Fundamentals of Surface Engineering: Mechanisms, Processes and Characterizations

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Lecture-38
Surface Modification Techniques: Sputtering and Ion Assisted Deposition

Hello I welcome you all in this presentation related with the subject fundamentals of surface engineering and we are talking about the surface modification using the various techniques in which the surface composition is modified in order to achieve the required changes in the surface properties. So that the wear resistance and the corrosion resistance of the surface layers can be improved for prolonged performance of the component.

And under this category we have we are talking about the vacuum based surface modification techniques and where in we have talked about the ion implantation and ion plating. Now we will be talking about the 2 other techniques these are like sputtering and ion beam assisted deposition.

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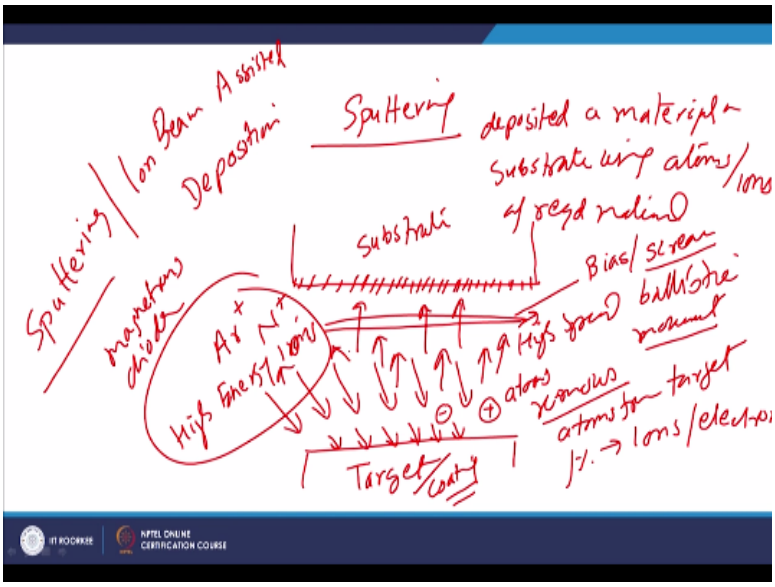

So these are the 2 different techniques will be talking about first of all sputtering. So what is the process of sputtering in case of the sputtering like this is basically depositing a material on the substrate using atoms and ions of required material. So basically there is substrate on which the material is to be deposited. So the material which is to be deposited is termed as the target.

This target is subjected to the application of the high velocity, high energy ions. So impact of these high energy ions with the substrate displaces or removes the atoms from target as well as about 1% of the atoms will be coming in form of the ions and electrons. So ions which are coming are positively charged and electrons are the negatively charged. So at the same time the atoms will also be coming out from the target surface.

So some of these atoms and ions which are coming out from the target, they move out from the target surface at very high speed just like the ballistic movement is achieved in these atoms and so these atoms and ions will be moving in the different directions and when they move in the different directions they will be depositing here and there, some of these high energy ions and atoms will be moving and depositing are impacting at the surface of the substrate as well.

And there they get deposited, so basically we are getting the high energy atoms and ions from the target material which is basically material to be quoted. So the target or the quoting which is to be deposited on the substrate is subjected to the high energy ion beam. So that the material from the target or the coating material is removed in form of the atoms and ions and some of these are of very high energy come out like a ballistic movement.

And they will be impact with the various surface is which are all around including is substrate surface and they get deposited. So once they get deposited they will be forming a kind of the films. So this is the general principle of the sputtering. So basically we can use the argon ion beam or the nitrogen ion beams for producing the high energy atoms and the ions from the target material.

And for producing these high energy ions we may use magnetrons or the diodes which will be directed on to the surface target material and then whatever the ions and high energy atoms are achieved they are for the accelerator towards the substrate using suitable bias created between the target and the screen. So basically in between the substrate and the target have 1 bias which is also called screen will be putting in high different between and screen and the target material.

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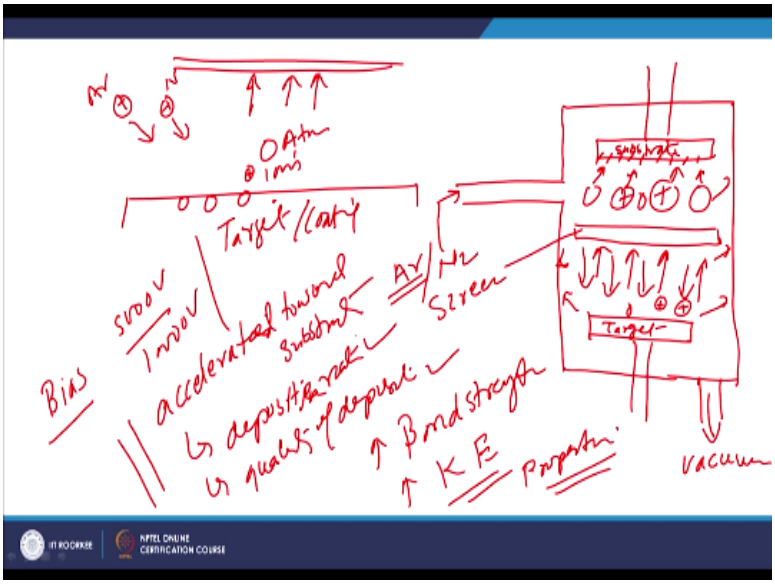

So that the high energy ions and the atoms can be for the accelerated towards the surface of the substrate. So these are the important features related with this process. So now will see like this the ions of the argon or the nitrogen are directed at high with high energy on the substrate or on to the target which is basically coating material which is to be applied. So with these impact and will be producing some of the ions of this target material and the atoms are also removes.

So atoms as well as the ions are produced and then these are accelerated towards the substrate using suitable bias, so that they can be deposited in very a controlled way over the substrate, the kind of arrangement which is used here is like this, like there is 1 chamber and on this is our target or the material which is to be deposited and here we have 1 opening for the vacuum and then the other side we have the substrate.

Substrate or the work piece material and between these 2 we have 1 screen which is used to create the bias between the target and the screen. So the iron beam is directed on to the target material. So ions and atoms are released from the surface and these are accelerated towards the substrate by putting in the sufficient bias between the target and the substrate. So this is our screen.

This chamber is filled in with the ion forming gas like the argon and this is the substrates. So these ions and the atoms accelerated towards the substrate will be impacting with the substrate material and so they will get deposited. So all these will move towards the substrate ions+the atoms, since there is not much control over the direction in which designs and atoms

will be moving. So there will be very high tendency that whatever the atoms and ions are being released.

They will get deposited in the inner wall of the chamber as well and that is why the deposition efficiency of this process is very less we will be losing the target material significantly through this sputtering process, but the kind of material are the amount of metal which is deposited on the substrate is very less. Because whatever material is removed in form of the atoms and ions that will be deposited in the internal surfaces as well as the surface of the substrate.

So these are the different constituents as far as the sputtering process is concerned and for ionisation or for having the high energy ions we need to use diode or the magnetron and high energy ions can be generated using the argon or the nitrogen gas mixture which will be filled in the chamber. So these are the some of the features as far as the sputtering process is concerned.

In this case the extent of the bias of like 5000 volt or 10000 volt will be determining the way by which the ions and atoms are accelerated towards the substrate and therefore it will be affecting the deposition rate on the substrate material as well as the quality of the deposition. In general increase in the bias will be increasing deposition rate as well as the bonding of the material which is been deposited with the substrate.

Because this will be affecting the energy associated with the atoms and ions being moved towards the substrate and which in turn increases in the acceleration or increasing the energy with which they will be impacting with the substrate will be increasing bond strength of the deposition with the substrate or the coating for the film which is been deposited that will be increasing with the increase of bias with the increase of the kinetic energy.

So increase in bias will also be increasing which also improve the mechanical properties of the modified surfaces when the higher bias, bias is used which will be leading to the increased acceleration of the atoms and ions based on the surface of the substrates. So this is the general principle of the sputtering process we use the high energy ions which are directed on to the target material.

And this target material will be producing the atoms as well as ions this will be moving coming out at a higher speed from the target material and then this will be moving here and there, some of these will be moving and impacting with the internal surfaces of the chamber as well as some of these atoms and ions will be depositing with the substrate. In order to have very controlled disposition at higher control disposition over the substrate using this ions and the atoms which are coming out for the target material.

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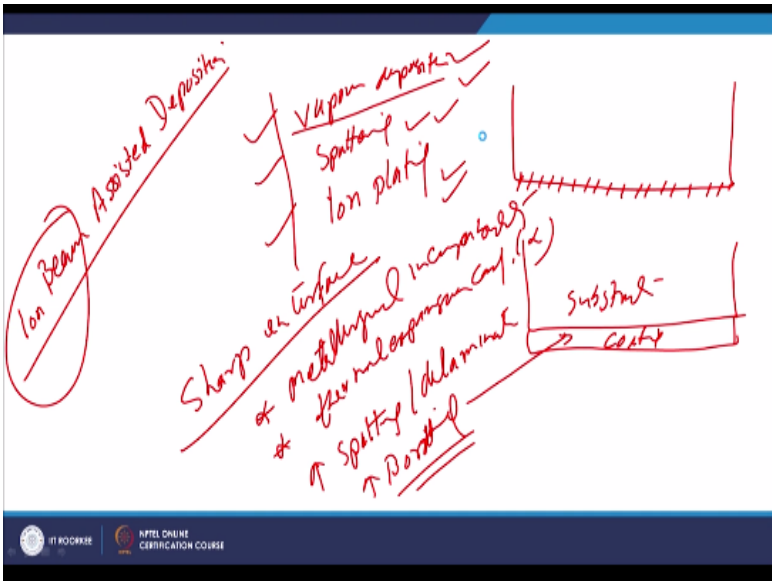

Bias is used of the sufficient distance so that these can be accelerated towards substrate anal to have with bond strength as well as sufficient deposition rate. Now will be what is the another very useful surface modification technique by changing the chemical composition, that is the iron beam assisted deposition. So as we have seen in case of the vapour deposition and sputtering in both these cases are iron plating.

In these 3 processes all those which are performed under the under the vacuum conditions the kind of the material which is deposited on the surface of the substrate it does not form the bond of the very good strength with the substrate, in vapour deposition the metal vapours rising with a low energy and impacting with the substrate and getting posted in case of a sputtering all the energy is quite good.

But still the bond strength is not that good qualities of ion platting the metal vapours are ionized and then they are directed on towards the surface using the suitable potential difference between the substrate and the target material. So that this can be accelerated but

still the bond strength is not good the primary reason for that we have very sharp the interface is very sharp like this is the substrate.

And this is the coating material which is deposited either using vapour deposition, sputtering or iron plating. So because of the sharp interface we find lot of problems especially when there is metallurgical incompatibility or there is a difference with regard to the thermal expansion coefficient. So if the alpha is 2 different are the metallurgical incompatibility exists.

Then the sharp interface leads to the increase tenancy of the spalling or delamination and the poor and kind of that happens primarily due to the poor bonding of the coating or the film which is deposited with the substrate. So this issue is primary address of all these 3 processes, if the iron beam is used in combination with a vapour deposition or sputtering or iron platting.

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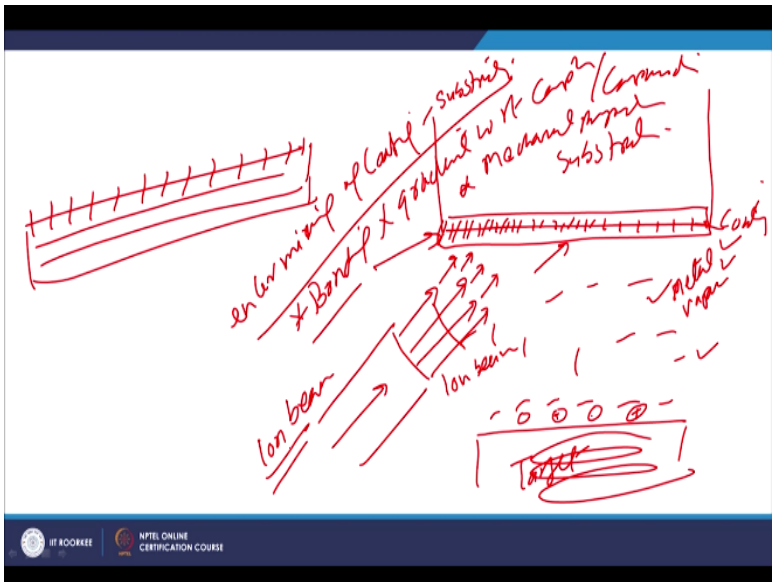

So in that case what basically we do is that the target material which is been deposited like say this is the target material and target material either we are applying heat, so that it is evaporated and get deposited on the surface of the substrate at very low energy or we are applying the iron beam on the substrate. So that the high energy ions and the atoms are achieved from the target material.

And they also get deposited on the substrate in case of the sputtering process. So in case of the metal vapours position metal vapours are used in case of the iron deposition non-metal

vapours are ionised and then they get deposited in case of sputtering the ions and the atoms which are obtained through the sputtering process get deposited on the surface of the substrate. In all these cases we find very poor bonding.

So in order to increase the bonding what we do once during the process of the deposition either by metal or vapour deposition or the sputtering or the iron plating we use iron beam individual source of the ion beam and that is directed towards the surface of the substrate on which the material is been deposited through the various approaches either through the metal vapours or the sputtered ions and the atoms or the metal ions.

Ions which are obtained through the ionisation of metal vapours and these material deposited is subjected to the iron beam treatment where in the iron beam impacting with very high energy onto this material deposited on to the substrate. So this will be leading to the proper mixing of the material being deposited by the various other techniques. So when these iron beams are applied over the coating that has been deposited over the substrate.

So substrate and this is the coating on the film which has been deposited when it is subjected to the iron beam this leads to the very good intermixing of the coating and substrate material and once this mixing is facilitated we get very good the bonding of the surface material with the substrate and very good gradient between the surface and subsurface properties obviously the concentration of the modified at the surface the concentration of the depositor will be more.

And it will be regular gradually decreasing towards the surface we get very good bonding as well as we get the gradient with respect to the composition and the compounds which are being formed and this in turn will be leading to the very good gradient as well as an ingredient in respect to the in respect of the mechanical properties as well. So what we are getting intermixing is facilitated extremely good metallurgical bonding.

And very good gradient with regard to chemical composition and the mechanical properties. So whether we are using the vapour deposition or we are using the sputtering or iron plating in all these cases if the iron beam is used and applied on to the other surface is being modified to these approaches. Then it will help to enhance the performance and the properties of the surfaces in much better way.

So and this is achieved primary due to the extremely good intermixing of the coating material with the substrate. In addition to this there are many other benefits which are achieved when iron beam assisted deposition is used. So what we have basically ion beam assisted deposition, they are 3 benefits we know that whenever ion is used directed on to the surface, all surface impurities fine thin oxides are removed. So it is a self cleaning process.

So the cleaning external cleaning are prior to the modification, prior to cleaning is not there crucial. So the one advantage is that self cleaning process and it ensures very good inter mixing of the material which is being applied with the substrates and this in turn helps to increase the very good bonding of the coating material with the substrate. So coating substrate bond is extremely good.

And the process is cleaning achieved in this process is very good and this offers the very good gradient in terms of the composition, in terms of the properties and this gradient helps in reducing all undesirable effects related to the cracking or undesirable combination of the mechanical properties. And because of the very good intermixing we get the reduced metallurgical incompatibility issues.

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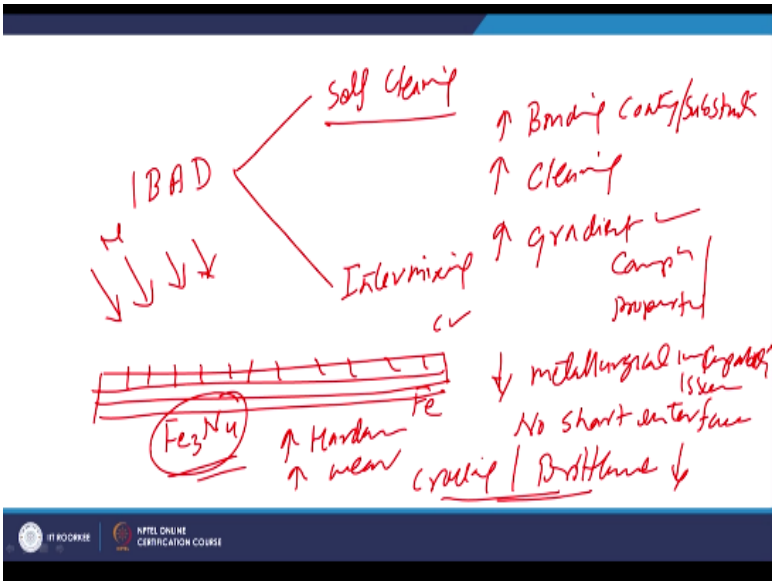

So metallurgical incompatibility issue is reduced primarily because there is no sharp gradient, no sharp interface while it has proper intermixing and the very good gradient with respect to the composition and the properties exist. For example if we have deposited particular element

at the surface like chromium over the surface of the steel and then iron beam is apply using the nitrogen then will be getting the extremely good mixing of the iron nitrite Fe3 and 4 .

And the concentration will obviously be gradual less at the subsurface and more at the surface regions. So this continuous gradient will be leading to the extremely good improvement in terms of them hardness, in terms of the wear resistance and when the gradient is good mixing is good despite of forming a Fe3 and 4 the cracking tendency and brittleness tenancy is reduced.

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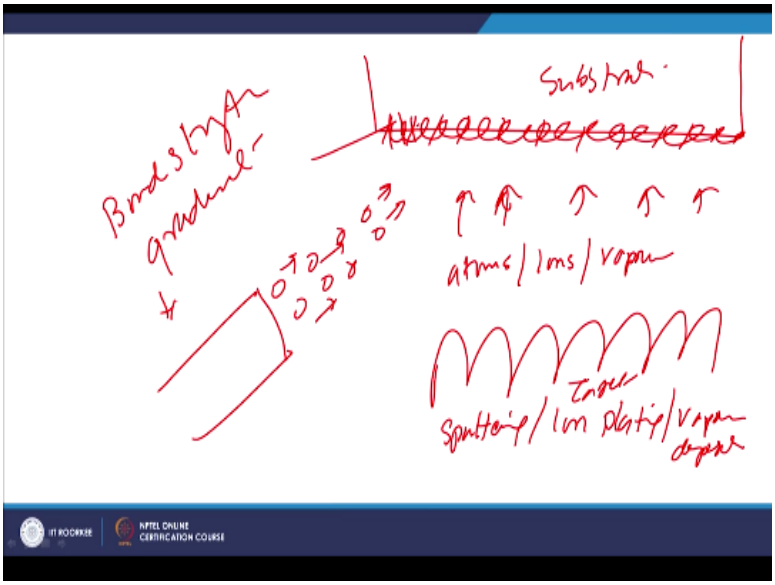

The cracking tendency and brittleness tenancy is reduced when iron beam assisted deposition is used. So the general principle of this process is what substrate and the suitable source of the target material which is to be deposited and maybe in case of the sputtering, in case of the ion plating or in case of the vapour deposition. These target material will be providing the either atoms, ions, vapours which will get deposited, which will move towards the substrate.

On the substrate they will get deposited using a suitable independent source of the iron beam or this beam is a directed on to the surface which is being modified, so this ensures extremely good mixing of the material deposited and this mixing improves the bond strength traces in very good gradient, that gives the metallurgical issues and other cracking tendons associated with this process.

So with regard to the iron beam assisted deposition it offers the number of advantages over the conventional sputtering ion beam plating and the vapour deposition especially with regard

to the improve body strength and reduce metallurgical incompatibility. Now I will summarise this presentation, in this presentation basically we have talk about the 2 techniques, 1 was the ion beam associated deposition and another was the sputtering.

So in case of the sputtering deposition is achieved through the atoms and the ions while in case of the iron beam assistant deposition we can use the atoms and ions or the metal vapours using various techniques like sputtering and platting or the vapour deposition, but in all these cases we need to use the iron beam. So that the surface can be cleaned and a good intermixing can be realised or improved properties of the surfaces, thank you for your attention.