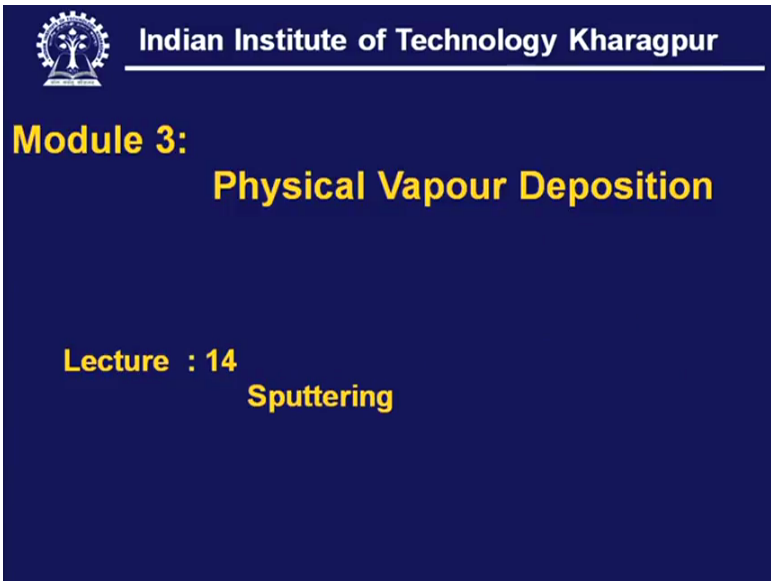
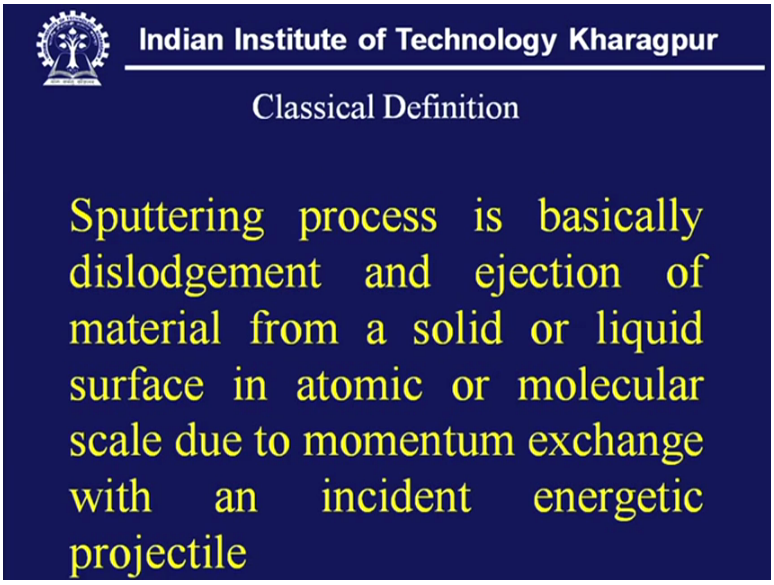
Technology of Surface Coating
Prof. A. K. Chattopadhyay
Department of Mechanical Engineering
Indian Institute of Technology Kharagpur
Module 1
Lecture No 14
Sputtering

(Refer Slide Time: 0:25)





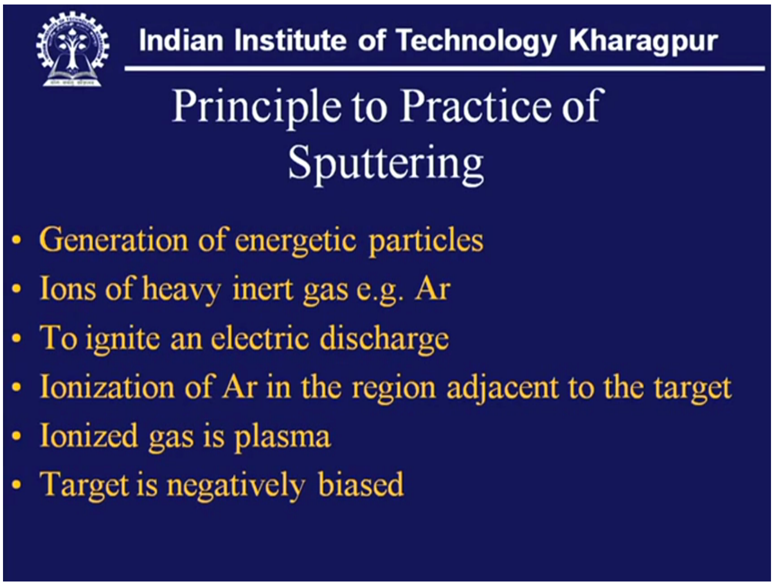
Okay this is physical vapour deposition and today we shall discuss on this topic what we know as sputtering. Now sputtering as a classical definition and this is a process which is basically dislodgement and ejection of material from a solid or liquid surface in atomic or molecule scale due to momentum exchange with an incident energetic projectile.

(Refer Slide Time: 1:08)

Now the sputtering is actually a physical vapour deposition process which can be used for depositing various types of elemental metal, it can be a compound or it can be an alloy, so depositing of sputtered material, how does it work? We can have a very close look. So depositing of sputtered material, actually what happens sputtering is ejection of the material, dislodgement of the material from a surface which we call in the language of sputtering as the target.

This is not actually the deposition process, in fact the material or the surface which we need to coach or covered with a layer that has to intercept this flux of material which will be ejected by this impeachment of the energetic projectile and this is called actually the deposition process and sputtering is the rejection of the material and intercepting that by the substrate material which will condense over the surface of the substrate that is actually known as sputtered deposition process.

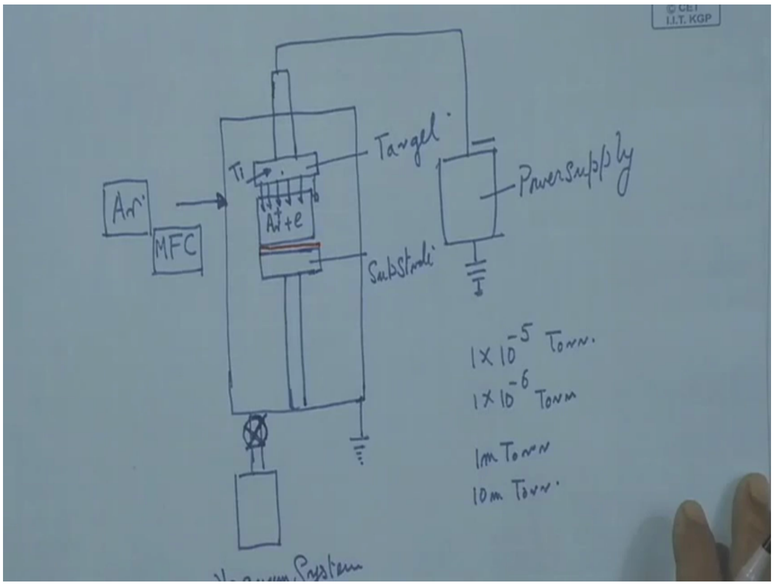
(Refer Slide Time: 2:43)



Now here comes very interesting thing that principle to practice of sputtering that means how to put this principle or theory of sputtering into a practice and a process of practical interest. So 1st and foremost thing one has to do is generation of this energetic particle, now this sputtering is conducted in a closed vessel or a chamber which is evacuated and inside that chamber on has to generate energetic particle and which will be the ions of heavy inert gas like argon.

Now to get this ionisation again one has to ignite one electric discharge and in that electric discharge ionisation of the argon that will take place in the region adjacent to the surface of the substrate and this ionised gas of argon that is also known as plasma and in the process obviously within the chamber 1 to keep on cathode and anode to initiate that electric discharge and this whole process that target material that means the source material from which the material will be dislodged and it will emerge out like a flux, like a stream of sputtered material that is actually kept as cathode. So this target which will serve as cathode that is actually negatively biased.

(Refer Slide Time: 4:51)



Now scheme of sputtering apparatus, now let us have a quick look, so here schematically we can show like that. This is a chamber of which has to be evacuated, so it is connected with the vacuum system, vacuum system and obviously there will be one target which is actually the source material, so this will be the target and that will be isolated from this chamber valve and it will be negatively polarized, so this side polarized, so this will be grounded and other same time the body of the chamber can also be grounded, so what is going to happen?

In this process here we can keep the substrate that means the material or the object which need to be coated. Now here this substrate this is actually the substrate material which can be grounded which can be also biased, so this can be in the ground state or it can be also polarized, so what is going to happen? Say for example this is titanium target that means basically it is titanium disk or a titanium plate having a cylindrical surface or a rectangular surface and this is the negatively polarized target with this power supply, so this is evacuated down to at least 1 into 10 to the power minus 4 to 10 to the power minus 6 torr.

So that is the order of at least one has to reach there and then actually what we have to have one entry point for argon which will be high purity argon and this high purity argon will be admitted in a metered quantity into the chamber so that its pressure can build up maybe from 1 millitorr to 10 millitorr and in that case it is highly polarized and in that case there will be one electric discharge because of the electron which are available on the surface of this target this floating electron that will be attracted and that will heat this neutral argon in this zone, in this zone and here we have splitting of argon, ion plus one electron and this splitting will occur because of this electron will be flown in this direction because of this negative positive polarity on this side.

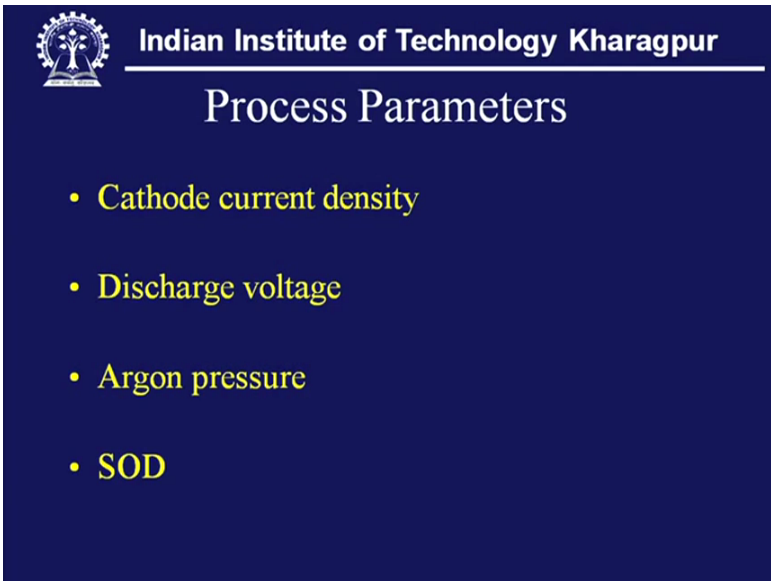
So there will be one cathode and one anode. Even this valve of this chamber can be anode or we can also put one auxiliary anode and during this course of moment in in the space between the substrate and the target what is going to happen? This electron will strike and have a collision splitting this neutral argon to positive argon and has a result this positive argon now will be accelerated towards this negatively biased surface and that will strike on the surface and it will transfer the energy and as a result of the material will get dislodged from the surface and other same time it will also emerge.

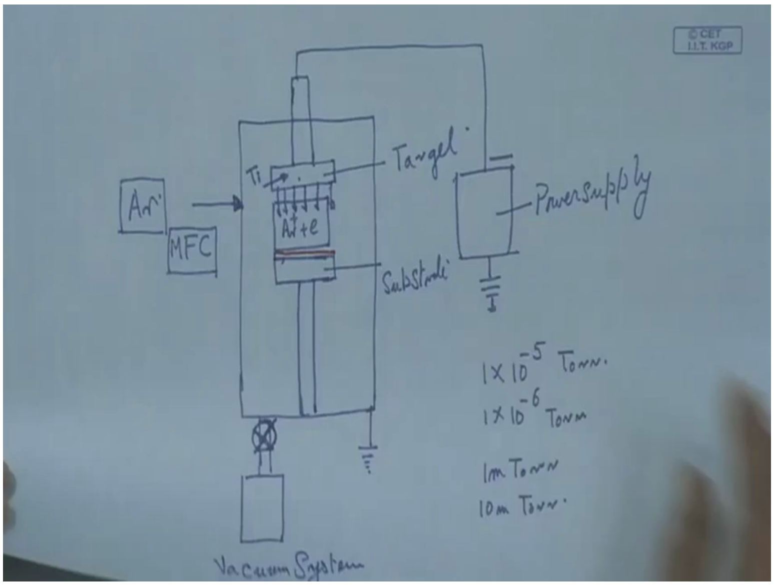
It will be ejected from the surface and it will flow in this direction like a flux of sputtered material and if the substrate is placed in front of this target in that case the substrate surface will intercept this stream of titanium vapour and that will deposit over the surface on this and it will condense over, so atom by atom titanium will build up and will grow and it will finally appear as a coating of metal, so this way one can look into the basic process of sputtering and obviously what has to be done?

That control of the pressure, this control of the pressure on one side here of course we have a metering valve like a throttling valve to control the pressure inside the chamber and then we have metered quantity of argon which will be flown through one MFC, so that is the quantity which will be admitted the pressure is controlled by this throttle valve on the downstream side, so there should be one pressure sensor continuously monitoring the pressure and we have to have some polarisation of this target and the power supply, so with all this one would expect that sputtering from this target surface and it is the deposition on the substrate.

So this is actually called a DC planar diode because it is working like a DC mode and it is like a diode and it is the plane surface, so it is called a DC planar diode mode very simple form of sputtering apparatus but even with this simple form of this apparatus, one can see how this process can work and the same time how this material can be deposited from this target and there will be continuous gradual erosion of this material from the target and this will be depositing over this surface.

(Refer Slide Time: 12:04)



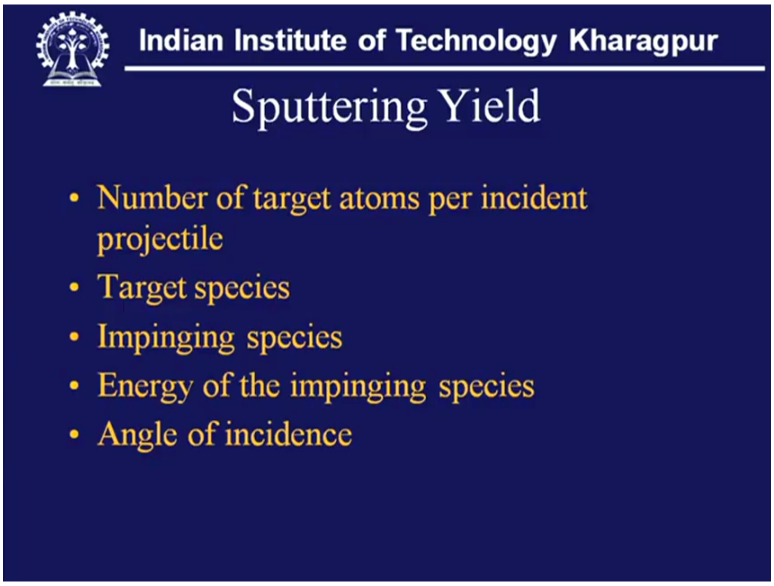


So here one has to obviously operate the process parameter that means there must be some process variable which has to be handled with delicacy and so that the desired outcome, we can have the desired outcome, desired outcome means at least we are interested in the growth rate of this coating, this is point number 1 that means how many Micron of this coating is building up on this substrate surface, number 2 uniformity of the coating over this entire surface of the substrate this is also another issue, very important issue considering various engineering application and the number 3 is the structure of the coating, smoothness of the coating, density of the coating is there be any contamination, any poisoning of this coating.

All these issues are to be properly addressed and then then comes the density obviously and adhesion of the coating with the substrate that means how this interface is built up at the very initial stretch so all this questions are to be properly addressed and this is exactly the sputtering process, so one has to look for this cathode current density that means when this voltage is applied, so once there is ionisation, so we can also find or we can determine straightforward the cathode current that means ion that is collecting on the surface and from the surface area, we can find out the cathode current density or even the power density.

Then also the discharge will change that means the voltage which will be also recorded on the power supply unit, so both cathode current and the DC discharge both will be record displayed and then argon pressure which will be monitored here why this throttle valve on the downstream side and then this SOD, SOD means the stand-off between this target and one anode plate, so actually this distance of the substrate it is in between, so substrate can be one anode or substrate can be also grounded and we can also have a separate anode, so this distance stand-off distance between this surface or substrate surface or a separate anode that is also one important para meters because the pressure inside the chamber and the mean free path that is 1.1 has to consider also the flight of this mass of sputtered material which will follow this path and it will finally arrive here, so when there is collision or it is moving freely all these are issues are also taken into consideration.

(Refer Slide Time: 15:50)



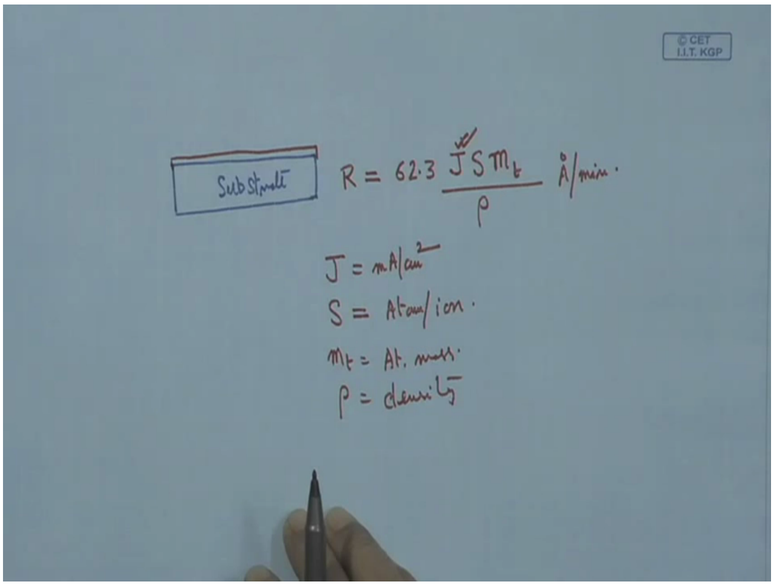
Now in the sputtering process one cannot just ignore this point that is called sputtering yield, sputtering yield is that the ions which are the projectile in this case which are going to hit on strike the target surface. Now one ion say for example one ion is going to strike the surface and as a result of that how many atoms will be ejected, so that is actually the capability of a single ion which can cause dislodgement followed by ejection and then this flow of the sputtered materials like a stream, so all these series of processes are actually are the result of this heat by this argon ion which is serving the like a projectile.

So this is one thing so that is actually sputtering yield, number of target atoms which are being ejected per ion per single ion then it depends upon the target spaces at means it is the atomic mass of the target and then also it is impinging spaces that means it is also the atomic mass of the argon in this case that is also one thing then also the incident energy that means it is striking with a velocity, so it is mass and velocity basically it is a kinetic energy with which it is going to heat the target surface resulting in ejection and this lodgement of the atom and also the angle of incidence and which angle it is going to strike, so all these things taken together they are actually going to finally determined what will be the number of atoms which are being dislodged and rejected per-unit ion.

(Refer Slide Time: 18:34)

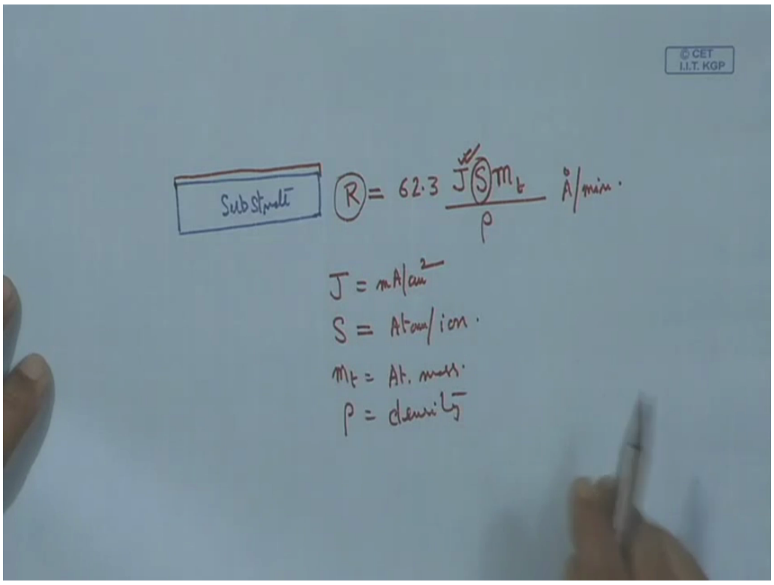
Now we go for sputtering yield and sputtering rate, so sputtering yield we understand that how many items are being ejected per strike per strike one ion per-unit strike.

(Refer Slide Time: 18:59)



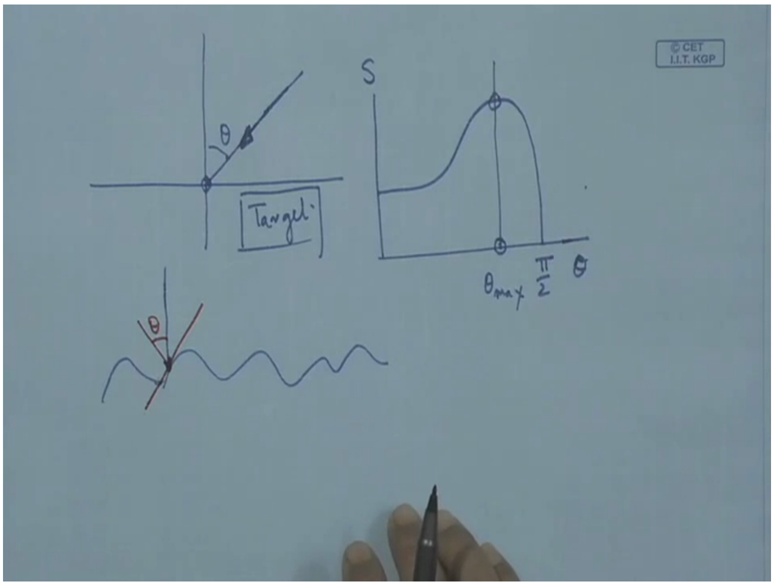
Now here comes the sputtering rate, sputtering rate means here if we consider this as the substrate surface, how it is growing? That means it will be say in nanometres scale or micro-meter scale, how it is building up on this? So a relation is already available that means that sputtering rate is given by 62.3 and it is J into S into M t and this is divided by rho, so many Armstrong per minute that is a relation one can look at and this is a very handy relationship, so what are this J is, that is actually ion current density and which is given ion current density milliampere per square centimetre of the target surface. What this S? That is actually atom per ion that means so many number of atoms of the target material per ion of argon. This is actually atomic mass of the target material, atomic mass and this is density, so with appropriate coefficient of coefficient we arrive at this, so this is an expression for the growth of coating which is continuously being built up on the substrate surface, so this is one very important relation from which one can assess the growth rate.

(Refer Slide Time: 21:06)



Sputtering yield and angle of incidence of the projectile, now this is also important in that that sputtering yield. This sputtering yield that sputtering from this relation we see, this is the sputtering yield it has a determining, it is a determining factor determining this growth rate.

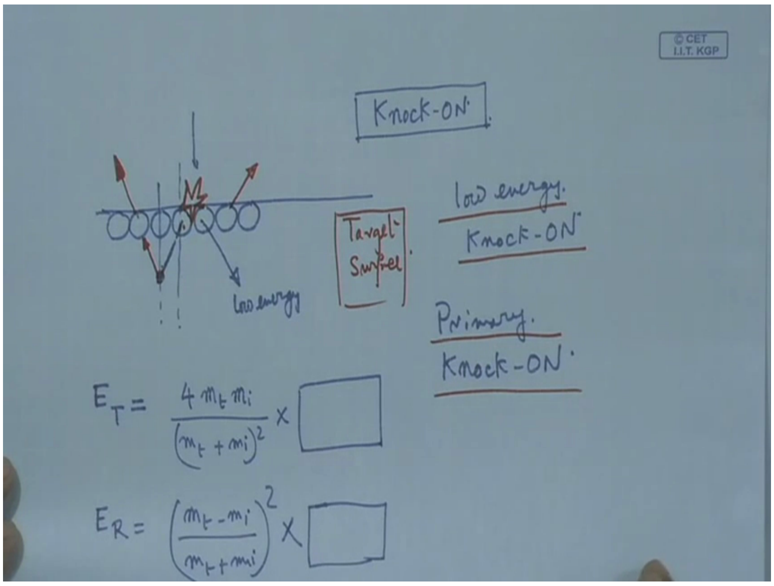
(Refer Slide Time: 21:40)



Now here this angle of incidence also it does come in picture and there is that this is actually the surface and if we consider this is a normal then it can have, this is the angle theta at which this incoming argon ion is going to heat or strike this target surface. Now there is a distribution by which one can see that this is sputtered yield and this is the theta and it is something like that, it goes like that and then it almost have a drooping, so this is almost 90 degree and here it is somewhere little below 90 degree, we get this value critical where watt is corresponding to theta max. Now this angle of incidence normally usually we consider normal angle of incidence, so it is actually argon ions which are going to strike under the action of this electric field normal to the surface but here what happens?

The surface what we are showing that is a theoretical one that means it is optically flat and horizontal but in practice this is not the case, we have unevenness on this target surface, so even if we have a normal incidence of the target on the target this argon ion depending upon the undulation on the surface, depending upon this undulation on the surface, if we consider this is striking at this point at this point which is normal with respect to the axis of the target however with respect to the surface this is not actually straightforward so here one has to draw one tangent and normal, so if we draw at this point one normal and one tangent then we get this angle theta and which is somewhere in between this 0 to 90 degree as a result we can see the angle of obliquity of this incidence and which is not always 0 degree, whatever may be the case, we see a distribution of sputtering yield with this angle of incidence.

(Refer Slide Time: 24:23)



Now comes this momentum exchange, it is actually a well-known principle of theory that it is momentum exchange between this incoming argon ion and the atom of this target particle. Now here if we try to, if we show surface and here we consider spheres as one arrangement of atom, so this is one arrangement of atom and what we can see? Say for example one argon ion is heating and it is intermediates, say it is actually heating the surface and it is in between these 2 atom on the surface of the target, so this is actually the target surface, so it is actually said in the theory that because of this strike what is going to happen?

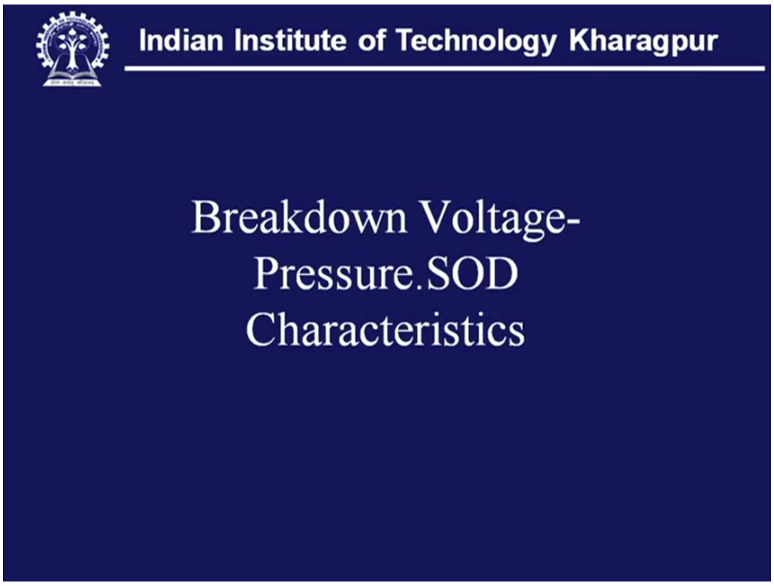
These 2, these 2 will be immediately affected, these 2 atoms, these 2 atoms are going to be affected immediately that means there are actually it is a knock-on, so it is called knock-on process, so one is called, one is called low energy knock-on and the other one is called the primary knock-on, primary knock-on. So as a result of this strike from this side, this atom is going to move in this direction and that we call low energy, low energy knock-on, low energy knock-on and during this process what is going to happen? As it try to move in this direction, it will try to displace this one this atom and as a result it has a tendency to eject in this direction, so this is going to be an ejection of atom because of this low energy knock-on.

Now comes the primary knock-on mechanism, primary knock-on means this one, this is going to be pushed inside this lattice, so this is actually the primary knock-on that will be pushed inside this lattice and it will it may come up to this point and then it will it will move in this direction just like a reflected atom, so it will move in this direction up to this point and then it will be reflected, so this will be the moment and then this will be the reflected moment and during this reflected moment each this atom which is actually is representing this primary knock-on, this is going to get this atom from the back, so it is from the rear is going to hit it, strike it and as a result of that it is also has every chance to get released, liberated and this is an ejection of the atom, so these are the 2 well-known principles of momentum exchange by which this low energy knock-on and primary knock-on take place.

So this is just a lateral movement and this is the side way, so it is a push from the side and this is because of the reflection, so this one is released and this atom is also released, so this way this ejection of the atoms from the surface of the target material that can take place and here one can also understand that this energy which is transmitted to this target atom, so energy which is transmitted to this target atom this will be actually if we consider this is the transfer, so this will be proportional to m t into m i divided by m t plus m i whole square.

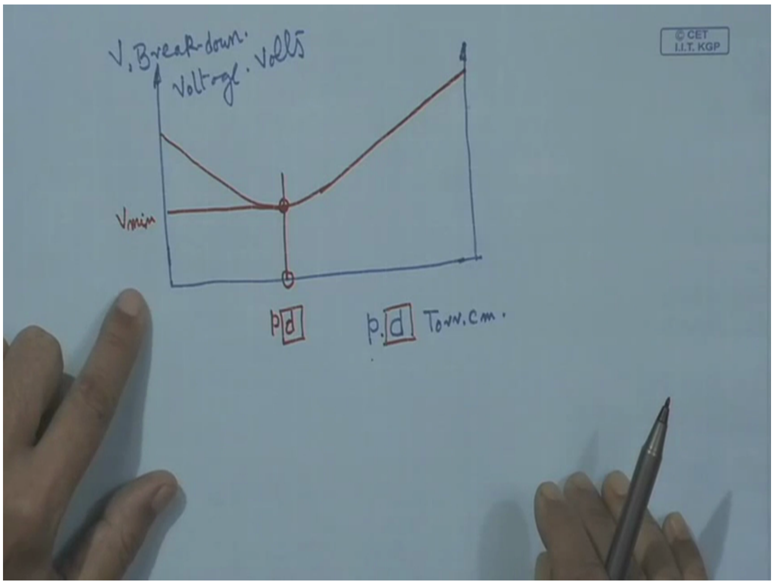
This fraction of the input energy that means the energy with which this argon ion that strikes, it will be back part of the energy will be transferred to this target atom and the energy with which this will be reflected from the surface that will be given by m t minus m i by m t plus m i that is whole square into this input energy of the incoming spaces that means this incident ion into the energy of the incident ion that part will be the reflected energy, it is rebounding, so this is actually transferred this incoming energy and this part actually reflected, this is the coefficient along with this one, so this is basically a momentum exchange process by which this rejection of this atom from the target surface that may take place.

(Refer Slide Time: 31:22)



Now all these things are done actually this velocity energy whatever may be that will be gained by this incoming iron as a result of the electric field and that is actually done created by polarising this target and which is serving like a cathode.

(Refer Slide Time: 31:50)



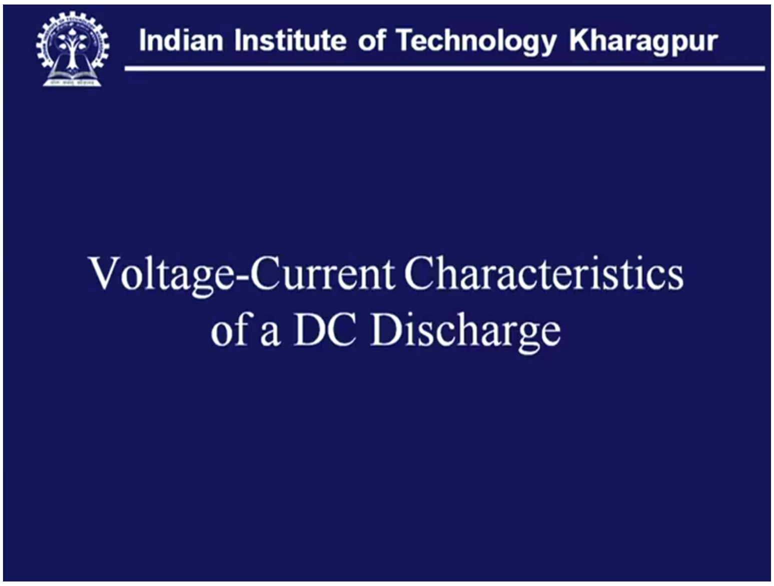
So here one graph is very important not only from Academy point of view but also for designing of the sputtering apparatus or the sputtering device and this diagram can be shown, illustrated in this form and this is in this way, so this side which show the voltage that is the breakdown voltage that means inside the chamber we have the cathode and the anode and a discharge is going occur and this discharge is initiated at that point of breakdown voltage and that is the threshold value but this is not just independent of anything, it has a relation or it depends upon 1 parameter it is not just a parameter, it is a combination of 2.

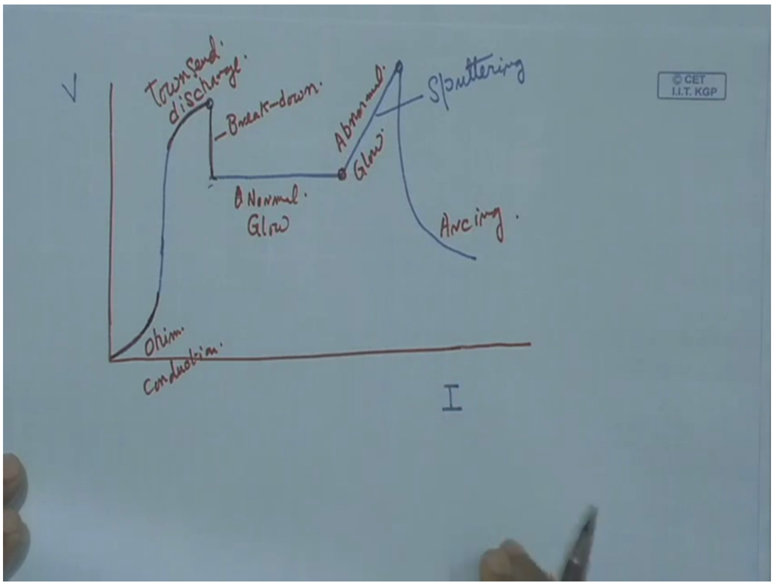
So on this y-axis we show breakdown voltage and on this we show it is actually p into d and that is called p into d torr centimetre, so on this side breakdown voltage that is in volts and this side we have torr centimetre and with that what we can find here this curve look like this, so one can find out immediately recognize point which gives the minimum value of this breakdown voltage, this is v minimum and that is corresponding to a particular value of p into d and on both the sides to excite this discharge to initiate this discharge one has to, one will require a higher value of breakdown voltage.

Now this is one thing we can look here, if we work with low-pressure, this is the low-pressure side or a shorter SOD shorter target anode that means inter-electrode space, so this inter-electrode space if it is short, if the pressure is low then p and d both will be low. So as a result what we find that the threshold voltage to cause the breakdown of this cause this discharge, initiation of the discharge of this plasma that also require a high-voltage. While on the other side, other end we also see there is a requirement of high voltage, the requirement is rising steadily and the side what we find, if you work with high-pressure or if the distance SOD stand-off, stand-off between the 2 electrodes if it is too high then also the required voltage, the demand will be quite high.

So this is one very important information and data which will be required by the designer of the sputtering machine and depending upon the working range of this machine one can design its operational range that means at what pressure it can work, what will be the stand-off distance or size of the vessel and at the same time what will be the available voltage as per the power supply, so that the machine can become an useful source of deposition process, so this way one to look of this minimum voltage for a given p into d that value.

(Refer Slide Time: 36:47)



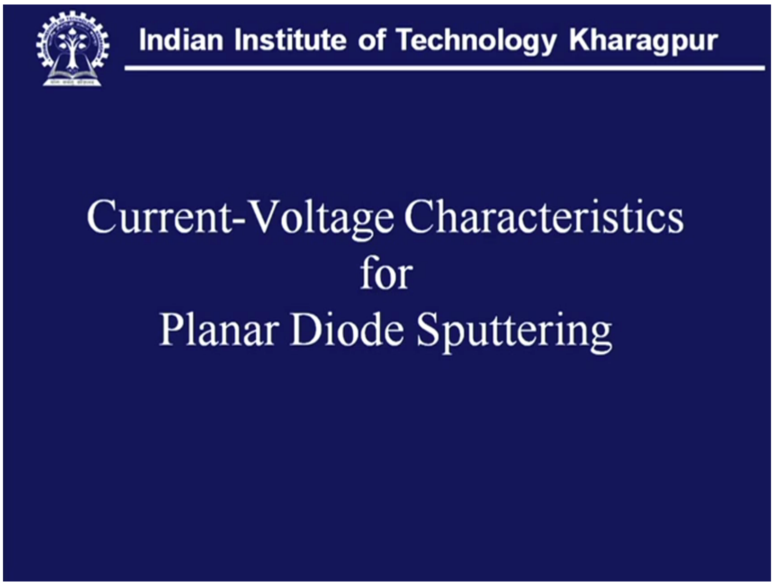


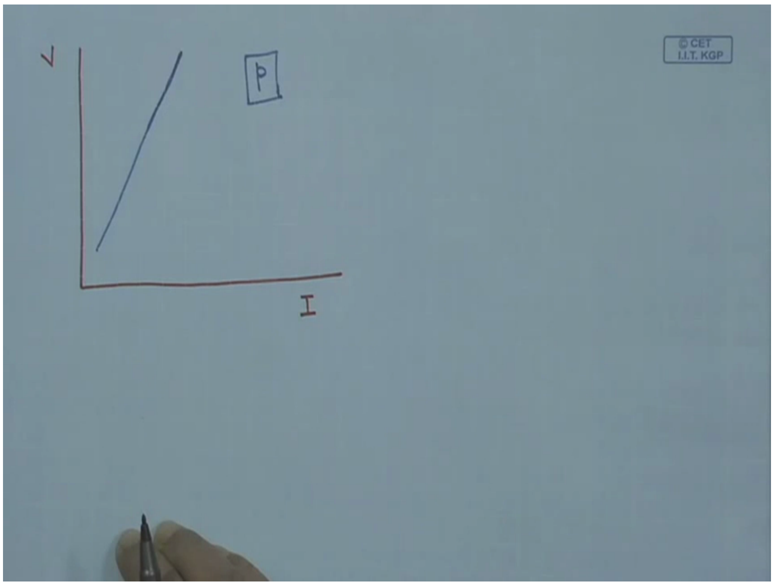
Now this is voltage current characteristics of a DC discharge. So this voltage current characteristics of a DC discharge it is very relevant to sputtering, so one can consider this one, so here what we find, so this is actually the voltage and this is the current V I, V I characteristics it goes like this and this is the peak point and then it drops down then it becomes steady over a white range and then again it rises and finally it has a fall and then it is also rising, so let us identify various section of this graph.

Now this part is called from this this part that is called ohmic conduction. This side that is called townsend discharge, this is this drop fall of voltage without any change in current this is actually called breakdown process of breakdown after this what is interesting that without any change in further rise of voltage the current keep on increasing and this we can see here, this is a typical characteristics of a DC discharge in a vacuum tube, so this goes and this is called actually normal glow.

It is actually discharge with glow and this part from this point what we see that if we like to increase current that will cause an increase in voltage, so this is called abnormal low and it is exactly where we carry out or conduct sputtering, so this is the zone where sputtering is conducted and after that if one try to increase current then there is sullen fall of voltage and what we see it is almost going to be an arcing, so we can see various stages variation of voltage with current and in that process when we find the abnormal glow that is the zone where this sputtering process occurs and that is conducted. Now this is actually current voltage characteristics for planar diode sputtering now what we have seen the voltage, breakdown voltage versus p into d this p into d means process pressure and the target anode distance that means SOD. Next what we are looking at that is the zone where we have abnormal glow that means here along with the current voltage is rising this is the zone where sputtering takes place.

(Refer Slide Time: 41:12)



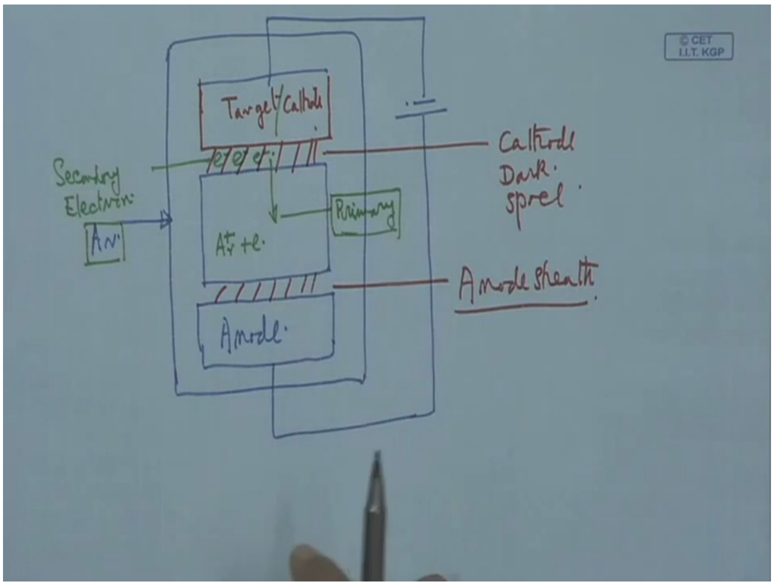


Now comes in the sputtering what we see that this is actually V I, V I characteristics, now here one has to particularly the designer of the sputtering device and the operation for that this V I characteristics is so important. Now say we can draw one curve like that and this curve it is true for a sputtering device having a fixed dimensioned that means fixed SOD and only what we can change say it is just for one target material, one this projectile material which is going to strike the target all these things are fixed. So what we are changing here it is only voltage and current, now what is our output, it is actually current is what we like to have? Because larger the current that means more will be the ionisation and more will be the ion current and that will have an immediate impact or effect on the deposition rate.

So one can immediately look into this fact and take necessary steps how to change the slope of this curve. Now this is say for a particular pressure, so this is actually process pressure, so with this process pressure we can have a V I characteristics however if we change this process pressure is characteristics may change. Now this change means what all practical purpose from design and operation point of view, from engineering point of view one should look at the current and the voltage that means with what voltage we can achieve that cathode current? Obviously lower the voltage benefit more will be the benefit, so the point to be considered here is with what ease we can have this large magnitude of ion current and this is one of the subject in the design of the cathode.

Now it is a planar it is a planar DC diode very simple, so here what we find that this curve is very it rise is quite steep that means physically it means for a small value of current you have to go with a very large value of this volt it can be few thousands of volt few kilo volt and we cannot even get a high value of current. Now for all sputtering operation one may expect to have certain cathode current means certain cathode current density, power density with certain pressure and the reasonably applied voltage which is not too high, so for this special consideration has to be made in the design of the cathode that means with the small value of voltage with a pressure range which is very favourable to get one of the very best structure of the sputtered coating one can get a high value of cathode current, so this is one of the requirement in the design of the sputtering system.

(Refer Slide Time: 45:45)



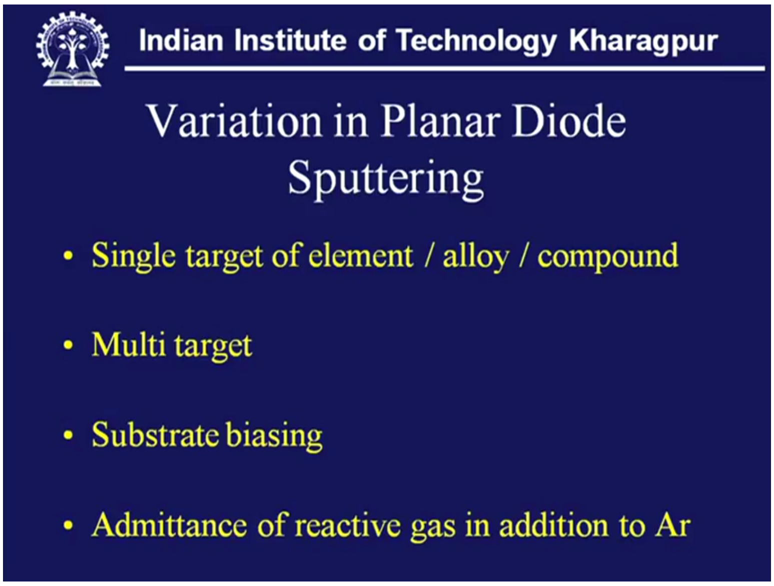
Now comes planar diode sputtering, one can look into this planar diode sputtering that means here actually if we have one target or cathode which is cathode and on this side we have the anode and the whole thing is within a chamber, so this is polarized we have argon entry all are all polarized obviously these are all polarized. If this is a situation, then what we can find out here, we have 3 distinct zone this is the main plasma volume this area which is shown by this this area and this space, this space this is called actually cathode dark space and this zone anode sheath, so what happens?

the electrons which are available very close to the target surface ease are known as primary electron that means electrons which are available here these are called primary electron and these have to be brought in within this main plasma volume and for that we have one accelerating voltage and during this process these are known as that means the electron which are in close vicinity, close neighbour of this target or the cathode, this is target or cathode, so these are called secondary electrons, so these are actually secondary electron.

Now when they are brought in by this accelerating force inside, they are called here this E that becomes the primary electron. Now they have gained certain energy here they are very weak, so now they are within this field they are the primary electron. Now this primary electron they are going to strike make collision with the argon neutral and here it is very important that this strike or collision must result in argon ion, one argon ion plus one electron and with that this argon ion is going to, now it will be accelerated on the surface and with that it is going to strike the surface causing that means what has been already mention that means this injection and dislodgement of the target but at the same time this argon ion can also cause emission of what we call secondary electron.

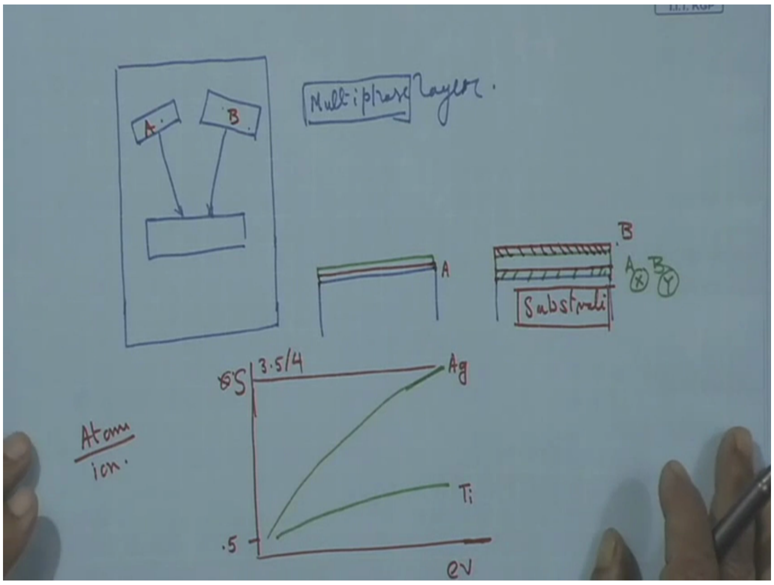
So one argon ion that is going to reject the atom from the target but at the same time to generate secondary electron and which once it enters this plasma volume that becomes the primary primary electron and this way the process repeats itself, so it is very important that this time it electron must generate argon ion and this argon ion will be accelerated towards this circuit surface. So this is a just a cycle process and this way the process will keep on going and in this what is important? That partial pressure of argon, this target voltage, this breakdown voltage and this cathode anode this distance, those are put together they have a combined effect and accordingly we can see as the output what is the cathode current and also the deposition rate. So this is what we know as very simple planar diode sputtering.

(Refer Slide Time: 51:14)



Now in planar diode sputtering economic have lots of variations, so though it is sample it can have lots of variation that means it can be a single target machine at just means that means one cathode, it can be an elemental cathode, say any metal it can be titanium, aluminium, copper and so on it can be one alloy it can be even compound it can be an alloy of silver, copper, it can be nickel chromium alloy, it can be titanium aluminium alloy, it can be a compound say for example aluminium oxide, molybdenum disulphide, tungsten disulphide something like that but instead of single target we can also have a multi target machine.

(Refer Slide Time: 52:23)



Multi target machine means we have this kind of vacuum chamber and the target may be positioned like this and here we have the substrate, so the deposition this is intercepted, so there are 2 materials and which can have simultaneous deposition instead of 2 we can also have 4 target, so here it is an intermixing that is also possible but by this multi-targeting, what we can have? by this multi-targeting we can have either instead of Mono phase, we can have a multi-phase, multi-phase layer that means both are injecting material, so both will form an alloy so it is not a Mono phase it becomes a multi-phase layer but it can be Mono phase multi-layer, it can be just, so it is multi-phase single layer that it can be a Mono phase multilayer that means it can be interrupted, so say this is target A and this is target B.

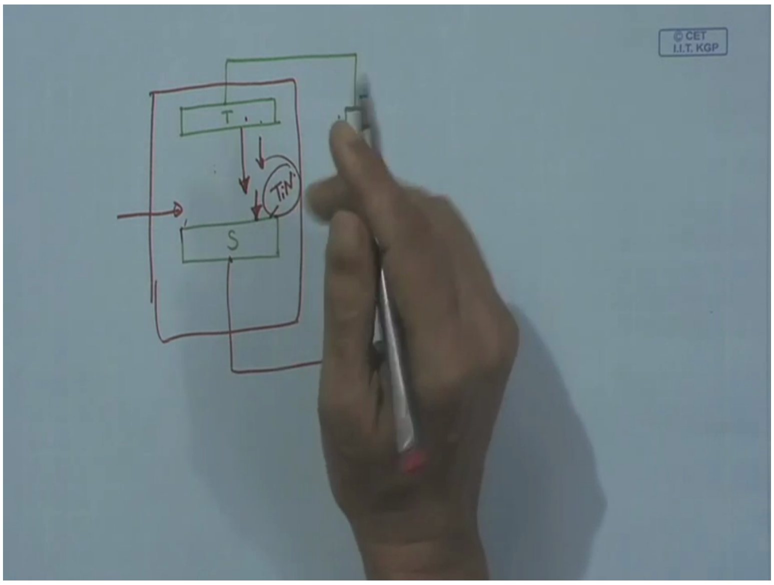
So it can be just like an alternate layer A and after that we can put another layer of B and this way the process will repeat. Of course in this case we need a precisely control automation to run the system to have a perfect blending of this multilayer having the required thickness, uniformity of the thickness, then structure of this each layer, so those issues should be there but the advantage is that by this alternating by just sandwiching a mechanical property for example can be remarkably proved by this way but it can be also a graded layer, graded layer means we can start up this way say this is just the substrate and with this substrate what we can have A it is A here 100 percent A but then what we can do, we can have a grading over this, this may be a thick layer.

So this is A and here what we have this is actually A and B together, say this is A x B y in that combination, we can have a buffering, with this buffering the value of x and y can keep on changing continuously, so from A to we get A x B y and as we go in this direction that means as the coating keep on building and thickness keeps on increasing, what we have finally at this end, we can have just pure B, so we start with 100 percent A in this position and then it is gradually converted into A x B y value of A x is at the very beginning very high, y is slow but as the coating thickness keeps on increasing, value of x will be decreasing and y will be increasing and finally it will become 100 percent B.

So this A is compatible to the substrate however B has the required property, functional property, so B to substrate that can be handled by this sputtering and in this case obviously, we can change, we must know the sputtering rate of this cathode A and the sputtering rate of this cathode that means target and that one to look from this curve and this is actually what we know that this sputtering yield which if we say this is S and here we have the this energy which is given in electron volts EV that is the energy and with that we can have available energy, we can have a sputtering rate like there is for a material we can have a sputtering rate like this, say for example we can give this illustration say it starts with say 0.5, so 0.5 means S is what is S?

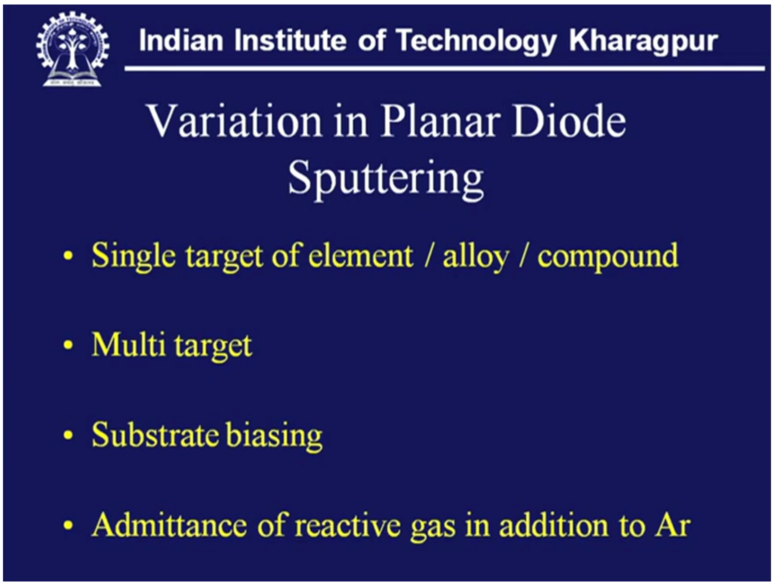
S is actually target atom liberated by the strike off one single argon ion, so it is so many atoms of the target material for one single strike off one argon ion, so this can be as I as say 3.5 to 4 and here it is as low as 0.5. So it depends upon material, so it can be on this side high end it can be silver and on this side it can be titanium but this graph should be available and one can find out from this graph and doing some experiment and trial run, he can find out what should be the actually the sputtering rate, sputtering rate and accordingly one can, one can find out what should be the cathode current for A and what should be the cathode current of B and gradually that has to be adjusted to see that it is an absolutely graded layer which can give you that super quality of the composite coating, so this is a multi-target. Now comes substrate biasing, now this is also one important issue at what we have so far considered.

(Refer Slide Time: 59:30)



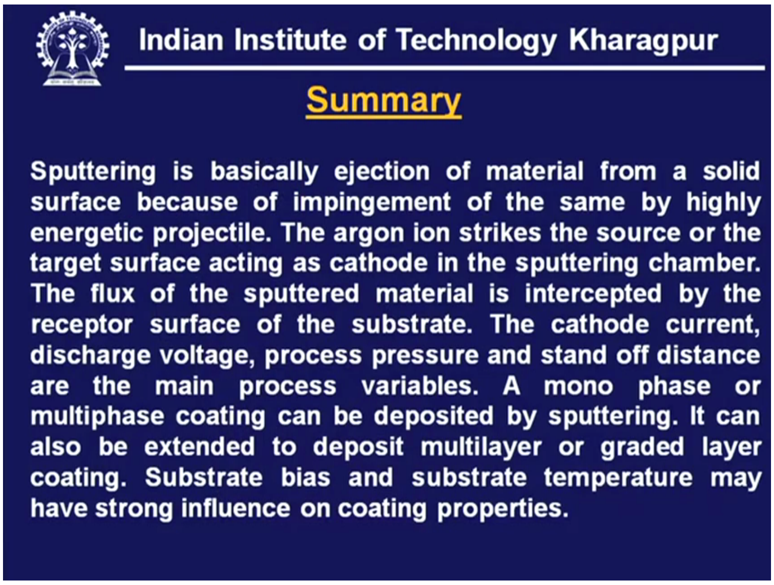
It is just the target it is just the target and here we have the substrate, so target will be negatively biased and this is grounded and this is actually the chamber, so it should be the substrate and here one can look into the substrate and so here we can have some kind of biasing and with this also we know that with this we can have substrate biasing that means it can be during sputtering it can be before sputtering and that can be used for cleaning the substrate and also changing the structure of the substrate during sputtering, so it is just not that argon is going to strike the surface or getting this ejection of the material but can be also very closely precisely controlled impingement on the surface to have proper structuring of this built-up layer.

(Refer Slide Time: 61:08)



Similarly what we can have we can also have admittance of the reactive gas in addition to argon, so when we have added material falling on this, we can also see that if we have one reactive gas then this reactive gas and this material which is getting condense over the surface they can also form a coating of a product which is the reaction, say titanium from this target and nitrogen, so we can have also TiN, so this is called reactive sputtering.

(Refer Slide Time: 61:49)



So with this what we can see that in summary sputtering is basically injection of a material from a solid surface because of impingement of the same by highly energetic projectile. The argon ion strikes the source of the target surface which is acting as the cathode in the sputtering chamber. The flux of the sputtered material is intercepted by the receptor surface of the substrate. The cathode current, discharge voltage, process pressure and the stand-off distance other main process variables. A mono phase or multiphase coating can be deposited by sputtering. It can also be extended to deposit multilayer or graded layer coating. Substrate bias and substrate temperature we have strong influence on coating properties.