Fundamentals of Surface Engineering: Mechanisms, Processes and Characterizations

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Lecture-36
Surface Modification Techniques: Vacuum Based Surface Modification I

Hello I welcome you all in this presentation related fundamentals of surface engineering and you know that we are talking about the surface modification techniques and among the surface modification techniques there are 3 broad categories in 1 where the surface methodology is modified and the in second where surface chemistry is altered as per the requirement and in third where the material of the suitable properties is applied on to the surface.

So that required improvement in properties can be achieved and this is done through the development of films, coating and claddings etc. So we are talking about second category of the processes where surface chemistry is modified for achieving the property modification of the surfaces. So that required enhancement in the tribological performance of the component can be achieved.

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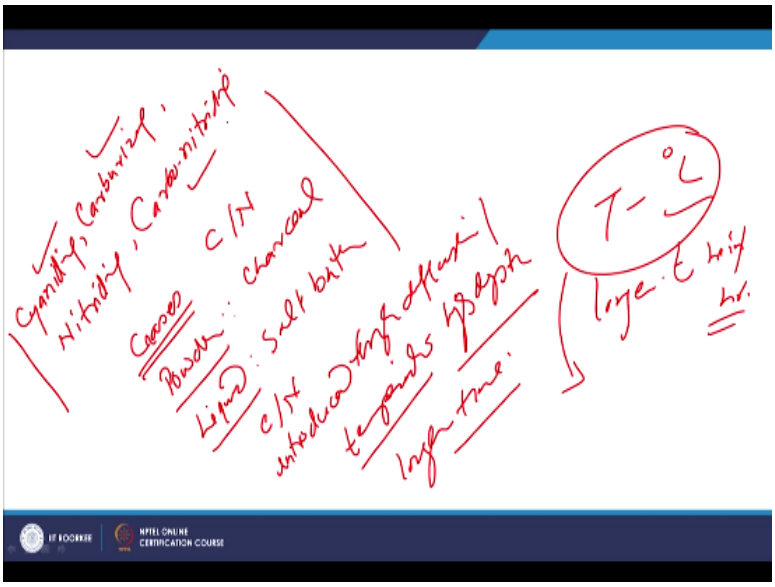

And under that we have talked about the processes like cyaniding, carburizing, nitriding and carbonitriding and in this process basically we can use gaseous mixture of the suitable gases. So that the elements to be incorporated in form of carbon and nitrogen are made available at the surface of the component modified it can use the solid in form of the powders like a

charcoal are ionisers also used in case of the like a pack carburizing we can use liquid in form of the salt bath.

So but since in this processes the required element in form of the carbon and nitrogen is introduced through the diffusion which is significantly governed by the temperature and to achieve the higher depths we need the longer time. So basically the high temperature and the longer time these are the 2 main troublesome areas it may be in minutes or in hours as per the process.

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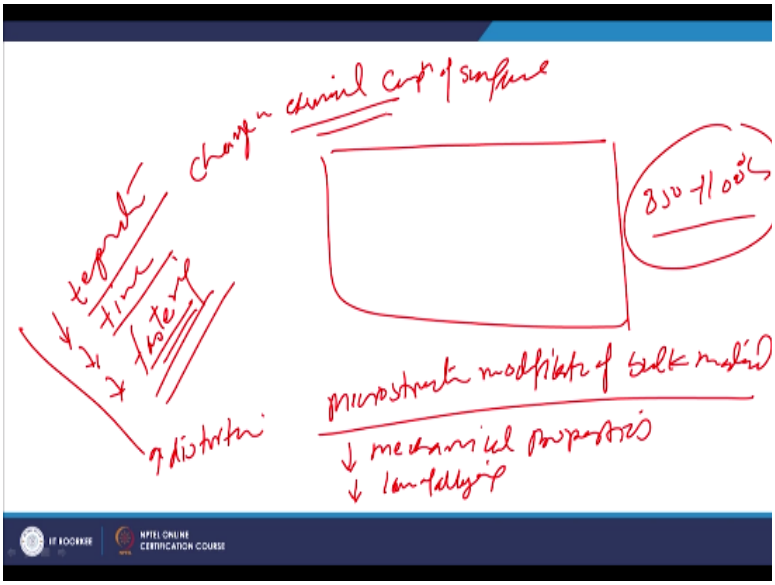

So since the longer time is higher temperature is the problem especially in case of the carburizing, cyaniding, carbonitriding processes we know that any component given exposure to the high temperature for longer time like 850 to 1100 degree centigrade, then it leads to the microstructural modification of the bulk material also due to the prolonged exposure at high temperature.

And this kind of the microstructural modification if it is leading to the reduction in the mechanical properties then it is considered unacceptable, second problem is that too high temperature exposure for longer time can lead to the loss of alloying elements from the bulk material. At the same time it also increases the tendency for the distortion undesirable change in the size and shape of the component.

So and the main origin for all these undesirable features associated with the cyaniding, carburizing, nitriding is the high temperature for longer time. So it is preferred that we use

this category of the process where in either the reduction in temperature is achieved or reduction in time for high temperature exposure is realised and or which will be fastening or making the process faster during the process are increasing the rate of the diffusion.

So those category of the processes where required change in chemical composition of surface is achieved without using much high temperature and using surface modification for shorter periods and using the higher diffusion rate or modifying the chemical composition using such kind of approaches which will accelerate the chemical composition modification requirements or mechanism of the chemical composition modification.

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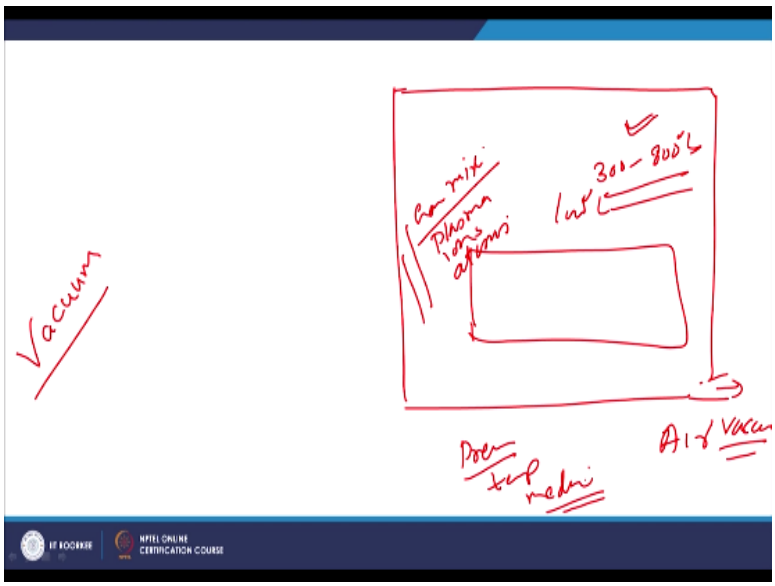

And for that there is a special category of the processes where we use vacuum. So the components whose surfaces are to be modified is kept under the low pressure conditions. So that all atmospheric gases are extracted out. So this will be used to create the vacuum and chamber. So there is a vacuum chamber which will be used to create the low pressure by extracting air and the component to be modified are placed in this chamber.

Now the temperature is increased reasonably maybe like 300 to 800 degree centigrade or even lower like hundred degree centigrade. So such kind of the lower temperature which will be assisting the surface modification chemical composition modification of the surfaces with the help of the like the gaseous mixture which is being fair it use the plasma it can use ion beams or the any other metal which is to be deposited in form of the atoms.

So such kind of the suitable medium is made available around the surface of the component which is to be modified at reasonable low temperature and for sufficient time. So here the pressure, temperature and the medium which is being used for surface modification plays a crucial role in achieving the desire the surface chemistry modification for a required improvement in the surface properties.

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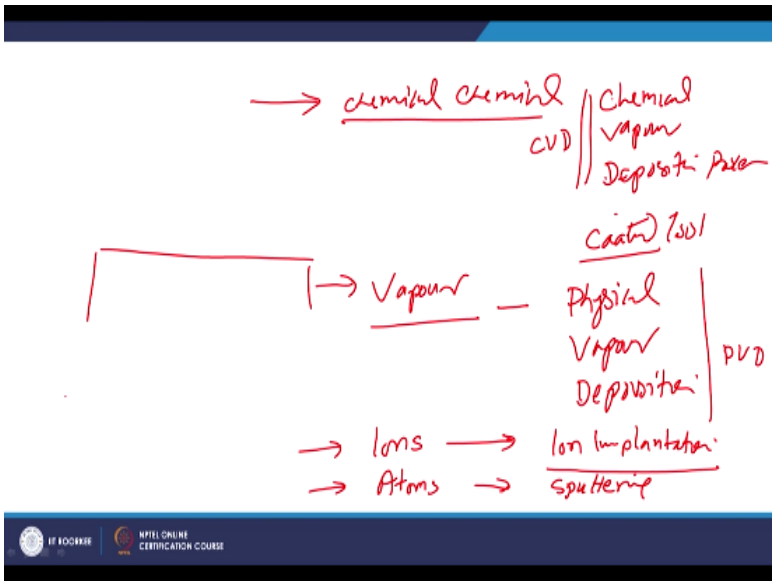

So basically there are 3 things are used for chemistry modification, 1 is the chemical reactions at the surface and this is basically used in the chemical vapour deposition process. This is used extend is this approach is extensively used in case of the like the tool inserts where multiple coatings are the single coating layers are deposited over the carbide tools. So that coated tools are basically manufactured using the CVD process.

And it uses the chemical reaction to form to introduce the elements required at the surface, so that the suitable compounds at the surface and near surface layers can be formed for enhancing surface properties and then it can also use the vapours so here the elements to be deposited or evaporation by heating and then they are accelerated are ionised in form of ionized metal are ionised and they then deposited over the surface of the substrate.

Those category of the process where vapours of the target materials are to be used are called physical vapour deposition processes and in short these are termed as PVD and these are termed as CVD. Then it can also use the points of the suitable the constituents like the nitrogen or argon, gases are ionized. So basically gives ions of the suitable medium and there a direct at high speed surface of the substrate for modifying the surface metallurgy.

As well as the surface chemistry in case of the processes like ion implantation. So these are the 3 the kind of the mediums which are used for modified surface chemistry and accordingly the different processes are used and when the material target material of the material to be coated is used to form of the atoms and then they are deposited over the surface of the substrate. The process is called sputtering.

So by these atoms of the material which are to be applied on the surface of the substrate are produced using a suitable means. So that they can be applied or deposited on the surface of the substrate. In this case they will be deposited at the surface and then subsequent item pressure the diffusion will facilitate the composition of modification of the surface of the computer which is being considered for the improvement of the surface properties.

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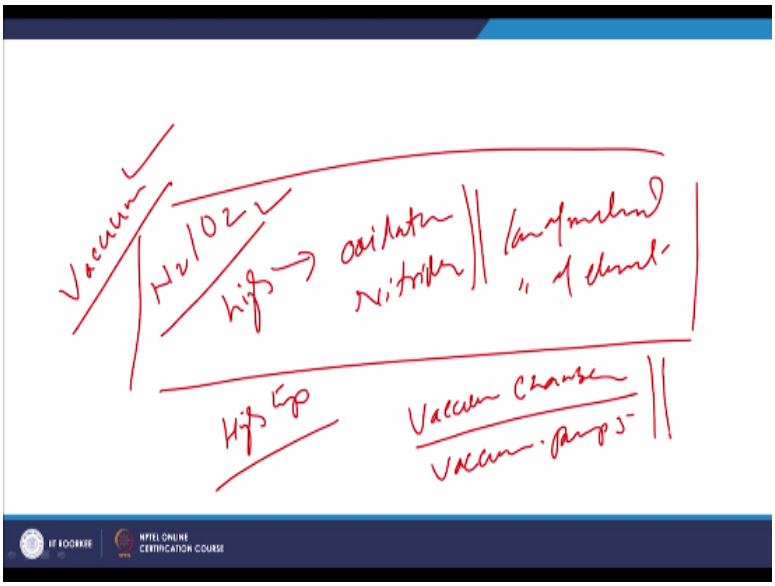

So apart from these we also use since the use of the vacuum eliminates the possibility for the nitrogen and oxygen are which are normally found in the ambient condition and at high temperature these gases normally called the oxidation nitride formation at the surface. So such kind of the oxidation and nitrate formation will be leading to the loss of material and loss of the elements from the function of surfaces which are being modified.

If the high temperature exposure is given under the ambient condition, but when the vacuum is used in this category of the processes these gases are eliminated from the vacuum chamber. So despite of use of the high temperature absence of this gas does not cause any loss of

material or the elements due to the oxidation of the nitriding of the nitrite formation at the surface because of the vacuum.

All these processes vacuum is used invariably so in this process is the vacuum chamber which are normal large in size. So that number of components can be modified in one go and vacuum pumps. These are the 2 main components of degree of the processes where vacuum is used with it is PVD, CVD and implantation sputtering etc. but there is another you can say the limitation side of this category of the processes.

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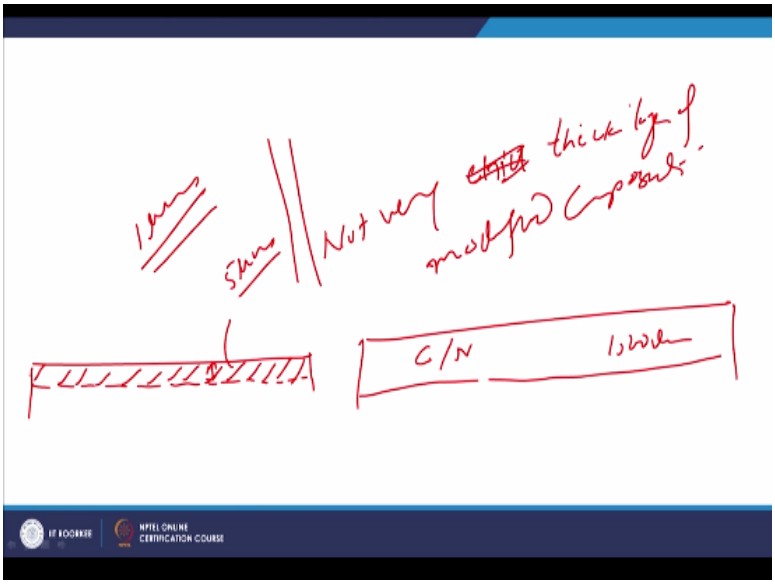

And not very thick layer of the modified composition is achieved like we have seen in case of carburizing nitriding which can be up to like 1500 micro metre for carburizing 1.5 m is very common for nitrogen 200, 300, 500, 600 micro metres also. But this is true for the carburizing or nitriding or cyaniding kind of processes but when we use vacuum based processes these are limited to very thin layer.

So compression modification of the surface and near surface layer happens up to a very less depth and this depth of the modified composition maybe maximum or so up to like say 5 micrometre. Otherwise it is usually limited to the 1 micrometre. So when for the applications where such a thin layer of the modified surfaces is sufficient for performing the expected functions or required function from the surfaces.

Then only this can I have this category of the processes are used. So especially those applications where this much of the modified surfaces of sufficient coefficient function this

kind of process will be ok. Otherwise using another group of the process were we really required the greater thickness of the modified surfaces. So the common surface modification processes where the vacuum is used.

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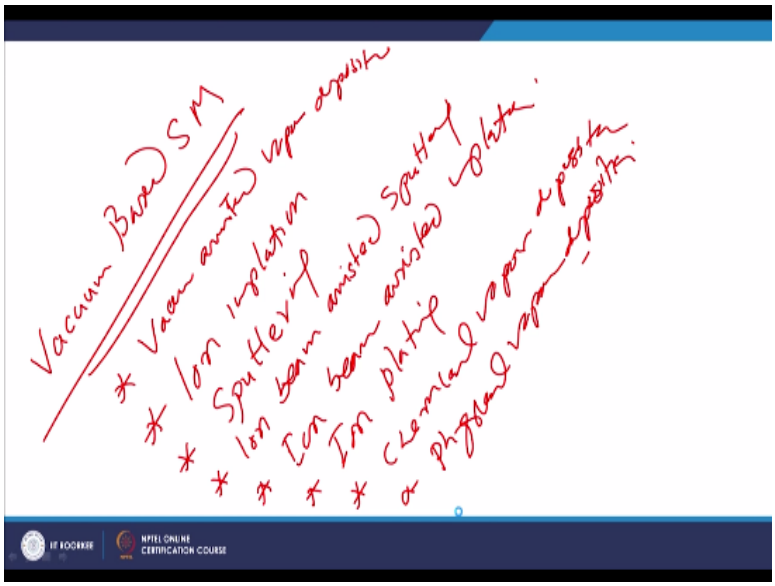

So we can say the vacuum based modification techniques is 1 is the like vacuum assisted vapour deposition is 1 process and then ion implantation is another process where nitrogen or organised are normally used. So in that case it is termed as nitrogen ironing implantation. Then sputtering is another process where the target material is bombarded with the ions beam of ions.

And then other atoms which are released from the target material have deposited on the surface of substrate. In case of the sputtering process and then we have ion beam assisted sputtering, another processes ion beam assisted implant and then iron plating. Then chemical vapour deposition and also all these processes where vapours are used which are made available through the evaporation of the metal.

Then it can be ionized or it can be those vapours are accelerated and applied on the surface of the substrate. So that the coatings can be formed on the surface of the substrate and subsequently diffusion at high temperature will you facilitating the completion modification of surface and near surface layers. So physical vapour deposition processes. So these are the some of the processes where the vacuum is invariably used for modifying the surfaces.

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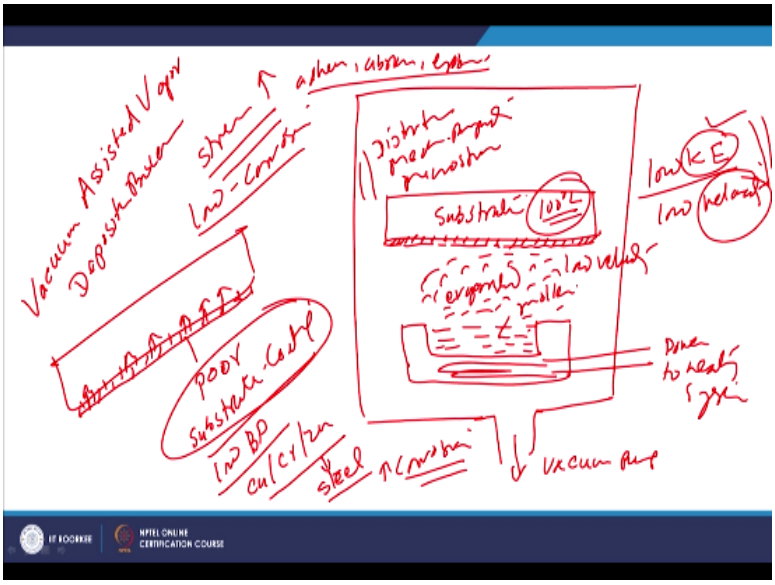

Now will be talking about the 1 particular vacuum surface modification process where vacuum assisted vapour deposition process. So in case of the vacuum assisted deposition process we use large chamber like this and this is connected to the vacuum pump to create the required vacuum and this is the chamber. In this chamber we use the heating arrangement which will be providing the required heat.

So that so this you can say power to heating system and here the metal which is to be applied on to the surface of the substrate so the coating material are the material which is to be applied is brought to the molten state and then it is heat it is evaporated. So the gases which are being formed are evaporated from this layer or from the molten bath will be moving up at low velocity towards the surface of the substrate.

On the top of it we put the substrate of the component to surface to be modified. So the low velocity moving gases will be impacting with the under surface of the substrate and after that they will get deposited. So that the metal which is evaporating and impacting the substrate it will get deposited over the surface of the substrate. So the energy with this vapours is very low because of the low velocity.

So low kinetic energy with the same the gaseous particles which are moving up and impacting the surface of substrate it is moving at low velocity. So because of these 3 properties of gases which are being used to modify the substrate surface the kind of the bond which is created between the substrate and the coating which is being formed in this case this bond is very poor.

So the substrate coating bond is this is very poor and at high temperature was this coating is formed it will be getting diffused inside the substrate gradually. So now here what we have we will have a certain good aspects and the negative aspects related with this approach like the material which is to be applied on to the substrate should have a low boiling point to form the vapours.

So low boiling point and therefore chromium, copper and zinc kind of the metals which can be separated to apply on the surface of the substrate can we use and these are the common metals which are deposited at on the steel substrate primarily for improving the corrosion resistance was this coating is applied since the this kind of the coating is formed using the weapons which have kinetic energy due to the limited velocity.

So the bond is poor and therefore this kind of the coatings cannot be used for the applications especially when the stresses at the functional surface is high. Because they will get removed in that case is the higher stress conditions. So such kind of the chemical composition modification of the surface is good especially when the stresses acting on the functional surface is very low like corrosion condition.

But if the stress magnitude is high like under the adhesion, abrasion and erosion and erosion and this kind of the coatings will not survive when they will get removed from the functional surfaces easily and this will primarily attributed to the poor bonding of the coating material with the substrate, but apart from this 1 aspect there is another good side, that this kind of during this process the temperature of the substrate is limited to the 100 degree centegrade.

So which is quite low as compared to the other carburizing and nitriding kind of processes. So the low temperature will be favourable from the integrity or the maintenance of the substrate structure and properties. So that damage to the substrate in form of the distortion tendency drop mechanical properties or microstructural modification. All these adverse effects will be very less and this kind of process.

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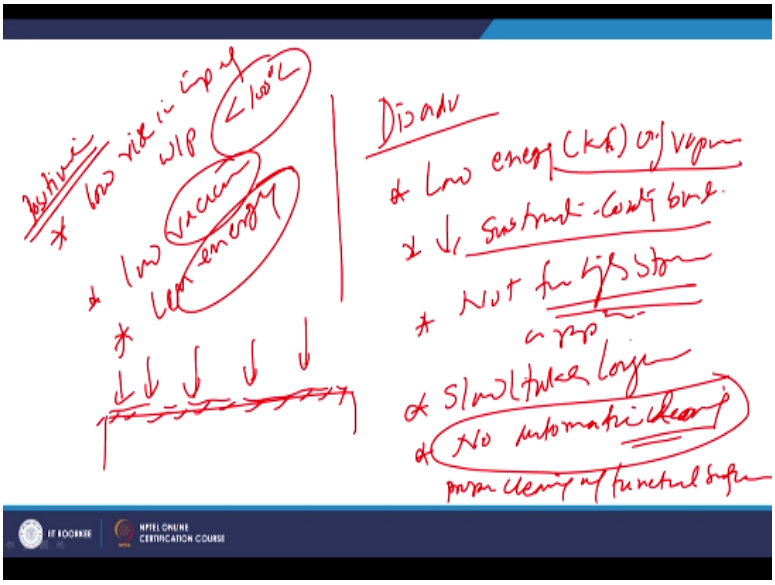

Because very minimum rise in temperature or rise in temperature is limited to the 100 degree centigrade. So there is no thermal damage which this kind of processes and to the substrate. Now some of the positive points some other positive points related to this vacuum assisted vapour deposition process is that low limited rise in temperature of workpiece or substrate less than 100 degree centigrade.

It needs the low vacuum is another favourable side so that I do not need much time to create the required vacuum unlimited work is to be done to create the vacuum which is required for the use of the low vacuum is another positive set related with the with this energy. If requires less energy to modify the function of surfaces. However the low energy associated to the vapours will be causing the negative side related with this process.

And on the other hand the negative aspect are the disadvantage associated with this process is that low energy or kinetic energy of the vapours leads to the limited substrate coating bond and because of this it cannot be used for the higher surfaces. So good for the limited stresses not for high stress applications or like abrasion, adhesion and erosion conditions. Another thing is that this process is very slow.

So it takes longer for modifying the surface and there is no automatic cleaning of the surfaces, there some of the surface modification techniques where the inherent nature of the process is such that surface impurities are damaged broken and the surfaces clean automatically but in this case where vapours will be directly depositing on the substrate to form the good bond and the good surface modification.

It is necessary that the surfaces are cleaned properly, so that all the impurities from the function of surfaces can be removed. So the disadvantage associated with this process that there is no arrangement for automatic cleaning, but we need very proper cleaning of the functional surfaces for surface modification. So the positive side is that low rise in temperature limited rise in temperature limited vacuum and limited energy consumption.

But the negatives are that limited kinetic energy of developers causes the poor coating and substrate bonding and because of this we cannot use kind of the surface modification technique for the higher stress conditions like abrasion, adhesion and erosion and the process is slow so it takes longer as well as there is no automatic cleaning during the process. So we need to clean the surface properly.

So now I will try to summarise this presentation, in this presentation basically I have talked about the vacuum assisted surface modification techniques, basic principle of the vacuum assisted service modification techniques and we have also talked about the details of the vacuum assisted vapour deposition process, how it can be used to modify the composition of the functional surfaces. So that the improvement and surface properties can be achieved, thank you for your attention.