Fundamentals of Surface Engineering: Mechanisms, Processes and Characterizations

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Lecture-40
Surface Modification Techniques: Laser Alloying

Hello I welcome you all in this presentation related to the subject fundamentals of surface engineering and you know we are talking about the surface modification techniques and under the surface modification techniques especially we are talking about those methods which are associated with the change in surface composition for improving surface properties.

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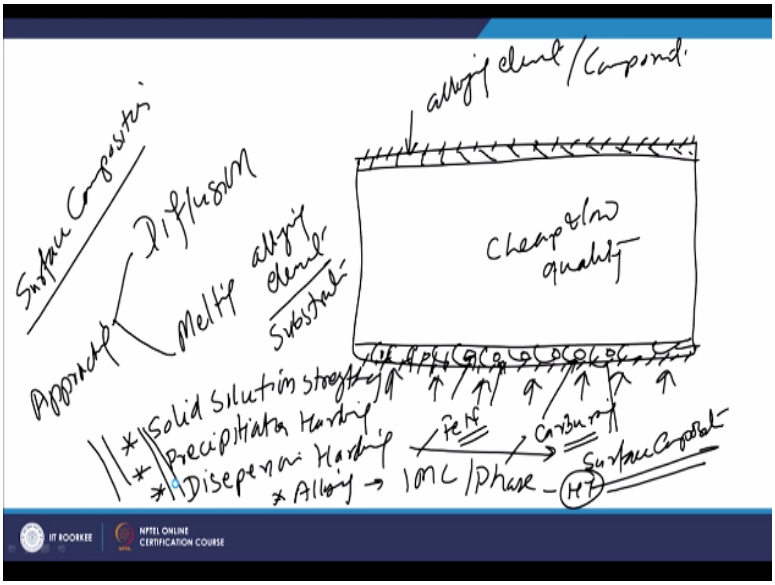

So in this broad category of the surface modification techniques where surface composition is modified to get the required set of the properties, you know in the surface engineering we normally use the main component of somewhat cheap and low quality material which is able to take the major load of the system. But the surfaces properties are not good enough to perform the expected functions for longer time.

So in the surface modification of such kind of the substrate materials surface properties are enhanced through various surface modification techniques. In one of the technique new surface layers composition is modified, so that the required change in surface properties can be achieved for expected performance of the component. So this change in surface

composition means we have to introduce the alloying elements or we need to have those compounds at the surface.

So that the properties can be enhanced. There are 2 broad approaches which are used to introduce the alloying elements at the surface and subsurface layers of the substrates. So the broad approaches of modifying the chemical composition includes one is the diffusion whatever element we want to introduce at the surface and subsurface of the component environment enriched with that element is created.

So that because of concentration gradient at high temperature diffusion can be facilitated and there is another approach where the melting of the alloying elements as well as substrate, both is used to introduce the elements at the surface layers. So what happens whenever we add these alloying elements from outside either using the diffusion or the melting.

The enrichment of the elements in control way at the surface and near surface layers can work in different ways. For example enrichment of the elements can lead to the solid solution strengthening. So the surface gets hardened and strengthened which in turns to helps in improving the adhesion and abrasive wear resistance. There is another way like if may facility to the precipitation hardening**.**

So introducing some of the elements at the surface layer subsequently on the heat treatment the form heart precipitates which will help in improving the surface properties. Then we have the dispersion hardening where in the such kind of the constituents are introduced at the surface and near surface layers which will maintain their integrity and will get formerly bonded mixed with the surface and near surface layers.

So these kind of situation leads to the case where the surface composites are developed. So the reinforcing agent in form of the hard particles are particular soft constraints like graphite they are introduced at the surface layer. So that the required change in properties can be realise. So dispersion hardening especially utilized when the surface composites are made and sometimes the alloying elements are introduced primary to achieve the required intermetallic compounds or the phases at the surface and near-surface layers.

After the subsequent on heat treatment, so this is the approach which is used like this modification is used in case of the carburizing, so high carbon martensite we can get in carburizing while like iron nitrides are formed in case of the nitriding. So those process for chemical elements are introduced for the purpose of having a particular kind of phase of particular kind of the intermetallic compound.

Similarly we can have the variety of elements in the surface and sub substrate layer of the component which will be helping to improve the properties to one or combination of these mechanism for improving the surface properties. There are various approaches for modifying the surface composition and the surface layers of the different materials are developed.

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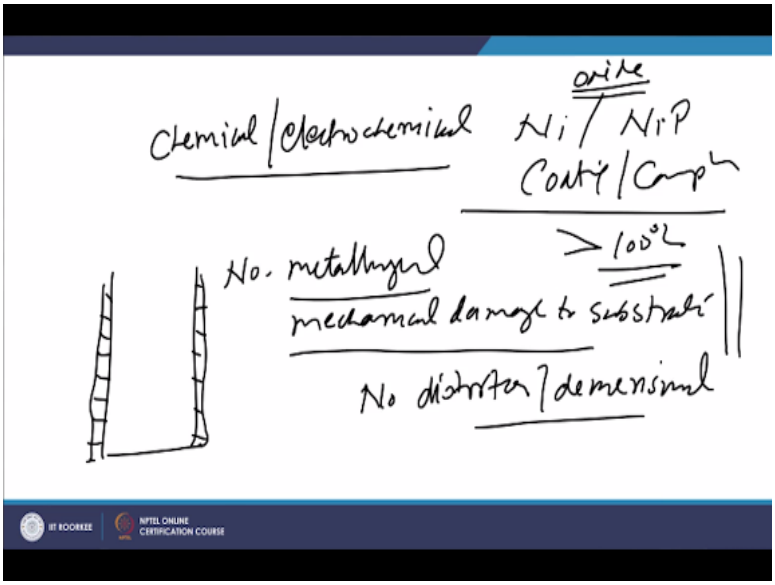

So 1 method is where the chemical or electrochemical reactions are used. So this kind of method is used for depositing the core in Nickel or nickel phosphate coating and modifying the composition of the surface layers. So in this case the temperature of the substrate is maintained well below the 100 degree centigrade. So in this category of the processes is the temperature is maintained within 100 degree centigrade.

So there is a no metallurgical or mechanical damage to the substrate properties. So this is one of the good side of the chemical and electrochemical methods where the layer of the required material at the surface will be developed using the chemical reactions or using the electrochemical and based techniques for developing such kind of the layers or the coatings on the surface.

Oxides of particular kind of the metals can also be deposited using this category of the process is a good part of the speed of the processes that during the surface modifications the temperature of the service that remains the below 100 degree centigrade and which does not lead to any kind of adverse effect on the metallurgical properties of metallurgical characteristics of the subsurface material.

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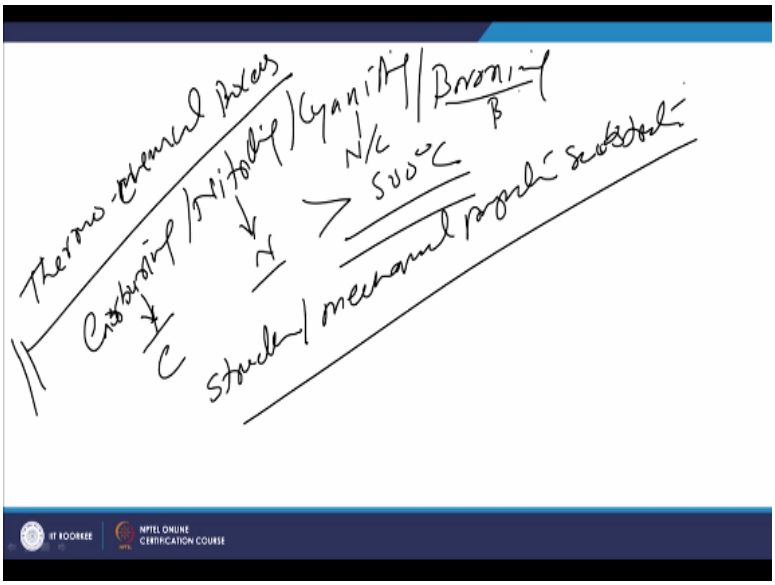

And there is no damage to the mechanical properties of the substrate as well as and because of the lower temperature will see then no distortion and the dimensional variation related issues. So this category of the processes are good in that way, then another category of the processes thermochemical processes. So in this category we have the carburizing, nitriding, cyaniding, boronizing.

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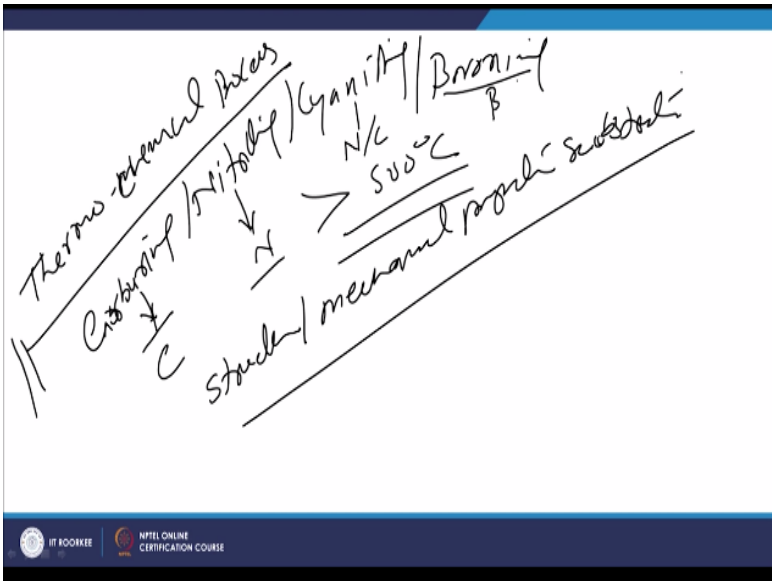

In this processes temperature used is greater than 500 degree centigrade and because of this there is every possibility are change in the structure and mechanical properties of the substrate. So the substrate characteristics and properties are expected to get modified when the components process through the thermochemical processes because they are performed at high temperature for modifying decomposition of the surface and near surface layers.

Like carburizing will be increasing the carbon content nitriding will be increasing the nitrogen content of the subsurface layers carbon cyaniding will be increasing both nitrogen as well as carbon at the surface layer. Similarly boronizing will be enhancing the boron content at the surface layers and these will be performing the different kind of the constitution for enhancing surface properties.

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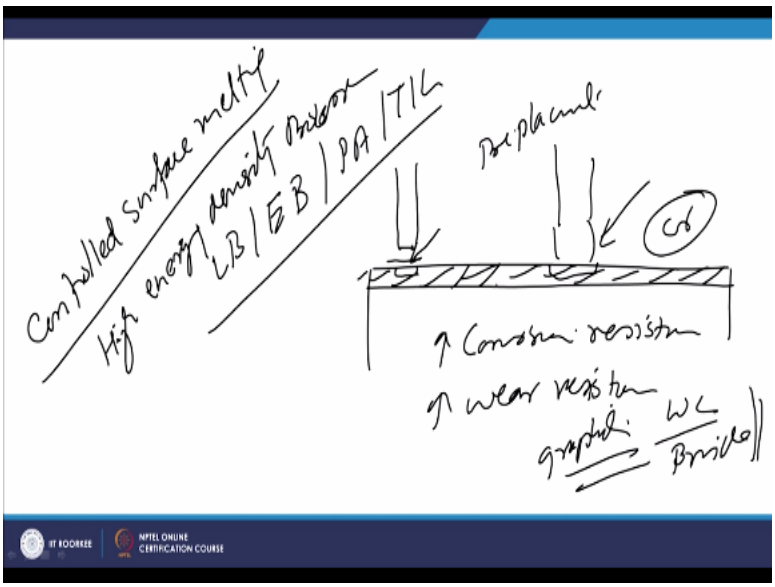

There is another approach where in the controlled surface melting is used using the high energy density processes like we can use the laser beam, we can use the electron beam or we can use plasma or even the GTA or TIL R is also used. All these are non consumable and processes where the consumable is fed in the heating zone if we want to apply or we want to deposit anything on to the surface.

So in these cases the approaches very simple the surface which is to be modified is subjected to the application of the heat source which is high energy density, heat source, heat is applied over a small area and heat is applied in large quantity in very small time for small area, so the quick melting of the substrate layer is facilitated and in this zone either we preplace the

alloying elements which is to be added at the surface or will be feeding in at the source or in the heating zone.

At the same time in heating source is applied, so there can be like pre placement technique the alloying element to be applied to be introduced at the surface layer is pre placed and then it is melted using the suitable heat source or when the heat source is being applied at the same time will be feeding the alloying element in very control. So mixing of both mixing of both alloying element as well as the substrate material takes place in the molten state and good metallurgical bond is created.

And the chemical composition modified surface layer is formed in this approach only condition is that energy density is to be high. So that the first melting is facilitated and the melting of the base metal in combination with the alloying element to be introduced is realized. So the control melting of the substrate as well as control melting of the alloying elements is done for proper intermixing of that tool.

So that the surface composition can be modified and this kind of the approach is used for increasing the corrosion resistance by modifying the composition of steel surface by adding like chromium or it can also be used to increase the wear resistance by adding the hard constants like a tungsten carbide and borides which are hard and brittle or it can also be used to enhance the wear resistance by introducing the graphite at the surface.

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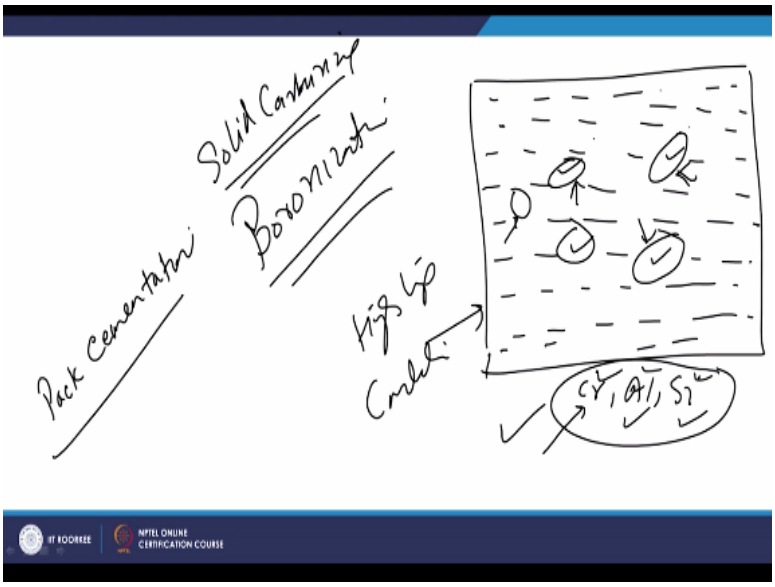

So in this case is near surface layer composition is realized so the controlled fusion of the material to be introduced and the substrate both in very controlled way. Then there is another group of the processes with called like pack cementation where the material enriched with the required element like chromium, aluminium, silicon etc. So these are the various elements if you want to introduced we will be using the process like chromizing or aluminizing or synchronising the material in which with these constituents in powder form is kept in a chamber where in the component whose surface is to be modified is also placed.

So these are the components whose surface is to be modified, these elements the powder points which are in contact with the components whose surface is to be modified under the suitable high temperature conditions, these elements diffuse into the surface of the component and change the composition of surface and near-surface layers boronizing is a 1 typical example of this kind of the pack cementation.

Similarly the solid carburizing is also an example of this kind of pack cementation and likewise the chromising, aluminizing and synchronising is also used where the material enriched with the required element in powder form is kept in a box, in that box we also put the components surfaces to be modified and then enter chamber it is kept at high temperature for some time. So that the diffusion of such elements at the surface and near surface layers can be facilitated to modify the surface composition.

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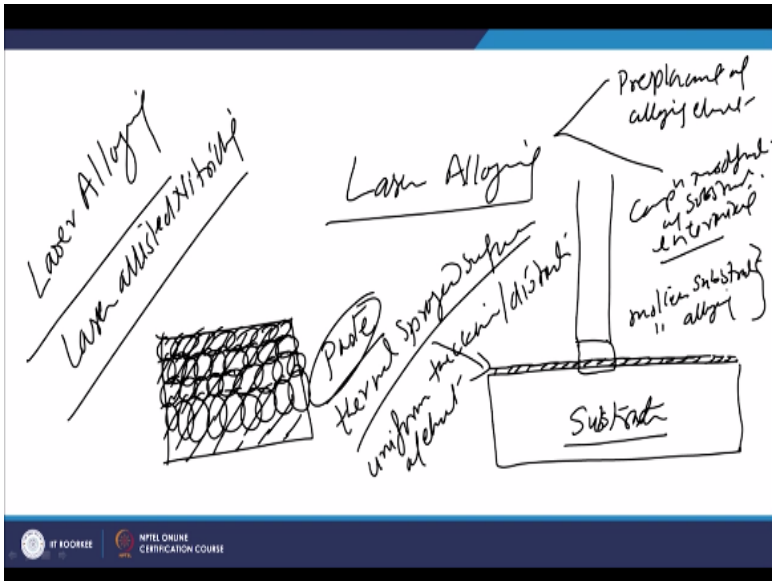

So as to achieve the enhancement in surface properties, now will be talking about the 2 processes based on this approach 1 is the laser alloying, and another is the laser assisted

nitriding. So in this kind of the processes first of all we will talking about the laser alloying. So here laser is high energy density heat source which means in very less time it can supply lot of heat for facilitating the melting of the substrate.

So there are 2 broad approaches laser alloying technique 1 is like pre placement of the alloying element at the surface of the substrate. So in solid form in powder form the material to be introduced the element to be introduced at the surface is applied first in the pre placement technique. This can be applied in form of like paste or the element is dissolved and then it is applied in form of the solution over the surface or it can be thermal sprayed over the surface.

So thermal spraying gives more uniform thickness or the distribution of the element which is to be applied over the surface of substrate, while paste is applied manually so there can be inconsistency as far as the thickness of the layer which will be applied, once this layer has been applied over the surface of the substrate will be applying this laser source laser as a heat source onto this on the surface where the required element has been applied either that may use in the paste or using the thermal processes.

And then use of the laser helps to melt both surface layers having the alloying element and the substrate and thereby the molten substrate and molten alloying elements in the mixing of both facilitates the compositional modification of surface layers. So this is what is there once the surface layer melt and mix up with the molten base metal and that in turn after the certification insulating to the surface of the modified composition.

So the laser beam is applied one by one over the entire area like this is a surface. So it will be applying the alloying element to be introduced using the paste or the spray process over the surface and then laser beam will be scanning one by one the entire area to melt the alloying elements and the substrates so that proper intermixing of both can place and we can have overlap between the different process of the laser beam of like say 15 to 25%.

So that the proper mixing and uniform of the composition over the entire surface area can be achieved. So like this we can have the number of process to cover the entire area. Now what are the factors which are important as per as this laser alloying is concern and factors which

will be governing the composition like say we have applied the particular amount of the element like say chromium we have applied on the surface.

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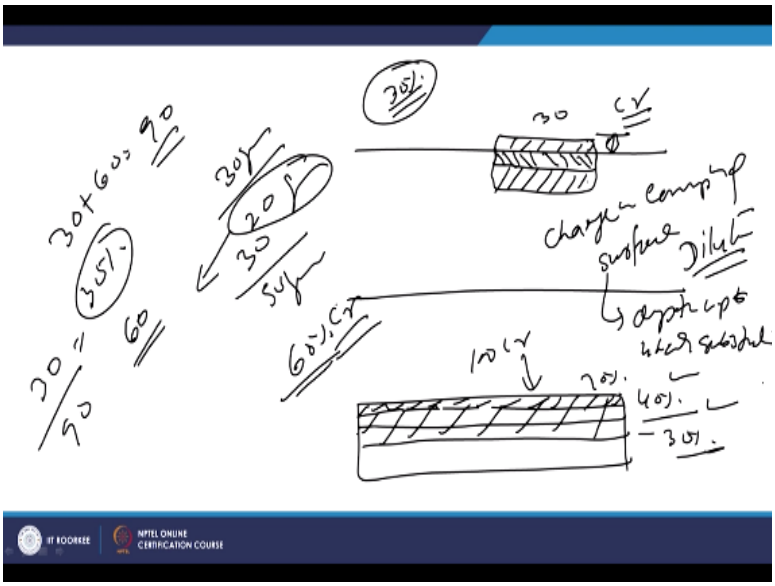

And the amount of the chromium that we want to introduce say 30% at the surface. So just addition of the 30% of the chromium at the surface and melting with the base metal makes to get metal will be reducing the concentration of the chromium at the surface. So what will be doing basically if the melting is taking place up to small depth and same amount of the chromium which has been applied at the surface after mixing with the base metal will be reducing the compositions due to the mixing the alloying element which was applied at the surface was 30 grams.

And the melting of the base metal is also taking place say 20 gram then what will happen the total will be 50 gram in the molten state out of which we have 30 gram of the chromium. So in this case there will be 60% of the chromium and if the more if the deeper melting of the substrate is taking place of 2 any substrate is being melted up to the great rather than the amount of the base metal will be more it will not be 20 gram.

Maybe say the melting of the base metal is taking place up to say 60 gram then total will be the 90 gram 30+60 will give the 90 gram of the molten zone and then it will try to calculate the percentage of the Nickel in this total mass which will be getting up to the solidification it will be 30%. So there will be significant change with regard to the volume of the with regard to the depth of twitch melting of the base metal is taking place.

So this change in composition of the surface layer is being influenced by the depth up to which substrate is melting. So 1 simple criteria is used like if this is the thickness which is being applied or there is very simple way like we have added 100% chromium and obviously after the melting the base metal of the chromium at the surface layers will not be 100% because of the intermixing.

So there will be reduction in the chromium content, so the chromium layer which was there at the surface 100% after the mixing it may be reduced to 70%, if the deeper melting of the substrate is taking place reduced to the 40%, if the further deeper melting of the base metal is taking place, then it may be reduced to the 30%. So this kind of the change in composition which is being influenced by the extent of which base metal is melting or substrate is melting.

This one is called the dilution, so more is the dilution lesser will be the presentation of the alloying elements, we always want that dilution is as less as possible however it is sufficient just to ensure that proper mixing of the base metal with the alloying element is taking place. So that the good metallurgical bond and good composition modification can be facilitated.

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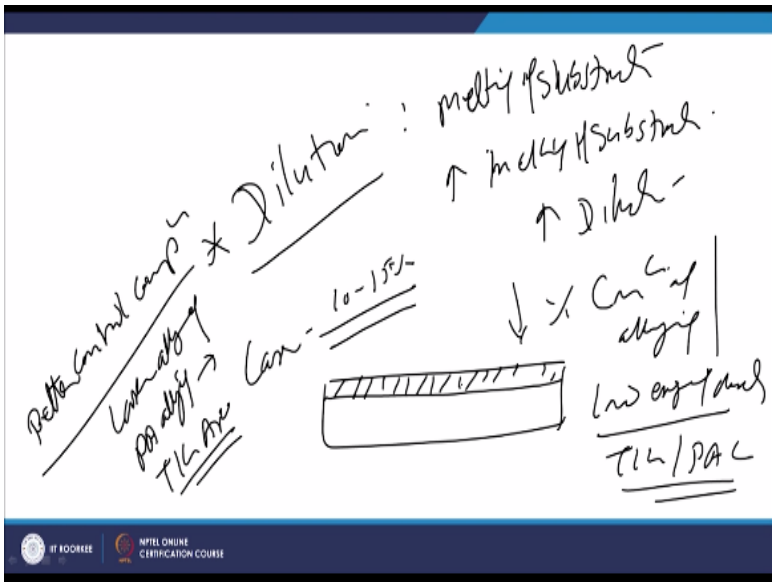

And this so this is the general approach to one thing is which is governing the composition of the surface layer is the dilution which is happening due to the melting of substrate, the greater is the melting of the substrate greater will be the increased in melting of substrate greater with the dilution means there will be reduction in the percentage or the concentration of alloying elements.

That is why as far as always made to reduce the dilution level. This is the case of in case of the laser alloying like say maybe 10 to 15% is the kind of the dilution which is observed and if you are melting the base metal up to the greater depth then like in case of the low energy density processes, energy density processes low energy density processes like the TIG plasma or so in those process the depth of at which melting of the base metal will be taken place that will be greater.

And which in turn will be reducing the alloying concentration increasing the dilution. So we have much better control over composition by surface alloying in case of the laser alloying. But if we use the plasma or alloying in that case greater depth of the melting of the substrate will be increasing the dilution and leading to the more reduction in the concentration of the alloying elements.

Similarly in the TIG arc process where the TIG arc is used for melting the surface and surface layers of the substrate and melting of the alloying elements which have been applied either by the pre-placement technique of another technique that will be leading to the greater dilution and more reduction in the concentration of the alloying element. Another approach is that where the surface of the substrate is applied with the suitable heat source maybe arc or laser.

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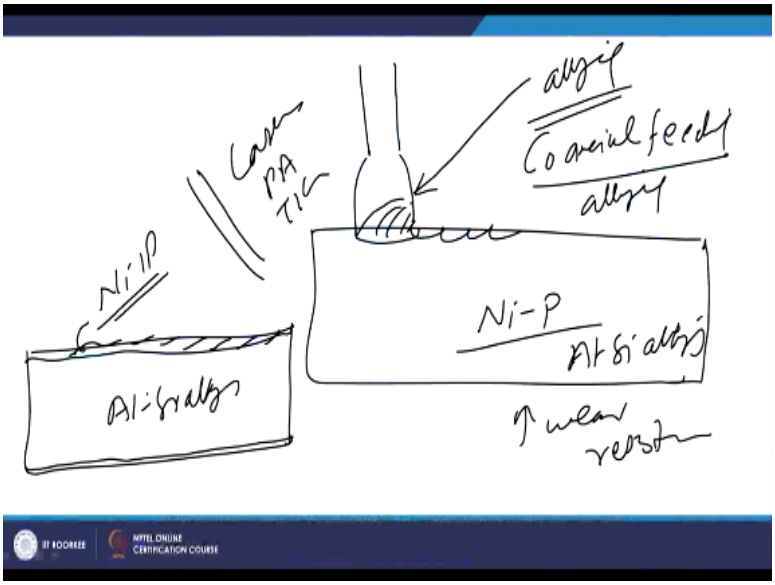

So this arc or laser will be melting the base metal at the same time through the external source the element to be introduced is fed in this zone. So melting of this one is also facilitated, there can be coaxial feeding of the alloying elements which are to be introduced at

the surface or they can be fed using the suitable powder feeders or at the surface. So that the composition of the surface and near-surface layers can be modified.

In this case the know a pre placement is needed but at the time when the external heat source is applied in form of the laser or the plasma arc or in case of TIG arc or in the heat source itself we have to feed the alloying element using suitable feeders. So that meeting of the both alloying element as well as the substrate can be realised for proper intermixing of the tool. So that the required surface composition can be modified.

One typical example for this kind of modification is where the nickel and phosphorus, nickel phosphate layer is applied on the surface of the aluminium silicon alloy substrate for increasing the wear resistance. So in that case what we have basically the substrate is of the aluminium silicon alloy and the surface we have the Nickel phosphate layer developed by the control laser alloying.

So nickel and phosphorus conference concentration at the surface layers will be more through the controlled for enhancing to the wear resistance. Now I will summarise this presentation in instrumentation basically I have talked about the melting or fusion based approach for modifying the surface composition and any high energy and density heat source can be used for the laser alloying wherein at the surface we apply the required element to be introduced.

And then it is fused with the substrate using the suitable heat source, so that the surface layer composition can be modified, however we have to keep the control over the delusion level during the melting of the substrate, thank you for your attention.