Surface Engineering of Nanomaterials
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Lecture - 08
Physical Modifications

Hello. Today we are going to start our new lecture on Physical Modifications. In the last slide, if you remember that we have discussed about the different consequences and different factors for which we are doing the surface modifications. So, this slide will discuss about the only the physical modifications for surface engineering.

So, what are physical modifications? In simple word we can say that physical modifications is something like that that we are going to give a top onto the base metal or maybe you are going to put a coating on the base materials, there should not be any chemical reactions in between dip. So, physically just we are putting a layer or maybe a barrier or may be any kind of means so that it will not directly contact with the environment.

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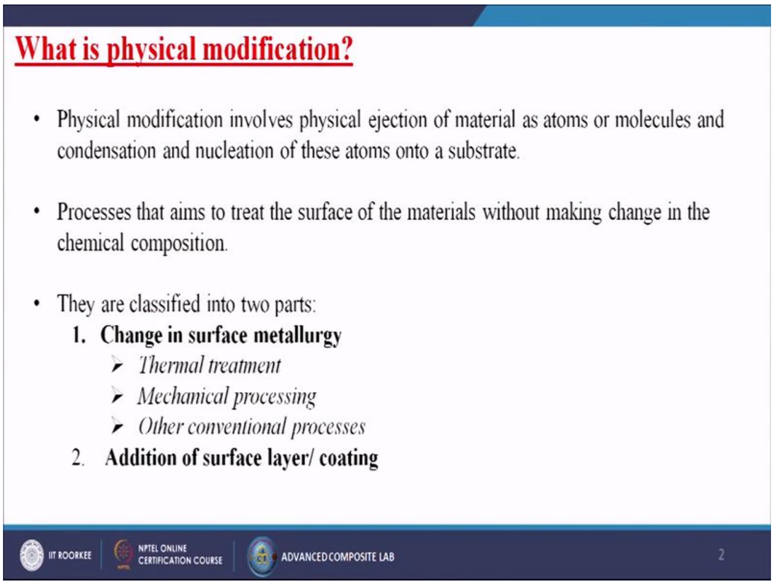

So, physical modification involves physical ejection of materials as atoms or molecules and condensation and nucleation of these atoms onto a substrate; process that aims to treat the surface of the material without making change in the chemical compositions. That means, we are not going to change the chemical compositions of that particular material as well as we are not going to change its any chemical structure, simply from just not changing its chemical structure from the outside itself we are giving a one kind of barrier or maybe the layer on to that material so that that material will not react with the environment or maybe it cannot react with some chemicals or maybe some other hazard materials.

They are classified into two types: one is called a change in surface metallurgy. That means thermal, treatment, mechanical processing, and other conventional process. And the last one is called the addition of surface layer or coating. So, we are not going to do any kind of chemical reactions over there just maybe we can use certain kind of pressure we certain kind of loads certain kind of heat so that the outer surface of the that particular material is going to be change, but its chemical structure or maybe the chemical properties will remain same.

So, what is the importance of the physical modifications?

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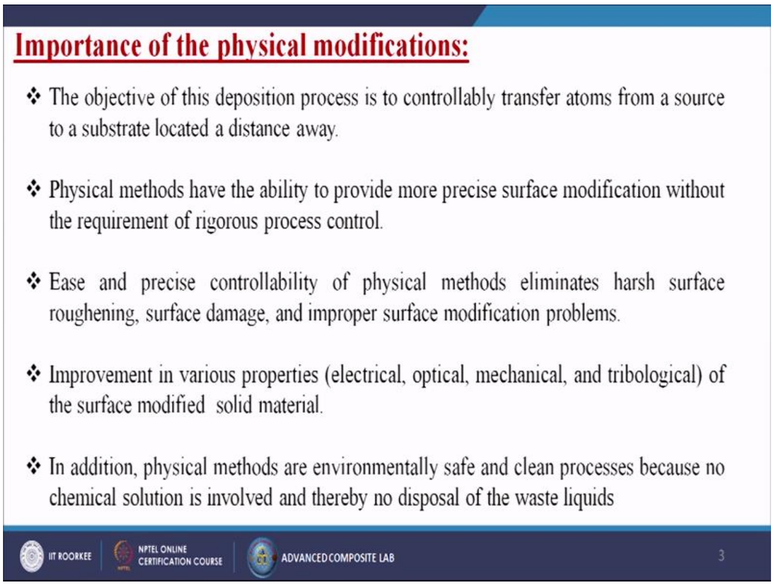

The objective of this deposition process is to controllably transfer atoms from a source of a substrate located a distance away. So, simply when we are trying to do the is modifications what you are using, we are using certain kind of substrate or materials we are agitating those materials so that it is releasing some kind of electrons or maybe irons and then that electron and irons is directly coming and it is depositing onto your material surface. So, we are not going to change the material chemical properties. Physical methods have the ability to provide more precise surface modifications without the requirement of rigorous process control.

Yes of course, if you are going to do the chemical reactions we have to keep that sample for a longer time, we have to maintain certain atmosphere certain temperature certain maybe that humidity control so that there should be the proper chemical reactions can takes place. But, when you are talking about the physical methods we are not going to change any environmental of things. Simple, we are putting that material into that particular equipment or maybe that into that particular machine. Simple, by clicking or maybe by switch on and off we can do these kinds of modifications.

It is easy process and precise controllably for physical methods eliminates harsh surface roughening, surface damage and improper surface modification problems. So, if there is any scratch or maybe there are any holes there is any dent so these type of problems can be easily solved by the physical modifications. Improvement in various properties like electrical, optical, mechanical, and tribological of the surface modified solid material.

In additions, physical methods are environmentally safe and clean process because no chemical solutions are involved. That means, there is no chemical reactions is taking place so no there is no generation of any kind of toxic gases which can harm our body or maybe the environment.

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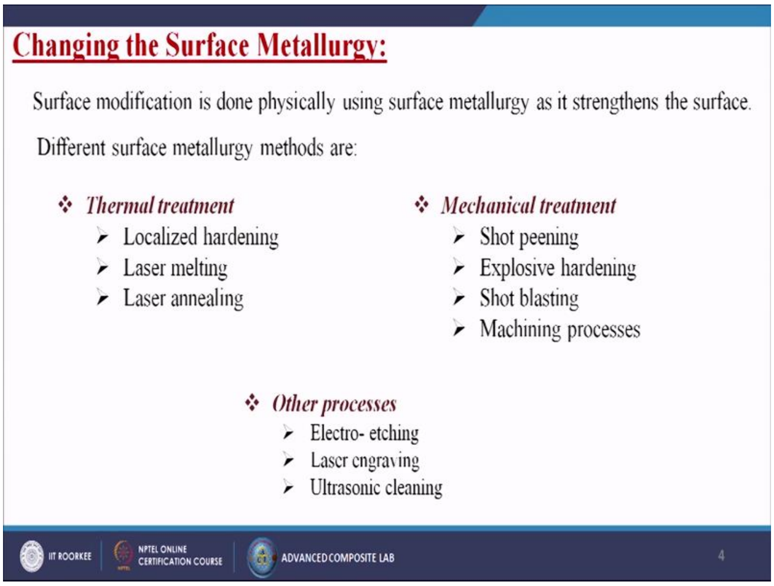

Next changing the surface metallurgy, so surface modifications are done physically using surface metallurgy as it strengthens the surface. Different surface metallurgy methods are: thermal treatment, mechanical treatment and other process. In thermal treatment it is call the localized hardening, laser melting, laser annealing. So, simple on the surface we are giving the thermal energy. Now there are various ways by which we can give the thermal energy. So, depending upon the various ways we are classifying is as a localized hardening, laser melting, laser annealing.

Then mechanical treatment means we are giving certain kind of load or maybe the pressure onto that material surface by which we are going to change the surface of that particular material. If there is any cracks or maybe pores simple we are heating that materials continuously so that the new crystal structure maybe formed or maybe that crystal structure can become praised, so that it can create a new crystal structure or maybe the new grain formations rather we can say it by which we can do the surface modifications. Like those shot peening, explosive hardening, short blasting and machining process.

And there are some other process also, generally we are calling it as a may be unconventional process or maybe some kind of latest techniques where we are going to use its call the electro etching, laser engraving and the ultrasonic cleaning. In the next slide I am coming one by one.

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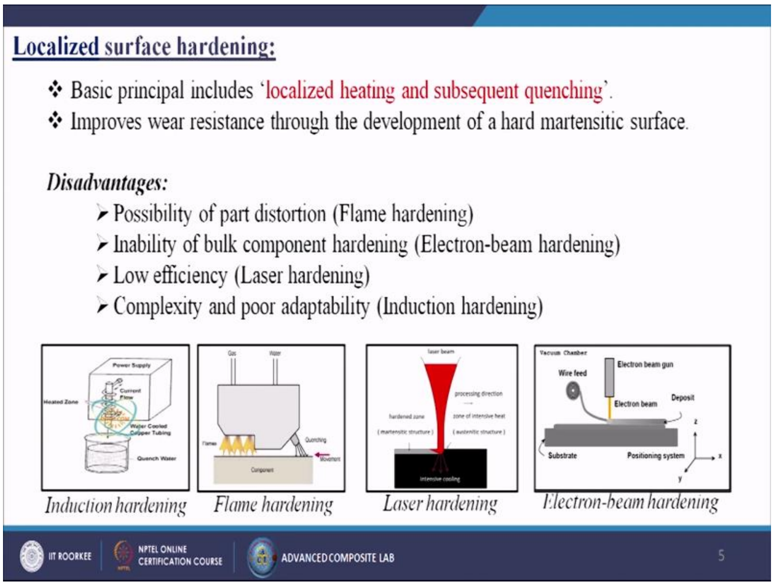

So, first is call the localized surface hardening; so basic principle include localized heating and subsequent quenching. The simple is that we are heating the material surface then the metal will be heated, but it should be the lesser than the melting temperature of that particular material sometimes it is more than the crystallization temperature of that particular material. So, it lies in between the melting temperature and crystalens temperature of that particular material, due to which the material new crystal structure will be formed and while heating.

So how we are going to do, first we are heating those materials, so when we are heating those materials; that means the banderols force in between the mole molecules is going to be decreased so that moles or maybe atoms is trying to detract each other. Then certainly we are cooling that material. So, what is happening? Certainly it regains the banderoles force in between the atoms or maybe the molecules, so they are trying to come very quickly and by which they are co-lighting each other, so whatever the gaps or maybe whatever the difference in between those previously exist now it will be removed. So, by doing this one we can do the surface hardening of that particular material.

There is certain kind of disadvantages also: possibility of part distortions flame hardening maybe, your shape and size can be distorted. Inability of bulk component hardening electron beam hardening. Means, maybe for small size materials it can be easily done for a bigger materials or maybe a bigger size materials we cannot do, because if you trying to put certain heat maybe that when the heat will reach at the middle of that particular part maybe the surface can be melted. Low efficiency by laser hardening we can etch the low efficiency and then complexity and poor adaptability induction hardening.

So, there are several types of methods by which we can do the localized surface hardening. One is called the induction hardening, then flame hardening, laser hardening, electron beam hardening. From these particular figures you can understand that the we are heating the material, but the means are different. In this particular case we are generating the some electromagnetic field by which we are increasing the metal temperature. Here, we are directly heating that material so that it can be heated up. Here we are using certain kind of lasers by which the material is heated up. And here we are using the electron gun or maybe that electron bombardment on particular material so that the temperature can be increased.

Next one is call the laser melting. So, from the name itself we can understand that here we are using the source of laser for heating those materials right. So, whole we are heating those materials it means that we are heating those materials up to certain temperature, below its melting temperature otherwise the metal will be in the liquid form.

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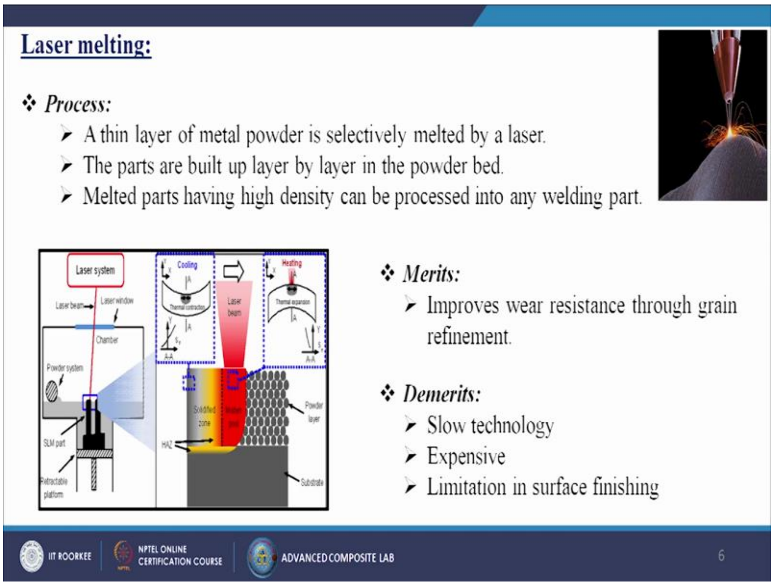

So what we are going to do? Here generally we are using some kind of carbon dioxide type of laser or maybe some kind of NDYAG lasers just to heating the material. A thin layer of metal powder is selectively melted by a laser. The parts are built up by layer in the powder bed. Melted parts having high density can be processed into any welding part.

So, sometimes what we are doing, simply we are heating that material so that its surface can be heated up and it can form the new crystal structure and the surface modification can be possible. Or maybe sometimes we are using certain kind of powders then we are applying the laser. So, due to that laser that powder can be melted up and it can put certain kind of coating or maybe the barrier layers onto that material surface. So, by two types also we can do it. The next one I will come into later.

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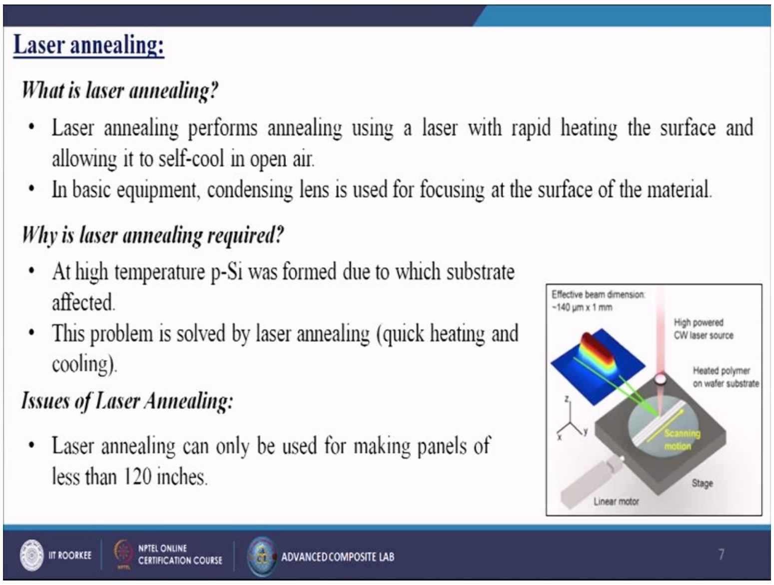

Next one is call the laser annealing. So, annealing and so one kind of metallurgical terms by which we are heating that material into a particular temperature then we are keeping that material in that temperature for a longer time then slowly slowly we are decreasing the temperature; laser annealing performance annealing using a laser with rapid heating the surface and allowing it to self cool in open air.

As I told already suddenly I am heating that material then slowly slowly I am cooling down the material, so that the material can release the heat slowly so that the crystal structure formation will be homogeneous. In basic equipment condensing lens is used for focusing at the surface of the material. So, from that particular figure you can understand that we are using certain kind of laser shots, and then here we are using the magnetic lens so that it can be converge in a particular point, so that the surface area will be less, so that the heat affected zone area will be less for that particular material. And not only that the laser can reach only the effected part not the surroundings.

So, at high temperature p doped silicon was formed due to which substrate affected. This problem is solved by laser annealing, quick, heating and cooling. Here, that p doped silicon is acting as a whole transport material. And issues of laser annealing are that laser annealing can already use for making panels of less than 120 inches so that we cannot go into the deeper. That is a small disadvantage of this laser annealing.

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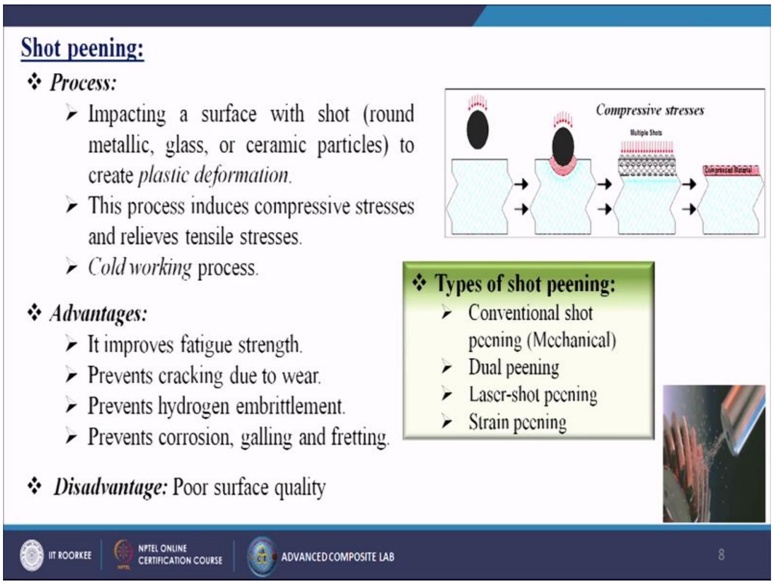

Next one is call the shot peening. Also in my previous slides already I have discussed about the shot peening, again I am telling it here. That here, we are going to use certain kind of ceramic balls or maybe that ceramic particles then a from a certain height we are releasing those particles, and while releasing when it is directly coming into the contact of that base materials it is gaining certain kind of kinetic energy. Due to that kinetic energy it is giving impact onto the material surface. By which we are compressing the material over layer so that if there is any cracks or maybe abrasions or maybe is there is any pores so everything can be compressed and the material will get a maybe high strength thickness layer on top of it.

So, impacting a surface with shot, round, metallic, glass or ceramic particles; this is the figure of that particular particle or maybe the balls to create plastic deformations onto the material surface. The process induces compressive stresses and relieves tensile stress cold working process; generally we are doing it into the room temperature. We are not going to use any kind of temperature or maybe the heating arrangement over there.

So, there are certain advantages: it improves the fatigue strength, prevents cracking due to wear, prevents hydrogen embrittlement, prevents corrosions, galling and the fretting. There are certain disadvantage also: poor surface quality because it depends upon the size of that particular ball, if that ball will be small maybe you can get a smooth surface, but the if the size of the ball will be bigger then maybe you can get certain kind of wavy surface too. So, there are several types of shot peening methods are available. One is called the conventional shot peening that, that is the mechanical process this is normally this is the schematic view of that particular process; then dual peening, laser shot peening and strain peenig.

The thing is that, the logic is same only the way how you are allowing those balls to directly come into the contact. Either you can mix it with some lasers or maybe you can mix it with some waters or maybe some kind of medium so that by which that balls can come and directly hit your material surface.

Next one is call the explosive hardening. So, from this name itself you can understand that we are using certain kind of explosive materials, and we are blasting those explosive materials. Keeping some distance from the material itself so that the direct impact from that particular explosives directly come onto the materials surface. Either that explosive can directly touch with your base materials or maybe there should be some gap. It depends upon how much impact you need for that particular surface.

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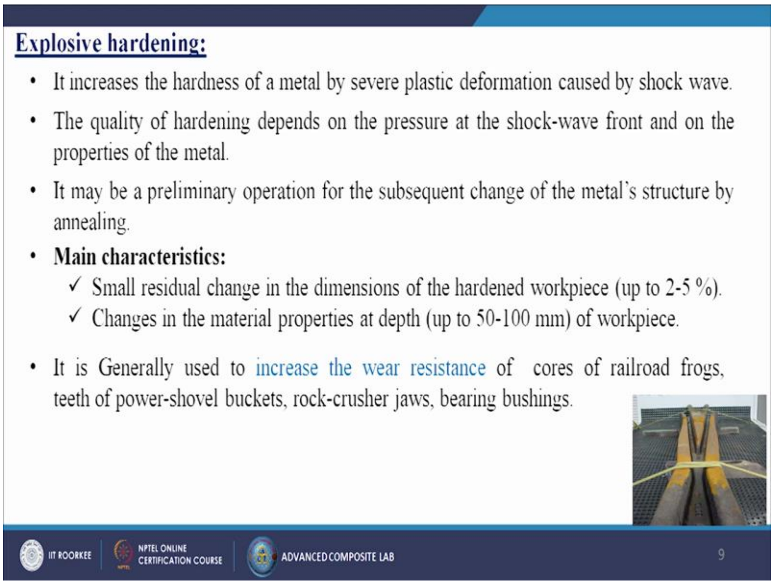

Then it increases the hardness of a metal by severe plastic deformations caused by shock wave. The quality of hardening depends on the pressure at the shock wave front and on the properties of the metal. It may be a preliminary operation for the subsequent change of the metals structure by annealing. So, the thing is that here simply we are applying that explosive for making a shock onto your metal surface.

Main characteristics: small residual change in the dimensions of the hardened work piece up to 2 to 5 percent generally we can observe. Change in the material properties at depth up to 50 to 100 millimeter of the work piece can be achieved. It is generally used to increase the wear resistance of core of railroad frogs, teeth of power shovel buckets, rock crusher jaws and bearing bushings. So, these all are the examples where we are using this kind of explosive blasting.

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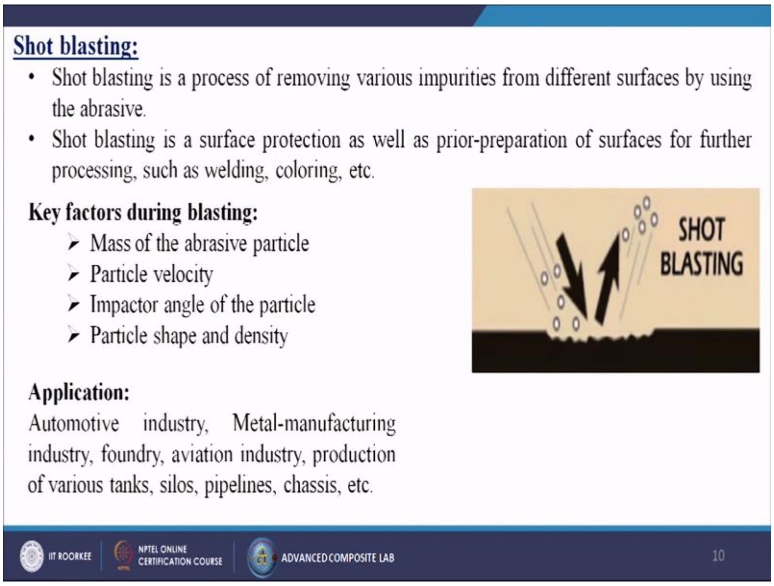

Next one is call the shot blasting. So, shot blasting is a process of removing various impurities from different surfaces by using the abrasive particles. It is also a one kind of shot peening process, but there in the shot peening process generally we are using the balls which is met by some ceramics or maybe some glass or maybe some metals, but here we are using certain kind of abrasive particles, and from a certain distance we are allowing those abrasive particles that it can come directly with the high velocity onto the material surface. So that it can do certain kind of rubbing onto a material surface by which your material outer surface can be changed or may be can be modified. So, shot blasting is a surface protection as well as prior preparation of surface for further processing such as welding, coloring etcetera.

Key factors: mass of the abrasive particles, particle velocity, impactor angle of the particle, particle shape and density. So of course, the surface of the particular material can depends upon from how much distance you are allowing those abrasive particles to directly come into the contact with your best metal. Not only that, how much velocity it is travelling. Then what is the particle size, if the particle size will be smaller than you can get a smooth surface if you can use the if you are using the cores particle size then whatever the surface will get that will be the rougher one.

Then next one we are discussing about the machining process. So, machining is one kind of mechanical process. There are several types of machining process are available. The whole machining process we can divide into two parts: one is called the conventional machining process another one is call none conventional machining process or maybe the unconventional or maybe the nontraditional machining process.

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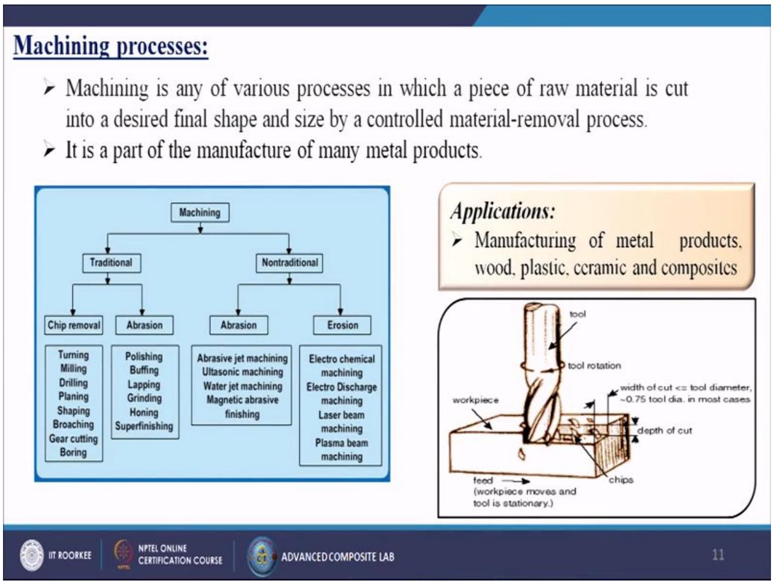

So, machining in any of various process in which a piece of raw materials is cut into desired final shape and size by a controlled material removal process. So, either we are doing the lathe operations or maybe some kind of drilling operations or maybe the milling operations or maybe the shaping operations by which we can cut the material, we can remove the layer of that particular material by which we can generate the new face new surface of that particular material and by doing all these things we can generate some kind of new surface of that particular base metals.

So, from that particular table we can understand or maybe the rather we I can say it as a chart we can say that there are two types of things, machining can be divided into two parts: one is call the traditional another one is call the nontraditional. Then traditional is called the chip removal and another one is call the abrasions. Both the cases you are removing the material, but one is in the bulk form another one is into the small form or maybe the small quantity.

So, when we are talking about the chip form there is having turning, milling, drilling, planning, shaping, broaching, gear cutting, boring. So, these all are the cases where the material removal rate is higher. And the reduction of that material will be more but, when we are talking about the abrasion base, so just you are rubbing the surface of that particular material. So, you can easily understand that the material removal rate will be lower. In that particular case what are those; polishing, buffing, lapping, grinding, honing and the super finishing process.

And the right side we are going to see what are the nontraditional process; abrasion base, abrasive jet machining, ultrasonic machining, water jet machining, magnetic abrasive finishing all those. So abrasive jet machining means, we are mixing the abrasive particles with the air then we are allowing that material to directly fall onto a material surface and it can do the machining operations. Or maybe you are using some kind of ultrasonic (Refer Time: 20:01) in which you are putting the abrasive particles. Due to the ultrasonications the abrasive particles is rubbing onto your material surface and it can do the modifications.

And next one is call the water jet. In the water jet machining you can use certain kind of particles over there with the mixing with water and then the whole studies coming onto a material surface and it is rubbing and it is doing the modifications. Then erosions; so there are certain things which is known as the electro chemical machining, electro discharge machining, laser beam machining, plasma beam machining, these all are call the unconventional machining. Where, we are not touching the material directly, we are not giving the material any load or pressure by means of laser by means of electrons just we are heating that materials and then we are doing the modifications of that particular base materials.

What are the applications? Manufacturing of metal products, wood plastics, ceramics and composites; from these particular figure you can understand that this is also a one kind of conventional machining process. So, this is one kind of milling process where we are going to generally this is call the fresh milling process by which that face of the tool is cutting your work piece materials and then it is removing certain kind of material from the top layer of that particular work piece.

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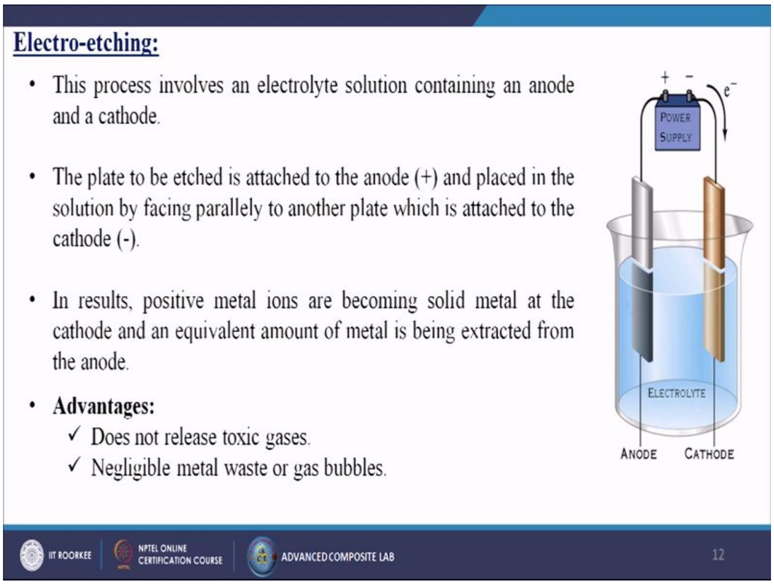

Then next one is call the electro etching. So, this process involves an electrolyte solution containing an anodes and cathodes. Simply, you have to deep your material into some electrolyte solutions. Then, the plate to be etched is attached to the anode that means into the plus side and the placed solution by facing parallelly to another plate which is attached to the cathode.

So here, it is your materials and here it is another material in results positive metals ions are becoming solid metal at the cathode and equivalent amount of metal being extracted from the anode. So, the anode from this particular anode the material in ion form will directly come and it will deposit on to that. So, by which way you can do the modification of that particular material also or by keeping your material into the anode side also you can clean your material outer surface too.

There are certain advantages: does not release the toxic gases, negligible metal waste or the gas bubbles. As the material removable rate is very very slow it can be easily controllable, so you can easily increase or decrease the layer thickness while doing the removal.

Next one is call the laser engraving. So, this is one kind of sophisticated techniques generally nowadays we are going to use.

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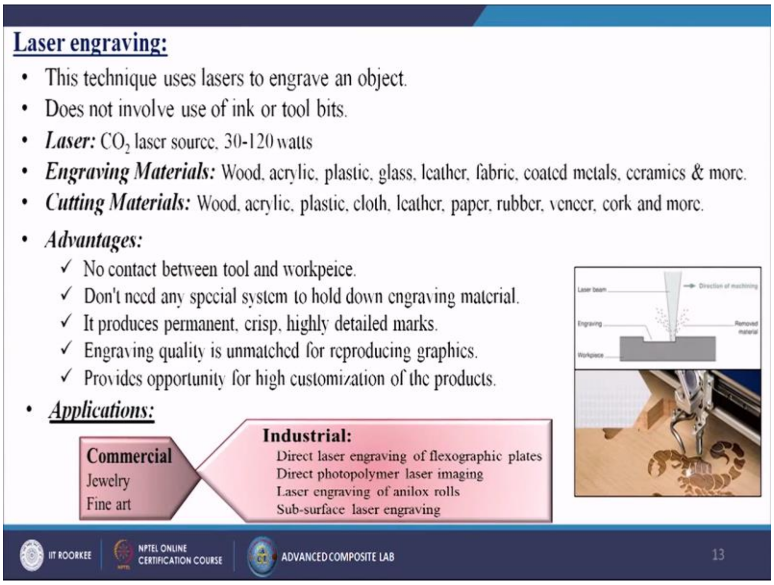

So, these techniques uses lasers to engrave an object, does not involve use of ink or tool bits, laser generally carbon dioxide laser we are using as a source and the power requirement is 30 to 120 watts. Engraving materials: generally wood, acrylic, plastic, glass, leather, so any kind of soft materials we can do any kind of decorating things either we can make certain kind of momentous, we can make certain kind of prize, medal, by doing this kind of techniques. Cutting materials: generally wood, acrylic, plastic, cloth, leather, paper, rubber, veneer, cork and more.

There are certain advantages also: no contact between tool and work piece, only the laser from a particular source it is directly coming it is directly falling onto that base materials and you are doing the modifications or maybe the designing. Do not need any special system to hold down engraving materials. It produces permanent crisp highly detailed marks. Engraving quality is unmatched for reproducing graphics. Provides opportunity for high customization of the products.

So, from these particular figure you can understand that you are having that work piece, now you can put certain kind of mask over there also or may be just keeping your laser beam into a the moveable form you can do any kind of design onto your base materials. This is the figure of that particular process. So, commercially we can make certain kind of jewelry or maybe we can use it for the fine art purpose, industrial purpose, direct laser engraving or flexographic plates, direct photopolymer laser imaging, laser engraving of anilox rolls, sub surfaces of the laser engraving. So, these all are the different types of industrial methods which we can adopt.

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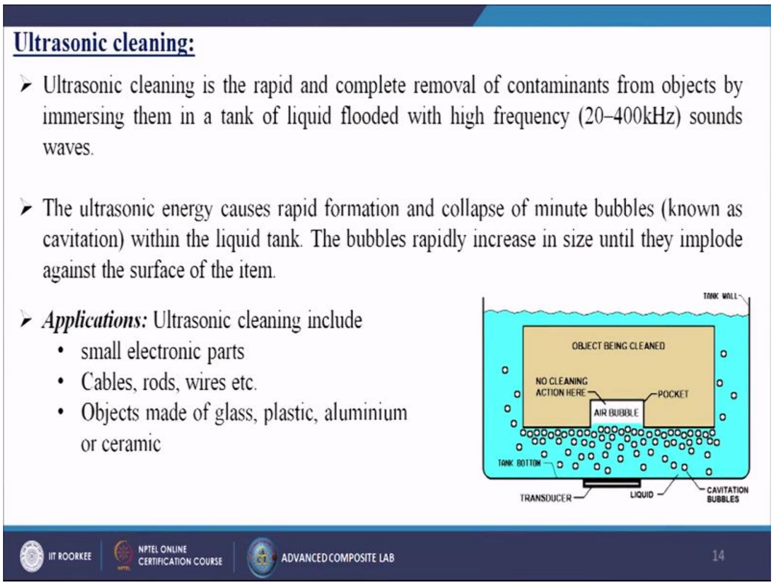

Next one is call the ultrasonic cleaning. Ultrasonic cleaning is the rapid and complete removal of contaminants from objects by immersing them in a tank of liquid flooded with high frequency 20 to 400 kilo hertz sound waves. So, simple we are putting our material into some ultrasonic, but then we are applying certain kind of ultrasonic vibrations or maybe the motions by which we can do this kind of cleaning.

So, the ultrasonic energy causes rapid formations and collapse of minute bubbles known as cavitations within the liquid tank. The bubbles rapidly increase in size until they implode against the surface of the item. So, we are generating certain kind of bubbles inside the liquid by the ultrasonic motions or maybe the vibrations and then that bubble is heating your object or maybe your material surface by which we are doing the cleaning of our particular material surface. What are the applications? Ultrasonic cleaning include small electronic parts; cable, rods, and wires. Objects made of glass, plastic, aluminum or the ceramics.

Next one is call the adding a surface layer or the coating. So, here till now we are directly discussing that how we are going to do the modification of that particular object by the physical means. Now, we are going to do this by any kind of putting any kind of layer or may be the coating on that particular surface.

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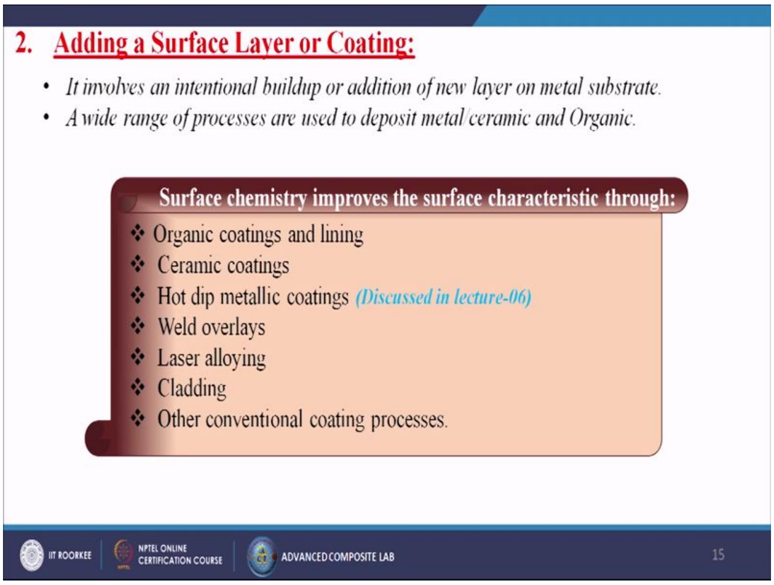

It involves an intentional build up or additions of new layer on metal substrate. A wide range of processes are used to deposit metal oblique ceramic and the organic one. So, surface chemistry improves the surface characteristics though: organic coatings and lining, ceramic coatings, hot dip metallic coatings; as we have already discussed in our lecture number 6, weld overlays, laser alloying, cladding and other conventional coating processes. So, these all are the different processes which involve by making any kind of barrier layer or maybe that coating on the material surface.

So, first we are trying to do the organic coatings and linings. So, before going to start simply we have to know that which one is call the coatings and which one is known as the linings.

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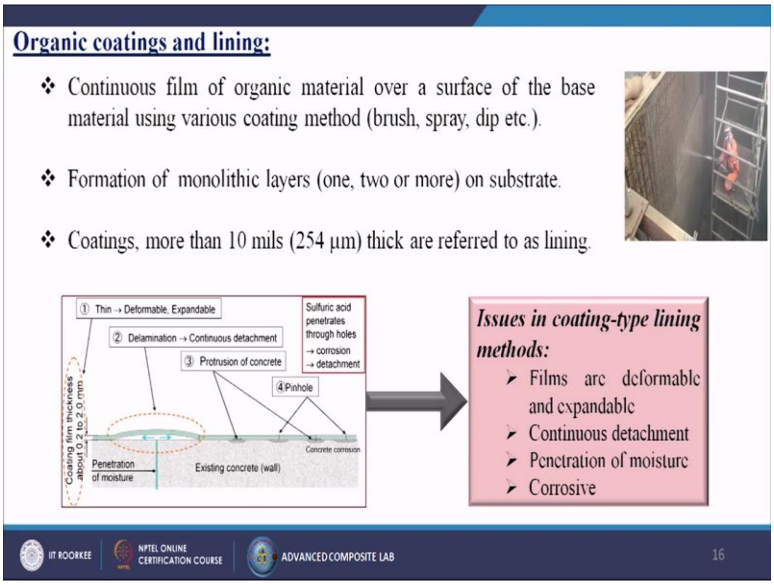

So, coatings more than 10 miles or maybe the 254 micro meters thick are referred to as lining before that it is known as the coating. So, in this particular figure you can understand that they are making some kind of liquids or maybe some kind of paints onto the metal surface. So, there should not be any chemical reactions in between them, so by which we are going to do the coating or maybe we are putting certain kind of coating onto the base materials.

Here, these all are the different problems which we can generally see or maybe which we can generally fill in our day to day life. Maybe we are putting certain kind of paint onto the wall right in our house or maybe everywhere, so after certain time we can see that paint can easily come from that particular surface. Or maybe there is some kind of cracks generally it is known as the pinhole on that material surface or maybe that concrete or maybe there is certain kind of water observations in between the layer of your paint and your concrete or maybe the inside concrete or maybe the beam of that particular concrete. So, these all are the problems.

And what are thus, films are deformable and expandable, continuous detachment, penetration of moisture or maybe some kind of corrosiveness. So, by doing the organic coatings or may be using some organic materials like paints or some in some other means we can do the coatings onto your material surface.

Next one is call the ceramic coatings from the name itself you can understand that that material whatever we are going to put on the base metal or maybe coating of the base material that is made by the ceramics or maybe that is a mixture of any kind of ceramic materials.

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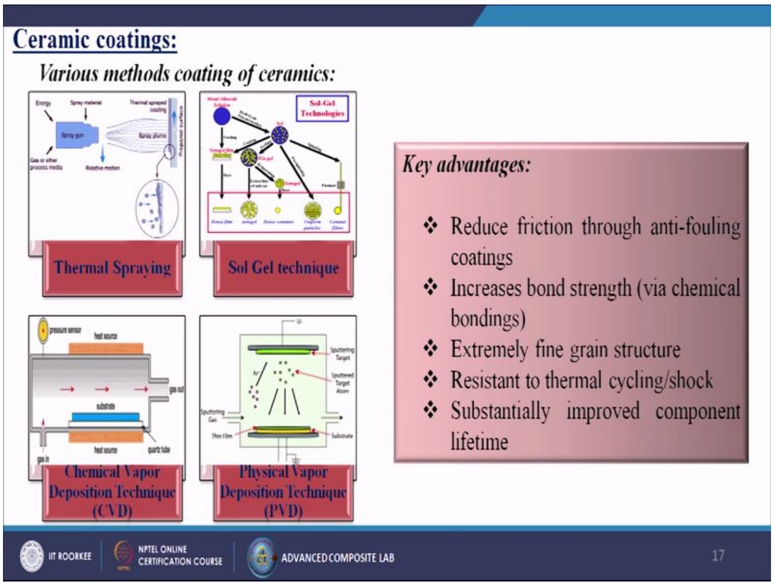

So, there are various coating techniques or maybe various methods we can adopt for the ceramic coatings: one is called a thermal spraying, then sol-gel technique, then chemical vapor deposition techniques or maybe the physical vapor deposition techniques. The key advantage is for that particular purpose: reduce friction through antifouling coatings, increases bond strength via chemical bonding, extremely fine grain structure because you can create those structure; means maybe either we can say it as a micros structure or maybe the nanostructure. Then resistant to thermal cycling or shock substantially improved the component lifetime.

So, these all are the key advantages of that particular material.

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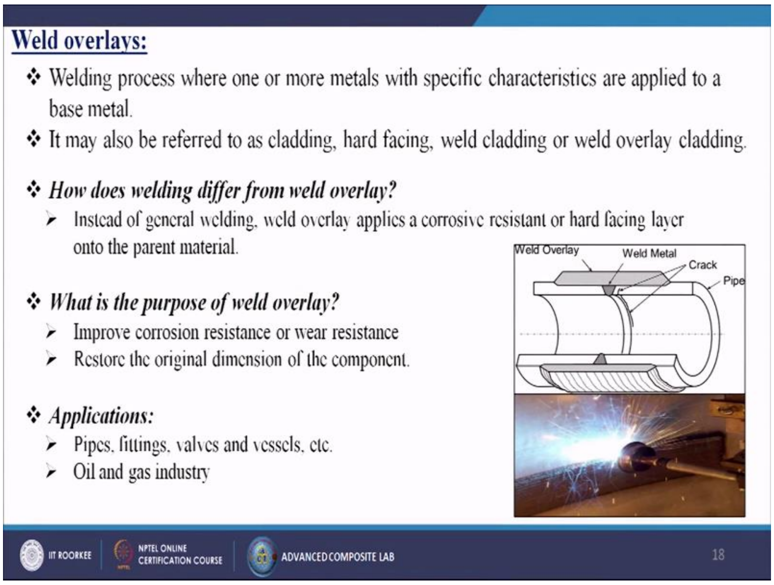

Then weld overlays: welding process where one or more materials with specific characteristics are applied to a base metal. It may also be referred to as cladding, hard facing, weld cladding, or maybe weld overlay cladding. How does welding differ from weld overlay? Instead of general welding weld overlay applies a corrosive resistant or hard facing layer onto the parent material.

So, the thing is that, first initially we are trying to join these two materials so we are doing the welding. May now we are having some kind of welding joint over there; so now, on top of that we are making a layer of some other materials by which we can do the welding overlays. So, what is the purpose of weld overlay? Improve corrosion resistance or wear resistance restore the original dimensions of the component. Applications: pipes, fittings, valves and vessels, etcetera; oil and gas industry.

Generally, we are doing a top cover onto that weld parts so that these part should not be affected by any kind of moisture or maybe any kind of oxygens from the environment or maybe it should not be any corrosions or maybe the rusting can be taking place.

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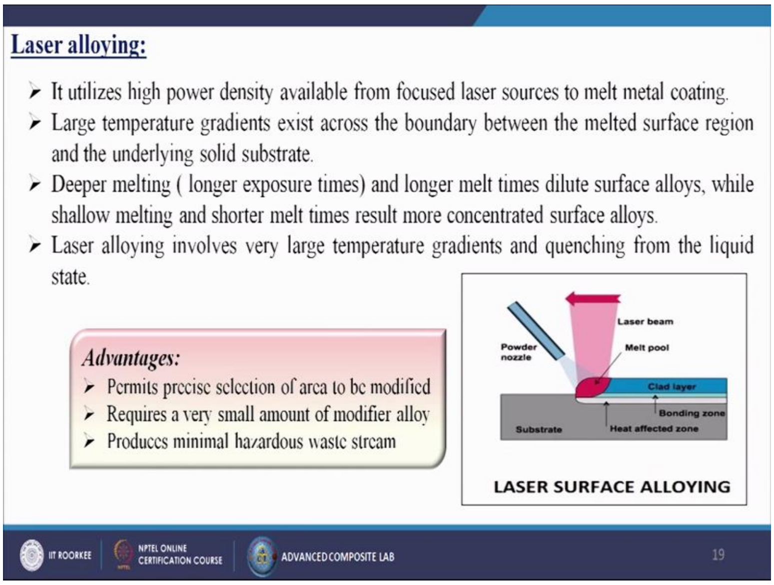

Next one is call the laser alloying. So, it utilizes high power density available from focused laser sources to melt metal coating. Here, in this particular figure we can understand that we are using certain kind of substrate over there. Then we are applying the laser beam. That laser beam can be moved to over there. And from another side we are using certain kind of powder either it maybe some kind of coated powder or maybe it some kind of anticorrosives antirusting powder, then by heating those powder on by this laser beam it is making layer onto that metal surface or maybe your base metal.

So, by which you are making a coating on top of your substrate. So, that is why it is called the laser alloying, and not only that there should be a bonding in between your materials and your substrate. So, it large temperature gradient exist across the boundary between the melted surface region and the underlying solid substrate. Deeper melting longer exposure times and longer melt times dilute surface alloys, while shallow melting and shorter melt times result more concentrated surface alloys.

So, it depends upon how much energy you are going to generate. If your surface are will be more so your energy generation will be more, so that material melting will be more, and if your focusing area will be less, so automatically the heat deposition will be less so that you can go for a small area. Advantages: permit precise selections of area to be modified, requires a very small amount of modifier alloy, produces minimal hazardous waste stream.

Next one is call the cladding. So, cladding means metal coating into the surface of the work piece by combining heat and pressure. So, till now in the laser alloying we have seen that we are using certain kind of particles then you are using the laser beams by heating that laser, powder materials is coming into the liquid form then it is making a layer onto your top surface. But, here simultaneously we are giving the heating as well as we are giving the pressure. So, maybe the heating under pressurized conditions we are doing these operations, so that is why it is known as the cladding.

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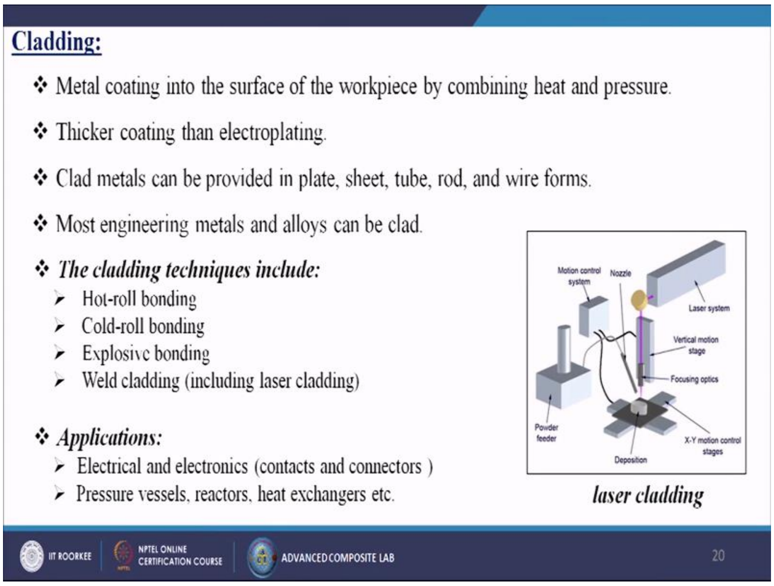

So, thicker coating then the electroplating; clad metals can be provided in plate, sheet, tube, rod and wire forms, most engineering metals and alloys can be clad. So, here from that particular figure you can understand that this your substrate over there, then you are giving the laser from this laser source, then you are having some powder feeter over there so directly that power is coming into the contact. Then, this whole thing is into some pressurized chamber. So, you are increasing the pressure as well as are increasing the temperature too.

So, the cladding techniques include: hot roll bonding, cold roll bonding, explosive bonding, weld cladding, including laser cladding. Applications: electrical and electronics applications generally for the contacts and the connectors we can use. Pressure vessels like reactors, heat exchangers, so any kind of thermal material or maybe thermal equipment we can use this kind of cladding techniques.

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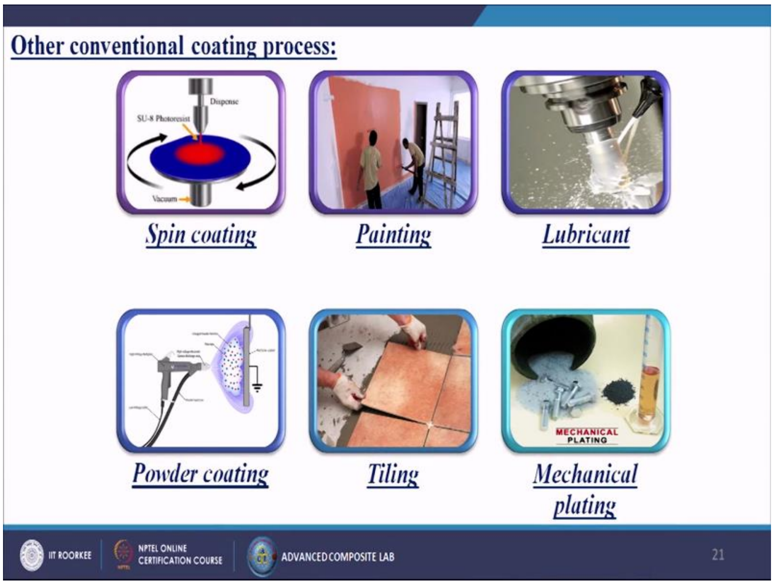

Then other conventional coating process: like spin coating we can do it, we are can do it painting, we can do it the lubrications, mechanical plating, tiling and the powder coating. So, these all are the different types of conventional coating process also available.

So now, let us come to the summary of this particular chapter or maybe the lecture.

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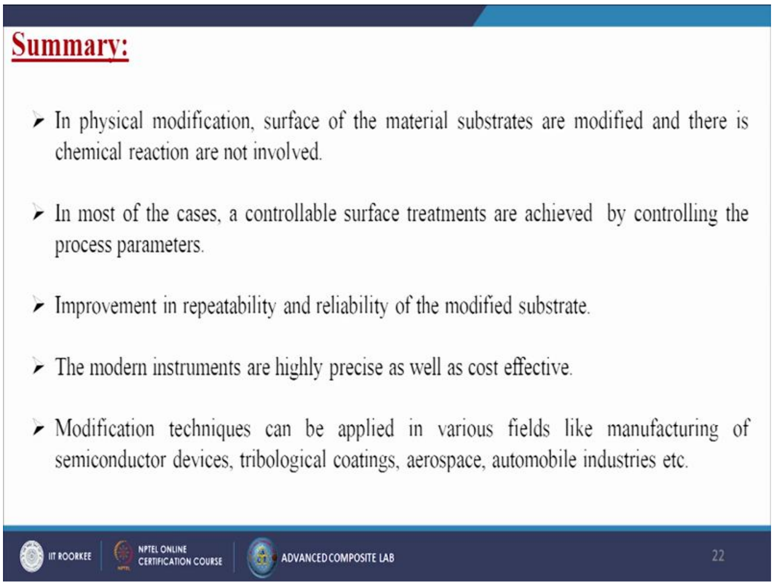

What are these; in physical modifications surface of the material substrates are modified and there is chemical reactions are not involved. In most of the cases a controllable surface treatments are achieved by controlling the process parameters. Improvement in repeatability and the serviceability of that particular material can be achieved. Any kind of wear; cracks or maybe any kind of damages onto the material surface can be easily repaired.

The modern instruments are highly precise as well as the cost effectives. So, by doing this kind of modifications in terms of physical modifications we can increase the service life of that particular material. Modification techniques can be applied in various fields, like manufacturing of semiconductor device, tribological coatings, aerospace, automobile industries, these all are the few; n number of applications where we can use this kind of physical modifications.

Thank you.