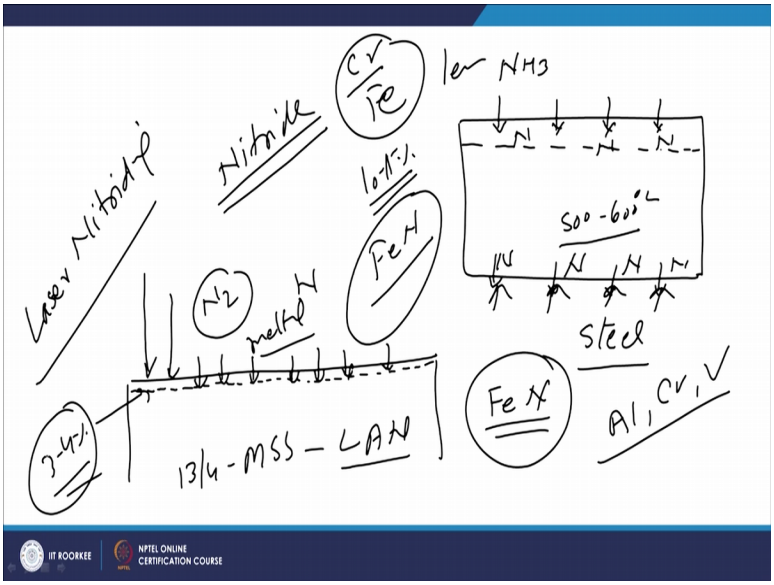
Fundamentals of Surface Engineering: Mechanisms, Processes and Characterizations

Prof. D.K. Dwivedi
Department of Mechanical and Industrial Engineering
Indian Institute of Technology Roorkee

Lecture-41
Surface Modification Techniques: Laser Nitriding and Developing Surface Layer

Hello I welcome you all in this presentation related with the subject fundamentals of surface engineering and you know we are talking about the surface modification techniques and under these techniques. Basically we are talking about the methods which are based on changing the chemical composition of the surface layers. So, that the sub improvement in surface properties can be achieved for improving the tribological behaviour and wear resistance of the components.

(Refer Slide Time: 01:08)



So, under this category the one last process about which will be talking is the Laser Nitriding. We have a seen where the simple nitriding process which is used really performed under the temperature conditions of the 500 to 600 degree centigrade this is a ferrettic zone for the Steels. So, and at this set in this temperature range the nitrogen rich environment is created using ammonia and which provides the nitrogen rich environment all around the component surface which is to be modified. So, the nitrogen sorry nitrogen content is enriched at the surface and subsurface layers. So, this is reverse trend.

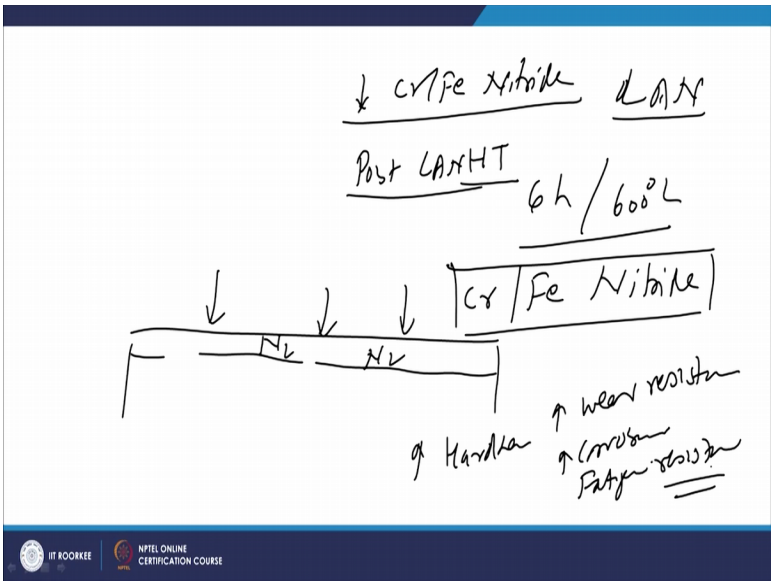
Because the nitrogen is to be introduced the surface and subsurface layers, so once the nitrogen has been enriched in the components in the desired level which will be like a 10 to 15% as well so this will be forming the various types of the iron nitrate. So, at the surface layer nitrogen content is more so it forms the hard and brittle nitrogen layer. While in the subsurface layer nitrogen concentration is less than other type of the nitrides are formed which are hard and stable and do not turn increase the cracking tendency much.

But in case of the laser nitriding basically laser is used here for melting the surface layers up to a very thin depth. So, very thin layer of the material is melted and this is carried out in the nitrogen rich environment. So, the nitrogen introduced in the surface and surface layers and thereby it will be forming the iron nitride. We have also seen that steel is having that alloying elements like aluminium, chromium, vanadium.

Than these nitrides of these elements are harder and stronger they are more stable. So, than effectiveness of nitriding process is much better like in one of the typical cases where 13/4 martensitic stainless steel subjected to the laser assisted nitriding when it is performed we get the nitrogen concentration in the range of the 3 to 4 %. And just after the laser nitriding we find that when nitride content of the nitrides like chromium, nitride ion and nitrites at the surface layer is less.

So, immediately after the nitriding when the nitrogen is introduced in this range the concentration the proportion of the nitrites of chromium and iron are limited.

(Refer Slide Time: 04:19)

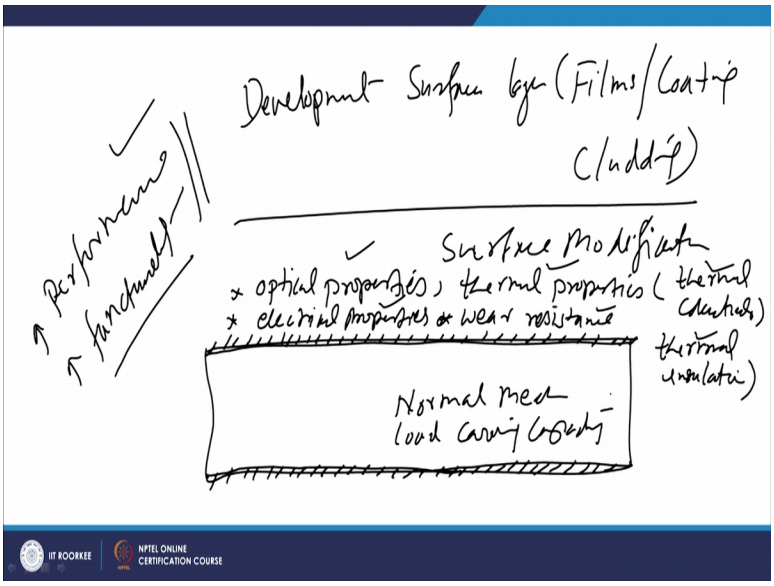


So, and therefore due to the limited concentration of chromium and iron nitrides immediately after the laser assisted nitriding we it is required to perform post nitriding heat treatment so post laser assisted nitriding heat is performed say it is performed for 6 hours at 600 degree centigrade then these kind of treatment helps informing the significant proportion for chromium and iron nitrides of the using the nitrogen which is present in this at the surface layers and near surface layers of the steel.

So, the laser assisted nitriding will simply increasing the nitrogen concentration near the surface layers and subsequent heat treatment will be facilitating the formation of the required nitrites of the chromium or iron in this particular case. And similarly if the nitride formula and elements are present in this field and effectiveness of this process will further be enhanced. And once these nitrates are formed at the surface it will be increasing, the surface hardness will be increasing the wear resistance.

And it also helps in increasing the corrosion resistance, fatigue resistance in terms of the mechanical properties. So, number of benefits are exploited and only case here laser assisted nitriding with respected to the conventional nitriding laser is being used as the additional heat source for facilitating for introduction or introducing nitrogen at the surface and near surface layers.

(Refer Slide Time: 06:17)



And now we will be talking about the third approach of the nitriding technique where development of surface layers in form of films coatings or claddings is used for surface modification. So this is the third approach of the surface modification. So in this case when we find that our component is made of a material which can provide the required support for the mechanical loading.

So, normal mechanical load carrying capacity offered by material of which components is made. But if you want that either for increasing the performance of the component or for increasing the functionality of component if it is required that surface of such kind of component is having the specific set one the properties.

Which are absent in the normal substrate and then these kind of the properties can be achieved by developing the layer of suitable material which can really offer properties which are desired for the surface for increasing the performance may be in terms of mechanical properties, tribological properties or any other properties which is required properties for improving the functionalities.

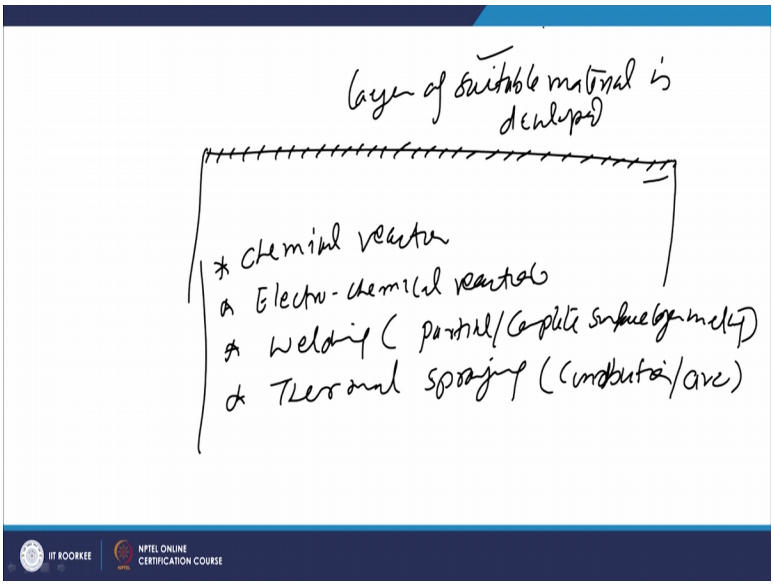
So, the substrate may be good with regard to carry the mechanical load but it may be having the poor property in respect of like optical properties if they are required at the surface or thermal

properties if they are required at the surface. This maybe in terms of the increased thermal conductivity or what we want reduced thermal conductivity. So, thermal insulation there may be purpose of the purpose of applying layer.

There may both at the applying layer at the surface either increasing the thermal conductivity or increasing thermal resistivity or increasing the thermal insulation. So, the last so, transfer of the heat across the surface can be reduced. It may also be decided to have the improved electrical properties of the surface layers or it may also be desire to have improved wear resistance which may be in terms of the abrasion, adhesion, erosion or corrosion.

So, if the substrate is not having the required set of the properties for improve performance of improved by functionality than those kind of the properties are imported maybe in form of optical properties, thermal Properties, electrical properties or tribological properties then it will be required that surface of the near surface layers of the substrates are modified using the suitable kind of the materials at the surface.

(Refer Slide Time: 09:54)



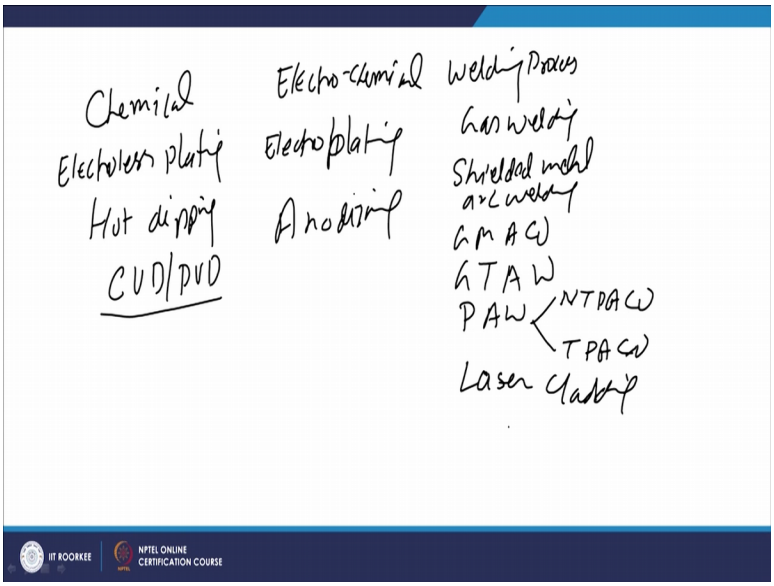
So the substrates surface is applied using a material which can offer the required set of the properties in terms of the optical, electrical, mechanical and tribological so, whatever kind of the property is needed suitable kind of material is applied at the surface of layer. So, the layer of suitable material is developed in this approach of the surface modification. For improving the

corrosion resistance for improving the wear resistance, for improving the electrical, optical or thermal Properties

Now how these layers can be applied there can be different methods for different mechanism for applying such kind of layers it includes like chemical reactions. There maybe electro chemical reactions there may be like welding using the partial or complete surface layer melting there may be thermal spraying using either combustion method where the other suitable fuel gas is burnt combustion method or electric arc is used for thermal spray purpose.

So, these are the various groups of the mechanisms are the approaches which are used for developing the suitable layer of the suitable material on the surface of the substrates.

(Refer Slide Time: 12:15)

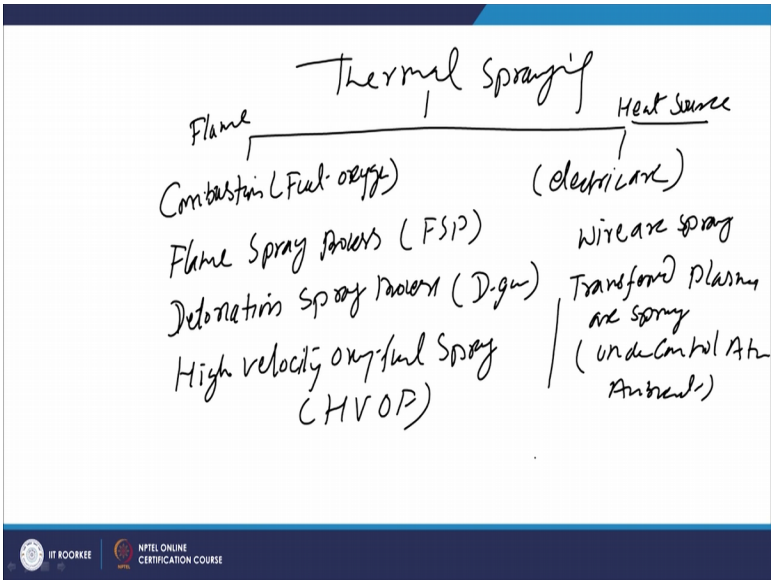


If we talked about the first the chemical methods then a chemical reactions involved like then electroless plating is one method, hot dipping is another and physical and chemical vapour deposition PVD and CVD. These methods are very overlapping in nature where surface composition is also modified or very thin film is developed at the surface of the substrate. Then we have the electrochemical based methods involving like electrolysis and electroplating method and anodizing.

Then we have those approaches where surface layers are brought to the molten state and the material which is to be applied is also melted and intermixing of the two leads to the development of the suitable layer. So, use of the welding processes or the welding methods it can use the gas welding, it can use shielded metal arc welding, can use the gas metal arc welding it can use the gas tungsten arc welding, plasma arc welding.

There are two variants non transferred plasma arc or transferred plasma arc welding so both these are welding processes. And then we have like laser is also applied for this purpose laser cladding is one of the commonly used process for modifying the surfaces.

(Refer Slide Time: 14:31)



Then we have a third group of the process which is known as thermal spraying. In case of thermal spraying the material which is to be applied on to the substrate is brought to the molten or partially molten state. And then it is accelerated at high speed towards the substrate and then after impingement with the surface of the substrate to get solidified and forms of a layer on the surface of the substrate for surface modification. There are two broad groups in this category one which uses the combustion involving the burning of fuel gas and oxygen fuel mixture for spraying purpose.

Another is where electric arc is used for developing the heat. Basically the group is based on the kind of heat source being used. And here heat source is electric arc and in this side heat source is flame which is obtained through combustion of fuel gas and the oxygen. May be it may be acetylene kerosene or any other kind of the fuel which can used for combustion purpose method

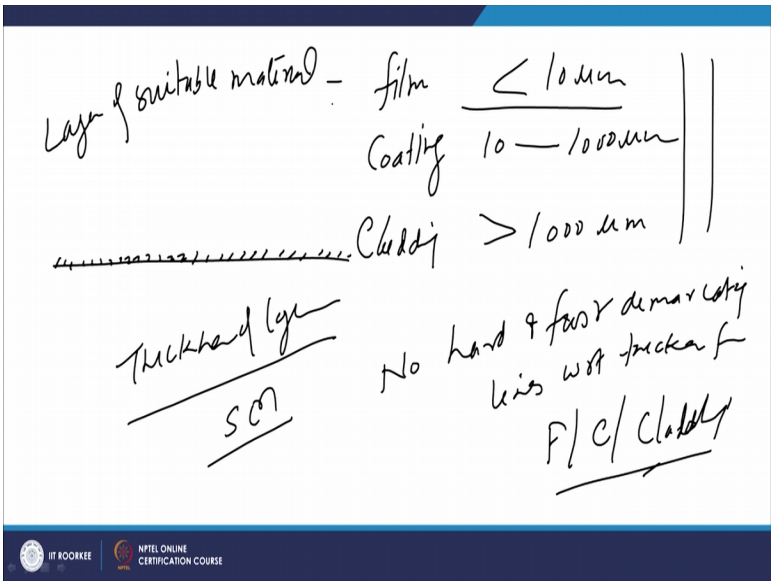
which are used in this category includes flame, spray process this is known as oxy-fuel flame spraying.

And when we have detonation gun detonation spray process there is a detonation gun which is used for the spring purpose that is why it is called detonation spray process. And then there is one more the combustion based process which is called high velocity oxy fuel spray process. In short it is known as HVOF process and this is known as the gun process and this is the flame spray process.These are the combustion based methods.

And in arc based methods there is a wire arc spray process and then there is a plasma based methods where like a I transferred plasma arc spray. Now this may be carried out that you were used this may be carried out in the controlled under controlled atmosphere or simple normal ambient conditions. So, accordingly it will it will be given the different names. So, the in transferred plasma arc process or atmospheric plasma arc is process.

This is commonly used for developing the cladding and thick layer of the suitable material on the surface of the substrate, so, that the required surface modification can be achieved.

(Refer Slide Time: 18:22)



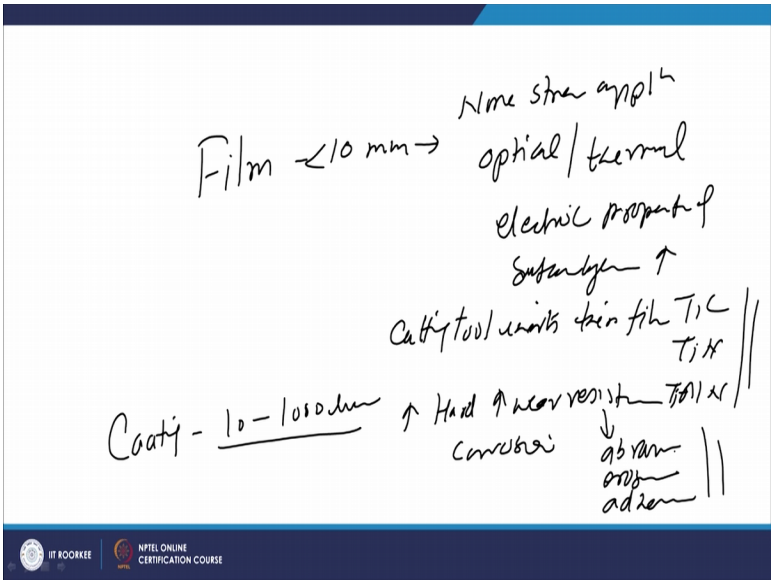
Now as I have said layer of suitable material is applied on the surface of the substrate or it may be applied in form of films, in form of coatings or in form of the cladding. So, in all these cases a thin layer is developed however thickness may vary and this a grouping is based on the kind of thickness of the layer which is being applied for surface modification. So, when the thickness of

the layer being applied is less than 10 micrometre we normally call that the layer being applied is a film.

Like PVD, CVD and very hard coatings DLC like diamond like coatings are applied in form of films which are very thin. Are very thin then the coatings are slightly thicker and they are applied in the range of likes a 10 to 1000 micrometre thickness and for further greater thicknesses the cladding are used like at greater than 1000 micrometre. So, this is this is a broad grouping there is no hard and fast demarketing lines with respect to thickness for categorisation of a layer in form of films or coatings or cladding.

But in general this is the kind of the range which is used in practice for grouping the developed layers for surface modification as film or coatings or claddings.

(Refer Slide Time: 20:37)



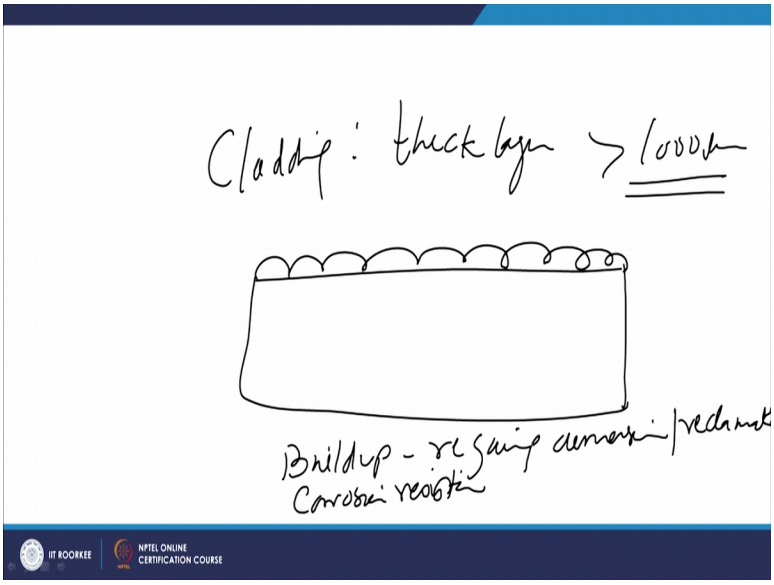
So, if you if we see the purpose for which films are normally used these are very thin like less than these are thinner than the 10 micrometers. These are normally and not used for normally used for non stress applications. Primarily where like optical thermal or electrical properties of surface layers is to be altered like we want to have greater thermal conductivity or we want to improve the increase the absorptivity, reflectivity of the surfaces.

Or you want to increase the electrical conductivity of or you want to decrease the electrical conductivity accordingly the suitable mate film of the suitable material will be developed. However that thin film is also applied in some of the case is like a cutting tool inserts thin films

of TIC or Titanium nitride or Titanium aluminium nitride coating are applied in the cutting tool inserts where the moderate level of the stresses will be acting on the surfaces.

On the other hand coatings which are thicker than the films generally in the range of 10 to 1000 micrometre they are used for increasing the surface layer hardness, increasing the wear resistance, increasing the corrosion resistance or where moderate level of the stresses are acting so like increasing the wear resistance under the abrasion and erosion, adhesion etcetera. For those purpose is all these coatings are used.

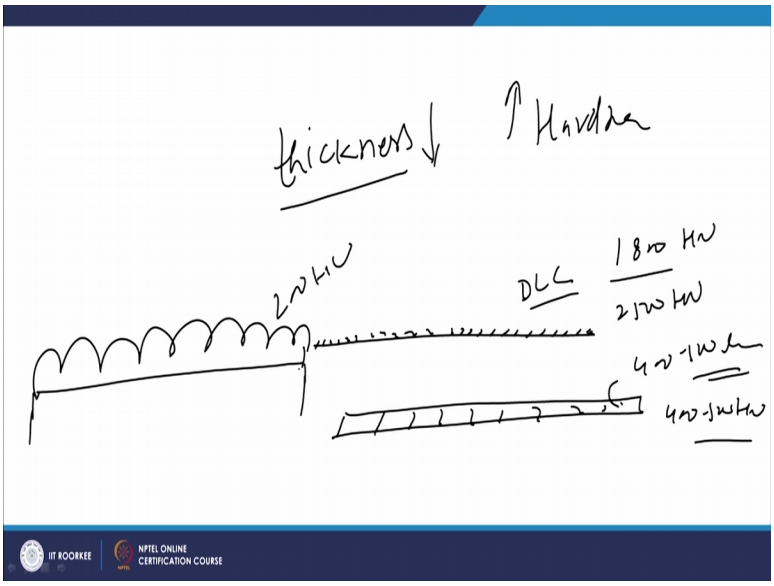
(Refer Slide Time: 22:55)



As far as the claddings are concerned in case of the cladding very thick, layer greater than the 100 micrometre is applied and objective of this building up of the cladding is to have the thick layer. So, that we can have a build up of the material for regaining dimensions after the machining we can regain the size and shape, so for reclamation purpose the cladding can be used. And another important application of the cladding is where the corrosion resistance is to be improved corrosion resistance is to be improved.

So, thick layer of the corrosion resistant materials will be developed on the surface of the substrate and it will help us to offer the longer travel tribological life of the component. So, these are the general features and the properties associated with the films and the coatings. Now will see there is a broad grouping of these processes which will be offering the different thickness, layers.

(Refer Slide Time: 24:26)



But there is one more aspect with regard to the thickness and the material which can be applied in form of thick or thin layer and its properties. In general higher is the hardness lower will be the thickness of the layer which will be build up on the surface. So, very hard like diamond like coatings having the hardness of like 1800 or 2500 HV thickness of the coating will be very less may be like 50 micrometre, 10 micrometre as per the hardness.

Like diamond like coatings will be developed in a form of very thin films but if the hardness is lower I like 400, 500 HV then maybe we can develop a thicker layer in form of the coatings of 400 to 500 micrometre. And if the hardness is further lower like austenitic stainless steel hardness of a like 200 HV about 200 Hv than we can have very thick layer in form of the claddings of the austenitic stainless steel.

So softer is the material thicker layers will be possible if the hardness is high then we can develop the three layers for proper and prolonged performance of such kind of the layers for the surface.

(Refer Slide Time: 26:03)

Now we will see in the kind of processes which can be used and the thickness which is normally achieved, so here if we have 10 to the power -5, 10 to the power -4 and 10 to the power -3, 10 to the power -2, power -1 1 10 cm mm and the thickness which is the thickness of the surface modified layer which is achieved. So, if we go by the thickness then then the welding based methods like this will be somewhere here.

The welding based methods will be there they are used for very thick coatings like greater than 1 mm or 1000 micrometre. Then thermal spraying may be used in the band of like say 50 to 1000 micrometre for thermal spraying and about 10 to 100 micrometre like Chrome plating on the other hand like Ion implantation is a for very thin layer and implantation .

Nitrogen and implantation is one of the commonly used method and then CVD and the PVD these are the kind of bands for CVD and PVD. So, there are wide range of the thickness is which can be used for surface layers and the different category of the processes which are used. Basically in this one will be focusing on the welding and the thermal spray processes we have already talked about Ion implantation PVD and CVD kind of the materials.

Where apart from the composition of modification of thin layer is developed in form of the film for improving the surface properties. Now here I will summarise this presentation. In this presentation basically first of all I talked about the laser assisted nitrating where we have seen that in presence of is a nitrogen is introduced at the surface layers improving the surface properties to the formation of the nitrides of the different elements which are present in the steel.

And there after we have seen the basic approach of the building up of surface layers for surface modification and how it can be used for improving the surface properties. Thank you for your attention.