Fundamentals of Surface Engineering: Mechanisms, Processes and Characterizations

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Lecture-54
Surface Modification Techniques: Plasma Spraying, Electroplating, Electroless Plating

Hello, I welcome you all in this presentation related with the subject fundamentals of surface engineering and we are talking about the different methods used for developing coatings and under this process or for this purpose their various thermal spray processes about which we have talked in addition to that will be talking about the plasma spray process under the thermal spray process category.

Thereafter will be taking out the two other processes like electroplating and electroless plating these are these processes like electroplating is based on the electrolysis and electroless plating process is based on the chemical reactions for developing the coating of the suitable material so that the improvement in surface properties can be achieved

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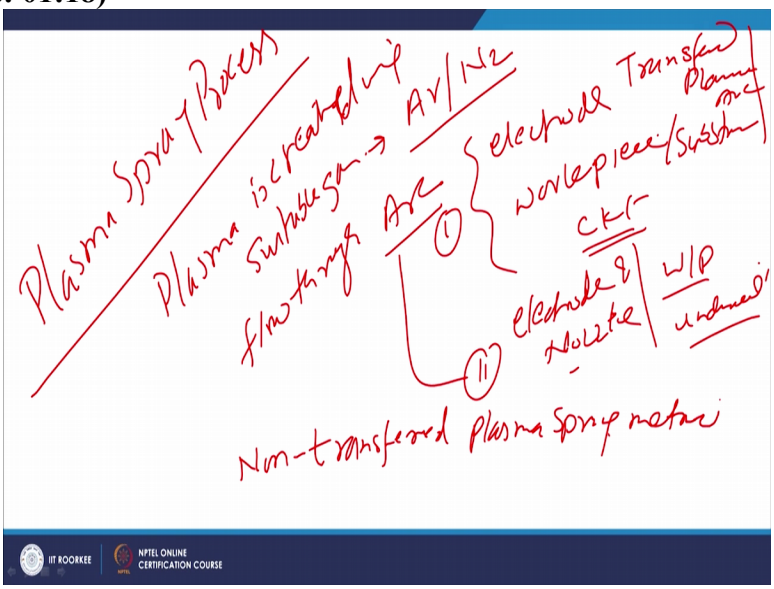

So, if you see the plasma spray process plasma spray process basically as we know that the plasma spray process basically the plasma is created using suitable gas like plasma forming gas which may be in form of Argon or the nitrogen. Now this plasma forming gas is allowed to flow through the arc. Now this arc established between the electrode and work piece or the substrate. This is case of the transferred plasma arc or the arc can also be established between the electrode and the nozzle.

So in this case the plasma arc is independent of the work piece. So, in this case work piece is a part of the circuit electric circuit work piece is the part of electric circuit and here work piece is independent. So, there is independence with regard to the distance between the plasma spray torch and the work piece. So, it is independent and so in the plasma spray process basically non transferred plasma spray method is used.

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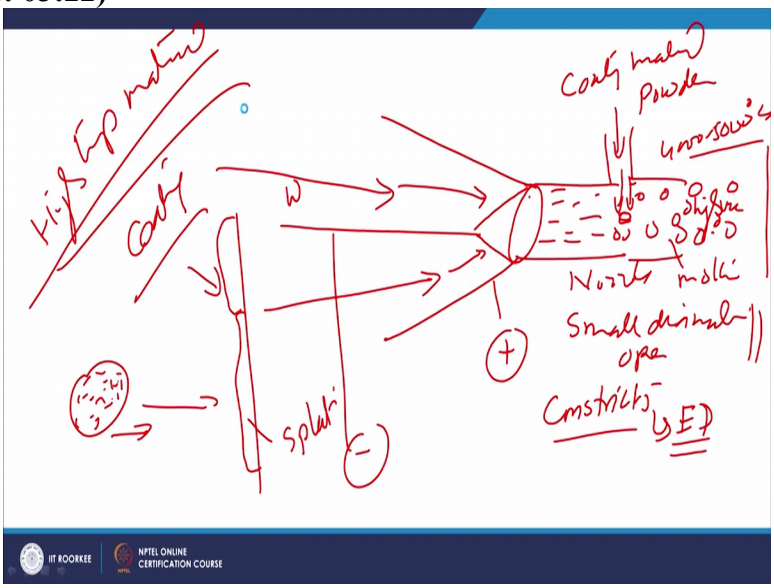

Which means there is one electrode and there is nozzle and this nozzle and arc is established between the electrode and the nozzle, so, electrode is primary tungsten which is connected to the negative terminal and the nozzle is connected to the positive terminal and then plasma forming gas is supplied so that the plasma is plasma forming gas passes through the arc and then this plasma is passed through the nozzle.

So, this nozzle is of the small diameter opening you can say orbit small diameter orbit is there in nozzle which constricts, constricts means reduces the diameter of the plasma which is flowing through the nozzle and so this constriction increases the energy density of the plasma and then in this plasma we feed the suitable coating material. Coating material normally it is fed in form of the powders. So, in the plasma we feed the material to be coated, since the plasma is at high temperature like 400 to 5, 4000 to 5000 degree centigrade.

So all the material is brought to the molten state, since the plasma will be moving at a very high velocity so the particles will also be moved at high velocity and they will be accelerated towards the surface of the substrate. So, basically the particles powder particles of the material to be

coated in the molten state are accelerated at high velocity towards the substrate where after the impingement they get flattened and form splat. So, deposition of the material is spread by this splat on to the surface of the substrate.

After the solidification leads to the development of coating since the temperature is quite high so it can be used for developing the coatings of high temperature material. So, this is the basic principle of the plasma spray process basically the plasma forming gas is allowed to flow through the arc. So, that the plasma is created and this plasma is allowed is forced to pass through the nozzle.

And where it is constructed in the nozzle we feed the material to be coated so that plasma heats the powder particles to the molten state and these powder particles in molten state then subsequently accelerated toward the surface of the substrate and after the impingement with the surface of the substrate it forms the splat and that the deposition of the material in form of the splat.

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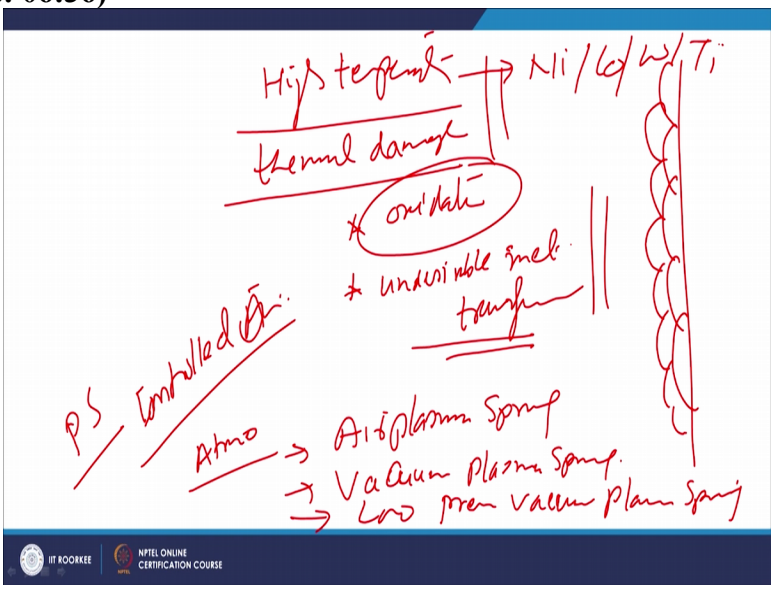

By splat deposition on to the surface of the substrate takes place. Now they are some of the issues like the velocity is not very, very high in case of the plasma spray process and the temperature high temperature is experienced by the material. So there is a possibility of the thermal damage of the coating material in form of the oxidation or interaction of the material with the gases which are present as well as undesirable metallurgical.

So, we cannot do much except that we cannot do much with the undesirable mythological transformations in the plasma spray that is why we should avoid the development of those coatings where such kind of the undesirable metallurgical transformation take place by the plasma spray. But certainly something can be done to avoid the thermal damage in form of interaction of the coating material with the gases present in the plasma zone or during this spray process.

And for this purpose only what we do plasma spray process is carried out in very controlled environment. So, when the plasma spray is carried out under the atmospheric conditions we call it air plasma spray. And when the plasma spraying is carried out under the vacuum conditions to avoid the form of the interaction of the coating material with the gases it is called vacuum low pressure vacuum plasma spray process.

And when we feel in some of the low pressure gases means when the spraying is carried out in somewhat low pressure conditions then it is called low pressure vacuum plasma spray process. So, they are different variants as per the kind of environment in which the spraying is carried out. And the plasma spraying is mostly carried out for the because it generates quite high temperature so it suits for the high temperature materials like in Nickel, Cobalt, Tungsten, Titanium etc can be done in this zirconia kind of the material can be deposited using the plasma spray process.

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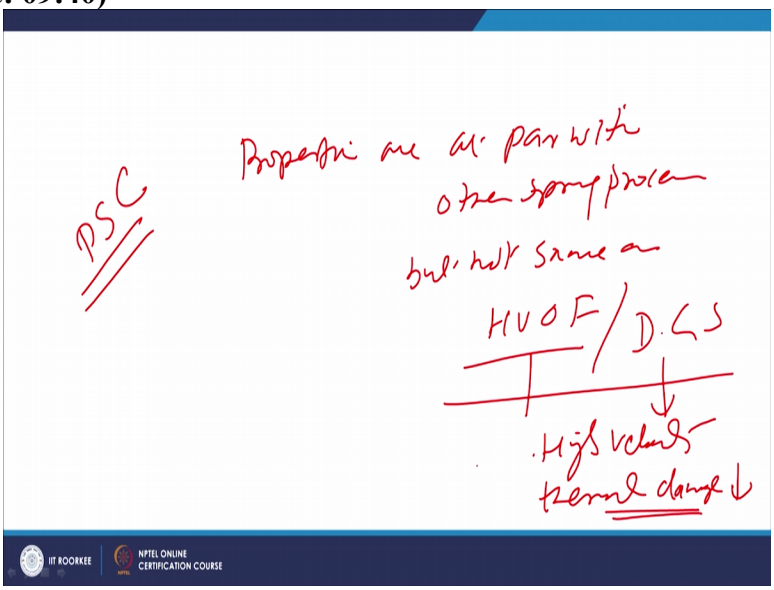

As far as the performance of the plasma spray coatings is concerned plasma spray coating properties are at par with other spray processes but not with same as HVOF and the detonation gun spray because in HVOF and detonation spray gun processes detonation gun process and this

process is the velocity attained high velocity is attained and the thermal damage due to the exposure of the material to be deposited for shorter period during the HVOF and detonation gun processes thermal damage is limited.

So, for high velocity and less thermal damage make these processes as compared to the plasma spray process.

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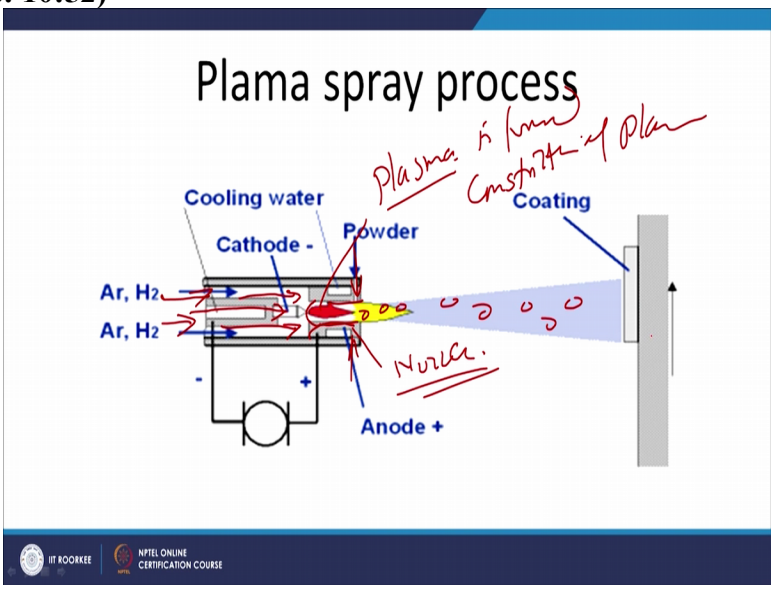

Now we will see the schematic of the plasma spray process where we can see there is one tungsten electrode which is made invariably connected to the cathode and anode which is a surrounding this cathode is basically nozzle and arc this is established between the electrode and the nozzle and then plasma forming gas like hydrogen, Argon or Nitrogen etcetera is passed through the arc zone.

So, that the plasma is formed now this plasma is now forced to pass through the small diameter nozzle having very smaller diameter. So, the constriction of the plasma takes place and here only we feed the, from the nozzle itself we feed the powder to; our material to be coated in the plasma zone. So, here it is heated and then accelerated towards the surface of the substrate and subsequently after the impingement to the surface of substrate coating is developed.

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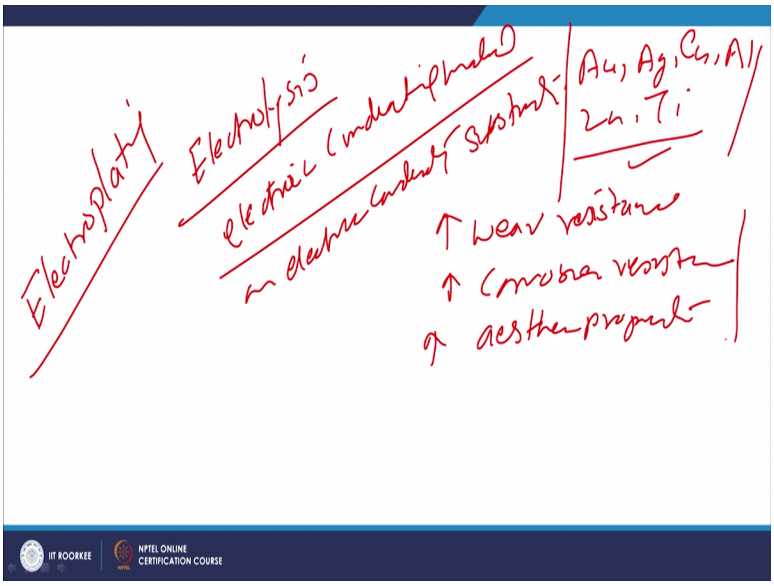

Now will take up the; another coating process which is basically electroplating process so, this is this process of coating is electroplating process it is based on the principle of the electrolysis. Primarily used for developing the coatings of the electric conducting materials on electric conducting substrate so means both coating material and substrate should be electrical conducting in nature.

In this process this process is commonly used for developing the coatings for improving the specific set of properties using the materials like gold, silver, copper, aluminium, zinc and titanium. So, if you want to develop a layer 3 layer of high quality material over the surface of the substrate of this kind of the material then electrolysis is electroplating process is found to be good.

And this can be used for improving the wear resistance improving the corrosion resistance and also improving the aesthetic properties like appearance are the colour etcetera is to be made to this team value of the product can be improved.

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In this case basically the electroplating process uses the electroplating process is Galvanic cell for development of the coatings which is nothing a big tank full of the suitable electrolyte. So, here it is full of the electro light which is used as for completing the electric circuit between the substrate and the material to be coated. So, there are 2 members one is say good material to be coated coating material and this is substrate or the component on which coating is to be applied.

For the component on which coating is to be applied is connected to the negative terminal of the power supply and this material to be quoted is the coating material is connected to the positive terminal. So, this is made anode and the substrate is made cathode and here the electrolysis reaction takes place so at the anode the anodic dissolution takes place. Here the material like say if this is copper on which the coating of the silver is to be applied so the anodic dissolution will be leading to the silver ions being produced to this electrolysis process.

And these ions through the electrolyte will be moving towards the surface of the cathode and here they will get deposited. So, the coating of the silver will get deposited on to the surface of the substrate. So, this is how; so what are the requirements a Galvanic cell having the suitable power source one substrate which is has to be electrical conducting. And the material to be coated also should be electrical conducting.

And then one electrolyte of course will be having the ions of that material which is being produced and the suitable medium or large scale metallic ions which are being dissolved and the medium which is there to act as electrolytes. Basically this there will be the charged particles in form of the positive and the negative ions in the electrolyte facilitating the flow of current.

So, in this case basically the dissolution of the material from the anode takes place and during this process material gets transferred through the electrolyte and deposited on to the surface of the substrate at the cathode to develop the coating. Like say if there are few projection on the surface of the component bit of the substrate then accordingly like say this is the coating and this is the substrate having regular shape.

So, this region is far away as compared to these zones. So, the regions of the substrate which are closer to the coating material their the value of the current will be much higher to cause the electrolysis electroplating as compared to the other zones which are far away. So, here the rate of deposition will be different at the different zones as per the spacing between the electrode and between the cathode and anode.

So, this we can say this process is this process uses the DC power where positive terminal will be connected to the material to be coated and negative terminal will be connected to the substrate.

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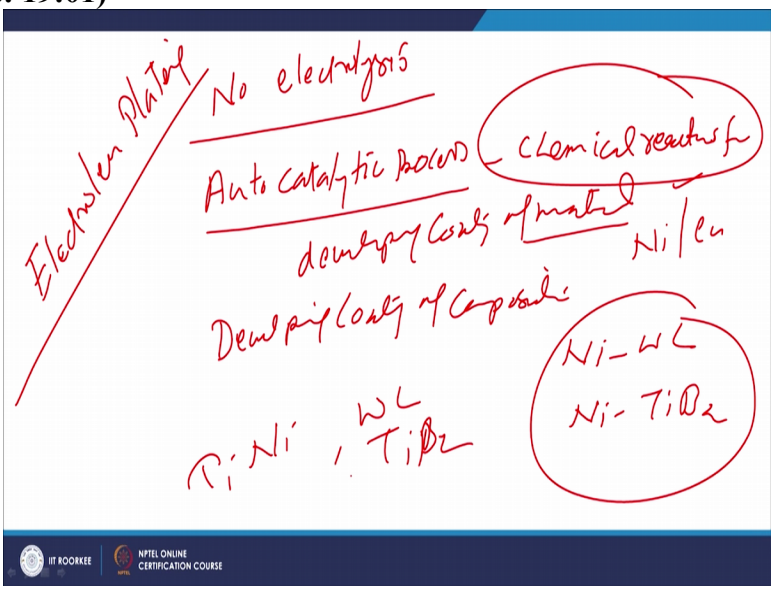

Now I will be taking up the electroless plating. Electroless plating there is no electrolysis, this is basically an auto catalytic process involving chemical reactions for developing coating of the materials like say the coating of the Nickel or Chromium or any other material can be deposited. But at the same time this is also used for developing coating of the composite materials. So, for this purpose like the Nickel Tungsten Carbide or the Nickel Titanium Boride these coatings can also be deposited.

Coatings of the composite materials as well as the materials in metallic form can also be deposited using the electrolysis electroless plating process. So, primarily it involves the chemical reactions for development of the coatings. And in this case basically the coatings of the Titanium Nickel Tungsten Carbide reinforced in Nickel Titanium Boride reinforced with the Nickel can be used.

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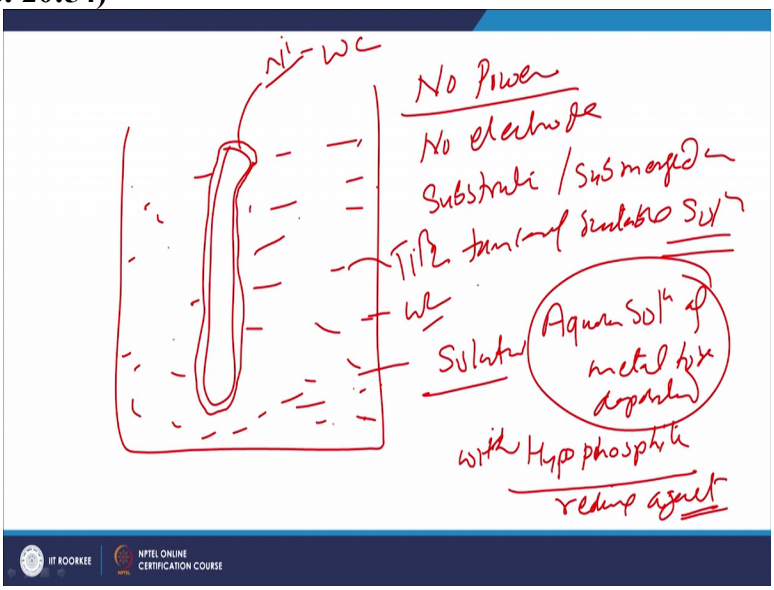

In this case there is no power requirement like in the electrolysis process where there was a; the flow of current and use of the DC supply and there is no electrode. Basically the substrate is submerged in the tank of suitable solutions where in the chemical reactions facilitate the development of the coating through autocatalytic chemical reaction process. So, in this case basically there is a tank having the solution like this.

And the component so this is the solution having the suitable; solution here basically this consists of the aquas solution of the metal to be deposited with hypophosphite with hyper metal to be deposited in aquas solution with the hypophosphite which acts as a reducing agent and helps in development of the coatings. So, this solution of the; should having the suitable material whose coating is to be deposited in this solution the substrate component is submerged like this.

So, through the chemical autocatalytic chemical reactions the coating is developed on to the surface of the component. This may be in form of only the metal metallic coating or it can be Nickel Tungsten Carbide or any other reinforcing agent but that we have to put into the solution like in form of TiB2 or Tungsten Carbide.

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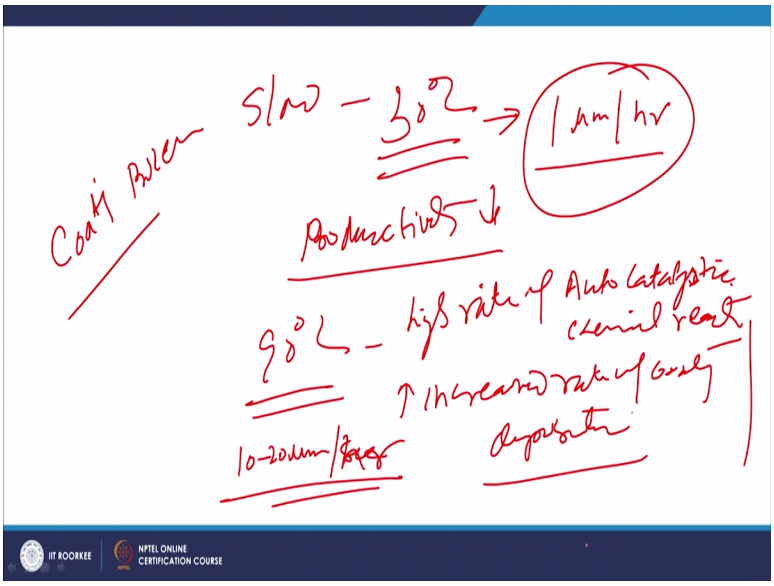

In addition to this as far as the coating development is concerned the coating process by the electrolysis process is slow. So, under the room temperature conditions like if we electro that the chemical reaction is taking place at the low temperature say 30 degree centigrade then the rate at which the coating is developed is very low that is about 1 micro metre per hour. So, this considering the low rate of the deposition process is considered very slow.

And it the productivity associated with the process productivity is very low in order to increase the rate of deposition and enhance the productivity so that the sufficient production rate can be facilitated the temperature is increased. So, say use of the temperature like 90 degree centigrade of the solution will be facilitating the high rate of the auto catalytic chemical reactions for increased rate of coating deposition.

And this increased rate of the coating deposition helps to develop the coating at the rate like 10 to 20 micrometres per hour. So, there is significant increase in the rate of deposition from one micron approximately 1 micrometre per hour 10 to 20 micro metre per hour.

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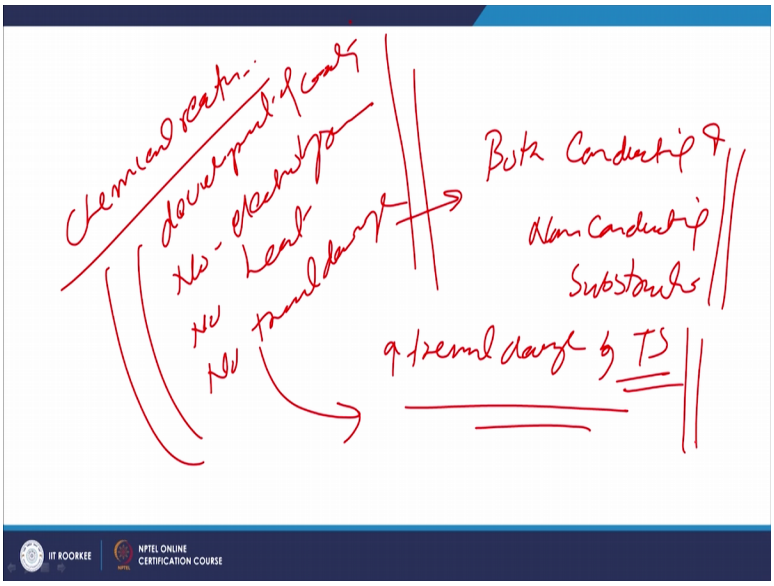

If we see in this case basically the chemical reactions are facilitating the development of coatings there is no electrolysis, there is no heat, there is no thermal damage and distortion tendency and that is why this process can be used for developing the coatings on both conducting and non conducting non electrical conducting substrates. So, this is very good side it can be used for developing the metallic coating for the coatings of the composite materials on both conducting as well as non conducting substrates.

Further materials which experience high thermal damage by thermal spray processes the coatings of those materials can be effectively deposited using the form using the electroless plating process. So, that those materials which experience significant thermal damage during thermal spray processes then this process can be effectively used. Conversely if we say when are the thermal spray process cannot be used for developing the coating of particular material on to the substrate then electrolysis process can be used for developing the coatings.

Now I will summarise this presentation, in this presentation basically I have talked about the plasma spray process electroplating process and electroless plating process. Plasma spray process reserves very high temperature of the plasma during this spray process that has the tendency for thermal damage as compared to the other thermal spray processes. At the same time electroless process basically uses chemical reactions for development of the coating.

And there is no thermal damage it can be used for both conduct a non conducting materials on the other hand electroplating process can be used only with the conducting materials only and so, this is how we complete all coating processes and all those methods are in layer of the suitable

kind of the material is deposited on to substrate for improving the properties of the surface so that the tribological life of the components can be increased.

Under this we have talked about the weld surfacing, thermal spray process, electroplating and electroless processes. Thank you for your attention.