Surface Engineering of Nanomaterials
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Lecture – 33
Plating of Nanocomposite Coatings-I

Hello. In this particular lecture we are going to discuss about the Plating of Nanocomposites; that means, we are going to do the coatings of nanocomposites by which we can modify the surface of that particular materials. So, before going to start we have to know that when we are going to do the coatings and how it is helping to the surface engineering aspects.

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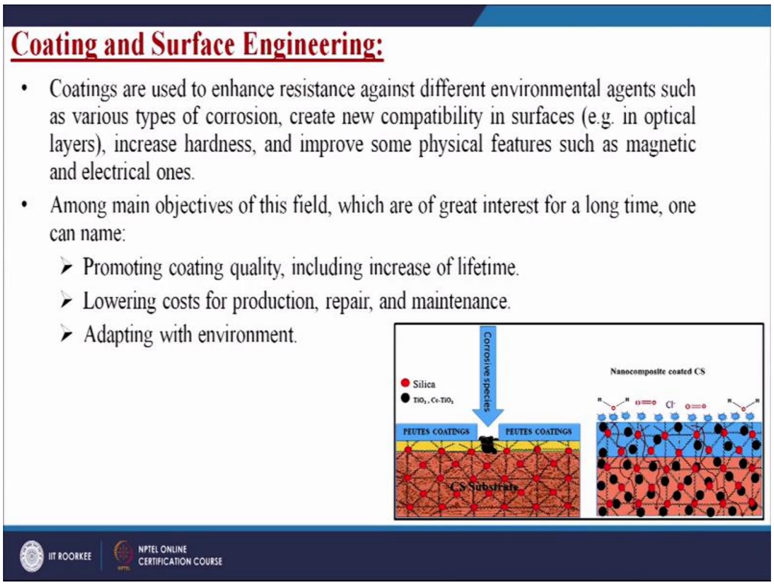

So, coatings are used to enhance the resistance against different environmental agents such as the various types of corrosions, create new compatibility of surface. So, these all are the things if you remember that from the first lecture I am discussing all these things; where discussed about the abrasions, we have discussed about the wear, we have discussed about the different problems which we are facing towards materials.

So, just to eliminating those problems just to make our surface more active more better than the previous one we are going to do the coatings of that particular materials. Not only that by doing the coatings the outer properties of that particular material it can be changed, like our material is hydrophilic by doing any hydrophobic coating so we can make it as a hydrophobic maybe it can work as a hydrophobic materials; or maybe we can made some kind of coatings by which our surface can be active and that particular mediums or may be inside some chemicals. So, these all are the different techniques or may be the difference reasons by which we are doing the surface engineering methods.

So, among main objective of this film which are of great interest for a long time one can name: promoting coating quality include increase of lifetime, lowering cost of productions repair and maintenance adapting with environment. Suppose when we are talking about some kind of cutting tools or may be the bearings, continuously the two surface is rubbing by which the temperature is generating and the material properties or maybe that surface is getting erode. So, when you are doing the coatings we can make or maybe generate the new life to that particular material not only that we can enhance the new life and we can enhance the new surface so that the material can work properly. And also it will reduce the production cost no need to make it the further or maybe it is cheap to do these kinds of coatings. And also it is useful for that particular environment in which it can work properly.

So, here are the some examples: when you are talking about some kind of coatings over there so from that particular case you can see that the red one is called the silica molecules and the black one is called the titanium oxide; so selenium titanium oxides. So, simple we are doing some kind of coatings, first initially we are having that substrate then on that particular mesh some cracking has been done by which the corrosion is taking place. So, here we are using some titanium dioxide coatings so after certain time these titanium dioxide is reacting with the silica or maybe that silicon and they are forming a new material which will be acting as anti corrosives one on or maybe that self healing of that particular material will be taking place.

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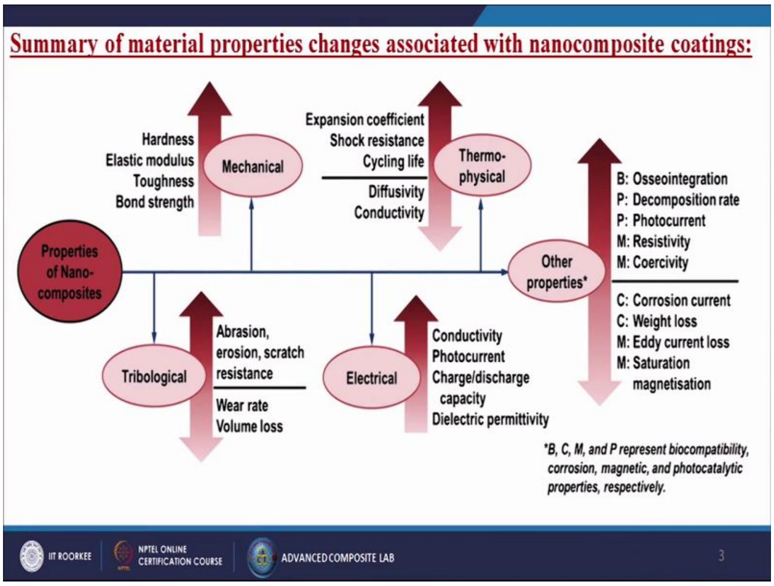

Now, here is the total summary of the material properties change associated with the nanocomposite coatings. So what are the properties generally we can get after doing the coating of these particular materials. First one is called the properties of the nanocomposites; when we are talking about the mechanical properties it can increase the hardness, it can increase the elastic modulus, it can increase the toughness, it can increase the bond strength. So, these are all that aspects for which we are doing the coatings of that particular nanomaterial.

It can increase the tribological aspects of those materials in terms of abrasions, erosions, scratch resistance, wear rate, volume loss. When you are talking about the electrical properties it can increase the conductivity, photocurrent charge, discharge capacity, dielectric permittivity. When you are talking about the thermo physical process means where as a thermal properties are getting involved for that particular case may be expansion coefficients shock resistance cycling life diffusivity and conductivity these properties can be increased.

When we are talking about the other properties like of osseointegrations, decomposition rate, photocurrent, resistivity, coercivity, corrosion current, weight loss, eddy current loss, saturation magnetisation may be decreased. So, the thing is that here it by it choosing the proper coating we can enhance some particular properties of that particular material. So, either we can enhance the properties we can decrease the properties or maybe one properties it should we need that it should be increased one properties it should be decreased by choosing the proper coating materials we can enhance one properties, we can degrade one properties of that particular material too.

So now, here the general concepts that how we are going to do the coatings of that particular materials, actually there are two different concepts: one concept is called that matrix-reinforce, where the reinforcing phase is within nanoscales and another one is called the layered coatings, where the thickness of individual layers are within nanoscale dimensions.

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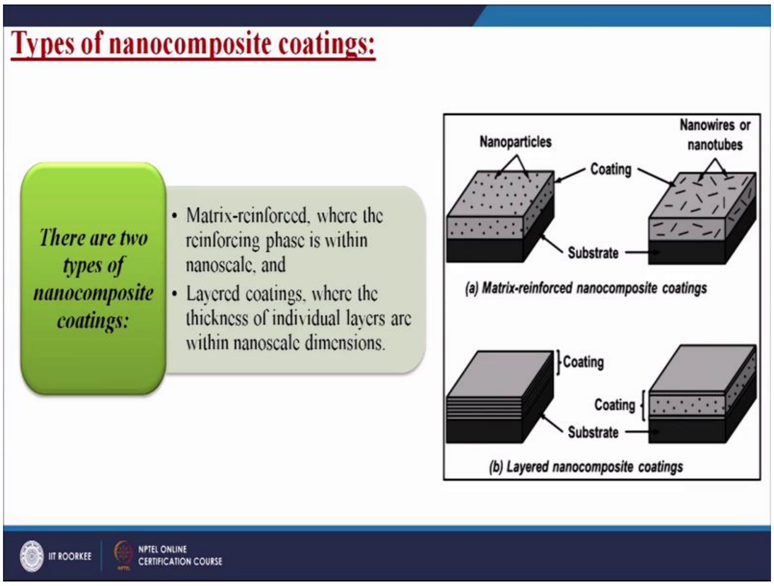

So here, the top of the coatings it is a composite types in which we are incorporating some kind of nanoparticles, it is mixed with some polymers or maybe some metals then it is from preparing a coating; a composite coating materials then that materials we are applying onto our substrate to do the coating. And for the second case simple we are having the substrate; suppose I want to make a coat of one material so I will give a layer of that material then if I want some another material I can give a layer of that particular material so by layer by layer techniques we can do the coatings of these particular materials or may be these surface engineering.

So, what are the functional coatings? So, there are several types of functional coatings, from the name itself functional coatings you can understand that when we are doing some kind of coatings of course they will enhance certain properties; not only that they will do some kind of reactions with the surface too. So, that is why it is called functional coatings; that they will functionalize the surface itself.

The term functional coatings describe systems which possess, besides the classical properties of a coating; that means decorations and protections and additional functionality it will generate.

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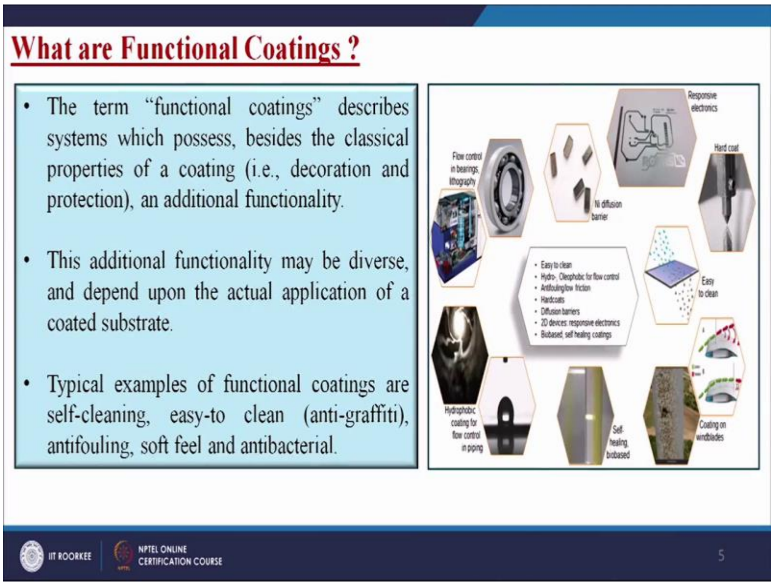

So, that is why the name of these particular coatings is known as the functional coatings. This additional functionality may be diverse and depend upon the actual applications of a coated substrate. Typical examples of functional coatings are self cleaning, easy to clean anti graffiti, antifouling, soft fill and the antibacterials; so these all are the examples of these functional coatings. From the right hand side figure you can understand that whether we are going for some kind of mechanical bearings, may be fasteners, some kind of electronic circuits, some kind of tools or may be some kind of cell feeling bio based materials or may be to make that materials may be hydrophobic or may be hydrophilic we can do these kind of functional coatings.

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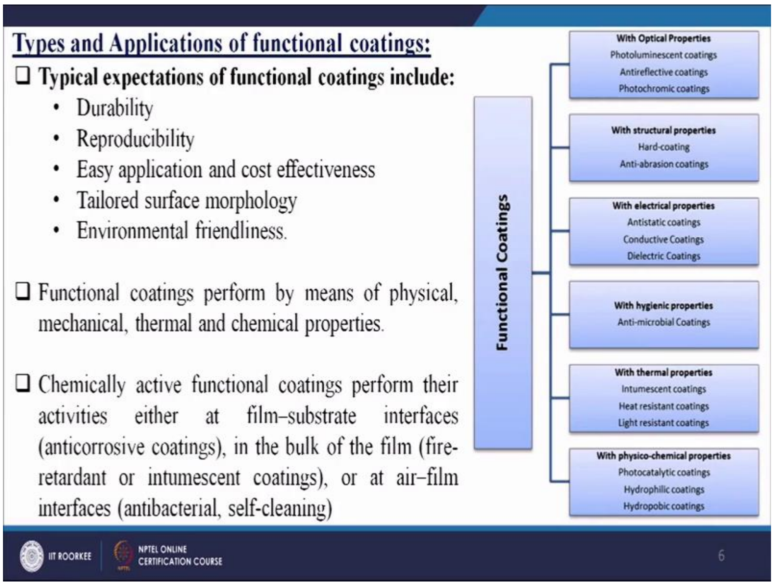

So here, the types and applications of the functional coatings typical expectations of the functional coatings include: durability, reproducibility, easy applications and cost effectiveness, tailored surface morphology, and the environmental friendliness. So, these all are the aspects by which or maybe for which we are going to do the functional coatings.

So, here the functional coating performed by means of physical, mechanical, thermal and the chemical properties. Chemically active functional coatings perform their activities either at film substrate interfaces; that means, anti corrosive coatings in the bulk of the film fire retardant or in to sense coatings or at air film interface antibacterial or maybe the self cleaning. Here, this is the chart of that what type of functional coatings generally we can do. So, for optical properties, photo luminescent coatings, anti reflective coatings, photochromaic coatings, generally we are using for our specs, we are using for some kind of biomedical applications, we are using for the glass substrates or maybe the glass materials this kind of techniques. For structural properties hard coatings anti abrasion coatings for making any kind of cutting tools or maybe that any kind of machining operations any kind of machines we are going to use these kind of coatings.

When you are talking about the electrical properties; anti static coating, conductive coatings, dielectric coatings, generally we are going to do for achieving some better electrical properties. With hygienic properties we can go for some antimicrobial coatings; generally we can use these kinds of techniques for our food packaging technology. Then with thermal properties instrumentation coatings, heat resistant coatings, light resistant coatings, generally we can do, when you are talking about some physical chemical properties, some photocatalytic coating, hydrophilic coatings, hydrophobic coatings.

So, there are several numbers of applications or maybe techniques are there by which we can change our material properties or maybe the surface of that particular material properties. First we are going to discuss about the anti corrosive coatings. So, when we are going to do the anti corrosive coatings generally we are applying these types of coatings for certain materials where that materials when it is working maybe it can create certain kind of corrosions. So, just to prevent that material we are doing a coatings which can acts as a anti corrosive in that particular environment. Here, organic coatings are applied onto metallic substrate in order to avoid the detrimental effect of corrosions.

The best example of these kinds of coatings is nothing but the paint. So, when you are doing any kind of welding, any kind of machining operations just to shape that materials from formations of any kind of oxides or maybe the sulfides we are doing a coatings of paints so by which it cannot react with the environment itself so that it will be anti corrosions; acting as an anti corrosions materials.

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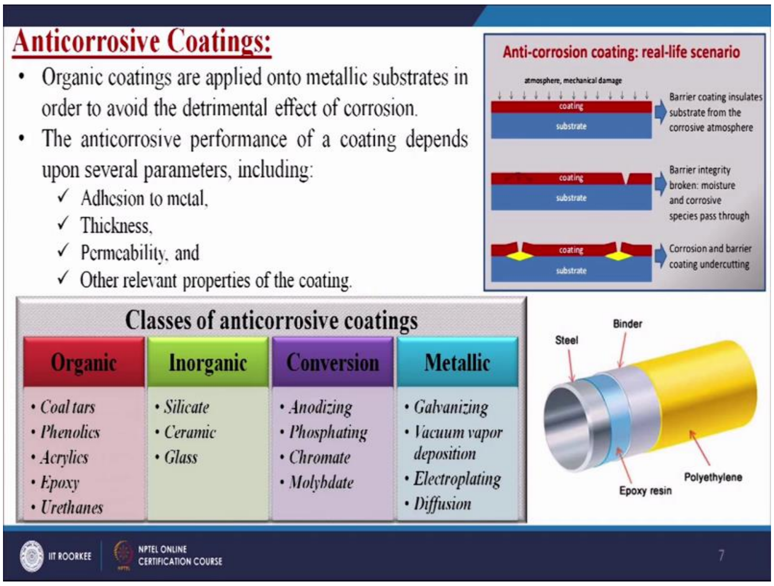

The anti corrosive performance of a coating depends upon several parameters like adhesion to metal, thickness, permeability, other relevant properties of the coating. Yes of course, what type of material I am going to use, whether it will properly attach with our substrate or not. And then what is the thickness, because if the thickness will be lesser then simply the moisture or maybe some kind of gas it can go inside with the best metals and it can react.

Then what is the porosity of that particular coating material, if the porosity will be bigger. So, any kind of molecules like water molecules or maybe vapour molecules or maybe any kind of other impurities that can easily go inside and do the reaction with the base metals. So, these all are the parameters by which we have to choose the anti corrosive coating materials. So, classes are anti corrosive coatings generally organic types: coal tars, phenolics, acrylics, epoxy, and urethanes; inorganic types: silicate, ceramic, and glass. Conversion: anodizing, phosphating, then chromate, and the molybdate; and the metallic coating: some galvanizing, vacuum vapor depositions, electroplating, and the diffusions.

So, these all are the different types of anti corrosive coatings are available. Here, generally when we are talking about that anti corrosive coatings how it is the real life scenario. So, we are having that substrate on which we are doing the coating, and top of the coating the atmosphere or mechanical damage is taking place; that means, that it is reacting with the environment or maybe some other shocks.

Then what happened? After certain time the barrier integrity, broken, moisture and corrosive species pass through these materials and then directly it can react with the substrate and it can deteriorate the material properties. So, just to stop all these things we can go for the anti corrosive coatings. Here is the best examples that where we are using the coatings of some epoxy resins and polyethylene some kind of polymers on the steel. So, in between that we are putting certain kind of binder otherwise this polyethylene and epoxy will not properly adhere to each other; maybe after certain time they will segregate or maybe they will peel off each other. So, just to make them more sticky we are using the binder materials inside these tube.

Next one is called the high thermal-resistant and fire retardant coatings. From the name itself we can understand that these types of coatings we are using for certain materials which materials we are going to use for the high temperature applications. So, just to shape that materials that materials should not be degrade up to that high temperature, and the flame will not occur to that temperature just we are doing the coating of certain things which will help to make the material to work into that perfect temperature.

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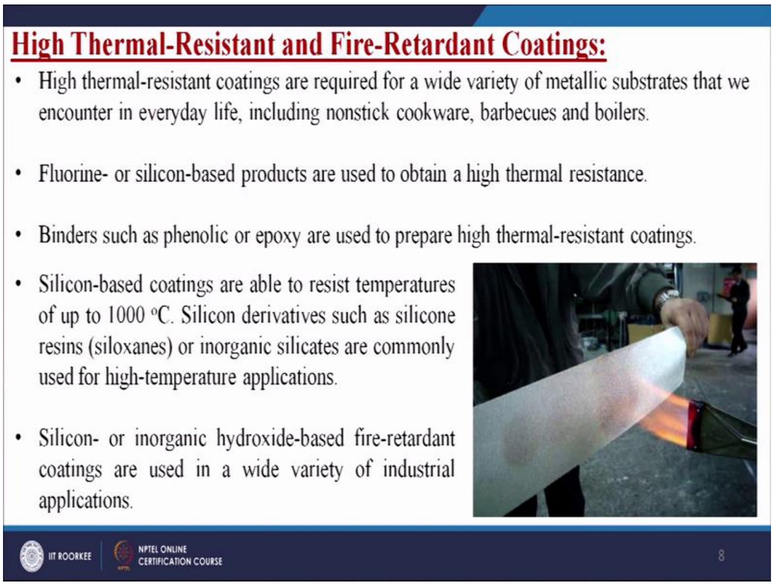

So, high thermal-resistant coatings are required for a wide variety of metallic substrates that we encounter in everyday life, including nonstick cookware, barbecues and the boilers; so nonstick cookware at the perfect example for this kind of techniques. Fluorine of silicon based products are used to obtain a high thermal-resistant. Binders such as phenolic or epoxy are used to prepare high thermal-resistant coatings. Here, you can see that we are using some materials at the flame also it is not degrading. So, these all are the different applications or maybe that some advancement of the surface engineering by using these high thermal-resistant or maybe the fire retardant coatings.

Next we are going to discuss about some scratch and abrasion resistant coatings. This one generally maximum times we are applying for our specs or with some kind of glass or maybe the windows or maybe some kind of equipment where we have to see what is going on inside. So, these all are the things. So, when the maximum times when you are just taking out our glass from the eyes maybe our fingers can touch with the glass itself, so what will happen the fingerprint will be stamped onto our glass. And also is sometimes we are taking this glass into the some rainy seasons, so maybe some water droplet or maybe some rainwater can directly comes onto the glass.

So, if the surface of the glass will not be proper so what will happen that water droplets or maybe the water bubbles will stick with the glass itself or maybe some fingerprint will already be present or with in to the glass or maybe there is some kind of scratches, because when we are wearing this glass and going through the environment means by walking or running or maybe driving. So, some kind of dust particle comes and they can do some kind of scratching onto the glass substrate or maybe the glasses.

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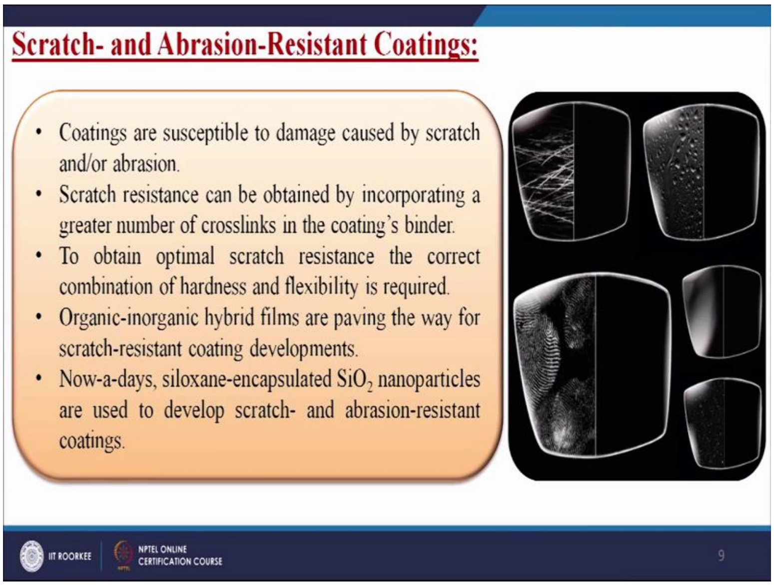

So, just to stop all this kind of nuisance we are can use certain kind of coatings which can help us to a use it as some scratch resistant or abrasion resistant glass coatings. So, coatings are susceptible to damage caused by scratch and abrasions. Scratch resistance can be obtained by incorporating a greater number of cross links in the coating binder. To obtain optimal scratch resistance the correct combination of hardness and flexibility is required. Organic-inorganic hybrid films are paving the way for scratch resistant coating developments. Nowadays, we are using some siloxane encapsulated silicon dioxide nanoparticles are used to develop scratch and abrasion resistant coatings. So, this is the some latest materials by which we can stop some kind of scratch or may be that some kind of abrasions onto the glass itself.

Next one is called the self cleaning coatings. From the name itself you can understand that here we are applying some materials which can be activated by the environment in itself. So, there is no need of any kind of binders or maybe any kind of outside activations to activate those materials.

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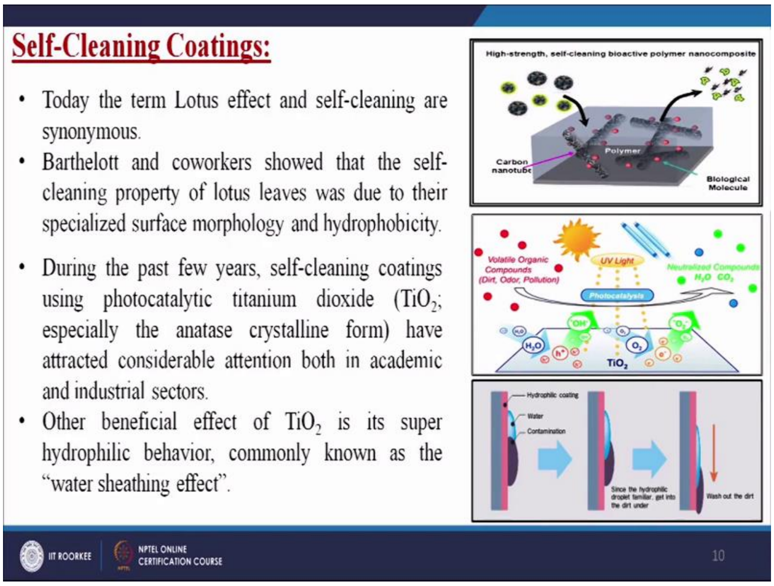

So, today the term Lotus effect and self cleaning are the synonymous. If we see the lotus leaf actually any water particles comes onto it, it will not stick with the lotus leaf it is totally fully hydrophobic materials or maybe that hydrophobic in nature. Not only that any dust particle cannot stick with the lotus leaf. So, this is the perfect example of these self cleaning coatings.

So, here we are not adding any outside materials or maybe foreign particles to that particularly leaf, the lotus leaf itself is having the self acclaim properties by which it can resist the hydro felicity or maybe that adhesion of any dust particle on to eat. So, Barthelott and coworkers showed that the self cleaning property of lotus leaves was due to their specialized surface morphology and hydrophobicity. During the past few years self cleaning coatings using photocatalytic titanium dioxide especially with anatase crystalline form or maybe annotates face generally we are calling it have attracted considerable attention both in academic and industrial sectors. Other beneficial effect of TiO 2 in it is it is super hydrophilic behavior commonly known as the water sheathing effect.

So, here is a one very good example generally we are giving it. Suppose we are having the substrate on that we are giving some hydrophilic coatings. So now, first may be some dust particle is coming and it is depositing on to the substrate. So, when you are trying to wash this dust particle we are putting some water particles from the top, but water particles will not go to that material unless and until there will be some dust particles, but if the coating material will be some hydrophilic materials so automatically it will attract the water particles inside.

So what water particle will do? Water particle we will try to go inside the dust particles and it will flush that dust particles from top of the surface. So, this is a very good example for the self cleaning coatings. Here also one very good examples of the carbon nanotubes generally we are using for some biological applications. So, that can be activated some properties by which some kind of virus or bacteria cannot go inside that material or maybe it can be reflected from the surface of that particular material.

Now, we can do this kind of coatings for the antibacterial applications also. So, nowadays when we are talking about some kind of materials like barrier materials, some kind of packaging materials, some kind of biomedical applications or maybe some kind of materials which can be used for some kind of sophisticated applications generally we are talking about some kind of antibacterial coatings.

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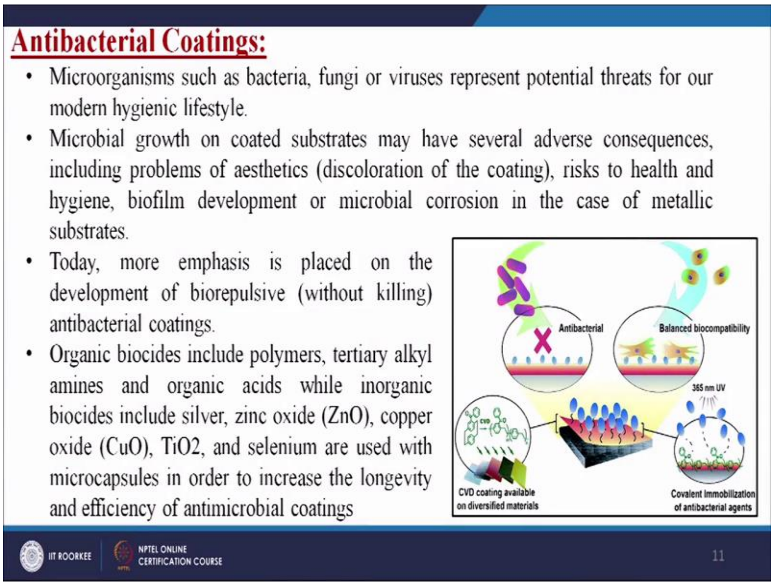

So, microorganisms such as bacteria, fungi or viruses represent potential threats for our modern hygienic lifestyle. So, microbial growth uncoated substrates may have several adverse consequence to stop all these things we are doing some kind of antibacterial coating over there. So today, more emphasis is placed on the development of bio repulsive without killing antibacterial coatings. Organic biocides include polymers, tertiary alkyl amines and organic acids while in organic biocides include silver, zinc oxide, copper oxide, titanium dioxide, selenium are used with the micro capsules in order to increase the longevity and efficiency of the antimicrobial coatings. So, simply we are adding some kind of materials on top of that surface so that any kind of bacteria or virus will not react with the substrate simply it will repulsed from the surface itself so that, that coating is known as the antibacterial coating.

Next is called the antifouling coatings. So, this is the best example that this material we are using for our ships for our submarines for naval purpose. Generally, when the materials is going inside the water if the water will flow in a particular speed there will not be any formations of any algae or any kind of other bacteria or may be the virus. But when the water speed will be almost less or maybe that the vehicle is totally stopped inside the water maybe some kind of algae formations, some kind of a virus formations, some kind bacterial formations can be possible on that particular materials.

So here, we are developing some kind of materials which will help that substrate material not to form the algae on top of that or maybe the deposition of that bacteria or maybe that plants or maybe some kind of marine animals on top of that.

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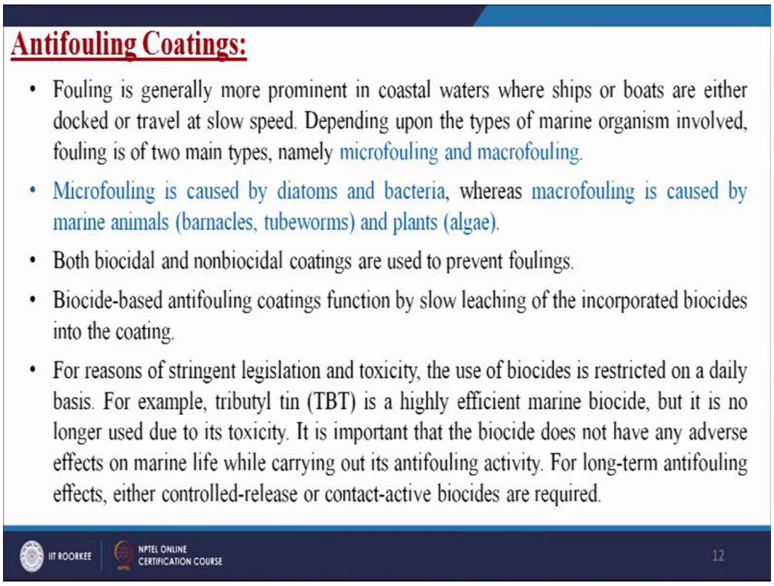

So that it can extend that ship life or maybe the marine life. For reasons of stringent legislation and toxicity, the use of biocides is restricted on a daily basis. Generally previously we are using some kind of biocides which will restrict to form these kinds of marine animals, plants, bacteria, are maybe that macro fouling onto the material itself. But, generally this kind of materials is having the toxicity; this is not good for the environment. So that is why we are going to use some kind of non biocide additional coatings which does not have any kind of side effects to the environmental also.

So here for example; tributyl tin is a highly efficient marine biocide, but it is no longer used due to it is toxicity. It is important that biocide does not have any adverse effects on marine life while carrying out it is antifouling activity. For long term antifouling effects either control release or contact active biocides are required, based on that; because it is going inside the water if it will generate certain kind of toxic gases maybe that is not good for the animals which they are presenting inside the water itself and maybe some kind of plants.

So, that is why we do not use these kinds of materials, but we can use some kind of materials which will be biocompatible so that it will not give any kind of toxic gases or maybe any harmful reagents to the water itself.

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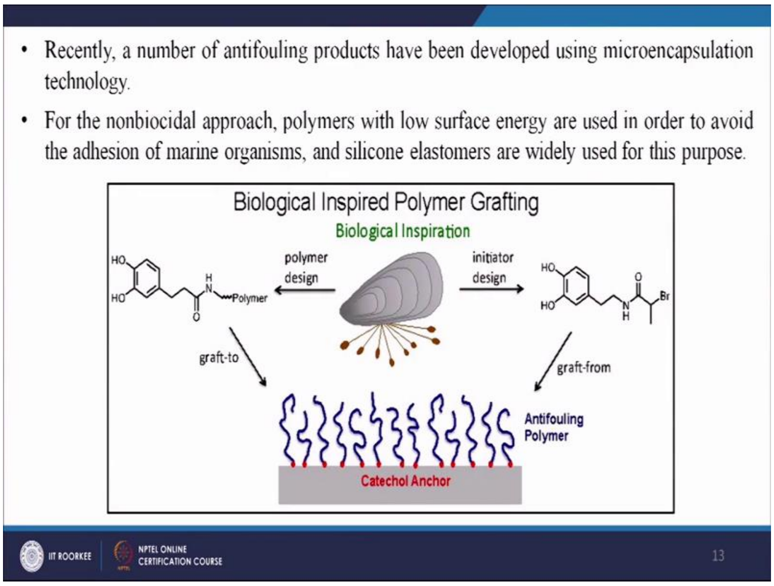

Recently a number of antifouling products have been developed using micro encapsulation technology. For the nonbiocidal approach polymers with low surface energy are used in order to avoid the adhesion of marine organisms, and silicone elastomers are widely used for this particular purpose. So here, from this particular figure you can understand that we are grafting some kind of polymers and which is acting as the antifouling polymers over there. So, we are putting some kind of initiators inside the polymers then when it is some kind of bacteria is directly coming with that particular coating materials, the polymer will be automatically activated and it will reflected it so that the algae formations or bacterial formation will not be taking place onto the substrate material.

Next is called the conductive coatings with the core cell particles. This is the best example suppose we are having some insulator materials. So, just to make the conductive in materials simply we are doing the coatings of some materials which are conductive in nature. So, like this way we can change the total material electrical properties.

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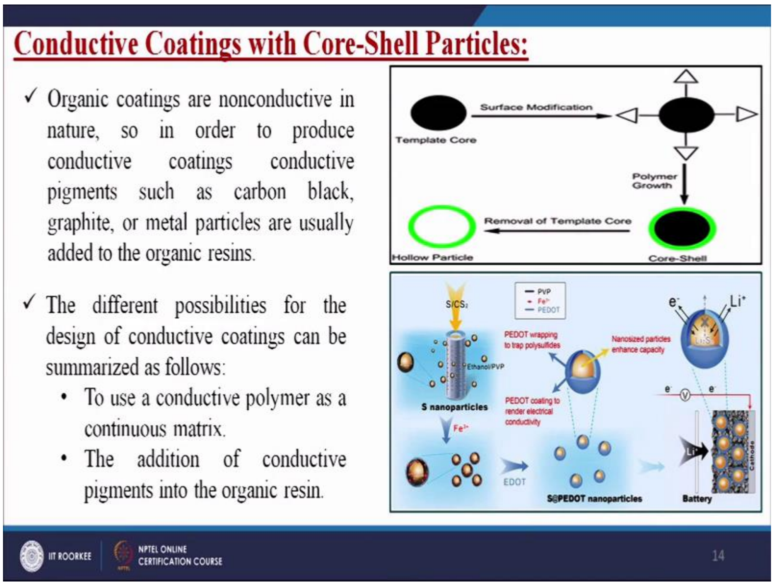

In this particular case some kind of organic coatings are non conductive in nature in order to produce conductive coatings. Generally, we are using some carbonaceous materials in terms of carbon black graphite or maybe some kind of metal particles are usually added to the organic resins. The different possibilities for the design of conducting coatings can be summarized as follows: to use the conductive polymer as a continuous matrix to addition of conducting pigments into the organic resins. From this particular figure you can understand that we are having some core we are doing some kind of surface modifications, then we are doing some kind of polymer growth. We are making it as some kind of core shells, and then from the inside we are removing the core material so the hollow particle it is acting some kind of conducting materials.

Here is also the same thing, for some kind of electronics applications we are using some kind of particles for the battery lithium ion battery for cathode terminal generally we are using some kind of materials. And then we are coating that material with some conducting materials to make it more conductive or maybe that more efficient.

Next enhancing coating functionalities with the micro capsules; generally we are using this technology for the micro capsule applications.

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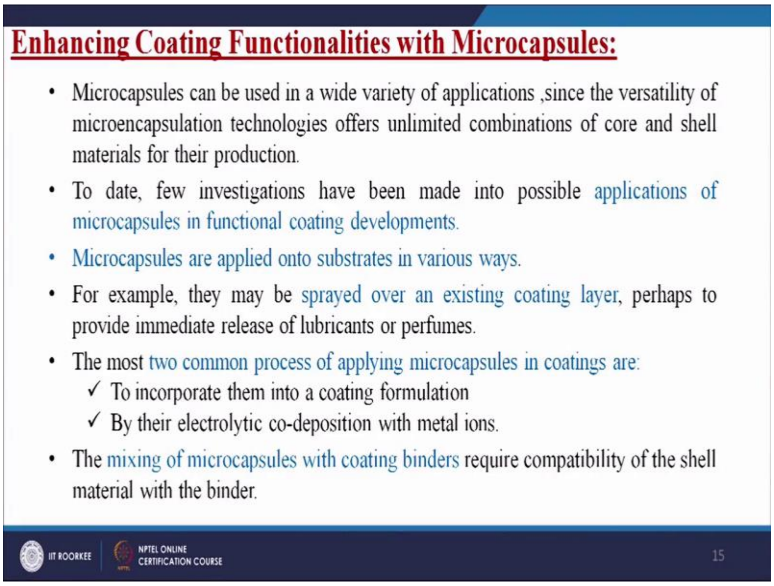

So, micro capsules can be used in a wide variety of applications since the versatility of micro encapsulation technologies offers unlimited combination of course and cell materials for their productions. To date, few investigations have been made into possible applications of micro capsules in functional coating developments. Microcapsules are applied onto substrates in various ways.

For example, there may be spread over an existing coating layer, perhaps to provide immediate release of lubricants or perfumes. The most two common process of applying microcapsules in coatings are to incorporate them into a coating formulations by their electrolytic core positions with metal ions. So, here is the examples that how we are going to use these applications for the technology for the micro encapsulations.

Another interesting example is to use the micro capsulation in the development of self healing coatings. For this micro capsule containing monomer cross linker or catalyst are incorporated into a coating matrix such that when a coating ruptures the micro capsules along with rupture break open and release their contents itself. So, that it is something the best examples of that like a puncher less tire, so puncher less tube. Maybe, whatever that if there will be any puncture automatically that material will come and it will get that healing so the tire will not lose the air pressure so that it can work perfectly fine.

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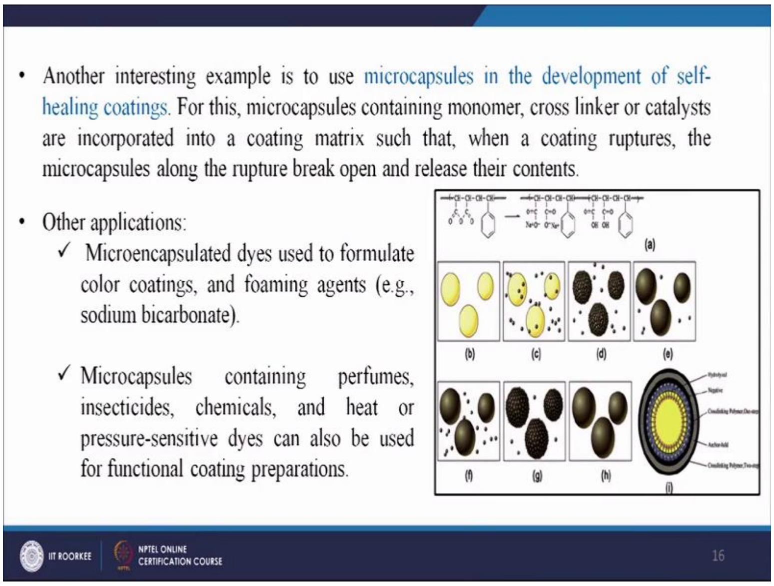

So, this is also a one kind of coating techniques by which if we are doing some kind of coatings if the outer side coatings will be damaged then the from the inside the material will come and it will heal that proper particular zone so that the coatings will remain same.

Other applications, microencapsulated dyes used to formulate color coatings and forming agents. So, like this for the targeted drug delivery we can use some kind of micro scale encapsulations by which we can detect that how our medicines or maybe the drug is working inside the body from the outside which can detect properly. Not only that micro capsules containing perfumes, insecticides, chemicals, and heat or pressure sensitive dyes can also be used for the functional coating preparations. So, here you can see that there is one material which is yellow in color inside the nail in the center. Now, we are doing the layer by layer coating techniques to make it more active or more maybe more functional.

So now, we have come to our last slide which is nothing but the summarizations of these whole lectures.

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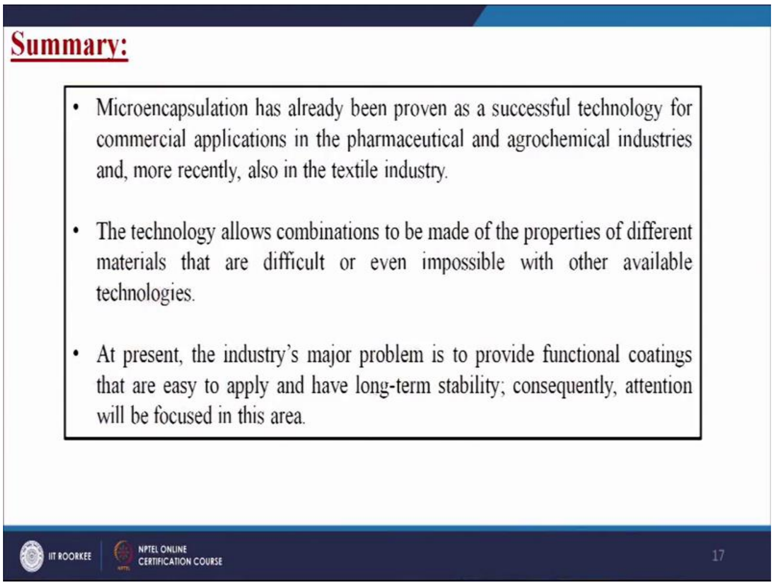

So, here the micro encapsulations as already been proven as a successful technology for commercial applications in the pharmaceutical and agro chemical industries, and more recently, also in the textile industry. The technology allows combination to made the properties of different materials that are difficult or even impossible with other available technologies.

Yes, because the same material we can use for the several applications based on the coating techniques. If there is any problem to that particular material we can do the coating so that we can increase the self life, we can change it is properties. Not only that we can change, we can increase the production rate, we can decrease the cost of that particular material by these kinds of coatings. Not only that whatever the exact application I made based on that I can choose that particular materials and I can do the coating.

At present the industry major problem is to provide functional coatings that are easy to apply and have long term stability consequently attention we will be focused in this area. So, nowadays lots of scientists lost or lots of researchers are particularly working on this particular topic to make the material more versatile and it is applications area will be more widely used.

Thank you.