Introduction to Machining and Machining Fluids
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Lecture – 12
Coatings on Cutting Tools

So welcome to the another lecture where we are going to study about the coating on cutting tools not only on cutting tools some other type. So, we can see like some of the coating you can do on workpieces also; further some of the applications and all those things ok.

So, in overview what we will see is that on tools how the coating processes will be done, which type of coating will be done what is the function of x type of coatings and y type of coatings and all those things ok.

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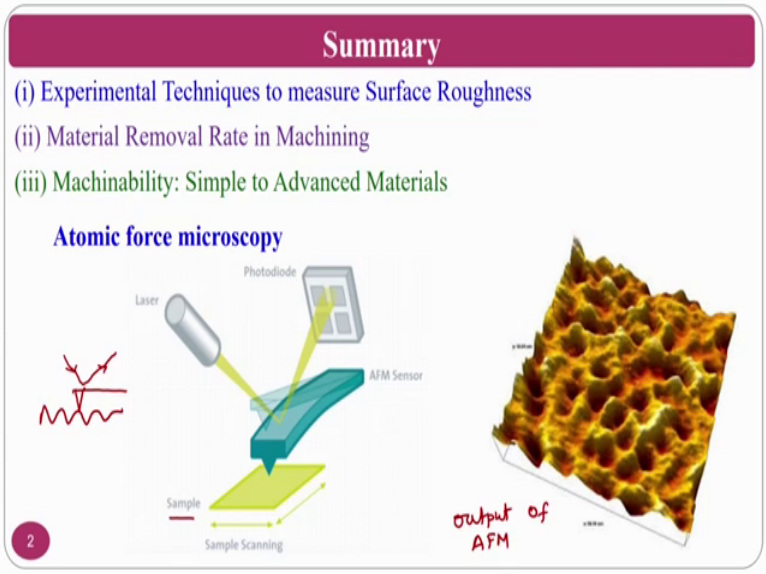

So, we will see what we have done in the previous class; we have done the surface roughness measurement material removal rate machinability and all those things. Just a point which I missed up in the last class I want to say that surface roughness and surface morphology can be also measured using the atomic force microscopy ok. So, the atomic force microscopy which I have missed out in the last class when I was teaching with the scanning electron microscopy and the transmission electron microscopy. This is the

another way of the technique where you can measure the surface morphology how the surface look like in a three dimensional and all those things ok.

You have a sample here. So, this is a sample and there will be a AFM sensor that is cantilever beam is there. So, if the surface roughness is like this; so, cantilever beam will be there and it will be move on. So, the laser light will fall on it and a photodiode will receiver will be the will receive actually ok. So, based on this principle if there is a up, down, valley, peak and all those things those can be measured in a three dimension.

So, it will be good quality picture normally in terms of 3D it will came ok. So, you can see this is how the output of a of AFM atomic force microscopy will be this is a three dimension where you will give the details about the surface morphology intricate details and all those things ok. This is the another technique along with the what we have studied in the previous techniques.

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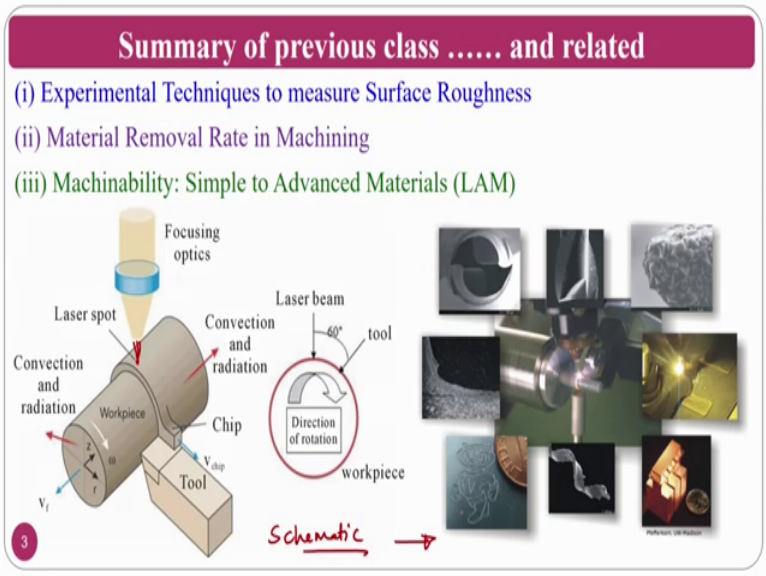

So, the other thing we have seen in the last where we end yesterday was a laser assisted machining; schematic diagram would have been a better option, but I have shown you some of the applications of a laser assisted machining those who. So, to brush up you how the laser assisted machining will be there. So, this will be a laser source which imparts a laser beam on this one and you can heat it.

So, that the brittle material converts into ducktail metal and then you machine ok. So, just I want to show you the how that single point cutting tool involve in the ducktail region machining of brittle materials ok.

That is what I want to show you. So, the schematic will explain you in a big way and this is the original image. So, and it not only the machining operation it will do many many operations on the brittle materials ok. This is about the previous class which are missed out and which are to be conveyed in the form of schematics for the explanation in a better way ok.

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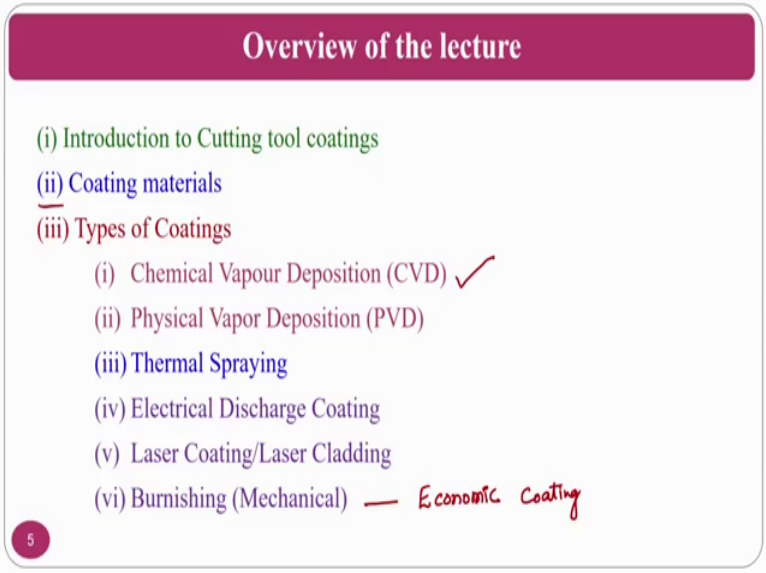

So, now, moving to the cutting tools coatings; so, there are overview what I am going to talk is introduction to cutting tool coatings; what and type of cutting tool coatings are required, why the cutting cool coatings are required and coating tool materials what are the materials that I you are going to see and types of cutting tool coatings like there are many various techniques like CVD that is chemical vapour deposition, physical vapour deposition.

Under the physical vapour deposition you have thermal spraying, plasma spraying and electrical discharge coating the electrical discharge coating do not come under the thermal spray, but it is a thermal assisted coatings on laser coating on laser cladding. So, the burnishing is also one of the coating techniques this is a economic one basically coating technique. If anybody want to work on the coatings using burnishing tools it is

very simple; I will show you. So, you can take up as your some of the projects like VTP or MTP and you can carry out this with coating and without coating of the machining performance particular tools ok.

So, you can do the some texturing and the tool then you burnish that will be better this is a from the research point of view ok.

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So, now we move to the basic need of coating ok; what is the need of coating? If you see some of the tools are there here these are all uncoated some of the slides which have talked in previous also. So, there are grey type of thing and golden type of thing are there. So, the grey ones are uncoated basically these are coated tools and this is well ok. So, to enhance the tool life normally this is the first and primary requirement fancies to utilize the same tool for a long time that will be the major motto.

So; that means, I want to enhance the life. So, how to enhance? You have to increase the hardness or you have to impart some special properties that what will happen your base material normally for example, tungsten carbide base material based tool will be there on top of it you will add a multi layers of very high hardness tool material coatings.

So, that it can enhance that is a one example I am telling about; that is the one way. The second way is to performance of machining. So, the performance means I have to cut more and more material at the same time without any peculiar.

So, to reduce the requirements of cooling we will see what are the cooling problems cooling and providing the lubrication you have just seen the glimpse; how it will affect the humans and all those things. So, always the researchers try towards minimizing cutting fluid or eliminating the cutting fluid. If we can go for the better tools or the best tools you can avoid the coolant; normally coolant why you will use you will use because you want to take out the or extract the heat that is generated in the machining region and to lubricate the frictional area in the machining zone.

If tool can take over all these things; there is no need of cutting fluid. So, that is why normally the technology of cutting tools and tool coatings is continuously growing in the market for betterment of the machining ability ok. So, these are the cutting tool instructs where the you can see the coated uncoated; normally diamond damaged tools you can see the damaged tools how the damage is taken ok. So, in order to minimize this damage one will go for the tool coatings this is the one of the option I am I am saying.

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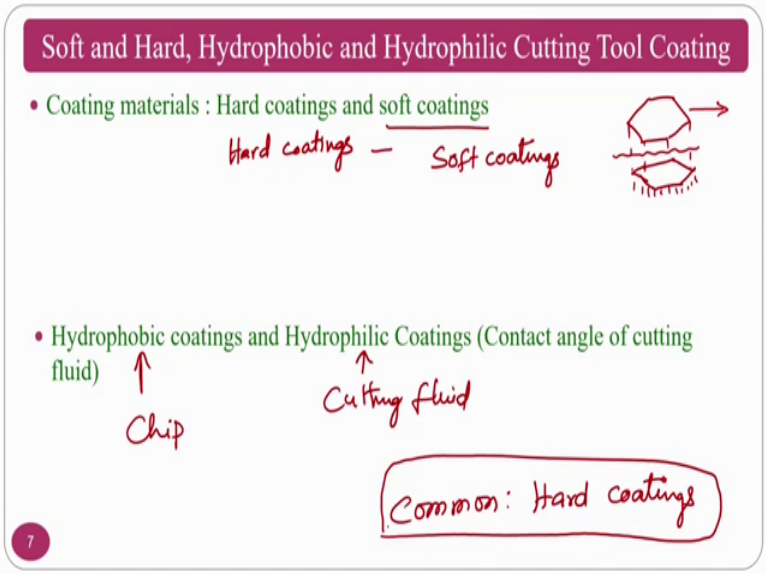

So, there are varieties of tool coatings the first one is soft and hard coatings depend on your application normally most of the coatings that people will do is hard coatings.

Normally these are the hard coatings we will do because we increase the hardness penetration resistance to penetration is what you require for that purpose you will always use hard coatings. So, some of the people also uses a soft coatings; soft coatings are the another coatings why soft coatings are used? For example, I want to coat mos two

molybdenum disulfide molybdenum disulfide which you have seen as a solid lubricants, it will have low shear strength graphite if I want what will happen it will have a hexagon where at the same time you will have a Van der Waal bonding where this is very easy to grow. So, it will shear off if it comes in between the chip and a tool interface what will happen? This bond will break and this goes off; that means, it will stay ok.

So, what I mean to say is that these are the low shear strength materials and this shears off. So, that it will act as a proper lubricant in the machining region, but you can do these soft coatings by burnishing technique ok. So, some of the people do this on the tool textures anyhow I will talk about some of the burnishing techniques and all those things in later, wherever I am talking about the sustainable machining and all those things. There are some other topics like hydrophobic and a hydrophilic coatings normally hydrophobic phobia means many people will have phobia like a if somebody want to undergo CT scan diagnosis you will have a some phobia ok.

So; that means, that you are fearing to it ok. So, like that if phobia means normally if you have the surface it will not stick to the surface it will have a phobia just I am telling you the analogy; it will have a certain contact is not proper in a hydrophilic surface you will have a proper filling will be there ok. So, some of the coatings will be like hydrophobic; so, that the sticking off chip will takes place and sometimes you need a hydrophilic from the perspective of cutting fluid let me explain from the perspective of chip you always required hydrophobic. So, that chip should not stick to the surface it should fear and goes on it has to go up.

So, in from the point of cutting tool cutting fluid what you need is you need hydrophilic coatings on fluid. So, that what will happen it will form a thin layer and try to cool the maximum surface as well as it will also lubricate. So, that is a beauty about the hydrophilic coatings and hydrophobic coatings on the cutting tool ok. So, technology is. So, developed that nowadays customerized tools are coming up; if you ask the companies they will give you a better tools with the better coatings also. But normally if you see you may not get this customerize in the market if you go and get this will be common type of tools where the hard coatings are there ok.

So, the commonly available what I mean to say is hard coating; you will see in the market hard coating tools on a tungsten carbide based on.

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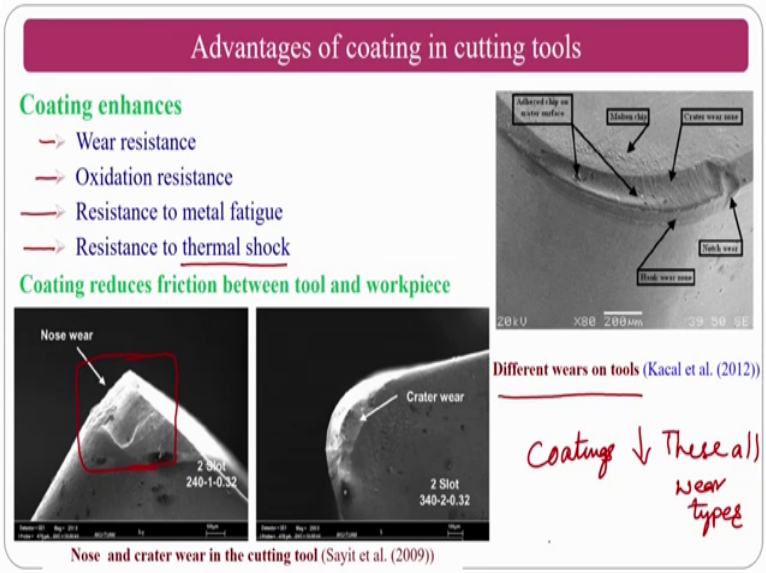

So, the coating what its functions are? It enhances the wear resistance, it enhances the oxidation resistance. So, the wear resistance means if the wear and tear will be minimum ok. So, you can see the nose wear here in this picture. So, I want the less nose wear for that I need to go for certain coatings where the wear resistance is more. So, that I can increase or enhance the tool life that is called the wear resistant coatings oxidation resistance it should not form the oxidation. Normally if you see a mild steel plate if you put in the atmospheric conditions assume that the rain comes and all the atmosphere reactions will takes place the rust will form on it ok.

So, whenever rust form you just scratch with name you can you can remove it because whenever there is a pure mild steel is there you cannot scratch it ok. So, when the oxidation forms the rust forms is nothing when the oxidation or a oxide film; you can easily scratch; that means, that the strength will go down. So, what I want is I want less scratching for that oxidation resistance to metal fatigue you require ok; it should not go in very few number of cycles and resistant to thermal shock normally in intermittent cutting and all those things what this is the basic problem is the shock ok.

So, like communicators now you see or whenever I am cutting a square type of rod in a lathe just I hold it a square type of rod and if you do it what will happen it is an intermittent cutting.

One edge will come another edge you will come and hit on the tool. So, there shock will be there and thermal shocks also because are the high temperatures thermal shocks will be also coming each other. So, the crater wear, flank wear this is the most wear you have seen and if you see on the isometric view one is the flank wear another one is a crater wear and the notch wear every wear are there. So, coatings tries to reduce these wears wear types that is our primary motto.

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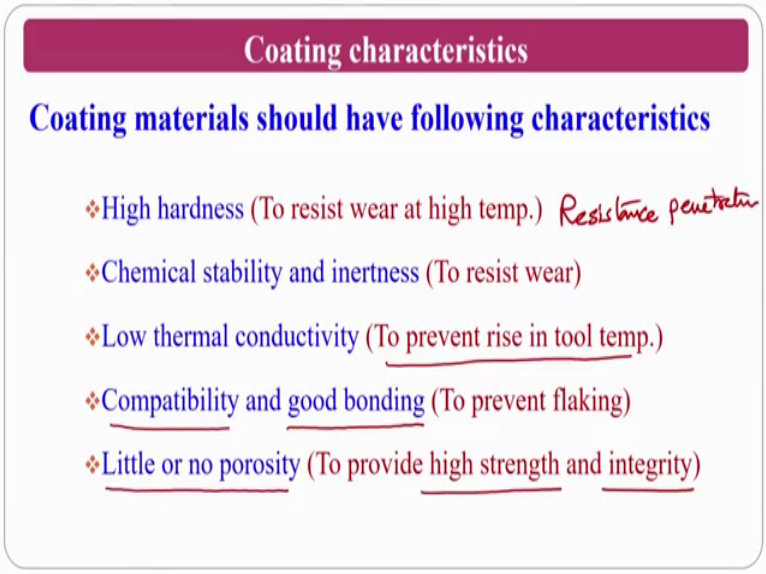

The coating materials should have following characteristics; what are the characteristics that I want whenever I am coating for particular machining application high hardness I said know very resistance hardness.

Hardness is nothing, but the resistance to penetration. So, resistance to penetration this is should be there and the chemical stability and inertness; it should not chemically react with the workpiece. At the same time it should not chemically react with the cutting fluid that is falling on the machining zone in that circumstances you will get a good output from the product side that should be there low thermal conductivity if it is low thermal conductivity what will happen? It will not conduct inside the tool where the bare material of that cutting tool material is there.

So, that it will prevent the rise of temperature of the tool; if the chip is moving on top of it and my tool this is my tool and this is chip if it is moving on top of it, this particular surface is a low thermal conductivity material what will happen? It cannot conduct into

the my tool for that purpose it should be always low thermal conductivity ok. So, that the chip with the carries 80 to 84 percent temperature or heat that is generated in the machining region will goes off; with low thermal conductivity to the tool.

Compatibility and good bonding whenever you coat a particular material, it should not delaminate as early as possible it should stay for a long time that is nothing, but it should have a good compatibility chemically and physically and it should have a good bonding ability. If it has a good bonding what will happen? It will act as a material single material if the bonding is proper; that means, that it is a very good material there is no delamination occurring in the cutting tool material during the machining operation ok.

Little or no porosity is not possible in any type of processes; but minimizing the porosity is only the possibilities. So, we have said that little porosity should be there or a minimum porosity should be there if the porosity is there extent of the coating goes off. So, you should be taken care of the strength and integrity of that particular coating. So, for that purpose porosity should be minimal.

So, that the integrity among the coating with respect to the substrate will be always good ok; this is the coating characteristics that I want. So, if a coating material if it has all these characteristics then that material is a good material to coat ok.

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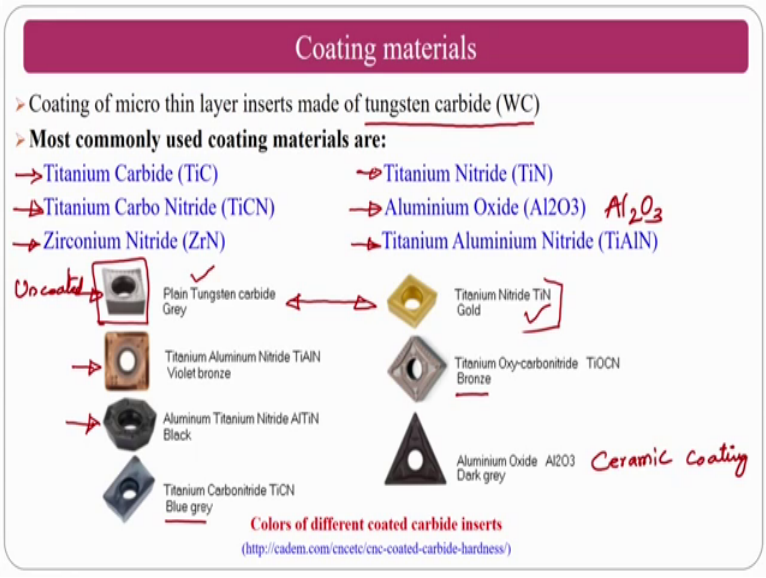

If you see the coating materials now we have seen the what are the characteristics that you should purchase and now we are coming to the various types of things; just as I spoke to you that bare material normally will be a tungsten carbide ok, this is the common material where the tools are used.

So, on top of it you will coat a multi layers. So, the most commonly used coating materials are like titanium carbide is the one material, titanium carbo nitride, zirconium nitride ok. So, titanium nitride is another material aluminium oxide it is a ceramic material titanium aluminum nitride is another material ok. So, these are the materials that one can use as a coating material ok; if you can see a plain tungsten carbide tool this will be a pain this is uncoated ok.

So, the students from B Tech's should understand what is coating and uncoating if you are not in there in the previous classes you should to be able to understand this is a plain tungsten carbide of course, there is no coating whenever you do the coating normally color changes, but similar materials also available titanium aluminium nitride which is a this is the coating is done on this one.

So, aluminium titanium nitride black type of coating is also done; titanium carbo nitride is done which is a blue gray color coating is done and titanium nitride ok. So, for the general explanation if you just compare these two tools ok; this is a uncoated tool and this is coated tool this is the only difference that you should note ok. So, the titanium oxy carbonitride this is the another branch color type of coating is done and aluminum oxide is a ceramic what normally what I say is the ceramic coating ceramic coating is done to enhance the better life; normally ceramic coatings ceramics have low thermal conductivity materials. So, just now I was speaking it should have a low thermal conductivity.

So, that the chip that is carrying a high temperature should not pass on this temperature to the substrate that is the substrate is nothing, but uncoated material this one this is a substrate on which I am coating many layers of hard tools ok.

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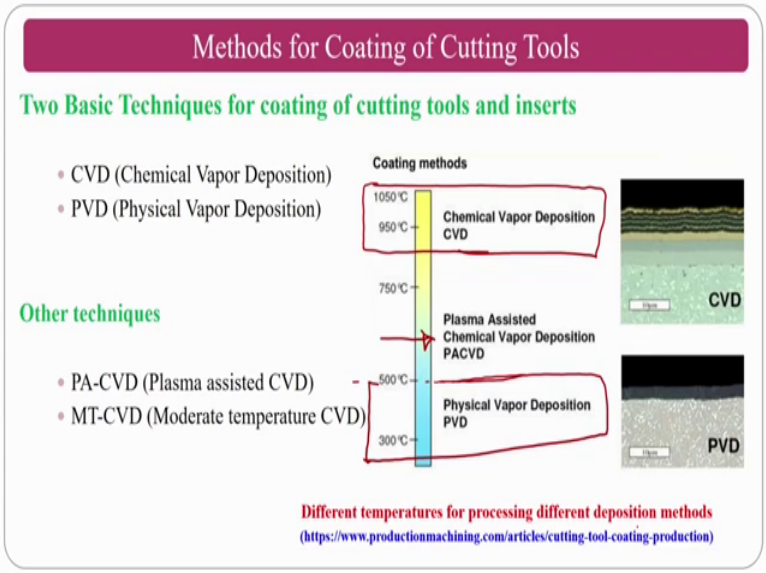

This is about the coating materials; methods of coating the cutting tool the basically there are two types of methods common methods I mean to say, but there are many many types of methods are there, but we discussed some of the techniques apart from CVD and PVD also. So, the commonly used material tool coating techniques are chemical vapor deposition and physical vapor deposition techniques. The advanced techniques to CVD and PVD also will be there that is called plasma assisted CVD will be there and moderate temperatures CVD also is there these are the another two variants of a CVD ok.

So, let me talk about why the requirement of this a PA-CVD and MT-CVD came into picture if you see the physical vapor deposition normally will be in this range ok. If you see the CVD that is Chemical Vapor Deposition it will be in the range of 1000 degree temperature whenever you want to do the chemical vapor deposition. So, the normally the temperature range will be in this range ok.

So, if you see the physical vapor deposition; it will be in this range ok. So; that means, chemical vapor deposition require higher temperatures, but the basic problem is whenever you go for higher and higher temperatures; the basic problem comes is if at all my composition have many elements in it some of the elements may goes off sub milled then the problem comes is the composition that I am coating on that particular material

may not be good that for that particular purpose what the people tries to do is they want to bring down the temperature of the coating ok.

The coating done at certain temperature b if you can bring down the temperature that will be best; So, that elements do not goes off from the composition that you are coating that is why plasma assisted chemical vapor deposition is came into existence whose temperature lies much below the and the CVD this is the at the same time PVD and CVD if you see here there is a color change for the similar materials and all those thing ok. So, different temperatures for processing of different compositions will takes place ok. So, now, we will move on to the chemical vapour deposition technique.

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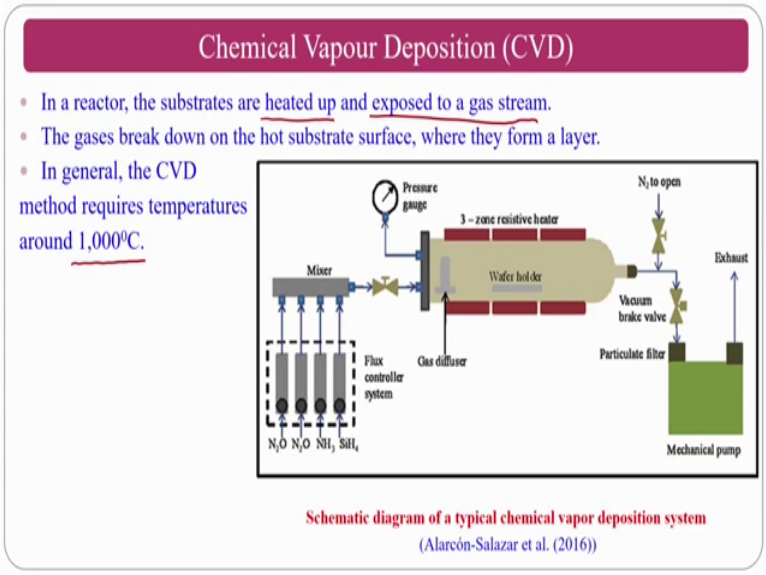

Now, how the chemical vapour deposition will technically takes place in a reactor substrate heated up and exposed to the gas of the steam it is heated up the substrate and it is exposed to the gas in the gas breaks down to the hard substrate surface where they form a layer in general normally as I said if we have the temperature at 1000 degrees the principle that we will see in the next slide this is a schematic diagram where you can see all the things zones and how the vacuum for the better up understanding; I will show you in the next slide this is just an overview how the CVD will takes place.

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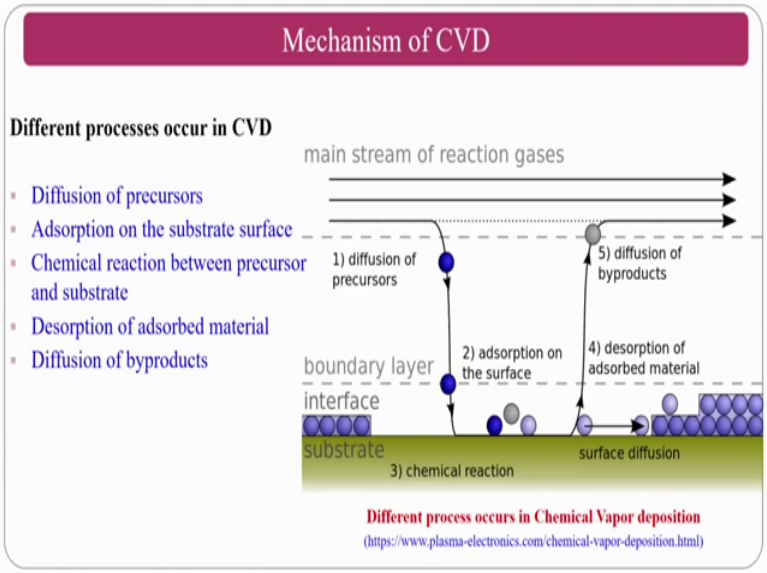

If you see this picture; the mechanism how the chemical vapour deposition takes place the first one is diffusion of precursors will takes place. Anyhow we can see the one corresponding to the diffusion of precursors the substrate heats then it will the gas will takes out. Then the second goes adsorption of the substrate surface this precursors will go and absorb on the surface it is service; then there is a chemical reaction between these two materials; the substrate material and whether the target material those are the precursor which is coming from the substrate will sit on the target material that and there will be a chemical interaction the reaction takes place for proper bonding.

Then comes desorption or a absorbed material ok; it will goes and the diffusion of the byproducts will takes place ok. If there is any byproducts that is forming it will goes as the fumes or as a gas or something these are the standard steps for the chemical vapour deposition technique.

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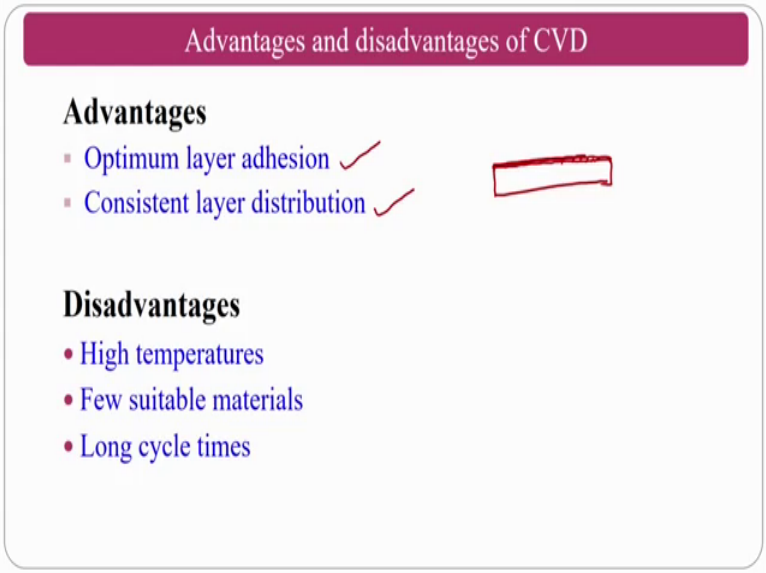

So, the advantages if you see the optimum layer adhesion will takes place and consistent layer distribution will takes place. Suppose that uniform layer will takes place on a substrate if I have a substrate uniform layer will takes place on this one without any disturbance ok.

So, this is the total widths about the CVD advantages. So, every process will have its own disadvantages; the disadvantages is the normally the temperature goes high that is 1000 degrees or a plus or minus some degrees it will go. So, some of the elements will goes off in a composition at the same time it is suitable for a few materials only if there is a melting point of that material is much below than the 1000 degrees what will happen it is not suitable for a long cycle times; it will take a long time to do the coating operation ok.

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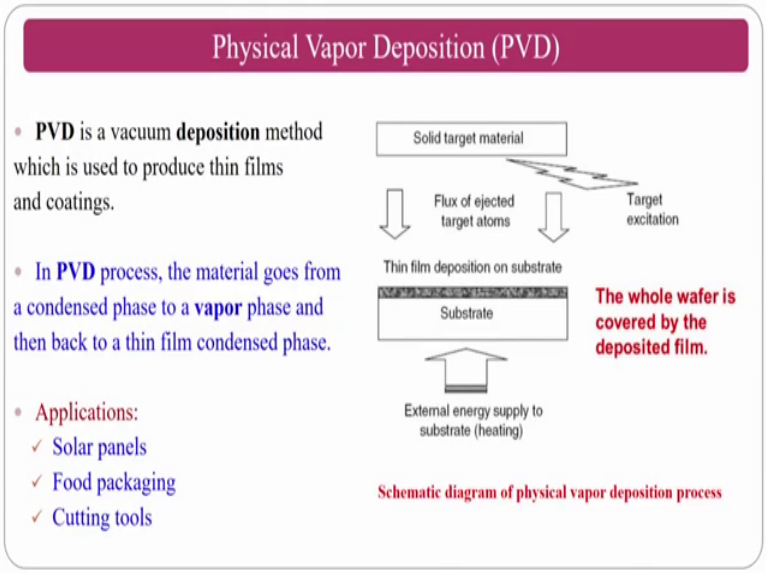

Now, we are coming to the physical vapor deposition ok. Physical vapor deposition done normally in a vacuum ok; it is done in the vacuum method which was used to produce the thin films or the coatings on the substrate material ok. So, in here schematic is here the in the PVD process the material goes from condensed phase to the vapor phase again come back to the condensed phase in the form of thin material ok.

So, what I mean to say is that you have a solid material substrate target will be there you just heat it up then this will go into the vapor phase solid is there; it will go into vapor phase it will occupy the target wherever it has to coat then it will condense there and form a thin coating that is called vapor deposition.

Physically it is occurring there is no chemical reactions in the previous case there is a third point that is called the chemical reaction takes place; on the substrate material with a target material here there is no chemical reaction that is why this is called a physical vapor deposition technique ok. If you see the substrate is there external energy what is you are going to supply is a external energy to heat the substrate you will do; then the thin film deposition will takes place and the solid target material is there just you target on it anyhow you we will see the mechanism in the next slide anyhow, but; however, you just see the applications of this one.

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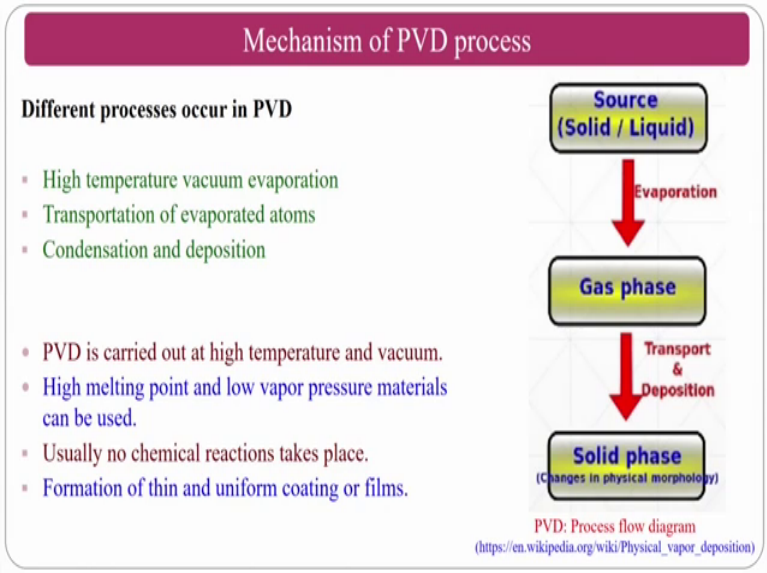

If you applying mostly on the solar panels food packing and cutting tools which we are talking about is mostly the cutting tool applications is one of the biggest applications in physical vapor deposition. If you see in elaborative mechanism high temperature vacuum evaporation will takes place, transportation of evaporated atoms and condensed and deposition will takes place. If you see there is a source from the source evaporation takes place gas phase it will form ok. So, from the gas pose phase it will form on the target and the target it will solidify by a condensation process or the deposition process that is what is a mechanism ok.

If you; so, PVD carried out at a high temperature and vacuum not like a CVD. In this PVD also the temperature ranges vary from for material to material high temperature melting point low vapor pressure materials normally used and usually there is no chemical reaction takes place between the material that is depositing on the workpiece; that means, at a substrate and the material that is depositing as well as the substrate; there is no chemical reaction that is what is emphasized here formation of thin and uniform coating on the field will takes place.

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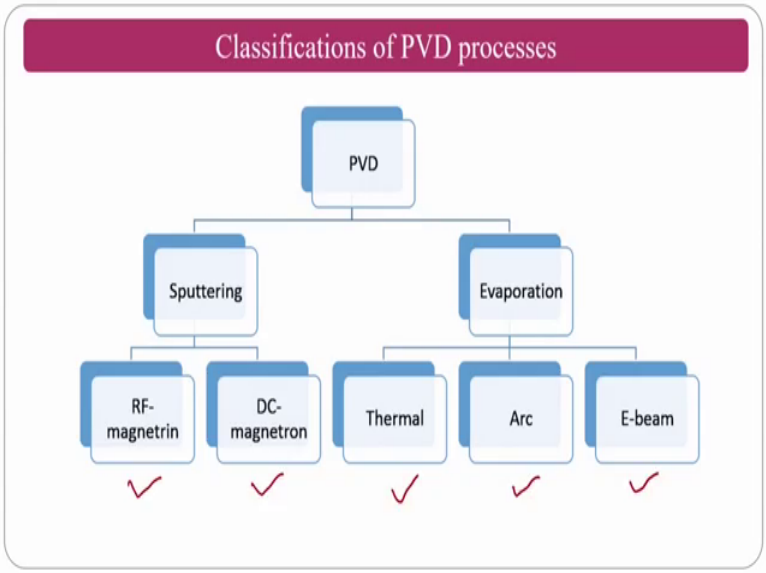

Here also you will get the uniform ok, but if you see the classification of the physical vapor deposition there are many many techniques are there like sputtering and a evaporation.

So, in the sputtering normally RF sputtering will be there and DC magnetron sputtering will be there. In the evaporation techniques thermal spectral thermal evaporation technique arc e beam some of the techniques are there laser and all those things it may not I am know I am not going to talk about exactly the classification since it is not the core area of our manufacturing needs who works on the metal cutting operations; it is a separate subject in a material sense where the coatings technologies are a very very big technologies.

So, I just talk about briefly some of the techniques how these perform in the coating operations ok.

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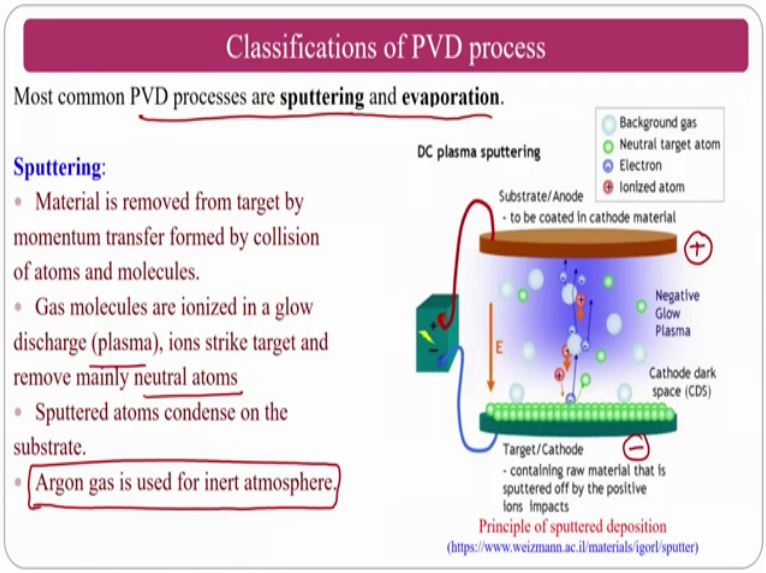

So, the PVD the first one will be the sputtering techniques. So, some of the works which also we also do using RF sputtering radio frequency sputtering; So, the most commonly used PVD process is a sputtering process which works on the sputtering and the evaporation techniques ok. If you see here the target is a cathode and the substrate is an anode basically whenever you give the some charge a negative terminal to the this one negative terminal and here the positive terminal what will happen? There will be a charge deposition.

Material is removed from the target by the momentum of transfer by the collision of atoms and molecules ok. The material is removed from the target basically ok; so, we will have the target and we will have the substrate material the target is one the gas molecules are ionized in a glow charge that is called plasma ions will strike the target and remove mainly neutral atoms. The sputtering atoms condensed and it will form on the work the material where on which you want to deposit ok.

So, basically the argon gas is used as a inert atmosphere I said you know in the physical vapor deposition normally vacuum will be created. So, at the same time you can also use the argon as a one of the gassing agent. So, if you see the schematic which we have already seen the negative terminal positive terminal once ah; if you give the charge what will happen? There will be a deposition takes place on the material that I want this is about the sputtering ok.

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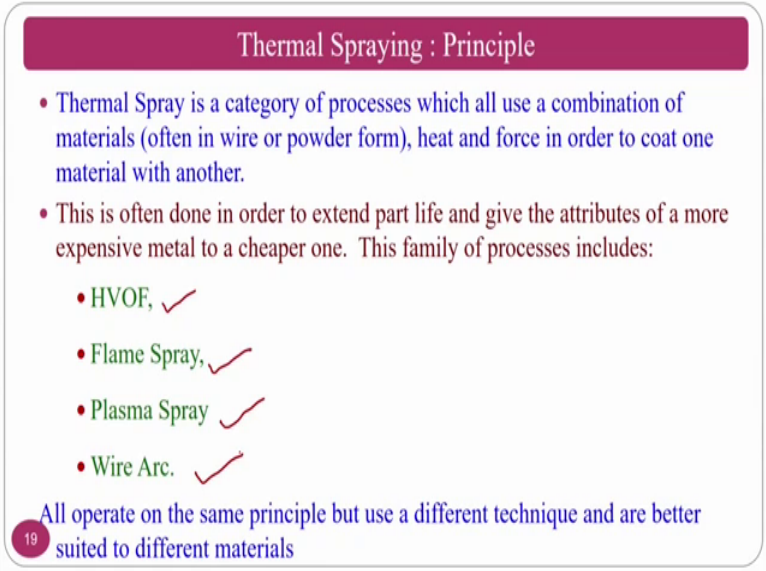

If you see thermal spraying is one of the most thick coatings if at all you want thermal spraying is one of the techniques ok. Thermal spraying categorized as a one of the combination material heat force in order to cope ok.

Where you also use the heat to melt the substrate material and to go on the target; at the same time you send with a high force; that means, I am in some of the techniques you just use only thermal in some of the techniques you use thermal plus force ok. So, we will see both of the things. So, often we used as the high velocity oxy fuel techniques is one of the things, flames spray technique, plasma spray technique wire arc technique many other techniques are there we will one by one we will go through.

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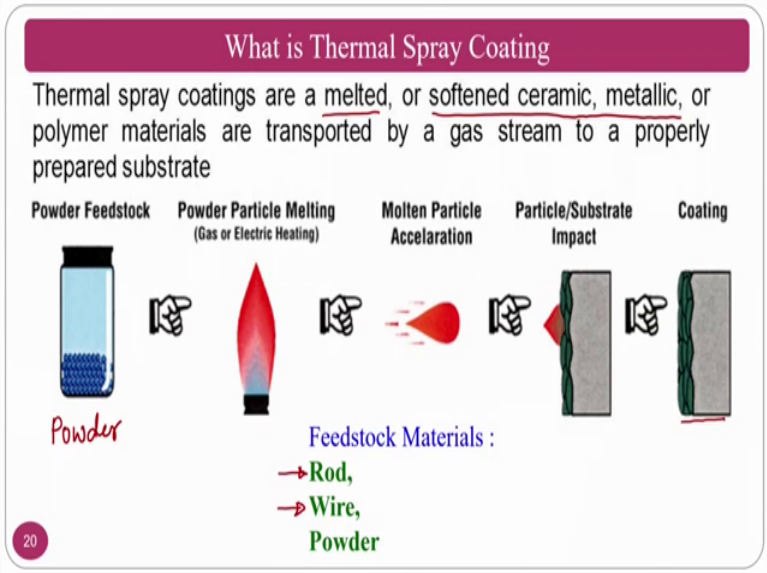

So, what is the thermal spray coating ok? So, the thermal spray coating thermal spray coatings are molt melted softened ceramic or a metallic polymer materials are transported by a gas stream and the property that is what I was telling.

You have a feedstock where you will have a assume that you have a powder which is a feedstock just you will do the melting; it will convert into the liquid form then these molten particles are accelerated with high pressure gas and it will deposit on the substrate without impact, then you cool it. So, you will get the coating ok. So, this is about the how we will do the thermal spray techniques. So, what I want to say here is here we are used only the powder one apart from powder; we can also use a rod and wire also as a precursors so, so that you can coat on some on the target.

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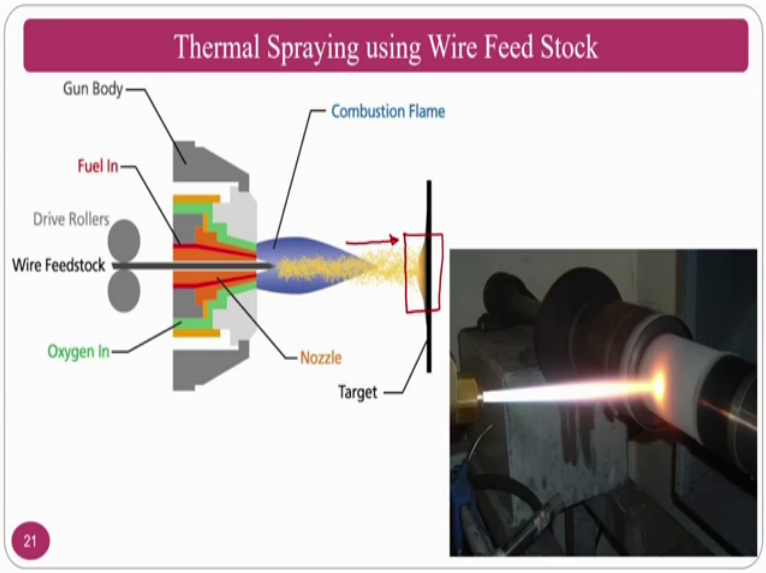

If you see the wire feed previously we have seen a powder now we have seen the wire feed stock if you are using the rollers drive rollers and just you feed it; now the fuel is in and if it is melting then you are sending with high pressure. So, you will get a coat on the target material this is the my target; where this molten material is going and adhering to the surface ok.

So, this is how the coating takes place in the thermal spraying technique. So, for example, if you see it is not only used for cutting tools; you can use for any other applications also like how where is the thermal barrier coatings are required and all those things ok.

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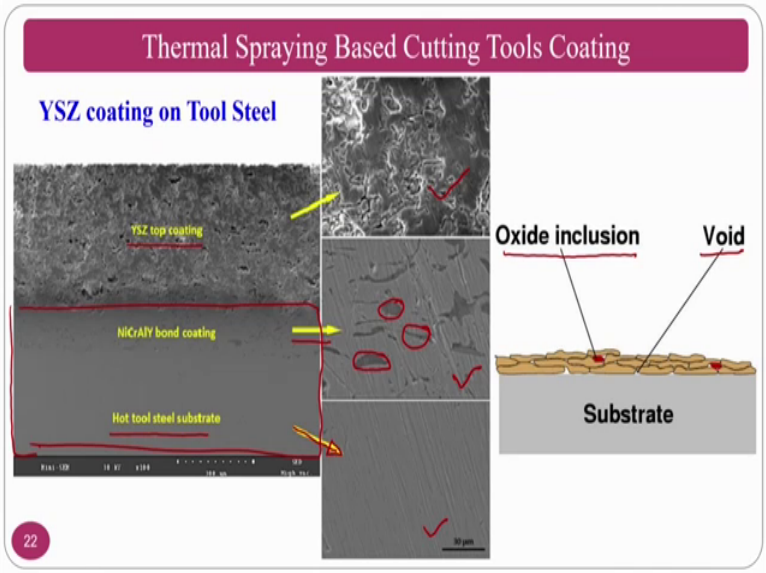

This is about the thermal spray if you see from the coating application towards the cutting tool ok. Since thermal spraying may be a multiple applications will be there; however, we want to see for our application like cutting tool application. One of the application that I have taken from the research papers is stabilized zirconia coating is done on the tool steel ok. This is a substrate material where this is the base material on the base material the coating is done using the yttria stabilized zirconia which is a ceramic.

If you see the intermediate layer if you see the substrate this is a substrate and this is the coating the top one is a coating and this bottom one is a substrate and in between you can see how the adhesion taking place in this middle one ok. So, the basic problem that you can observe from this scanning electron microscope is are voids are there see many voids and there is a phase changes are there and all those things that is a basic problem of thermal spraying technique. And there is a possibility of oxide inclusion because if you see in if you would have clearly observed in the previous slide the oxygen intake also is there.

So, whenever the molten substrate is there assume that I am sending a precursor through wire which is molten then you are passing through oxygen also; it will have a oxide inclusions in it ok. At the same time because of the pressure and all those things

variations and all those things voids also will form on this these are the some of the drawbacks of a thermal spray techniques ok.

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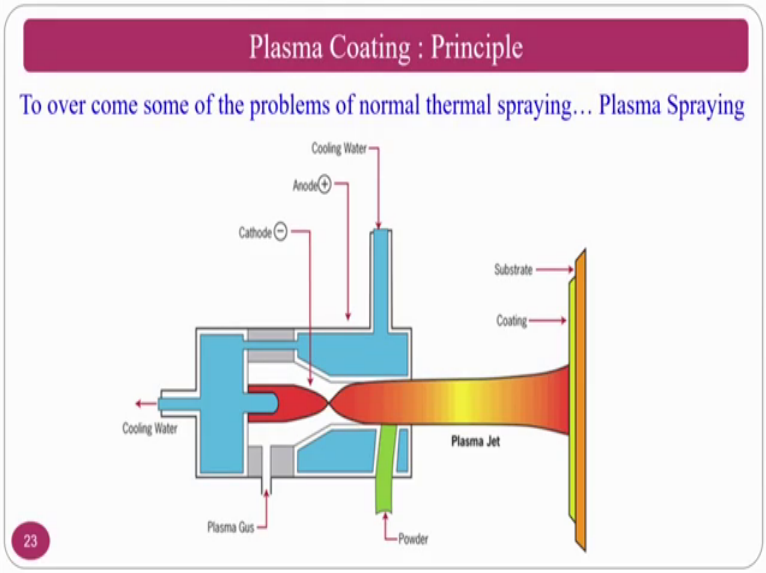

We will to how to overcome this one? So, over come of this one will be like a moving one with a plasma coatings ok; in the difference between thermal spraying and plasma is plasma as you know it is fourth state of a matter where this also will look like a gas, but the thing is that it will be a charged gas.

So, there are charges will be there and this charges plasma jet will go and impinge on my target which is material on which I need a coating. So, you can do the coating this is as simple as that one you note that in the previous case; the molten jet is going which is may be because whenever the gas is involved it may be a atomized gas, here it is also a atomized gas, but the thing what you have to observe is this atomized gas have charges that is positive and negative charges will be there for this charges that is why it is called as a plasma ok.

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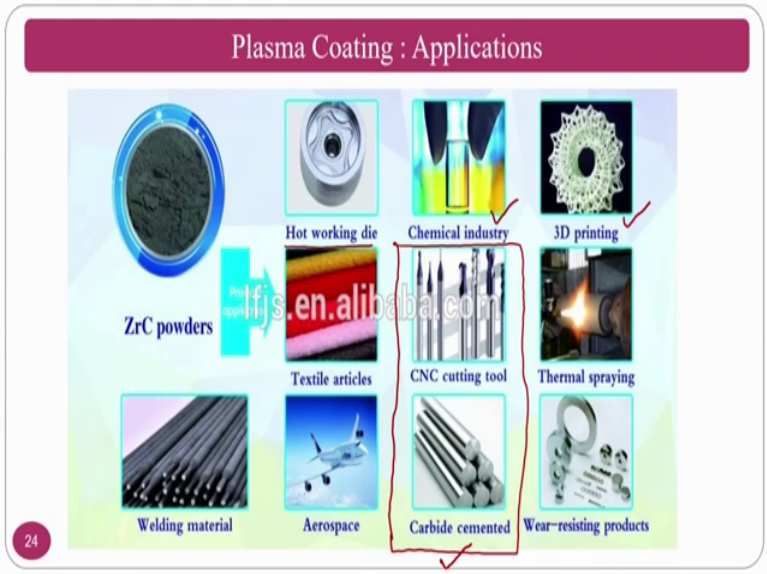

Some of the applications if you see if normally many applications are there hot working die is there, chemical industries are there, 3D printing also you can do using these techniques textiles and CNC cutting tools I have just I was mostly concentrating about these things.

Because we bother about two things that is a cutting tools, cemented carbide tools normally we will do or the same time tool coatings like a drilling coating, drilling cutters and all these coatings are done using this plasma coating process; this is one of the good example where you were the porosity will decrease compared to thermal spray and with the oxidation also you can induce; that is the beauty about the plasma that is why thermo spraying compared to thermal spraying people through for plasma spraying.

But it has its own disadvantage like cost fluid goes up. So, the cost of the initial equipment may be slightly higher than this one. So, the every process has its pros and cons ok.

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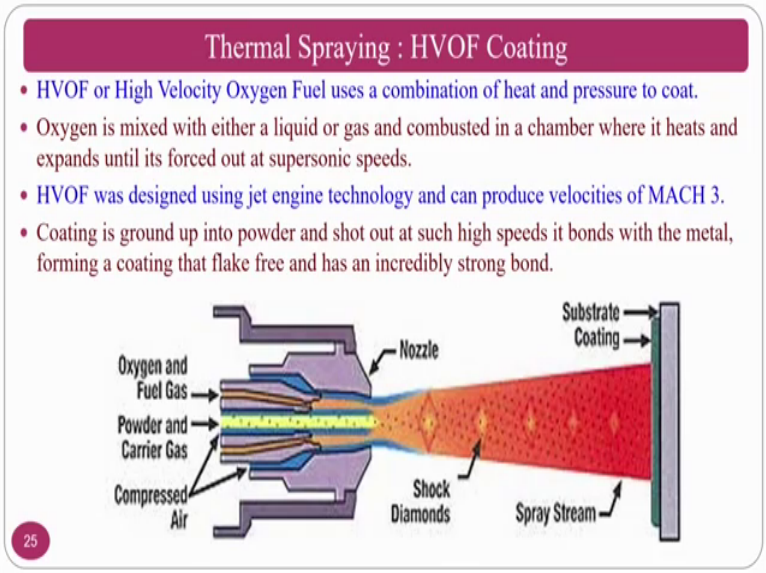

Then comes another thermal spraying techniques that is called HVOF coating that is called the high velocity oxy fuel coating ok, where here you will use the heat and pressure to cope ok. So, you will also use the heat that to melt the material that you have to coat on top of it and uses the pressure to coat on it. Oxygen is mixed with a liquid or a gas and combustion chamber will heat until the force at the supersonic speeds like mach 3 ok.

So, gas is mixed with this one and ejected with very high velocities at the supersonic speeds ok. Is designed like a jet engine technology can produce the velocities like mach three ok; so, it will be impinge with the high velocity on the substrate on which it has to coat. The coating is ground under the powder short and which is binds to the metal forming a coat it is incredibly strong bonding will takes place; that means, whenever it is impinging with a very high velocity on the substrate material it will have a proper bonding compared to our conventional thermal spraying techniques ok.

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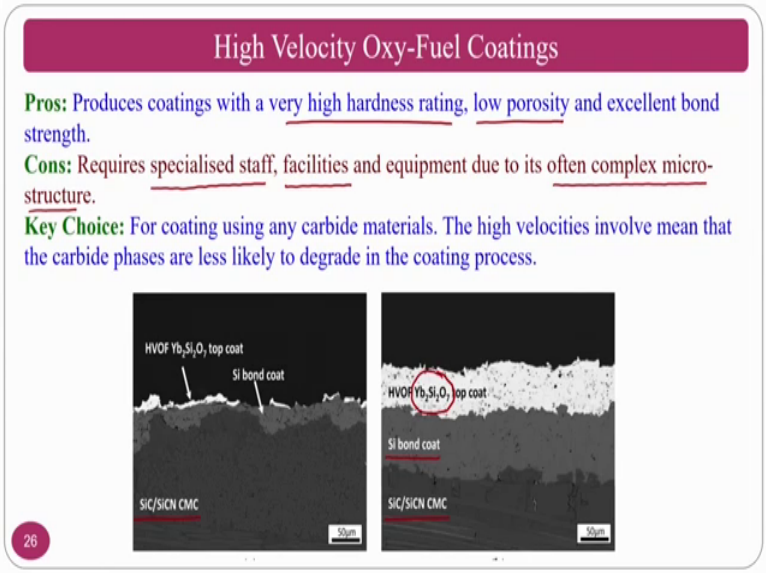

The advantage of this one is it produces the very high hardness coating with low porosity and the excellent bonding strength; it will have a proper bonding will be there porosity will be minimized and which have a high hardness because you are sending with high velocity. So, it will have a very good density; so, hardness will be; obviously, good ok. The cons will be it will be a specialized staff is required because a normal operator via unknown operator may not be sufficient to operate this one these facilities ok.

It is having a complex micro structures equipment. So, specialized people should only operate these materials; this is about if you see the substrate where SC SCN CMC is there. So, ceramic metal composite will be there. So, where Si silicon bond coating will be done then you will have a another coating on top of it ok.

This is how the coating will be done using a high velocity oxy fuel coatings ok. This is only thing that you have to observe here is it sends at very high velocity toward mach three and coating will be done.

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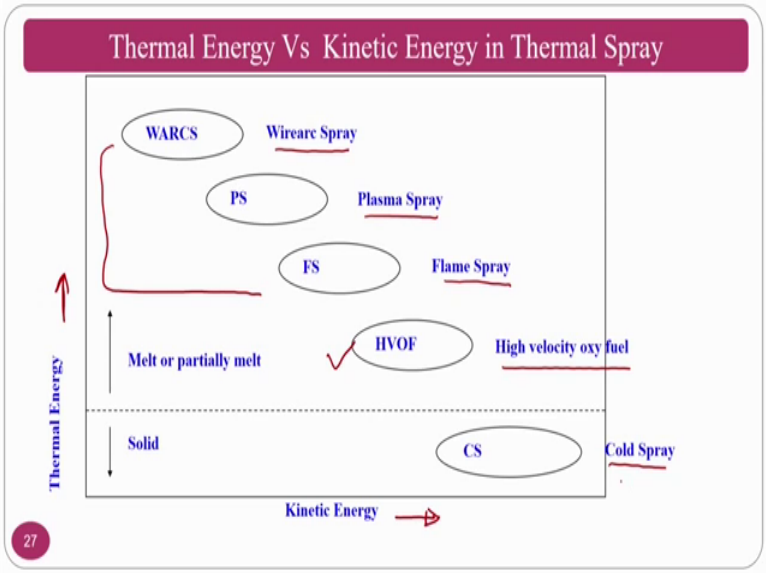

If you see the kinetic energy versus thermal energy; normally the thermal energy requirements are very high for arcs spray followed by the plasma spray, flames spray and high velocity oxy fuel and all those things ok.

So, high velocity oxy fuel cold spray this require more kinetic energy, but a thermal energy requires a wire spray because wire has to melt. So, for that purpose you need to give more thermal energy ok; plasma you need to give more thermal energy, but plasma can go easily with less kinetic energy also, but whenever you want to send the cold spray on top of a substrate to on which you have to coat, it cannot go. So, you need a high kinetic energy for a cold spray and anyhow you have seen a high velocity oxy fuel coating you also send with a mach 3 ok.

This about the kinetic energy versus thermal energy how do you manage so, that what is your requirement if I have a thermal source very good thermal source and a minimum cutting energies kinetic energy source what will happen? You just go for these type of things. So, if I have a good thermal plus kinetic energy source I can go for this and if I have low thermal and high kinetic normally you can go for the cold spray technique ok. That is how you will choose your options whenever you want to do the coating operation ok. So, electric discharge coating this is a another one coating where a thermal energy used.

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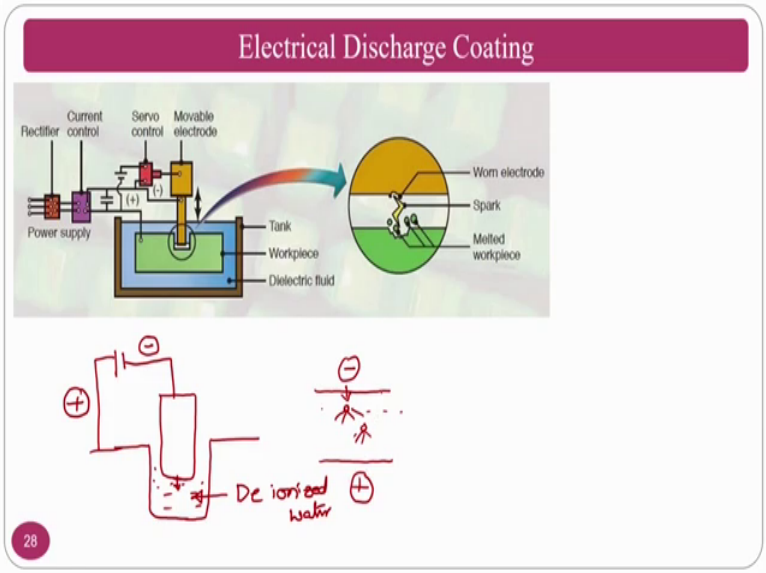

So, normally electric discharge machining many of you may know from the point of electric discharge machining ok. When the electric discharge machining will takes place electric discharge machining, normally you will connect the negative terminal to the tool and the positive terminal to the workpiece ok. So, the electrons start flowing from assume that I have a same schematically draw here if this is the just a schematic where my tool is there ok.

So, negative terminal is given here a positive terminal is here what will happen? You will have a dialectic fluid here; so, whenever the electrons start moving from this you whenever you give some charge to it what will happen the electrons start moving from negative terminal to positive terminal. This electrons basically whatever the dielectric fluid will be de ionized water consider it as a de ionized water.

What do you mean by de ionized water ok? It will help the charges are taken out that what mean I mean to say is it will have ions are taken out de ionization; that means, that ions are less whenever the electrons are coming from my negative terminal. So, if I zoom this portion of a sparking I have this one negative terminal and positive terminal, whenever there is a potential difference between these two I have a de ionized water the electrons released from this one and touches one dielectric molecule dialectic is de ionized water; that means, that it has less ions plus with more electrons.

So, it will dissipate lot of electrons and these electrons will go and hit again a dielectric molecule of the next layer; it will give this many many electrons, but few ions. In that way the electrons millions of millions of electrons will come and touch the by positive terminal the kinetic energy of my electrons will convert into thermal energy and melting and evaporation takes place. But if you see on a other side what will happen the ions are very less. So, this may not go and hit the my negative terminal; so, there is a possibility of deposition of the material will takes place.

So, if I do a reverse polarity what will happen? If my workpiece is made negative and a positive terminal to the tool what will happen? It will start depositing on top of it there is a less chance, but deposition some of the research papers shows the deposition is there, but in practical the deposition may takes place because there is no sufficient amount of ions, since ions are also in a big size against the gravity it has to travel and heating may not that much proper where the thermal energy can generate because of the kinetic energy of these ions. So, that is a possibility of a coating ok.

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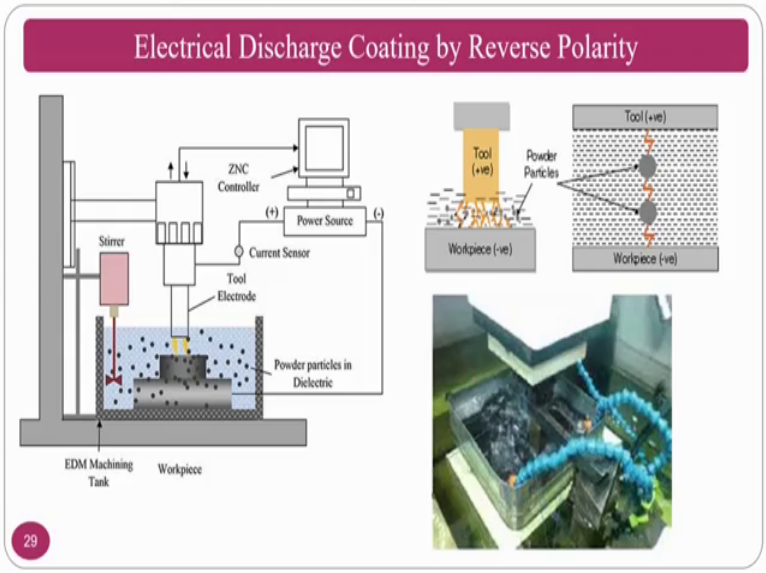

So, if you mix along with that one the powder mix that is what I was telling; if you do the powder mixing is done whatever the material that I want to coat in a dielectric fluid plus if I do the reverse polarity where ions and electrons interact change between workpiece and tool what will happen? There is a deposition takes place and the deposition these particles also play a major role. So, that the deposition may be better

and better this is a one of the hypotheses some of the people are proposing in the last 10 years of research ok.

So, you people if somebody want to take up as a masters theses are a protect theses or if you have a normally EDM processes are normally available in the small small universities also it is not a very big costly equipment. So, you can take up and you can mix very hard materials as your coating materials and do the reverse polarity and you try to get some coating and you can test on the machining the recast layer will from here recast layer will form heat affected zone will form and conversion layer and all those layers will form. So, the recast layer may be the composition of your particles.

If the particles are very hard then the your recast layer that is recast layer means what do you mean by casting the casting is nothing, but the molten metal you are for you are making into a certain shape. So, here what will happen molten metal is there it is re-solidifying there; that means, that casting is taking place in between if your particles goes and stick to that one it is good since your particles are harder.

So, it may have proper bonding and all those things very better chances are there ok; I am not saying that exactly. So, these are the some of the reports given by the some of the researchers in a newly in the research area in the electric discharge coating techniques ok. So, only thing that you have to always take care is whenever your colleagues also work in the similar areas or EDM; if they are working on electro discharge machining and you are working on electro discharge coating.

So, you should have a separate container where you will have your own fluid. So, that it will not contaminate with the your colleagues cutting dielectric fluid ok. So, please take care about these things and this can be a good work; if you rightly choose your particles and right click may with your input parameters like duty cycle and all other things ok.

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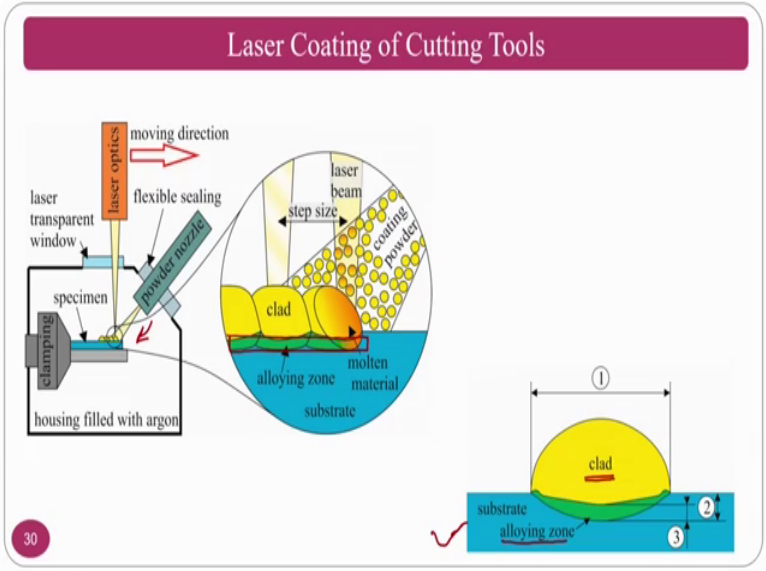

So, laser coatings nowadays many people are working; some people they call it as a laser claddings, some people they call it as a laser coating ok. So, there are some of the techniques that will be used by things like coaxial technique, pre placement technique and all those anyhow. If you see my substrate is there, the specimen is there and putting my powder from the powder nozzle and powder nozzle and I am going to put a laser source on top of it. So, that melting takes place at this end its alloying in this region alloying is done and then cladding will began ok.

So, you can see the alloying zone the green portion in this picture green portion is nothing, but the alloying zone and this is a clad zone; that means, that coating is done. So, what you are going to get this you are alloying will help you in great bonding that is what we want when the bonding is proper there on top of it your coating is there it is excellent for you ok.

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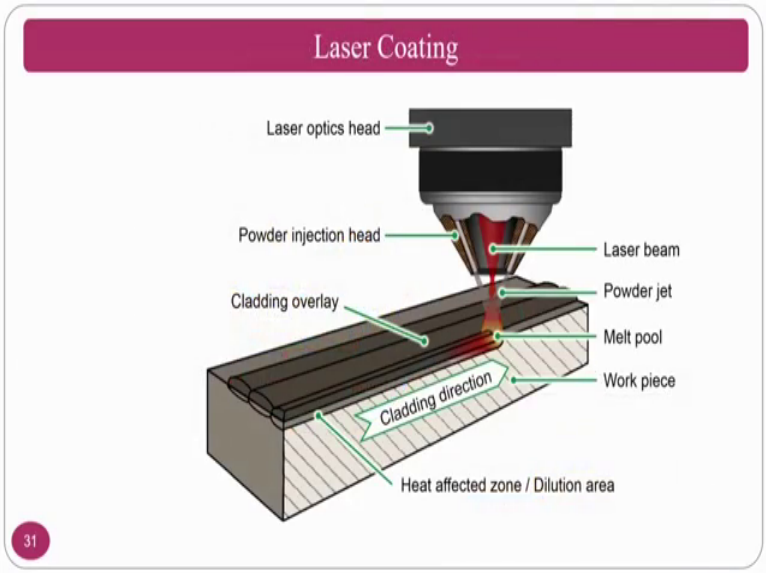

So, that is one of the beauty and you can see this is the cladding direction or what are the other things like a laser beam is there, powder jet is there this is the coaxial powder system is there melt pool is taking place and a workpiece ok.

So, the melt pool takes place; the molten metal will form two layers one is a alloying layer whichever reacts elementally reacts with is one elements with the substrate elements.

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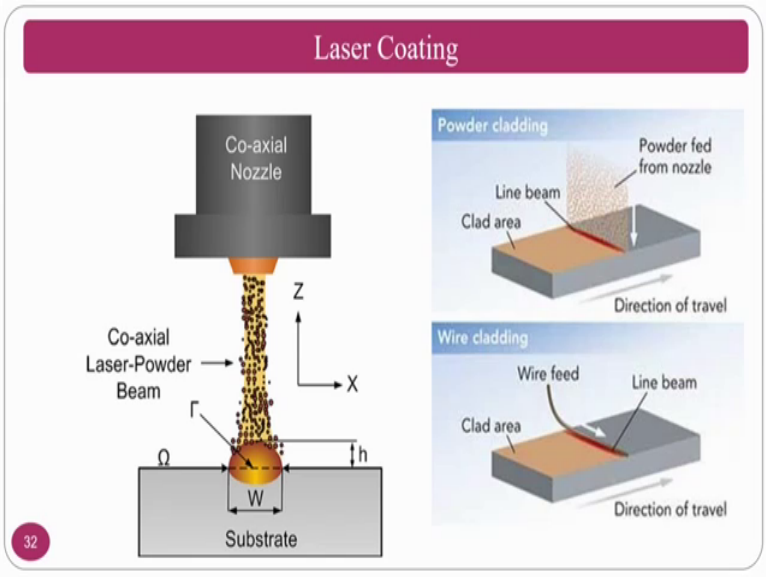

So, now you can get it the good layer of alloying plus cladding. So, the you can see the coaxial normally coaxial means either same nozzle if you are getting your powder particles plus laser that is nothing, but coaxial beam is there ok. So, a powder cladding will be done this.

So, if you see a line beam the pre place powder will be there on one side. And if you want coaxially it will you will also get these curves then powder will be there. And then it will be then with a line beam. So, the cladding will be done on the surface this about the coaxial.

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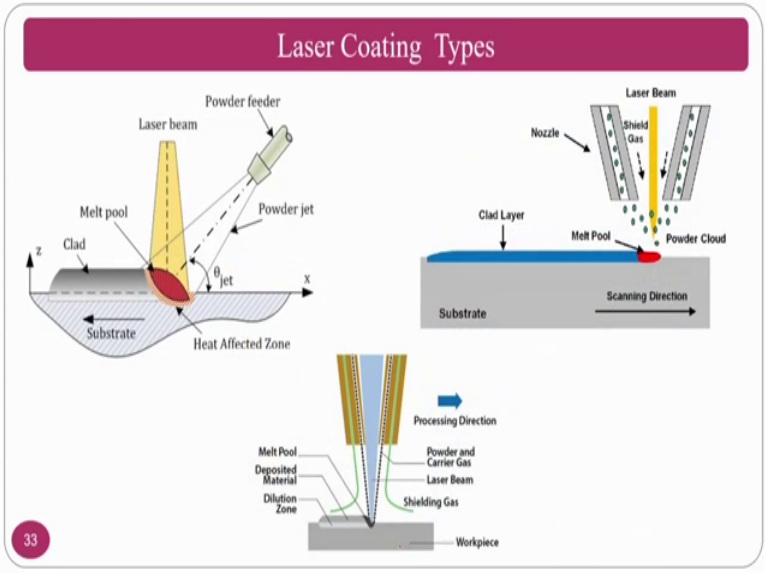

There are other varieties; powder jet will be supplied from sideways and laser beam will be done is projected from one direction. So, that you can have a clad plus alloy alloying region will be there and cladding will be then. So, coaxially you have seen already this is a coaxial where nozzle and the beam powder both will come in the same nozzle.

Another one some of the gas assisted powder will fall from sideways and the beam will come here. So, that this powder before it reaching to this area a preheating will takes place in the laser beam and it will clad on the surface. So, these are the three varieties or three types of laser coating are there.

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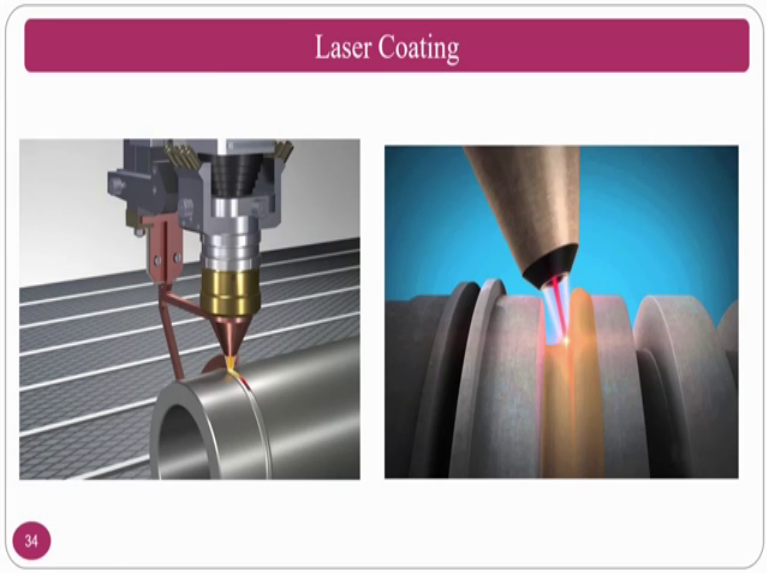

Not only on tools you can also do on various materials because nowadays it is becoming one of the important process because laser has very flexibility the huge flexibility of the laser will help in proper coating and proper bonding in the material ok.

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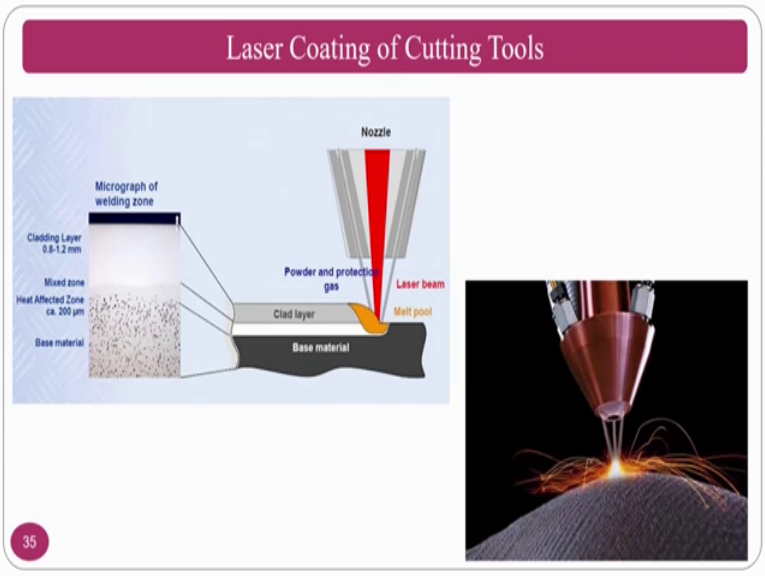

So, this is a another way of the coating you can see the laser coating area. So, the base material is there if you do the cross sectional study of this one the mixed zone is there, heat affected zone is there and cladding zone is there this how you do the cladding and

overview of the surface you can see many of people works with the laser cladding in the biomedical applications ok.

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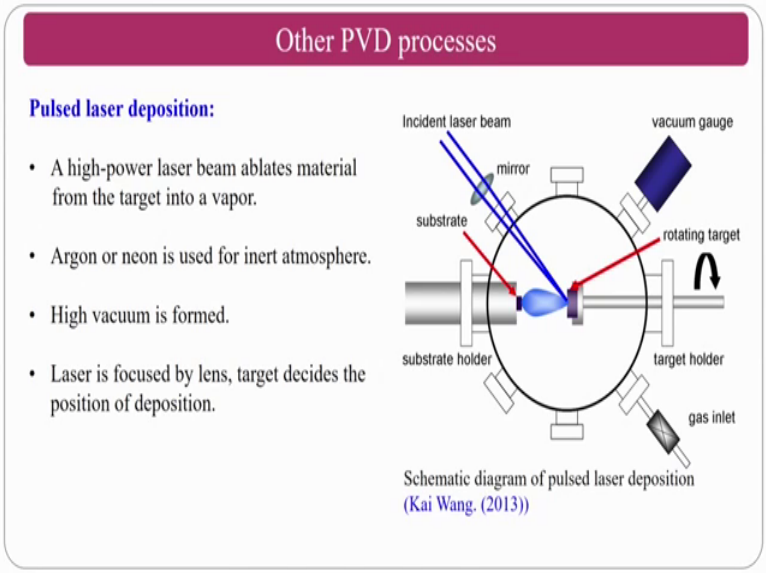

Other PVDs are pulsed laser deposition where high power laser beam ablates a material from the target whenever they you just send the high less power beam on the target what will happen? It will ablate the material is that it will become the vapors. Argon neon gas is used as a inert atmosphere and a high vacuum is formed and laser focused on lens and decide the position ok; now it will decide the position and it will deposit on top of it.

So, that it will deposit on the process this is called a pulse laser deposition, this deposition is one of the hard walls techniques and even some of the people at IIT, Guwahati are also working.

So, if you have a facility it is a very good technique you can use this technique and you can quote it ok.

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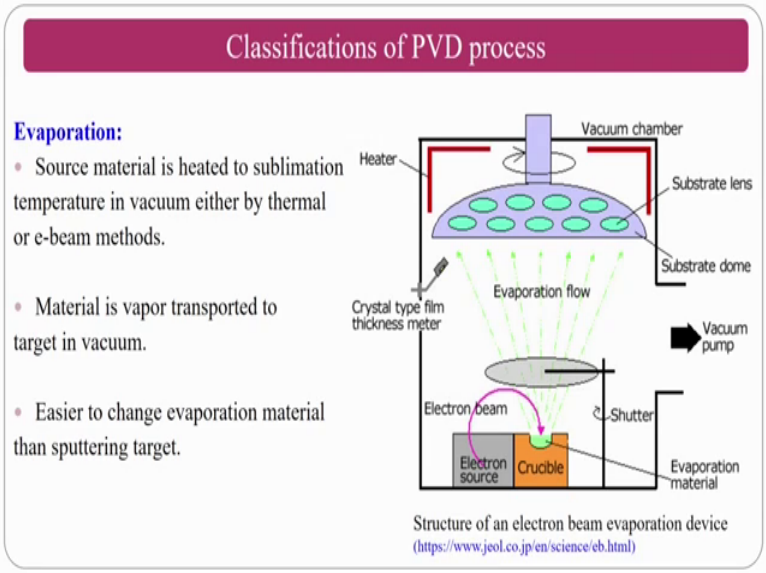

So, classification this is the evaporation techniques where the source material is heated to the sublimation temperature; then the thermal by the e beam method and then you can coat on the substrate material where you want to coat ok.

So, the material vapor transported to the target in the vacuum and you can easily coat on the workpiece material wherever you want to ok. So, here only thing here required is as I said in the PV PVD coating vacuum is required ok.

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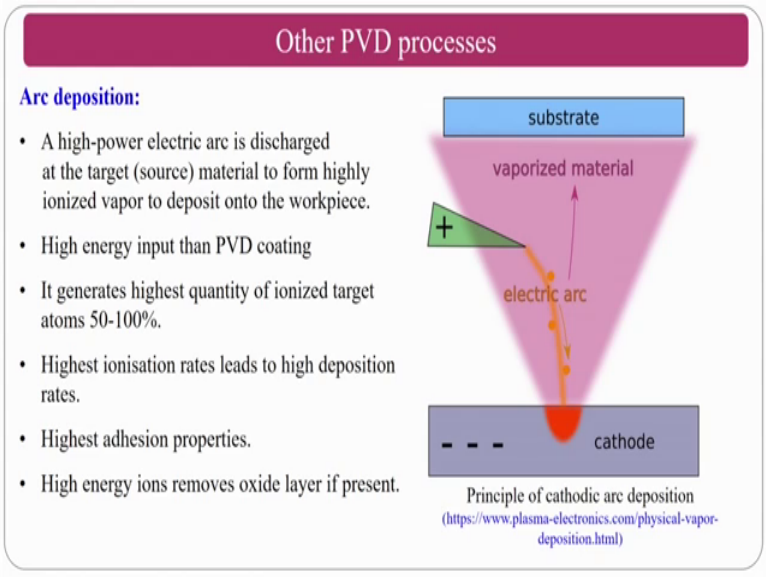

So, other PVD techniques is arc deposition technique and the high electric arc discharge at a target from the highly ionized vapor will come and deposit on the material ok.

So, these are all physically what is required is you need a temperature where the you hear a precursor which is the material where you just evaporate and it goes on the target and it deposit on the target ok. This is how you will deposit on the that material so, that you will get the good bonding and good coating ok.

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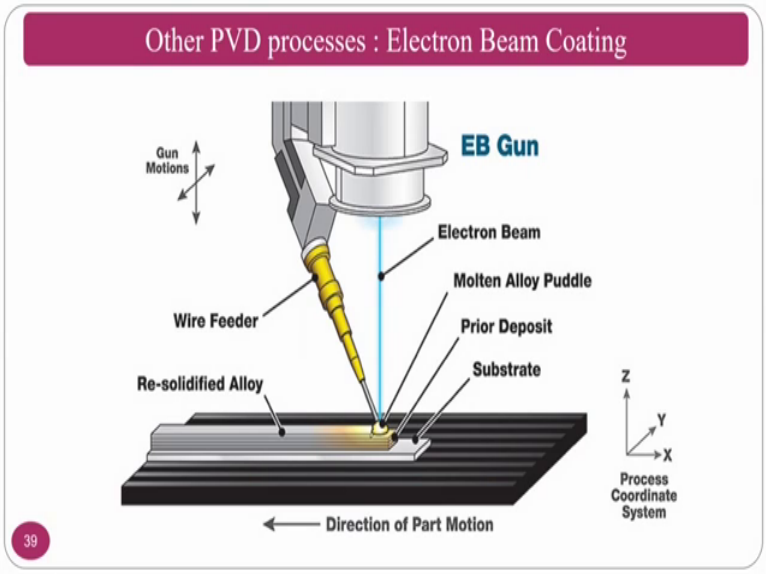

The electron beam coating see nowadays many people are publishing in this area, but this process is slightly costlier process because electron beam guns are very costly. So, here normally if you see there is a wide feeder is there; if you see there is a wide feeder and re solidified allowing zone is there. And once you have a substrate material on top of it the wire feeder gives the powder where sorry it will give a wire continuously wire.

So, electron beam will fall on it and it will melt and it will form a layer or a coat on top of it. So, this will be a more sophisticated technique where you can go for nanometers to micrometers thickness layer ok.

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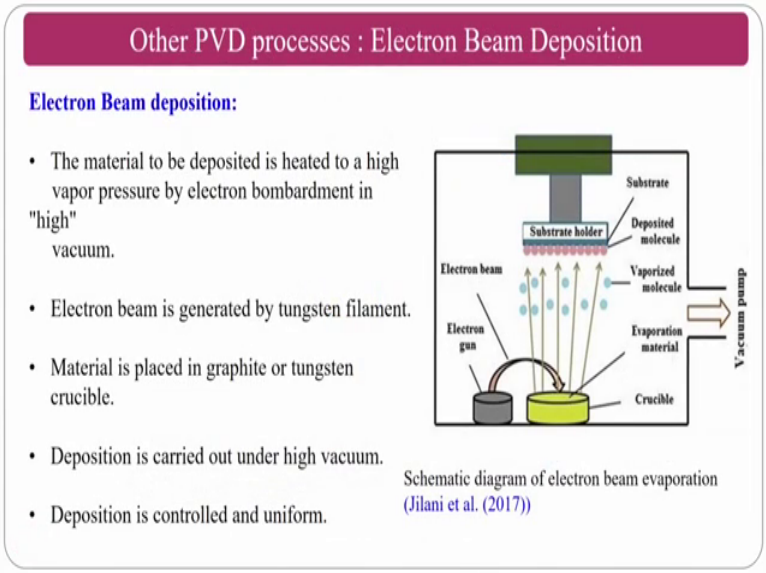

So, electron beam deposition also you can take a metal deposited it is heated to a high vapor pressure by electron bombardment and in the vacuum the electron beam generated by the tungsten filament normally tungsten filament is used to bombard and then the deposition is carried out in a vacuum and the beauty about this is the uniform coating will takes place ok.

So, only thing is that here you have to make your system vacuum; in the laser you may not required vacuum, but electron beam deposition and all those techniques you required the good vacuum conditions.

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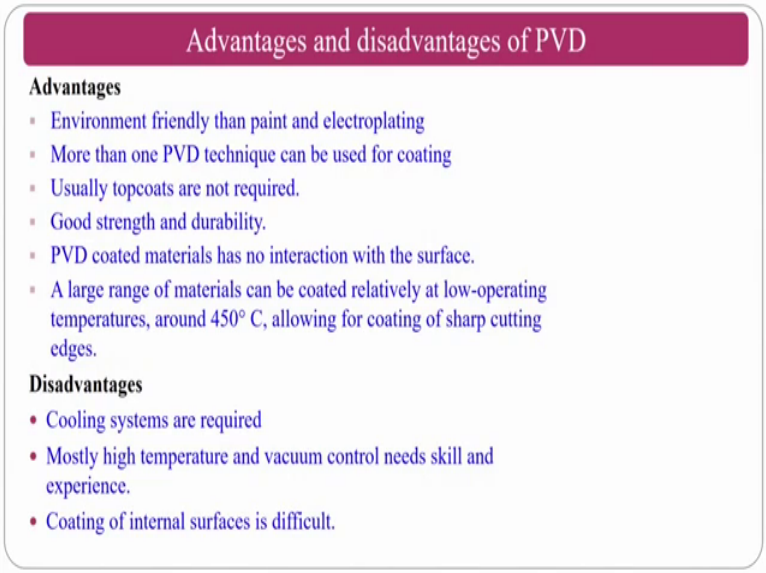

So, that you can form a uniform layer, but only I said the drawback of this process is it is slightly costlier. So, advantages and disadvantages of a physical vapor deposition; it is environmental friendly then paint and electroplating. So, more than one PVD technique can be used for the coating. So, one coating is done by one thermal spraying techniques you can do the another coating by front beam coating and all those things. So, you can use multiple because there is no chemical effect and all those things.

Usually top coats are not required; so, you do not require any layer to protect or something good strength and durability will be there the strength will be high at the same time durable would be will be very long that is what PVD coatings has no interaction with the surface. So, there is no interaction with this chemical interaction with the surface; the large range of materials can be coated relatively at low operating temperature that is around 450 degrees as you have seen the chemical vapor deposition done normally at 1000 degrees here this normally will be done at 450, 400, 500 in this range.

So, that the if at all you want to get the cutting edges sharp you may get it because whenever you want to coat with a high temperature what will happen? There is a grain structure will change it will enlarge and all those things. So, you may not get sufficient sharp enough. So, if you are doing at low temperature what will happen? There is a very less chance of grain size enlargement. So, you will get good sharp cutting edges and all

those things that is about the advantages of the PVD. So, disadvantages as I said every process will have its own pros and cons.

So, cooling systems are required mostly high temperature vacuum controls is required. So, you need any vacuum control in the PVD most of the PVDs. So, coating internal surface is difficult. So, if at all I want to coat some internal surfaces; so, it is may not be possible ok. So, these are the difficulties or the drawbacks of this process ok.

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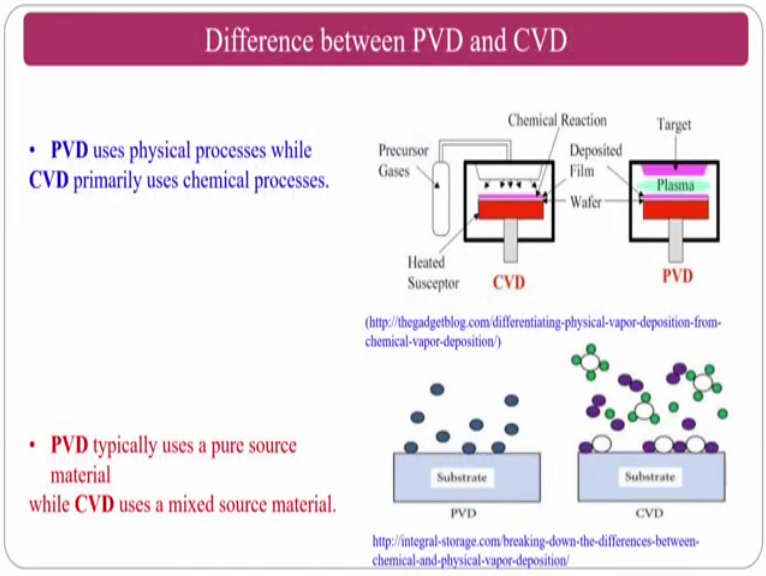

So, if you see the difference between PVD and CVD; till now we have seen many {VD varieties only we have seen the CVD only one. So, PVD uses physical source while CVD primarily uses a chemical process; so, that is a different.

It is a physically completely it is a chemically reaction will takes place for alloying surface area. The PVD typically pure source material, but CVD uses mixed source material what is what I want to say is that there the alloying is physically taking place here the chemical reaction taking place because of this you will have the mixed source that is what is a difference between physical vapor deposition and chemical vapor deposition.

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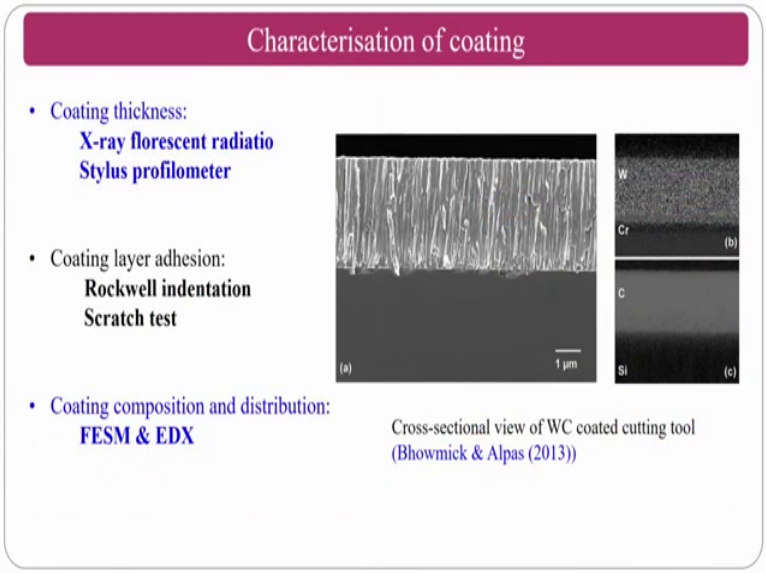

So, characterization of coatings is another big area which we have already seen. So, X-ray florescent radio stylus profilometer can be normally used; at the same time you can use 3D profilometers also to measure the thickness of the coat and all those things.

So, indentations normally if I want to check the indentations and all those things I can do go for weaker hardness tails hardness tails to measure the hardness of this one; And a coating compositions as I said in the previously in the characterization surface characterization, where I was talking about a scanning electron microscopy. So, slightly advanced version because these coatings are nano sizes coatings you have to go for filed enhanced scanning electron microscopy and EDX analysis I said a EDX analysis will tell you the elemental compositions in the material ok.

So, you can characterize elementally plus morphologically and metallurgically you can do all these things if at all I want to know the grain boundaries and grain sizes then you have to go for tem transmission electron microscopy and all those things ok.

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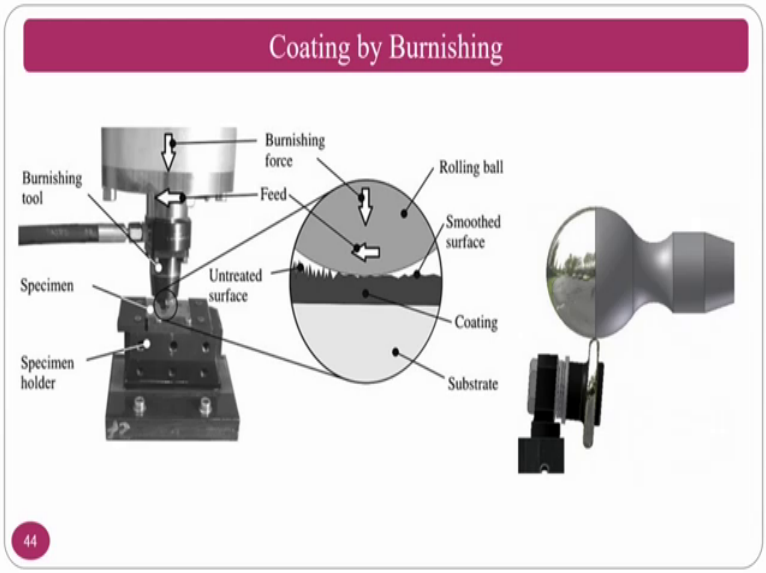

So, a mechanically we have seen all are thermally; now the only many processes are there, but the easiest I was telling you the economical is coating by burnishing process ok. So, you will have a rolling ball and if you see rolling ball is there and just you put certain pressure on top of it and you roll on top. So, that if you have a any surface roughness that roughness will deform plastically that is severe plastic deformation will takes place and it will give the good surface finish ok.

So, if you can add some of the particles that you want to coat in a molten state or in a powder form in a nano powder form; you just place these powders in the these rough surfaces then you do the burnishing. Then this deformation taking place will help those material to coat on the top of the surface and you will get very good fine surface plus alloy surface, coated surface you will get a partially alloying, partially coated surface also you will get.

So, you can see it will be normally used for a finishing application it is also can be used for the alloying and cladding applications by putting the powders in the rough surfaces; then you roll appropriate loading conditions then you will get a good burnishing surface ok.

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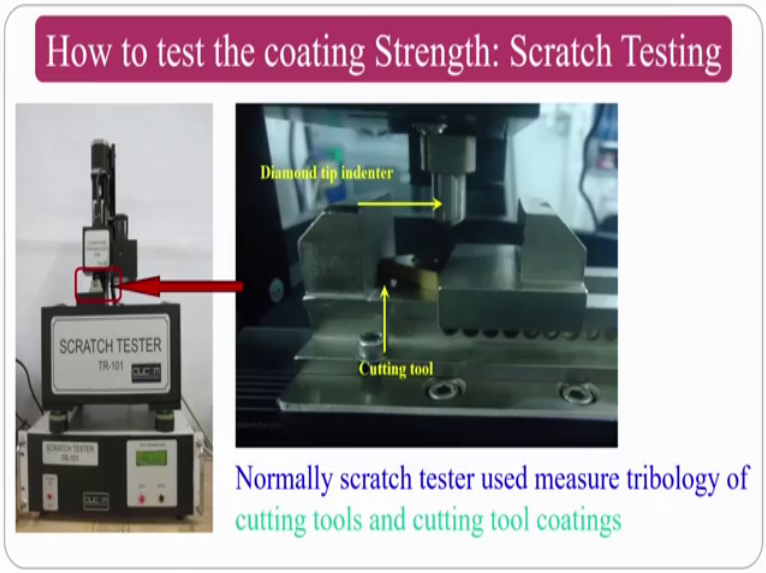

So, how do you test normally? You have done the coatings using thermal spraying technique electron beam coating, laser beam coating, CVD, PVD and all those things, but how to check what is the strength of the coating, how the hardness of the coating very whether the uniform structure is there or not and all those things the first and foremost is you have to check the strength of that one the strength of that one as I said one of the tribological technique is wear and tear the signs of wear and tear is nothing, but the tribology.

So, the wear scratch test is normally used to scratch off the tool coating ok; you just use the tool on which coating is there just you apply the load some load and you give some scanning speed. So, that it will scratch; if the denomination is taking place; that means, that that is not good if the delamination is not in cake taking place it is good. So, how do you cross check?

Once you do the scratch testing then you have to take the sample to your scanning electron microscopy there you just check phase analysis as I said the back scattered the at the same time you can also check the EDX analysis where the elemental diagnosis. If you are getting the elemental of the base material in the scanning index analysis; that means, that the coating is completely gone, if you are getting a still the coating material that is coated using any type of these things which we have discussed; that means, that is good ok.

So, the scratch test is the one of the base test to test the adherence of my coating strength of my coating with respect to some load and speed of the scratch ok. You can do the ramp of the load you can ramp the speed also you can ramp. So, that at what load it is going and going off or delaminating takes with the at what speed delamination is taking place and all those things you can check ok.

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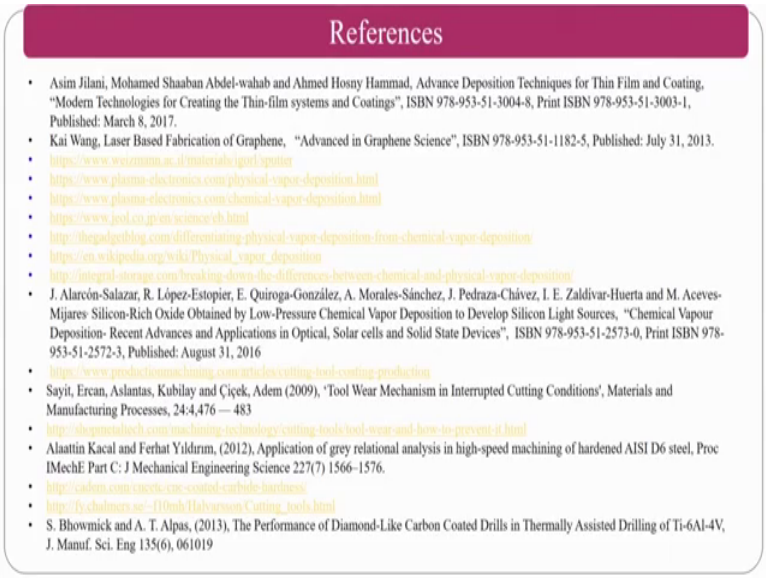

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These are the references. So, let me brief you today we have seen the coatings one is CVD coating you have started with the CVD coating, then followed by the PVD coating we have seen different types of PVD coating, thermal spray electron beam laser electric discharge these are the some of the techniques where some of the techniques follow vacuum, some of the techniques do not require the vacuum and all those things.

We have seen the mechanically one is the burnishing where the surface roughness is finished; if you can use the nano powders in the surface roughnesss then you do the burning operation you may get annoying plus coating. At the same time whenever once you coating is done how do you cross check whether the coating is good or not that also we have done, it is a basic study that is called the scratch test ok.

So, these are all that from the coating materials what are the requirements of the coating on the cutting tool to coatings, then followed by different different techniques of the coatings and principles of that one; then testing of the coating strength and all those things we have studied ok. So, this completes our class.

Thank you.