Fundamentals of Surface Engineering: Mechanisms, Processes and Characterizations
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Lecture-39
Surface Modification Techniques: Chemical Vapour Deposition and Boronizing

Hello I welcome you all in this presentation related with the subject fundamentals of surface engineering and we are talking about the methods of surface modification for improving the tribological performance of the components and under this heading we have talked about the various processes and as you know that there are 3 different categories of the surface modification techniques.

One we are just surface metrology is modified, the second where surface competition is modified and third where layer of the suitable material is deposited in form of films coating or claddings. So we are talking about the third or second category of the processes where chemical composition of the surface is modified and under the headings we have talked about various surface modification techniques.

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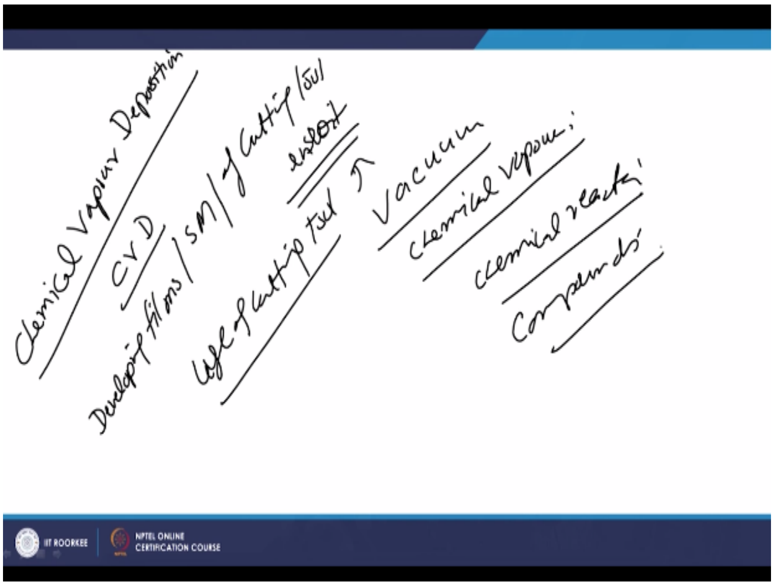

In this presentation we will be talking about the 2 surface modification processes, 1 is the chemical vapour deposition and another is boronizing. So initially we will be starting with the chemical vapour deposition process, in short it is known as CVD and this is one of the most commonly used process for developing films or for surface modification of cutting tool inserts.

So that the life of cutting tool can be enhanced in this process this process also performed by developing vacuum and it uses the suitable chemical vapours for required chemical reaction. So that the suitable compounds through chemical reactions at the surface can be formed for enhancement of the properties. So this is the process in general.

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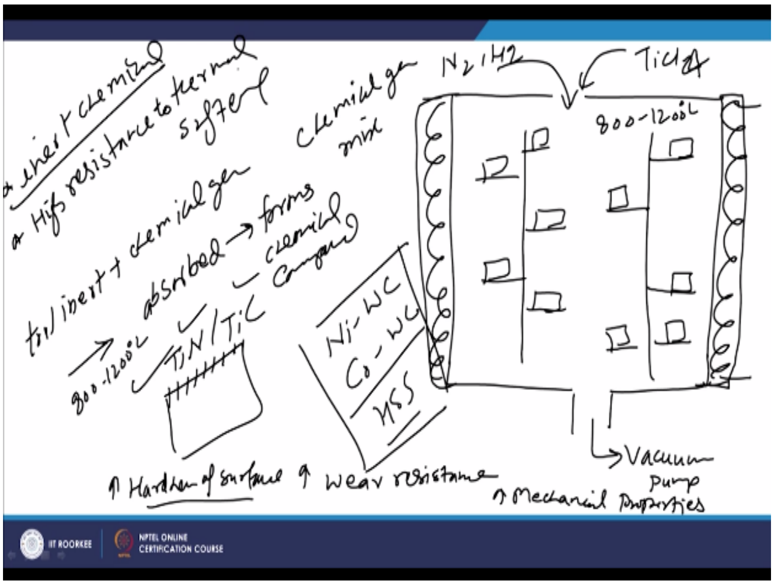

So what we use in this process basically 1 chamber which is made of the stainless steel is used is connected with the suitable vacuum pump for creating vacuum and then inside we have the suitable compartments for putting in the components to be modified for surface property enhancement. So here like since it is most commonly used for improving the properties of the cutting tool inserts will be placing the cutting tool inserts at the different compartments.

These inserts maybe of a like that tungsten carbide, nickel, based tungsten carbide or cobalt, tungsten carbide these may also be of the HSS. So these inserts which are made of these materials are kept in this compartment and then after creating the vacuum the chamber is filled in the with the suitable chemical gas mixture. So like nitrogen, hydrogen and titanium chloride, gas mixture is filled in the chamber.

And it is also made with the suitable arrangement for heating of the chamber, so we have the suitable heaters in this a stainless steel chamber for increasing the temperature. So the temperature inside the chamber is quite high enough like 800 to 1200 degree centigrade. So when such kind of the conditions are created so cutting tool inserts in the presence of the chemical gas mixture under the temperature conditions of 800 to 1200 degree centigrade.

These gases are absorbed and forms the chemical compounds. So in this particular case when the chemical compounds react they form over the inserts they form a films or coatings of the titanium nitrite or titanium carbide and once these films are formed over the surface these are very hard and stable materials. So obviously they will be increasing the hardness of the surfaces as well as on which in turn help in increasing the wear resistance of the cutting tool edges.

And when these kinds of the films are formed on other components it also helps in increasing the mechanical properties especially the tensile strength and fatigue resistance. So this is the kind of the process which is a normally used for developing the films and one such kind of the films are formed are not only these things are very of very high hardness but they also offer they are inert for chemical environments.

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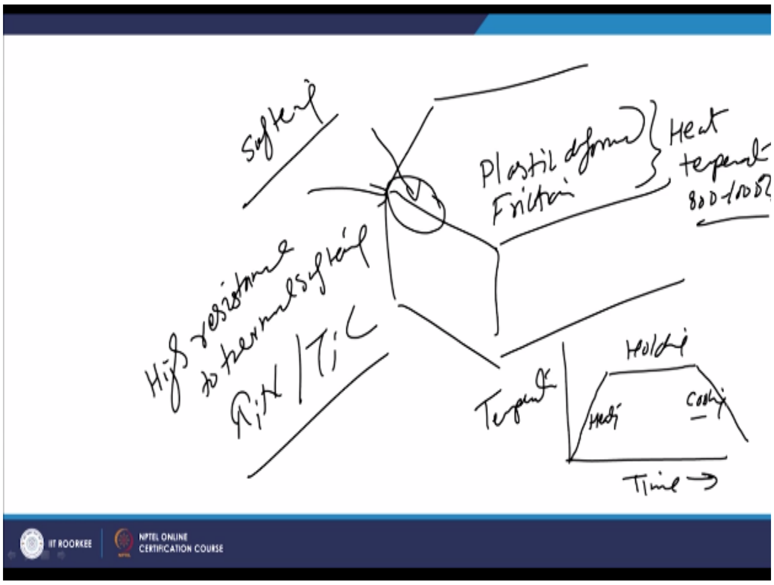

And also they offer very high resistance to thermal softening, so since we know that during the metal cutting like say during the metal cutting this is the cutting tool edge, at the cutting edge due to the work performed a work being done for removing the material by shearing lot of heat is generated due to the plastic deformation needed for the shearing as well as due to the friction between the chip and tool and friction between the tool and workpiece.

So both these components contribute to the generation of heat and this heat generation causes significant rise in temperature like say during machining of the steel temperature rise maybe like 800 to 1000 degree centigrade and such high temperature conditions the surfaces are the edges of the cutting tools which are involved in machining they will tend to get soften. So it is important what are the cutting edges of the inserts are being modified.

This show enough resistance to the thermal softening, so high resistance to the thermal softening is achieved with the help of development of such kind of the coating like titanium, nitride titanium, carbide and the surface of the cutting tools inserts, the kind of the thermal cycle which is used for the CVD process is like this in the x axis we have time and y axis we have temperature. So after putting in the components and creating the vacuum within the chamber the temperature is increased and the temperature is held for some time.

So this is holding time and this is the heating zone and then once the holding time is over form for absorption of the gases and the completion of the chemical reaction to form the required component the system is cool. So this is a kind of the thermal cycle which is used for performing the chemical reactions as well as for performing the chemical vapour deposition process.

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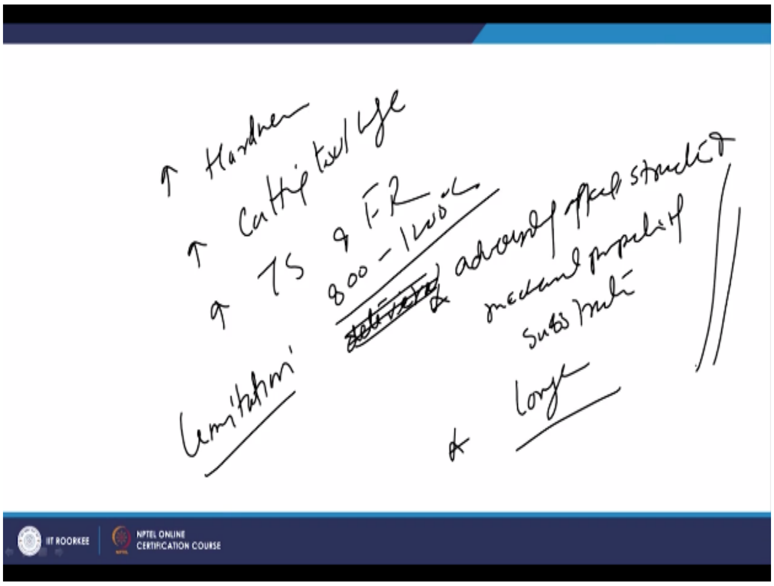

So in light of this if we see there are there are certain advantages related with this process that it is able to increase the surface hardness significantly which helps in increasing the cutting tool life especially with regard to the tool as well as it also helps in increasing the tensile strength and fatigue resistance of the component and the but apart from the positives associated with this chemical vapour deposition process there are few limitations.

Since the rise in temperature are the temperature which is used during the chemical vapour deposition process is in the range of 800 to the 1200 degree centigrade and such rise such a major rise in temperature of the substrate material can adversely affect the structure and mechanical properties of the substrate itself. So there is possibility for compromise with regard to the mechanical properties and structure of the substrate itself.

So this is 1 major disadvantage which will be increasing the tendency for that iteration in mechanical performance of the component due to the high temperature exposure further process take slightly longer to complete the chemical reactions required. So in order to overcome the issues related to the chemical vapour deposition process especially with regard to the high temperature for the advancement of the development in the chemical vapour deposition process have taken place where in the plasma assisted chemical vapour deposition process has been developed.

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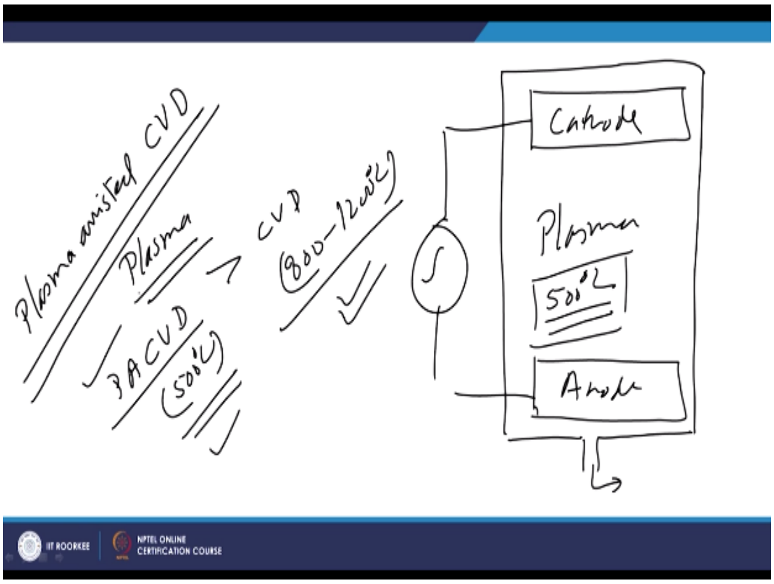

And advantage of this process is that it uses the plasma for absorption as well as a realising the required chemical reactions to form the compounds required. So in order to have for the plasma formation in this kind of system again will be using the vacuum system and apart from the things which are needed for the conventional chemical vapour deposition process it uses 1 anode and 1 cathode .

So that and then power supply, so there is 1 cathode and 1 anode, so and sufficient potential difference is established in order to convert the gases in form of the plasma. So with the help of by putting insufficient potential difference between the anode and cathode plasma is created and which will sufficiently be used for fluctuating the chemical vapour deposition process.

The advantages that this plasma assisted chemical vapour deposition process performed at 500 degree centigrade which is significantly lower than the conventional chemical vapour deposition process. So the plasma assisted CVD of the advantage over the conventional CVD process especially with regard to the temperature at which it is performed the plasma which is performed at 500 degree centigrade.

The conventional one is performed 1200 degree centigrade, so this adversely affects the substrate properties because of the high temperature exposure of the substrate as compared to that in case of the chances for the damage and tendency for that iteration in mechanical performance of the components in case of the plasma state CVD will be lower. If you take up the typical example where will see how does CVD affects the performance of the tool life.

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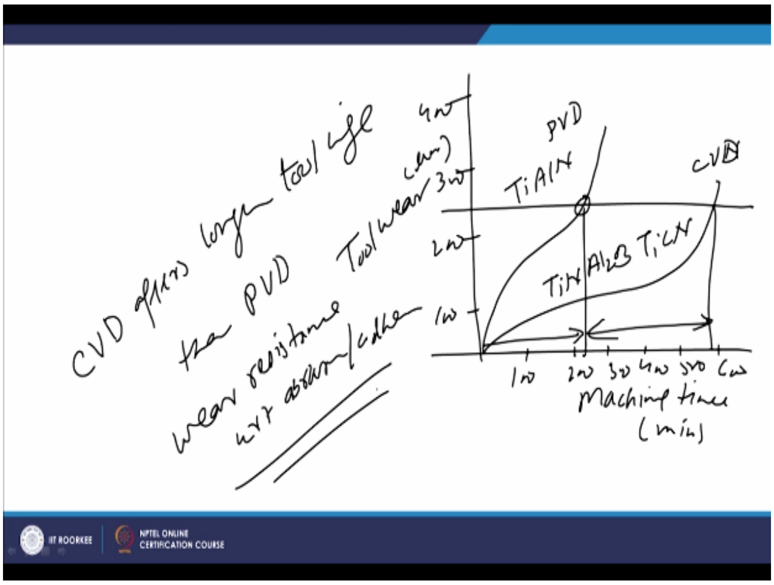

Especially the life of the component which is being modify say the cutting tool if in the x axis we have the machining time indicating the tool life in minutes and in the y-axis we have tool wear, so tool wear like say 100, 200, 300, 400 in micrometers and this is in cutting time. So her like say 100, 200, 300, 400, 500, 600 in minutes. So when we develop the coatings of the aluminium nitrite then we will see that the life of the tool is not improvement in the life of tool is not much say.

This is the PVD deposited titanium aluminium nitride and here if we see the chemical vapour deposited the film of the Al2O3 titanium nitride Al2O3 and Tic and titanium carbon nitrite. So these will be in, so if we see the curve for a given magnitude of the tool wear that time it takes up the time required to achieve particular value of the tool wear is very short. So the tool wearing which suggest that tool will be wearing out at much faster rate to reach like say the 250 micrometre tool wear.

In case of the TiAlN PVD deposited coatings as compared to the case when the CVD method was used for depositing the film of titanium nitride or aluminium TicN. So this offers longer tool life. So this is indicated that the CVD offers much longer to life as compared to that of the PVD. So if we see a CVD offers longer tool life than the PVD which means the wear resistance especially with respect to the abrasion, adhesion offered by the CVD coatings is much better than the PVD coatings.

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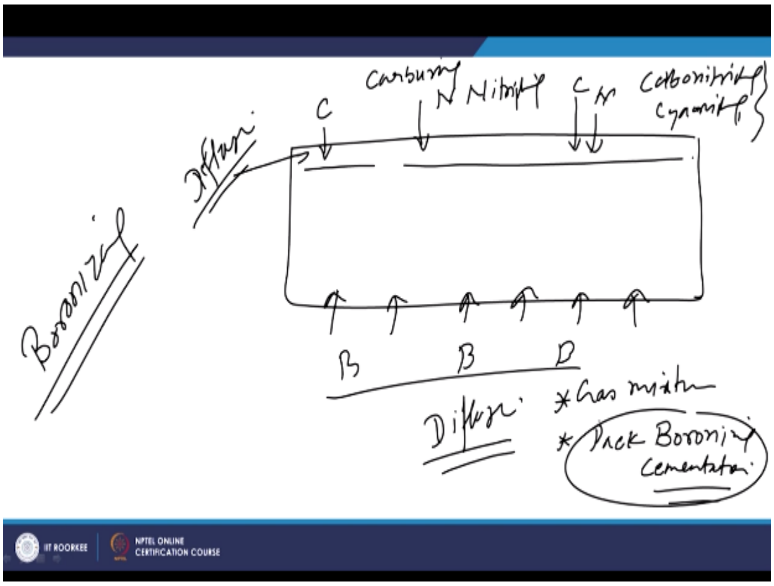

Now will take up the another process which is the boronizing, like we have seen earlier for modifying the chemical composition of the surface is we have seen so many processes like carbon is introduced in the processes like carburizing, nitrogen is introduced in case of the nitriding and mixture of both carbon and nitrogen is introduced in case of the carbonitriding and cyaniding.

So both these process is introduced the carbon and nitrogen, as the name appears in both these processes it is the diffusion through which the required element will be introduced at the surface of the component. So that either carbon concentration or the nitrogen concentration at the surface and near surface layer can be enhanced for forming required nitrides or forming the high carbon martensite in case of the carburizing, carbonitriding or cyaniding processes.

In the same line the boronizing is used to introduce the boron at the surface and near surface layers. So obviously it uses the similar concept of the diffusion where the boron which environment is created all around the component. So that the boron can be introduced through the diffusion at the surface and near surface layers of the component. So for this for introducing the boron at the surface and subsurface layers of the component there are 2 approaches.

One is we can use the gaseous mixture or we can use a track boronizing method. This is also called pack cementation. So pack cementation is the solid which process where powder mixture of the suitable constituents is used and in that mixture the component to be modified is kept at high temperature for sufficient and time so that boron can get introduced at the surface.

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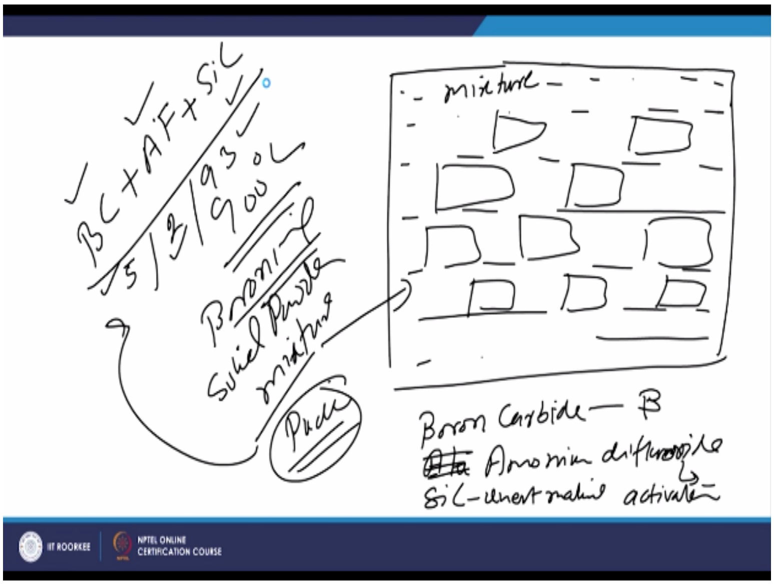

So now we will see boron for an example we use a pack of suitable mixture like this in a pack of the suitable mixture and it will be and the component to be boronized and will be kept in this pack at sufficiently high temperature. So solid powder mixture is termed as pack and water this packet consists basically this pack consists the boron carbide which provides the boron for this purpose.

And then ammonium difluoride this act as a activator and then silicon carbide is used as inert material**.** So the mixture or the pack primarily consists of boron carbide+ammonium difluoride+silicon carbide, this is activator, this is inert material and this is the consent which we will be providing the boron and in this pack in this mix are the components are kept in a closed chamber at high temperature.

So the temperature of 900 degree centigrade is used for boronizing and this measure will be providing the boron to get introduced at the surface of the component and there is a particular ratio of this mixture where the boron carbide is in proportion of 5 activator is 2 and the balance 93% is of the silicon carbide. So 5% boron carbide, 2% activator aluminium difluoride, ammonium difluoride and 93% of the silicon carbide inert material.

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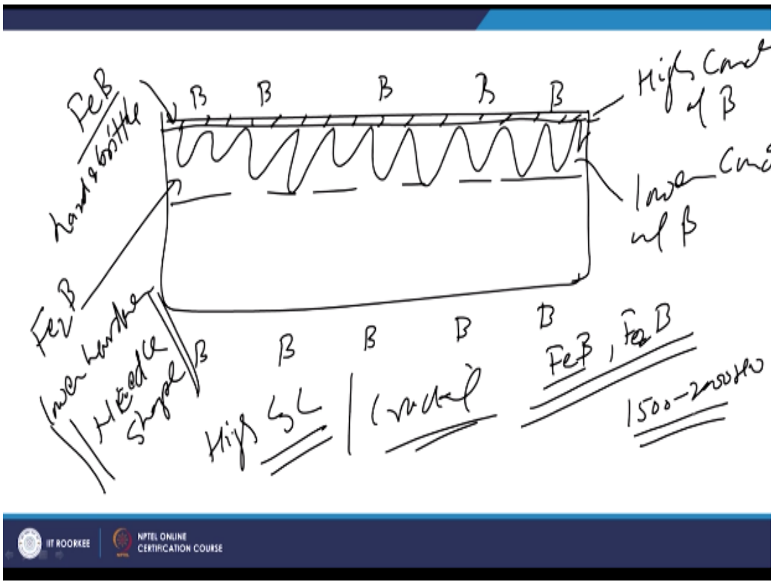

And this entire mixture is kept at higher temperature, so that the boron can be introduced at the surface of the components. Since in this case the boron is being introduced through the diffusion process. So in any case since the boron concentration is more all around the component and that is why it is getting diffusing to the component where the concentration is less. So the surface layers will have the higher concentration of the boron while the subsurface layers will have somewhat lesser concentration of the boron.

So there is up to some distance the boron will be getting diffused at the surface layers the concentration of the boron will be high. So high concentration of boron and here in the subsurface layer somewhat lower concentration of boron exist. So wherever we have higher concentration iron boride in case of the steel is found, this is a 1 type boride which is hard and brittle, while in the subsurface layer where boron concentration somewhat lesser.

Another type of the iron boride is formed which is Fe2B type and obviously it is of the somewhat lower hardness and its morphology is of the normally needle shaped which we can see. So this needle shape morphology is also is normally offers the higher stress concentration and tendency for the cracking. So it is always preferred that such kind of the morphology is avoided during the boronizing.

So that the crack in tendency can be reduced, whenever the boron is introduced at the surface of the component which it offers the extremely high hardness and so these iron borides whatever formed at the surface they offer extremely high hardness ranging from 1500 to 2000 Hv and as we know where the concentration of the boron at the surface layers if we see how the concentration of the Boron varies with depth like say 20, 40 micrometre 60, 80, 100.

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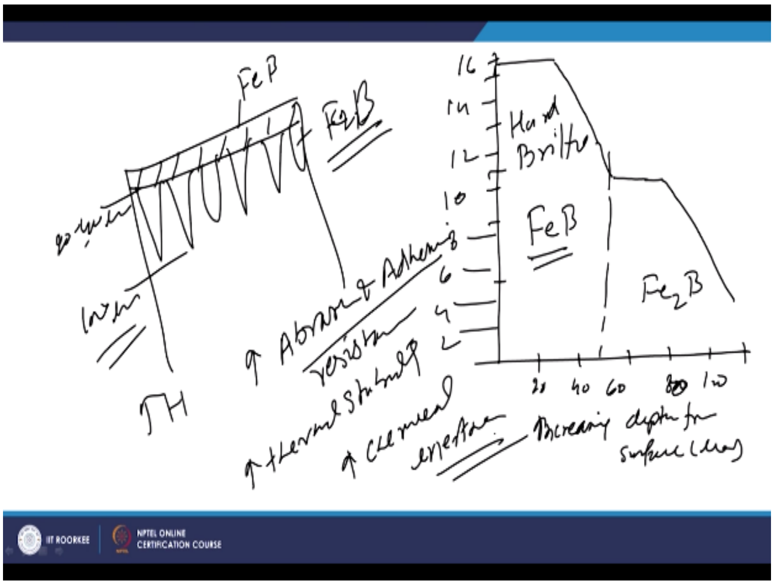

So increasing depth from surface in micrometre and in the y-axis we have the concentration of the boron. So obviously at the surface the concentration is very high. So like say the 16, 14, 12, 10, 8, 6, 4, 2, like this. So just at the surface this concentration is very high and then it will be somewhat lower then what will see or it will be reducing further.

So there are like say this is the band where primary will be having the FeB and this is the zone where will be having the Fe2B, this is the layer which is having the higher concentration of the iron boride like say greater than 10 or 12% and this will be very hard and the brittle layer. So if we see structure wise this is the top layer of the iron boride which is being formed like iron boride FeB.

And below that we get the needle shaped iron borides of the Fe2 Fe2B which is of somewhat lower hardness. So this distance is like say that 20 to 40 micrometre and below that it is lower. So this is 80 and then 100, so likes a up to 100 micrometre the surface has been enriched with boron concentration and whenever the iron boride insufficient is amount is found it increases the hardness.

And it because of increase in hardness we get the increased abrasion and adhesive wear resistance. So adhesion and abrasion resistance is enhanced further it increases the thermal stability means resistance to the softening is increased and this also helps in increasing the chemical inertness was the iron boride is formed.

So now I will summarize this presentation, in this presentation basically I have talked about the 2 processes, 1 was the chemical vapour deposition which is primarily used for improving the life of the cutting tool inserts and the another process was the boronizing where boron is introduced the surface for forming the iron borides and borides of the other compounds which are present in steel. So that the surface hardness can be enhanced for improved tribological performance of the components, thank you for your attention.