molecules anion surfactants and some acidic compounds whose pH is greater than pKa, finally some acidic compounds where the pH is less than pKa.

If you have these four types of molecules, then this form of the functionalized molecule where the pH is less than pKa will bind to all the four different types of species. However, when at higher pH these will be having negative charges, then they will not like to bind negative or anionic species. Hence, you see these are anionic surfactants this green ones they will not be adhering to this surface.

Similarly, these acidic compounds whose pH is greater than pKa will be having O minus charges and hence they will also not be amenable to be absorbed a bound to the surface because the surface itself has negative charges. So, this is like a filter where out of these molecules, 4 of them only 2 will be bound to the surface where as the other 2 will be released.

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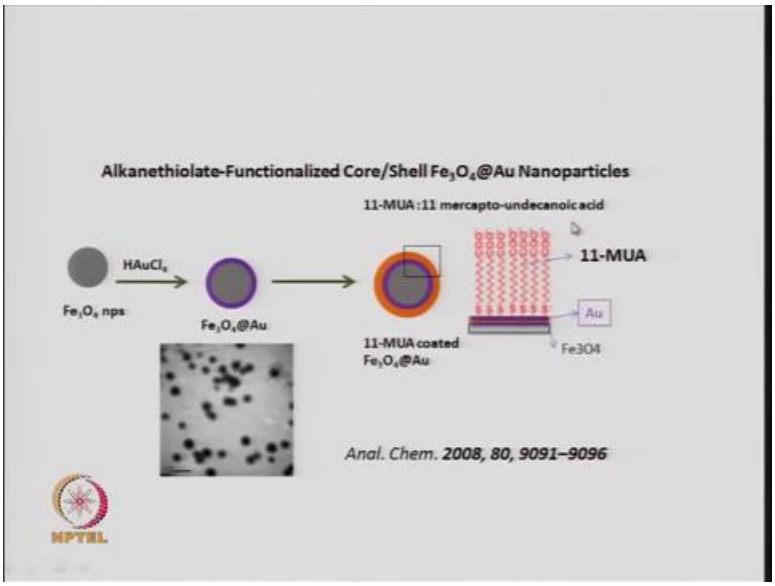

So, this is a good application of these core shell molecules, which have been functionalized by mercapto undecanoic acid and it is pH sensitive with respect to certain molecules. Hence, it only binds to certain molecules at low pH and certain molecules at high pH so that we can see here at pH low pH it is binding to almost all the systems of choice. Here, at high pH, when it is greater than pKa, then it is only binding to those systems which are neutral or positive.

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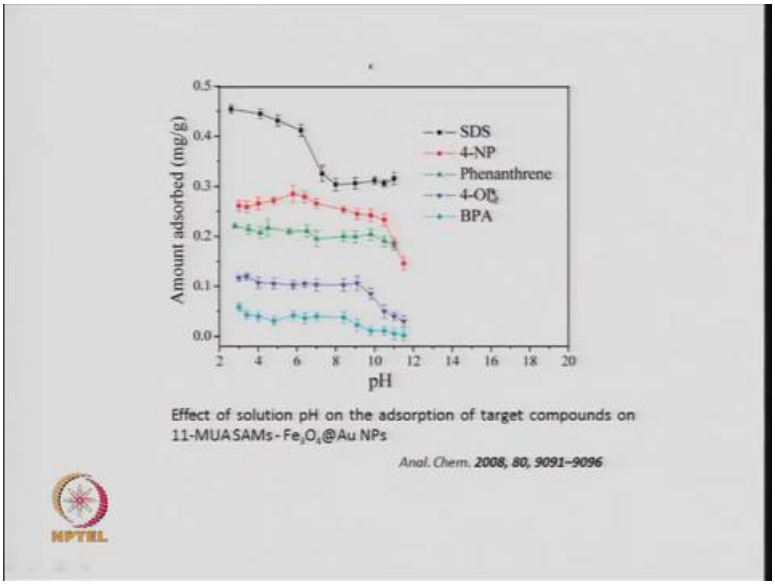

This can be plotted in a curve that at low pH, you see the amount absorbed is high for certain molecules like SDS at high pH the SDS is negatively charged at high pH when it is greater than pKa. Then you will have carboxylate groups on the surface and once you have carboxylate group on the surface, it will no more absorb the SDS because the SDS itself has an negative charge.

So, there will be a drastic drop in the amount of material which is getting absorbed on the surface. So, similar things have been done with other molecules where there is a drop at different pH for SDS the pH which it drops is around 6 for 4 nitro phenol the drop is around pH 10. So, the drop can vary, but in all this cases it drops after a certain pH and this is because of the surface charge of the functionalized group, which is generated when you change the pH to a value which is greater than the pKa of the acid group.

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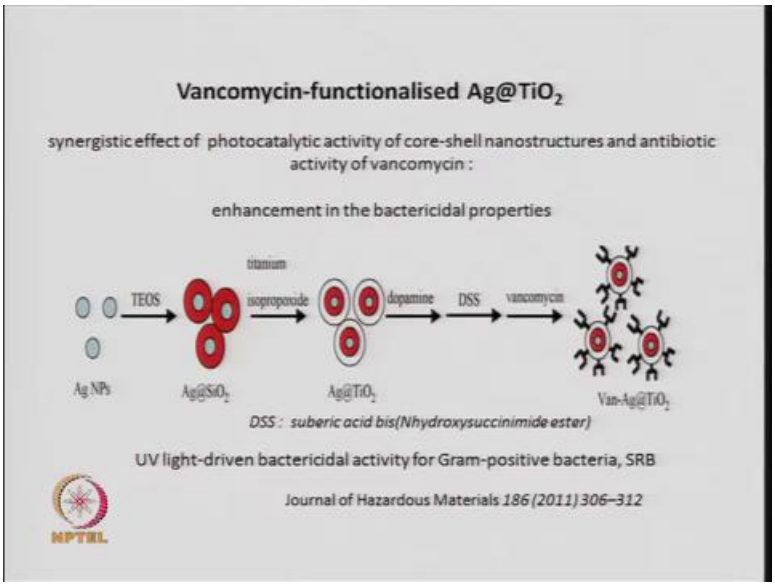

This is another example towards medicines, where vancomycin and an antibiotic is functionalized on a core shell structure. So, you have a core shell structure basically the core the inner core is silver and outside you have titanium dioxide and this anti biotic vancomycin is attached. So, we say functionalized to this core shell particle and then we use two properties why this is important is two properties will act vancomycin in an antibiotic and silver titanium is a very good photocatalyst. So, the synergistic effect of the photocatalytic activity of the silver Ti O 2 core shell structure and the antibiotic activity of vancomycin.

So, it will be a dual approach and you will see the effect it is called the synergistic effect because the two properties are acting insynergistically. So, how you make them is you first take silver nanoparticles, you make silver particles, then you make a silica layer on top of the silver nanoparticle using tetra ethoxy silane. On top of that, you make a Ti O 2 shell using titanium isopropoxide, so actually the silver is inside in between there is a silica shell Si O 2 shell and on top of that there is a Ti O 2 shell. Together, we are currently referring to this system as silver Ti O 2 core shell structure and we are not referring to the silica, which is in between.

Now, to this silver Ti O 2 core shell structures, you need to attach vancomycin, it is first necessary to add dopamine and another molecule DSS, which is suberic acid b is n hydroxysuccinimide ester. So, this molecule DSS and dopamine help vancomycin, which is an antibiotic to bind on the Ti O 2 shell. So, this black fork like things are basically showing you where vancomycin the anti biotic is bound on the surface of the core shell nanostructure.

So, once you get this vancomycin core shell nanostructure, then it can be used to act again some bacteria etcetera and study the bactericidal the activity from gram positive bacteria. So, one of these is SRB and will study under UV light because we know that silver Ti O 2 core shell structure is a UV photo catalyst.

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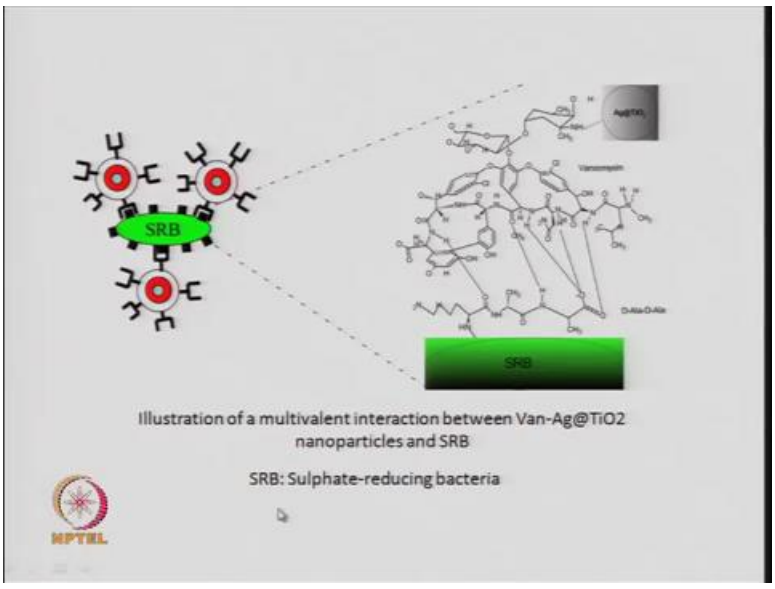

So, what happens when you react this silver Ti O 2 core shell structure conjugated to vancomycin, the anti biotic with sulfate reducing bacteria. So, these molecules attach to the bacteria and then presence of UV light, it degrades these bacteria, so the rate of the degradation is much faster if you use a combination of silver Ti O 2 and vancomycin instead of just silver Ti O 2 or just vancomycin. So, because two properties are acting simultaneously one is the UV photo catalysis of silver TiO 2 and the anti biotic property of vancomycin.

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Now, we can also make hollow shells, we were discussing core shells that means there is a particle core material on top of which there is a shell that is the core shell structure. Now, we can also make use of hollow shells that means there is a shell with nothing inside.

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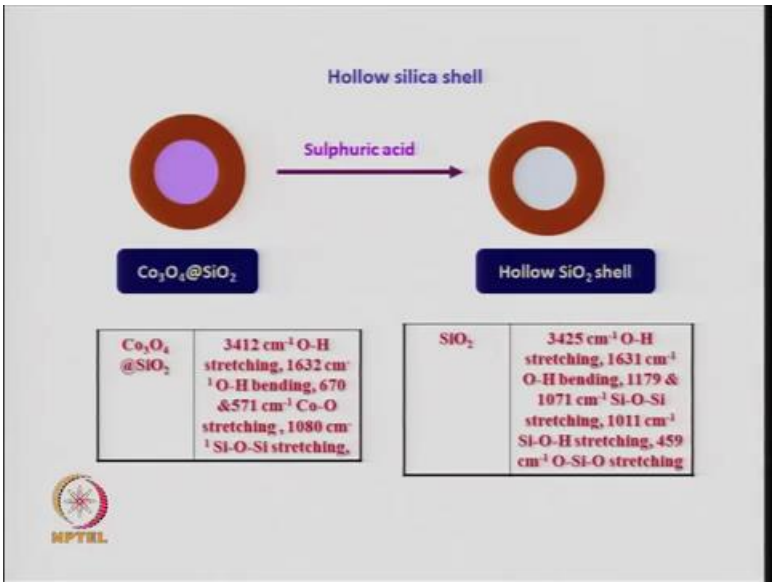

So, how do you make such hollow shells, for example you take this core shell structure of cobalt oxide and silica on the outside, you put it in sulphuric acid and then the core is eaten away and what is remaining is the hollow silica shell. How do you know that the hollow silica shell is formed is basically you will have from infrared spectroscopy. You will see the vibrational frequencies corresponding to OH groups, then Si OH group and O Si O stretching frequencies and you will not see any frequency due to cobalt oxide, which you can see in the original core shell nanostructure.

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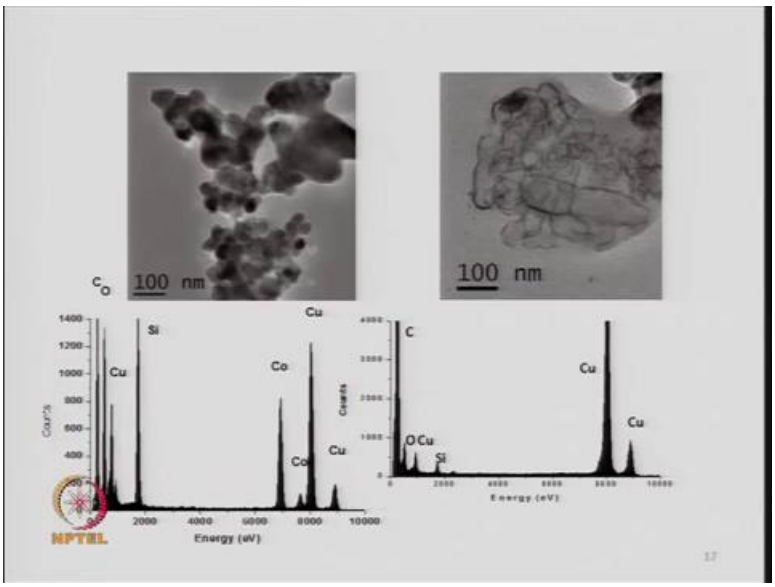

From electron microscopy, you can characterise such core shell structure. So, you can see these thick or dark particles of cobalt oxide surrounded by a thin shell and a you do a edacs, that is energy dispersive x ray analysis. You can see cobalt silicon oxygen from here copper from of course TEM grid and in the hollow shells, you can see that only the shell is present this internal part, which was dark in here is no more there and these are the hollow shells you got after you treated the core shell with sulphuric acid.

Then, this if you look under the TEM, you get this image and if you do a energy dispersive x ray analysis, you will see only silicon oxygen and of course copper from the grade and carbon due to impurities. You do not see any cobalt peak, which you can see here, which shows these are hollow shells.

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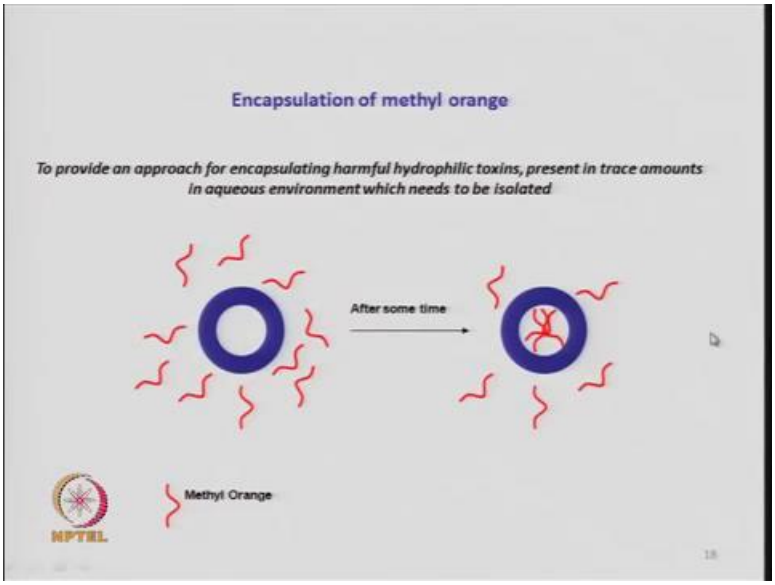

Now, how you can use these hollow shells is for example, you can trap some organic molecules, which act as pollutants and here you show that this is the shell and these are like your organic molecules, which cause pollution in the water.

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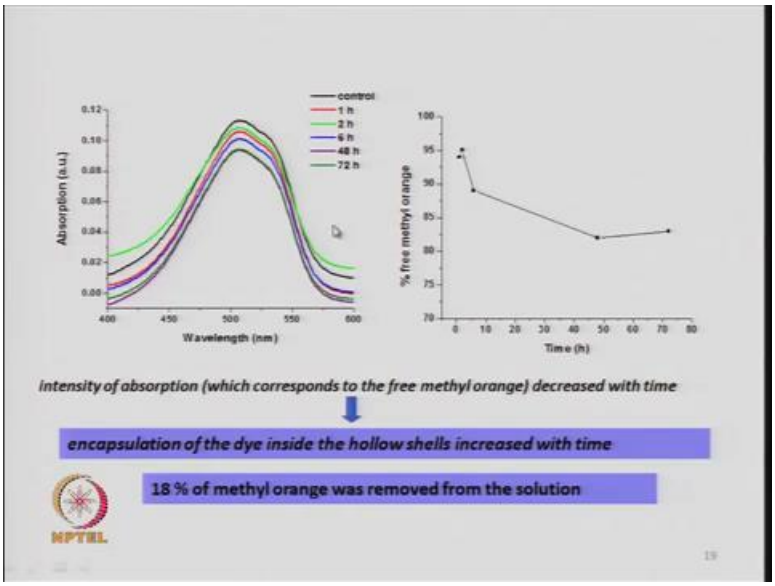

If you put this shells water, after some time these shells get trapped inside and how do you know that the shells are trapped, what you can do is you can measure the UV visible spectroscopy corresponding to the organic compound and the intensity. Suppose, the absorption of that organic compound A is peak around 500 nano meters, if you monitor the peak as the organic compound is getting trapped the intensity will become lower and lower.

So, here you can see that the control experiment is here which after a 1 hour, 2 hour etcetera, the intensities decreasing. So, for 2 hours, you see the green one and then after say 48 hours, you can see this black one, black one for 48 and 72 hours. Now, the intensity of the organic compound, which was methyl orange in this case decreases to some extent and then tries to constant and the decreases is around 20 percent here. You can get much higher decrease if you can design other types of larger hollow shell, but what this shows is hollow shells can trap the organic pollutants.

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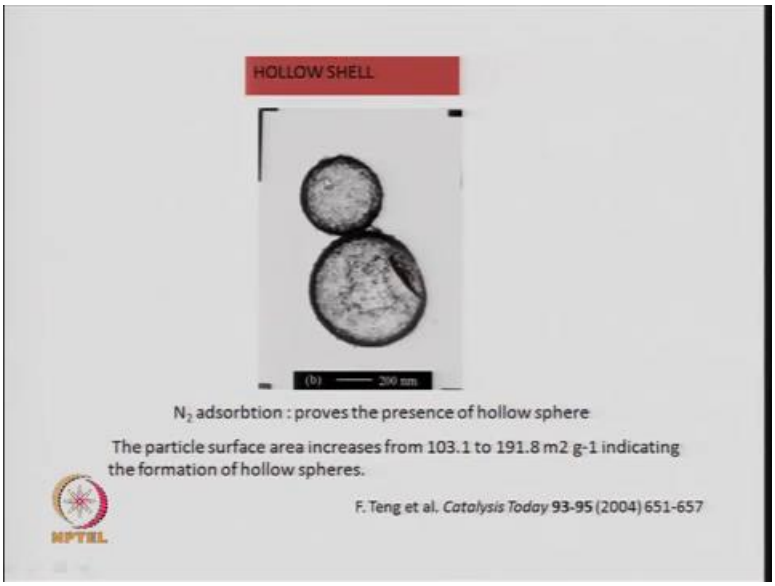

Now, this is an example of measuring or knowing that it is a hollow shell. Again, by TEM, you can see that, but you also use gas absorption which you can easily do in a surface area type of measurement the BET method and you can show the nitrogen adsorption increases. So, initially the particle surface area that you obtained from nitrogen adsorption experiments is around 103.1 meter square per gram.

After some time, it shows a surface of 191.8 meter square per gram and this increase in the surface area is basically because of increase of nitrogengas inside and that shows that it is a hollow shell to start with and hence can take up nitrogen gas. So, finally the surface area that you calculate will be much larger in the case when the nitrogen is absorbed by this hollow shell. That is exactly what happens from 103, the surface area goes to 191.8.

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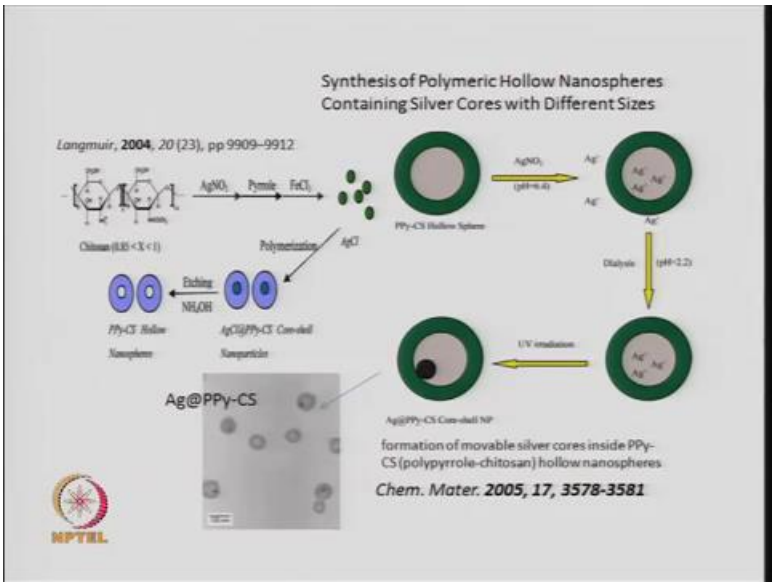

This is another proof that you are dealing with hollow shells, now this is an example of making movable silver cores insides hollows spears or hollow shells. So, you have to start with polymeric hollow nano spear and you want to make silver particle inside, but not the entire region should be covered, but only a small region should be covered with silver.

So, the silver particle can move around this internal surface like a ball, so what do you do you first make this hollow spear of a polymer with chitosan CSS chitosan and this is polypyrrole. To get this hollow spear, you start from chitosan, which is shown here and you use silver nitrate and pyrorole andiron chloride and you get silver chloride particles. Then, you polymerize and you get the polymer with the chitosan which is their are forming a shell around sliver chloride, so first sliver forms and then this sliver chloride is inside and this polypyrrole chitosan core shellstructure is form.

Then, you add ammoniaammonia hydroxide solution that eats away silver chloride, so it dissolve the sliver chloride which is inside. We call it etching, etching means removal of something, so you are removing silver chloride by using ammonium hydroxide and you are left with only the shell. So, you get this hollow shells or hollow nano spears of polypyrrole and chitosan.

Now, you take this hollow spears so the p p y c s hollow spear you take at silver nitrate at a certain pH. You have got silver ions inside and outside you removed silver ions outside

by dialysis at a low pH and you are left with a shell of this polypyrrole chitosan with silver ions inside.

If you now bring UV lamp near this particle, the silver irons will get reduced under UV radiation and they will become silver particles and so u will get this silver particle inside the shell. So, this is a small particle, so it can move around inside the shell and this is the t e m picture to show exactly how this looks. So, you can see the dark spot here that is the silver particle inside the polypyrrole chitosan shell and this has interesting applications of when the silver particle can change positions within the hollow shell.

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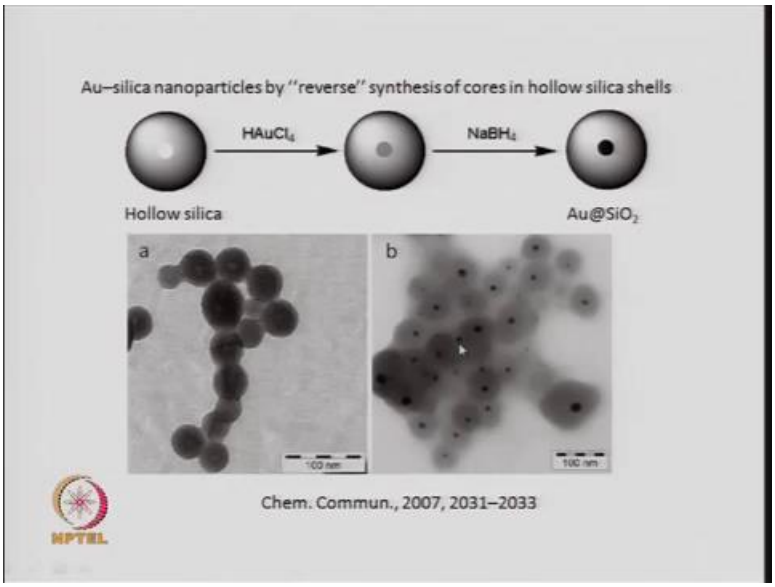

This is another example of how a hollow shell can be used to make a core shell structure, so this is an application of making a core shell structure starting from a hollow shell. So, you start with the hollow shell of silica there is nothing inside here this is silica shell add auric chloride that is the source of gold irons. Then, once you add auric chloride then you add sodium borohydride sodium borohydride is a reducing agent and it will reduce the gold irons which are here inside to form gold particle, so you will get gold which is encapsulated in silica.

So, this is the picture you can see the hollow silica and this is gold inside silica, so this dark spots here is gold silica made from hollow silica by reduction with sodium borohydride. So, this is an example a good example of gold silica core shell structure being synthesised from hollow shells of silica.

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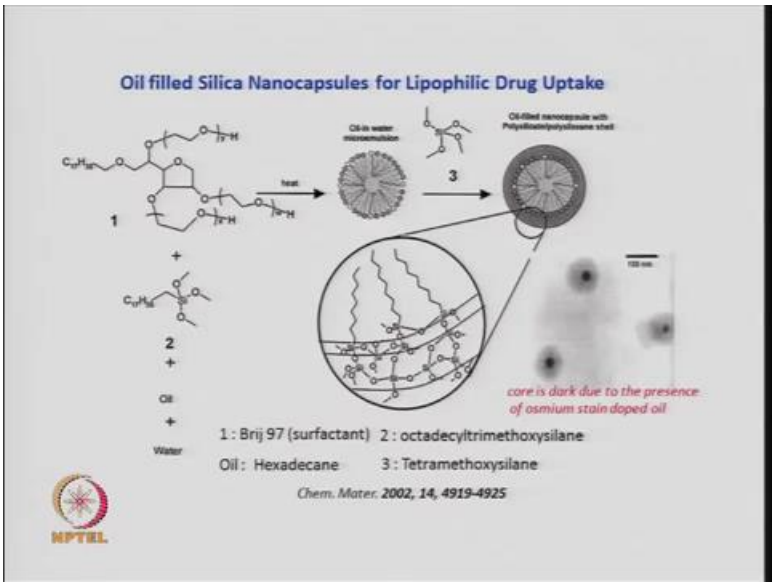

Now, you can also make oil filled silica nano capsules for taking drugs or medicine which are lipophilic which means they like oil filled lipophilic means philic means something which likes lipo means oil. So, something which likes oil which is soluble in oil, so that kind of drug if you want, then the oil phase should be inside. So, oil filled silica nano capsule you have to make now how do you make this oil filled silica nano capsule is you start with the this is the micro emulsion process.

So, in a micro emulsion you need a surfactant and oil phase and an aqueous medium, so the surfactant here is a neutral non ironic surfactant whose common name is Brij 97 and this is the structure of the surfactant. So, there are a lot of Ether linkages as you see in this brij 97 surfactant and typically most of the non ionic surfactants have this kind of a polyether linkages.

So, if you take one which is this surfactant plus you have this molecule is which is the non aqueous medium or the oil, which will be inside that non aqueous hexadecane. You add along with this oil phase is the hexadecane phase and this number two is actually octadecyl methoxysilane.

So, this octadecyl methoxysilane with the hexadecane oil that you will mix along with the surfactant and water and when you mix all these four the surfactant the oil and this octadecyl trimethoxy silane molecule and heat it. Then, you get this kind of a oil in water micro emulsion, so here the oil which is hexadecane oil which is will be inside and these

long chains these long chains are the hydrophobic part of this surfactant molecule which is Brij 97. You have this on in this inside you will have the hexadecane oil incorporated now then you add your this TOS material this saline.

Then, you get this core shell material with silica on the surface, so the silica will bond like this and you will have a shell of polythyrox in a polysilicate. If you want and this is filled with oil and the hydrophobic changes are all pointing inside towards the oil. The hydrophilic part these circles show the hydrophilic part that is the hydrophilic part of the polar part of the surfactant which are the ether parts the oxygen parts. They are on the surface of this micelle as also you will have the octadecyl trimethoxysilane will be there and tetramethoxysilane you add at step three to form the shell, so the shell is actually formed when you add this tetramethoxy silane.

This has formed you can know by doing the transmission electron microscopy where again you see the oil phase which is here shown in dark can be seen only when you use a stain is added to enhance the contrast in the electron microscope. So, that stain is basically an osmium complex is molecule of with containing osmium which is doped along with the oil.

So, wherever that oil goes these osmium molecule will go and since osmium is a heavy metal it has many electrons. So, it diffracts, scatters the incoming electrons much more efficiently and so you will see that portion to be very dark because the contrast will be high whenever you have more scattering from that region. So, this portion as you see is darker because of the osmium stain that you have used a doped in this oil, so this is an example of an oil filled silica nanocapsule, which you have made.

Now, you can use this for uptake of drug which is soluble in oil medium because you have an oil medium inside if you take a drug which is soluble in oil and your able to solubilise in this micro emulsion, then the drug will be stable only in the inner part. That is the hydrophobic or lipophilic part and the drug will not go to the shell because the shell is hydrophobic and this can be studied by looking at say a drug like quinolone.

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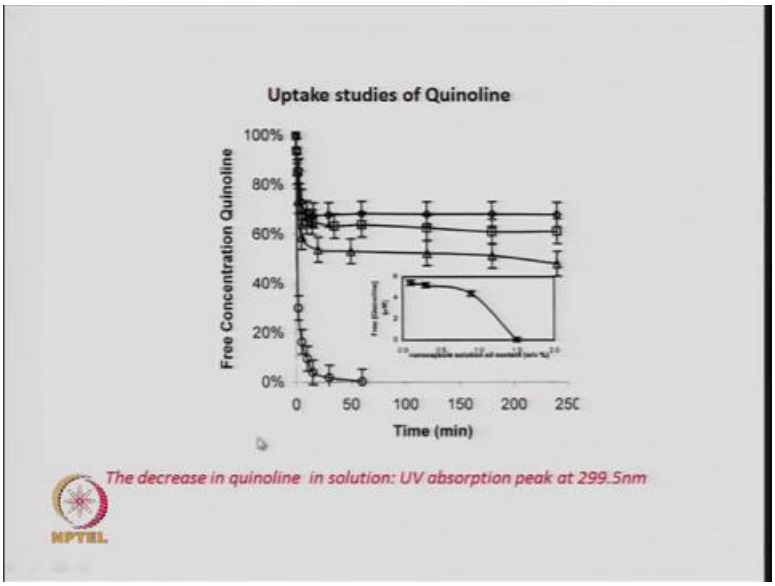

So, you add quinolone, quinolone is organic in nature, so it is kind of a non aqueous, so it is more like an oil and this drug will like to go in a place where it is more lipophilic or more hydrophobic. If you look at the change in quinoline in the solution outside the microemulsion.

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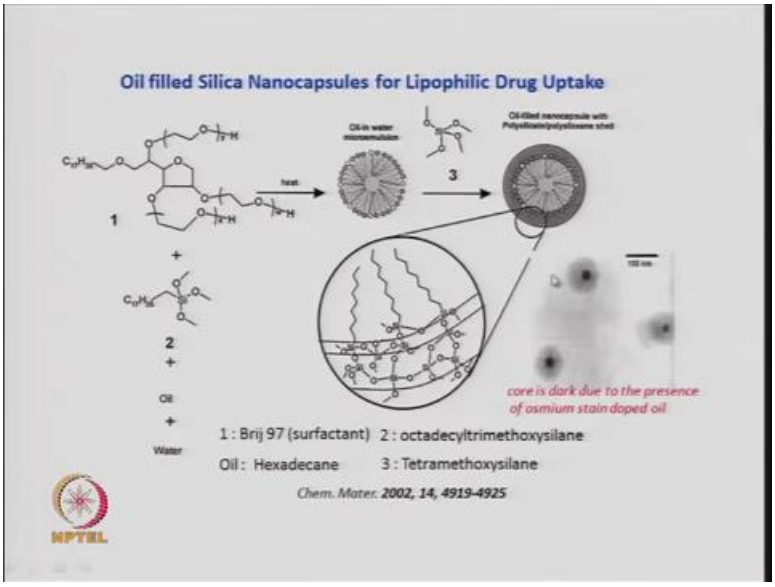

So, when you add quinolone, some quinoline will be outside and some quinolone will go inside which will go into the lipophilic region and with time there will be more quinoline inside than outside because the drug is being taken inside that portion which is of similar

type as the drug. Since the drug likes an oil type of environment a hydrophobic type of an environment, hence the oil will go the drug will go and sit where the oil is present. The oil is present in this dark part, so if you give sufficient time then the oil will slowly move into the darker region, which is the core of this core shell structure.

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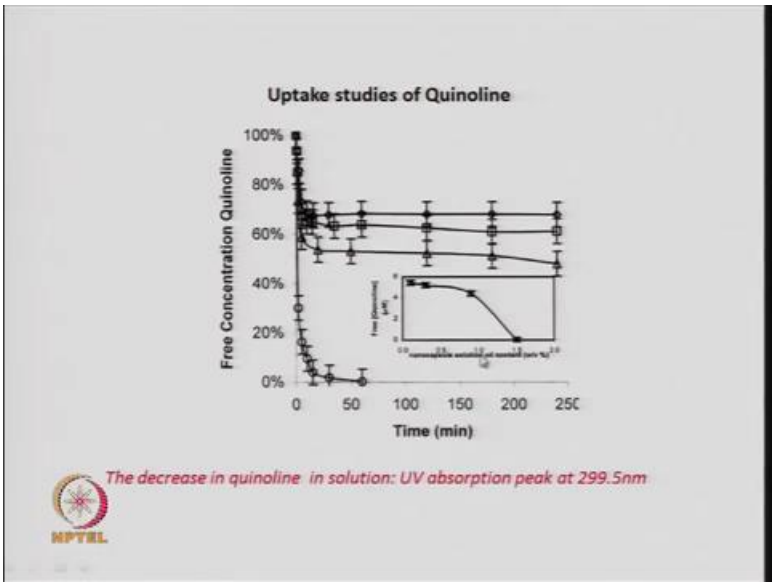

So, with time if you calculate the quinolone, which is outside, so the drug which is outside can be easily found out by doing an experiment and that experiment is basically looking at the UV visible spectroscopy of quinolone. So, quinoline has a particular absorption and if you do the UV absorption of quinoline at 299.5 nanometers, if you look at that, then with time as you see it will drop, so that says that the quinoline is less outside after sometime and more inside.

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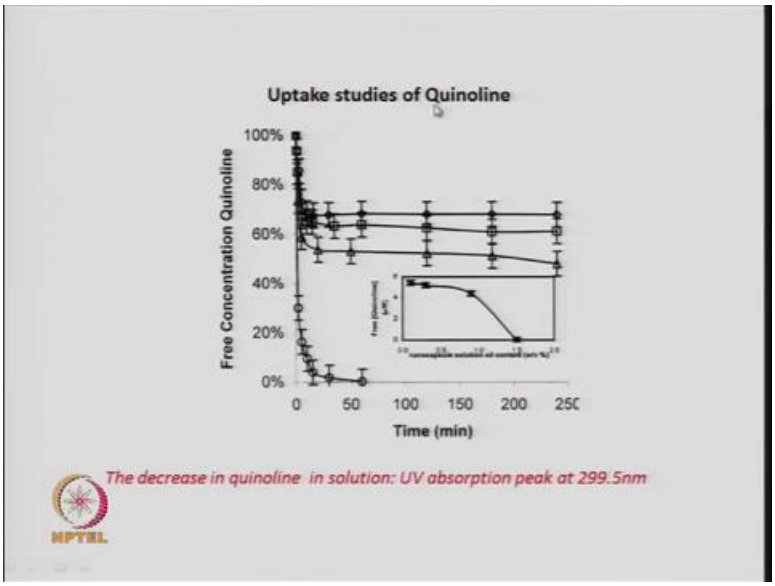

So, uptake studies of quinoline basically shows that initially there was lot of quinoline in the solution because it was not inside the core, but after sometime that concentration of quinoline decreased with time, because the quinoline was going inside. It cannot be found in the solution outside, so in the measurement you only measure when the quinoline is outside the core when it is inside the core then you do not get this absorption peak.

Hence, with time you can study the fall of the quinolone absorption and with nano this this, now you can call at a as a nano capsule because all of you know what is capsule, there is a medicine inside and there is a cover and inside the body the cover will dissolve and the medicine will come out.

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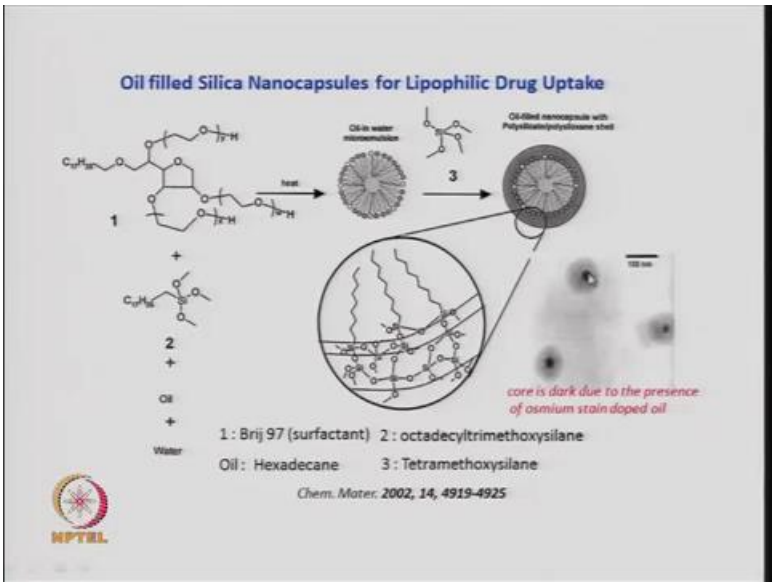

Similarly, this is a nanocapsule because you have a cover and the drug is inside, but this not a capsule which we can hold with our hand, because this is very small and this is called a nanocapsule. Now, you have very tiny capsules of the diameter of 100 nanometers, where the core is probably only 15 to 20 nanometers.

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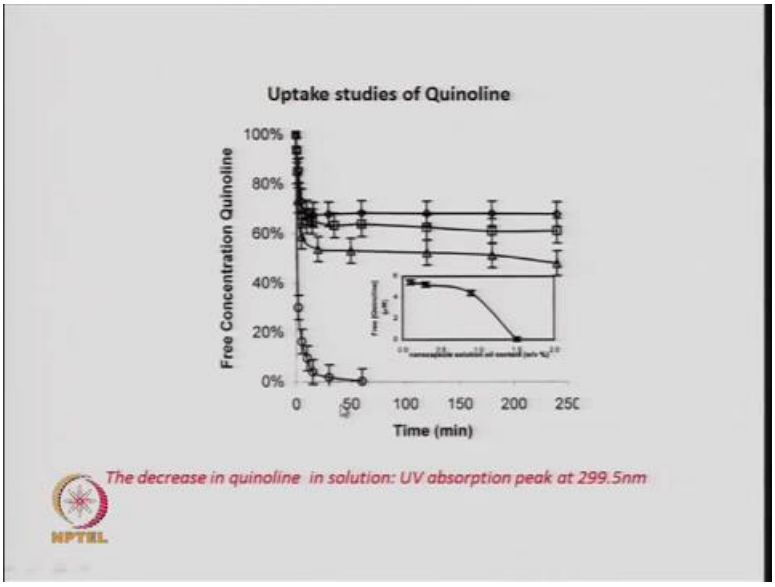

So, the drug gets encapsulated within that 15 to 20 nanometers, you can study as a function of time this uptake of quinoline which is given by the decrease in the intensity of the UV absorption at 299.5 nanometers for quinoline.

You can also vary the concentration of the nano capsule solution and free quinoline if you plot that you see that the free quinolone is decreasing as you are increasing the nano capsule solution oil content. That means if this oil content is very large, then you can take more drug inside, so that is what you are doing it may increase the amount of the oil which is in the core of this core shell structure. Then, the free quinoline is much less in a capsule which has got more oil because obviously more the oil more quinoline can be trapped inside the core shell structure.

So, this is what you can do with the study of core shell structures of molecules which are lipophilic in oil filled nano capsule and is a very important application of drug carrying capsules to targeted sides within the body. If you can target such capsules, you will need less quantity of drug to attract the same amount of bacteria or other diseased cells. So, with that we come to the end of this three lecture part of core shell structures and this was the lecture twelve of module three.

We have two more lectures in this module to complete fourteen lectures of module three and those two lectures will be given in the next two lecture classes, which will be on nano composites and basically we finished our study on core shell nanostructures. This has tremendous applications especially in drug delivery in nano medicine in protection of particles with mechanically stable shells, and now we will move on to the subject of nano composites in our next two lectures.

Thank you very much.