Technology of Surface Coating

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Lecture No 15

Magnetron Sputtering

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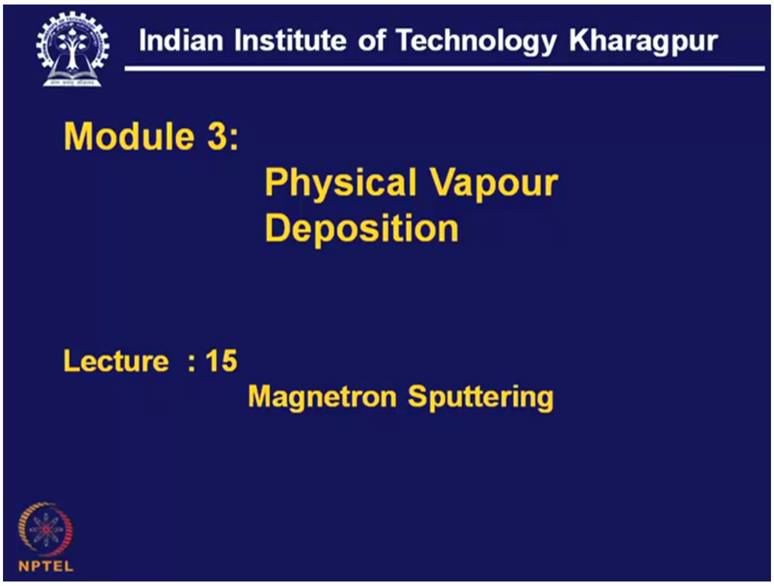

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Module 3:

Physical Vapour Deposition

Lecture : 15

Magnetron Sputtering

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Planar Diode Sputtering
(Non-magnetron Sputtering)

Today’s topic is magnetron sputtering, so it is one of the deposition process under physical vapour deposition technology and let us have a quick look to this non-magnetron sputtering which is commonly known as planar diode sputtering, what are those features and how does it differ from the magnetron sputtering.

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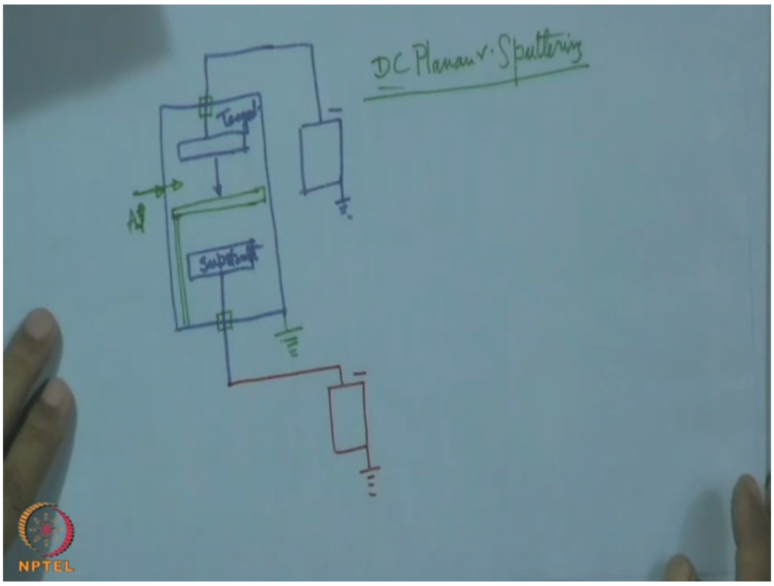

Now we can have a sputtering chamber and here located the target and this is the substrate, now these of the (())(1:15) which is connected this power supply and we have a negative polarisation and this can be grounded and this is actually the substrate that means receptor surface receptor of this coating material which will be dislodged and detected from this side and it will like a flux which will be intercepted by this substrate material. Now here what we can do further to what we have added that means this substrate can be also polarized that means it can also have one negative polarity which is independent of this power supply and in between we can have a plate which is called the shutter.

The whole idea here is to have the best possible clean substrate and clean target. Now this is one of the very speciality of sputtering process the whole idea here is to have the virgin surface of the target as well as the plane surface of the substrate in all of that we can have the best possible coating in terms of all the quality whether it is the mechanical property or electrical property or any functional property, so that the best effort is made here and this is here in this sputtering technology we get an edge over any other coating technology that in C2 during the process once the target material that means the source material and the substrate that means the receptor materials are admitted inside the chamber, then they are cleaned and this is done in C2 and that is the speciality of this sputtering process.

Now what we can have this like the shutter, so here it will be negatively polarized Similarly the substrate is also negatively polarized this is electrical isolation these are the electrical isolation and this can be also grounded, so these are separated, electrically isolated from this chamber and obviously here we have precise metered quantity of argon, argon gas which is admitted, so rest of the thing it is according to the principle of sputtering.

Now during this process what happens? This can be grounded with the with the chamber and what is going to happen in this case it sputtering will occur and that means ejection of the material will take place from the surface. Similarly dislodgement of the substrate surface that will also cover, so in this process if there be any contaminant any impurity oxide scale or anything any foreign material that will be removed and that may be collected on the both side of the shuttered plate and later that can be cleaned or that can be replaced and once that is done reasonably and this is a function of the operational parameter and the time.

Then what is going to happen in the shutter is removed and thereby extending this plasma over this and then the sputtering starts and this flux is intercepted by substrate, so at the very beginning what happens? At the very beginning the sputtering is done on this top surface and the incoming material is collected from the target. Similarly it is about the substrate and then it is also collected this material and then both are now absolutely cleaned and (())(5:43) surface.

So here this ions are used and this is more or less what we can call ion aching that means removal of the material, so this one can recognize this very special advantage of sputtering that this is still what we call DC planar diode sputtering, DC planar diode sputtering it is the simplest one but it is not independent of any difficulty, so in even after realizing that so many flexibility this process can offer but it has some of the basic weaknesses there has been numerous examples of efforts to improve the situation and to make the process more efficient more productive.

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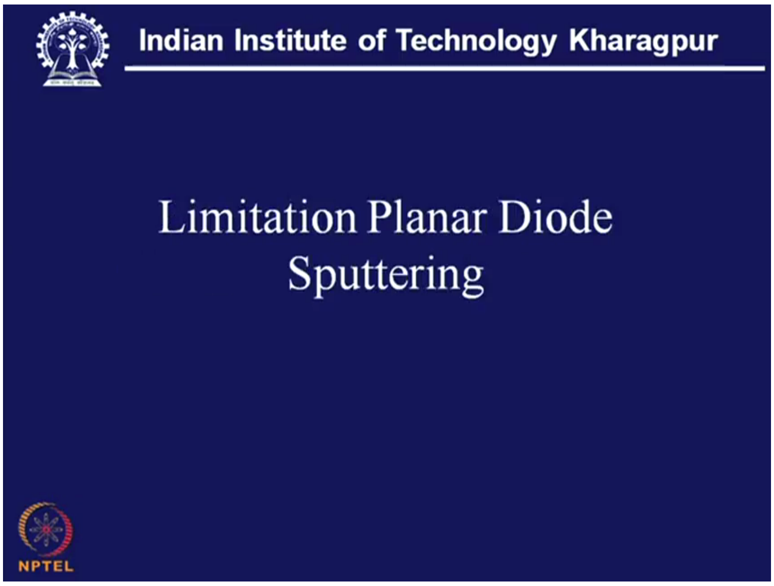
Planar Diode Sputtering
(Non-magnetron Sputtering)



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Limitation Planar Diode
Sputtering

And that is why what we see it is now called the non-magnetron sputtering that means there will be a magnetron and that is exactly what we call as magnetron sputtering. Now what other limitation of planar diode sputtering? Why one should at all go for this magnetron sputtering?

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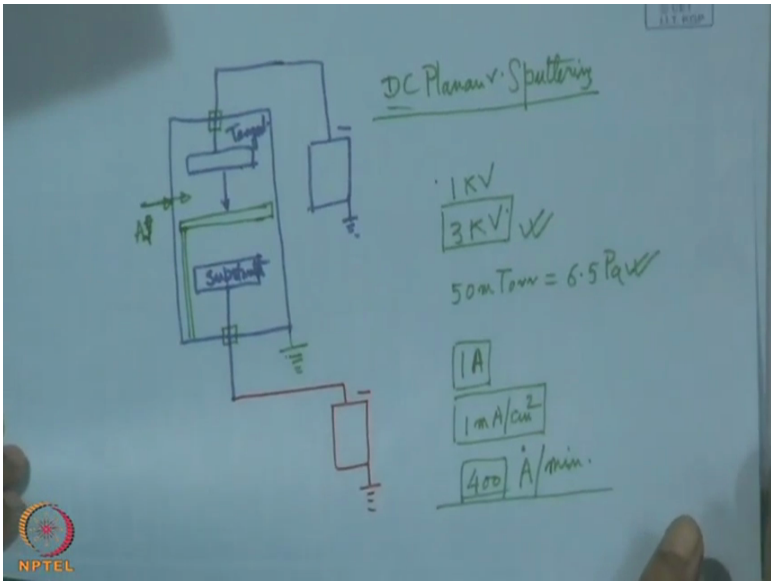

Number 1 is that to initiate this discharge what would require a very high voltage and this is in the order of few kilo volt it can be reasonably say 3 kilo volt, so this is 3000 volt that is necessary and then argon pressure, argon pressure may be 50 millitorr and which is equivalent to 6.5 pascal, so this is also another operational parameter, so high-voltage and high-pressure, now these are the 2 things which are at the high end and now our requirement is to maximise the cathode current that means the discharge current even with this the discharge current even it hardly reaches 1 ampere and as a result of that what we get?

A ion current density on this target surface hardly this is 1 ampere the discharge current which can be recorded and measured and this ion current density, it is hardly it is in this order that means 1 milliamp per centimetre square that this is the unit area of this target material, so even with the best effort what we can see that this is just the order of ion current density and sputtering rate that will be maybe around, say this is just an indicative 400 Armstrong per minute, so that maybe one of the indicator value for this. Now there has been a lot of attempt to increase this voltage but this increased of voltage does not mean that this material erosion rate or sputtering yield will increase rather it will keep on falling.

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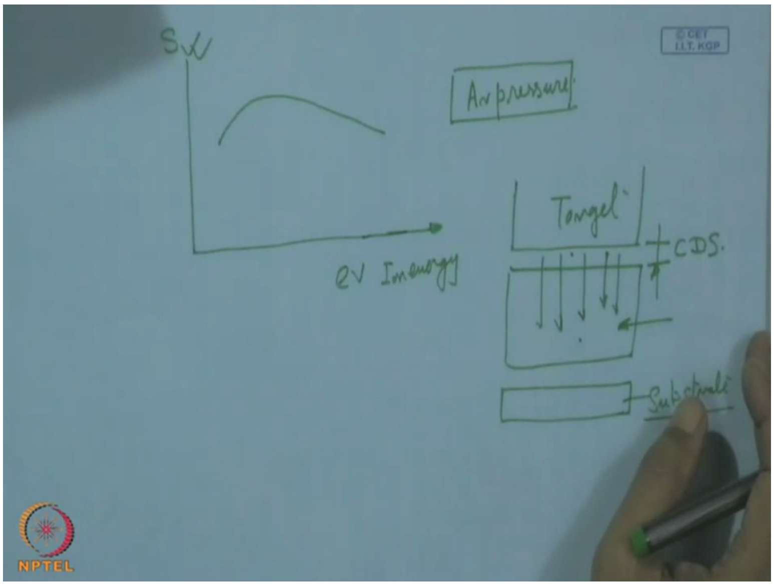

So if we consider sputtering yield S that means atom per ion it may take a shape something like this even with increased of electron volts that means when we increase this discharge voltage naturally what is what we try to increase that means the ion energy however at the same time ionisation cross-section that will keep on falling and as a result this sputtering yield will also keep on falling, so then it is actually the ion energy. So then it is not a very useful fruitful method.

Another way of doing the thing that means it is actually this discharge current enhancement augmentation that is done by this argon pressure however, okay so there we can see definitely an increase in sputtering yield with increase of pressure but too much of increase of pressure what happens? That also restricts the mobility of the sputtered flux of atom from the target and also easy movement of this iron or the electron that is also restricted because of the too much of crowding of this argon atom inside and that is because of this rise of the pressure.

So it is a fact that just by increasing this discharge voltage or this argon pressure marginal gain may be made but this cannot be considered as one of the very efficient process, so what we can summarise here that if we consider this target and the substrate here, then this is the plasma volume and this is actually the…this is the plasma volume this this area and this is we call cathode dark space. Now what happens this secondary electrons, they have a free axis and they can move in this direction and they can impinge on the surface of this receptor surface of the substrate and in this process it is high energy impingement thereby increasing the temperature of the substrate and also it could be that quality of the coating that can be also little bit effective.

So the whole thing is that the secondary electron it enters the plasma volume and that becomes the primary electron and then they are going to strike. So what we see from this whole process that this secondary electrons are not efficiently used in the close proximity of the target where we need the concentration of the ion and with high energy ion in this vicinity of this target surface, so that is the whole issue that how to make this secondary electron which are emitting from this target surface because of the striking of this ions argon ion is here. This not only just cause dislodgement of the target material but also it is also the emerging of the secondary electron, now how to make the secondary electron more efficient so that is now the main issue concerning this sputtering process.

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Magnetically Assisted Sputtering

NPTEL

So here what we find at magnetically assistant sputtering and that is exactly the origin of this magnetron sputtering. In fact this magnetron what we mean it is actually magnetically assistant discharge associated with sputtering that means in this sputtering device we have one electric field and in addition to that there is another magnetic field, so there come with their combined effect and attempt is made to make this electron secondary electron more efficient, useful that means a single electron under the action of both electric and magnetic field will become more efficient that means it is expectedly it will generate more number of ions by striking having more number of collision or hits with the argon neutral once it is coming in the way, so that is exactly where the magnet, magnetic assistant is provided.

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Charge Particle Moving inside Uniform Magnetic Field

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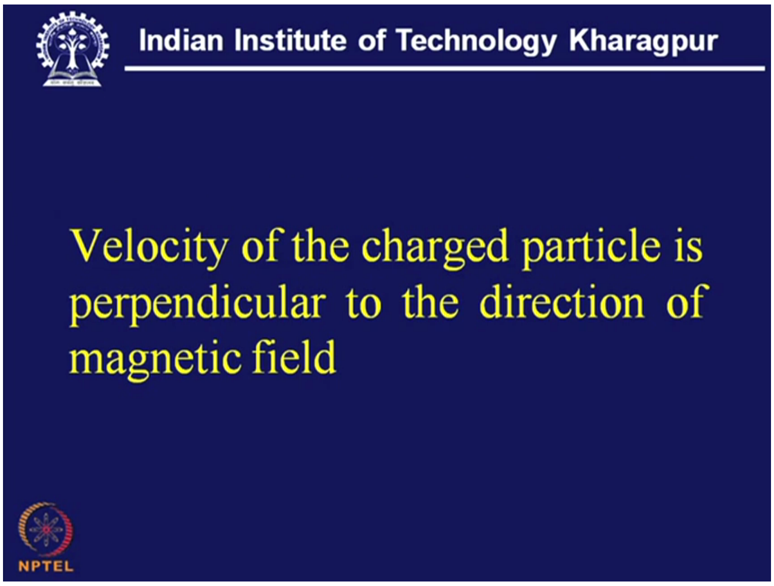

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Velocity of the charged particle is perpendicular to the direction of magnetic field

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Now let us look into this charge particle moving inside one magnetic field, what happens to that? A charge particle is moving inside a moving inside a uniform magnetic field and there are 2 cases in one velocity of the charge particle is exactly perpendicular to the direction of magnetic field.

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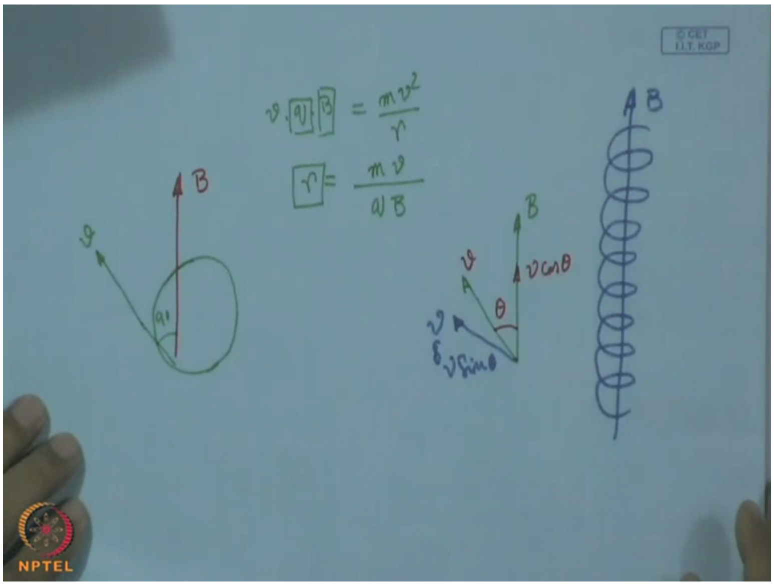

Say for example this is one charge particle having this velocity V and at the same time we have here one magnetic field and that is denoted by this symbol B and if these are at right angle, these are at right angle then perhaps it will be something like that, that it will have it will keep on orbiting and this orbital radius that will be given by, so here the force will be V into q into B where that is the charge, that is the magnetic field and that is the velocity and that can be equated by this centrifugal force to which it is subjected and from there we can get this radius of this spinning radius comes out to be here this is actually m v by q b.

So this is actually the radius, spinning radius, so here this is this angle is 90 degree, so they are at 90 degree. So here it will keep on orbiting around this and this orbiting radius will be r which is given by m v by q b. Now this can be, there can be another situation where it is not necessarily they are at right angle that means we have this velocity and then this is the magnetic field and in between there is one angle theta, so there will be a 2 component one will be a long B that means say if this is very then this will be v cost theta that means that is a long component and then there will be another component which will be the sin component which will be at right angle, v sin theta.

So in this case what is going to happen this is just not spinning, it will be a helical motion, so helical motion that means with this c cos theta it will have a drift motion along the magnetic field but at the same time it will keep on spinning and as a result we have this helical motion of this charge particle, it may be electron, so this will be the reaction of magnetic field and that will keep on spinning and it will be like a spiral motion.

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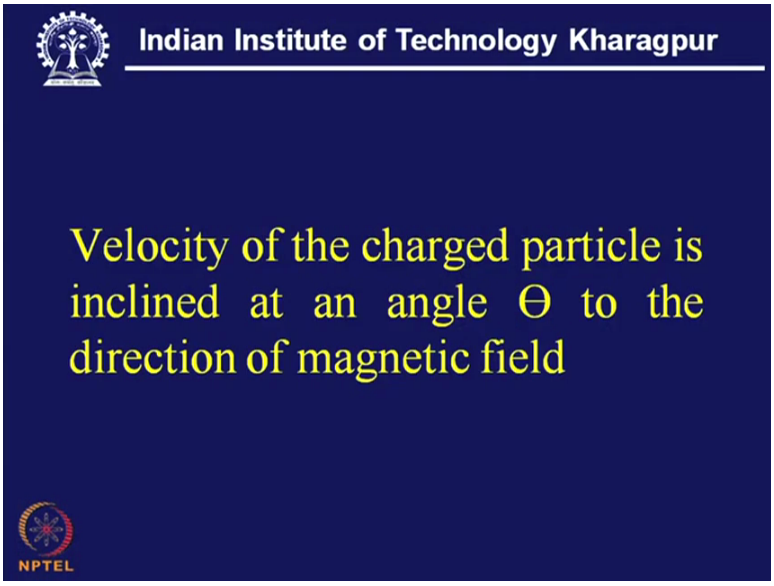

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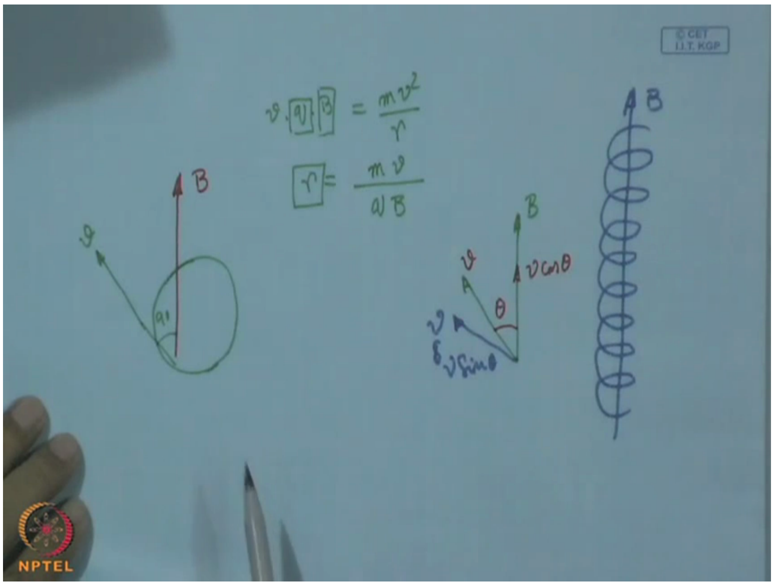
Velocity of the charged particle is inclined at an angle Θ to the direction of magnetic field



So that will be the motion of the charge particle when it is just not at right angle but it is making an angle theta with the direction of the magnetic field. So this is just 2 examples how this charge particle will behave when it is put in a magnetic field.

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Presence of an Electric Field in Addition to The Magnetic Field

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Now comes if we now have an electric field in addition to the magnetic field, so we are coming very close to a situation very close to a sputtering where already one electric field it does exist but what we like to have, we like to add one magnetic field and this electric field and magnetic field putting them together with their combined effect, the net result will be to make this electrons more efficient than we than the case with a without a magnet, so that is the thing.

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Presence of an Electric Field in Addition to The Magnetic Field

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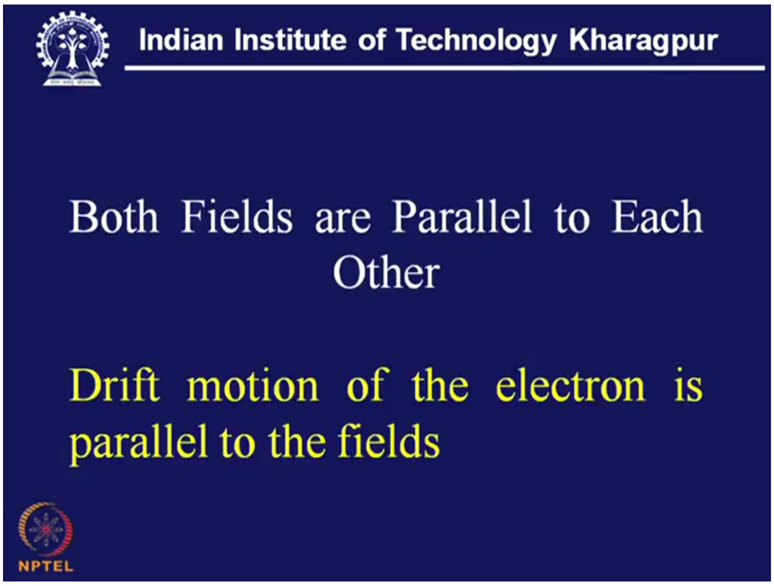

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Both Fields are Parallel to Each Other

Drift motion of the electron is parallel to the fields

Now the presence of electric field in addition to magnetic field here also we can have 2 situations in one case both fields are parallel to each other, this is one situation and in this case this electron discharge particle will have a motion which will be parallel to this field, both of the field they are in the same direction, so that drift motion will be along this field direction but if they are at a right angle to each other.

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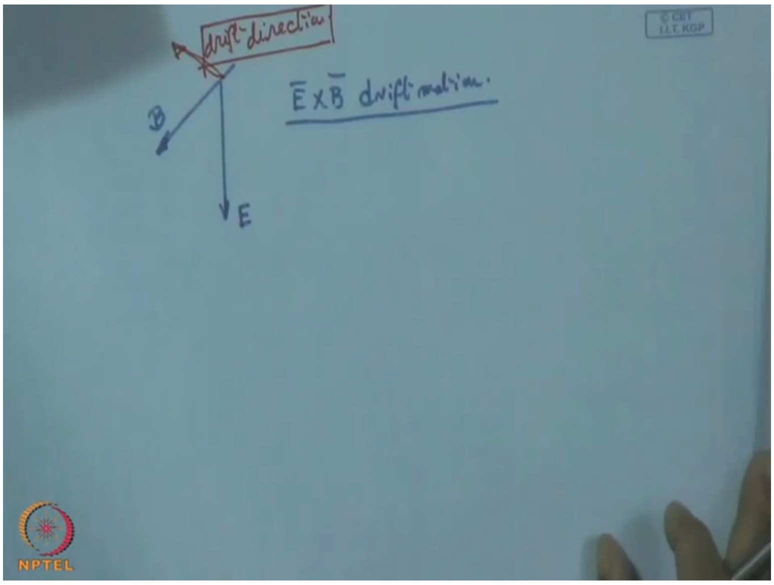

Say for example let us put this way this is one electric field E and then we have one magnetic field which is working like this, magnetic field and so these are the 2 fields which are very much present and then how will this charge particle will behave? Then there will be a motion called E B drift motion it is the crossed products so this is called E B drift motion and with this drift motion this charge particle will have a velocity with this E B in this direction, so that will be this E B drift motion that will be the direction. So this is very much applicable to this sputtering where this magnetic force is going to assist the sputtering process or generation of the iron, so this is actually going to be the drift motion that will assist in generating more number of ions or electrons collision and this is the drift motion.

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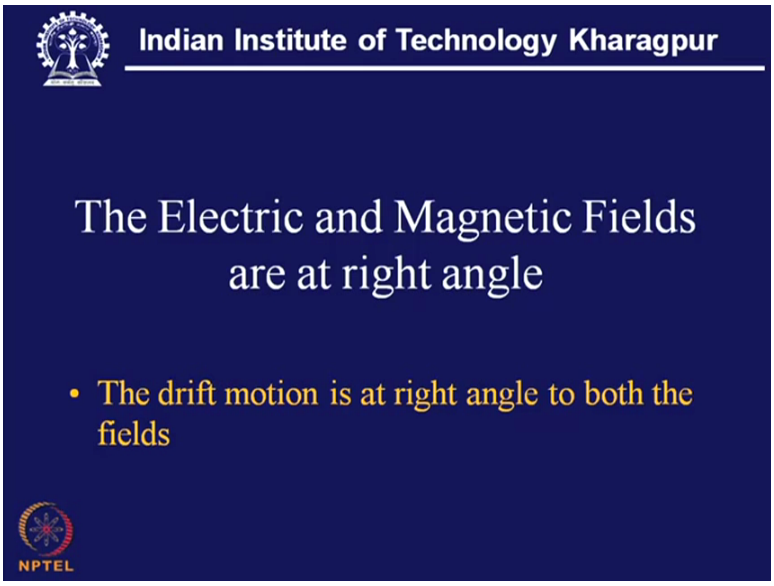

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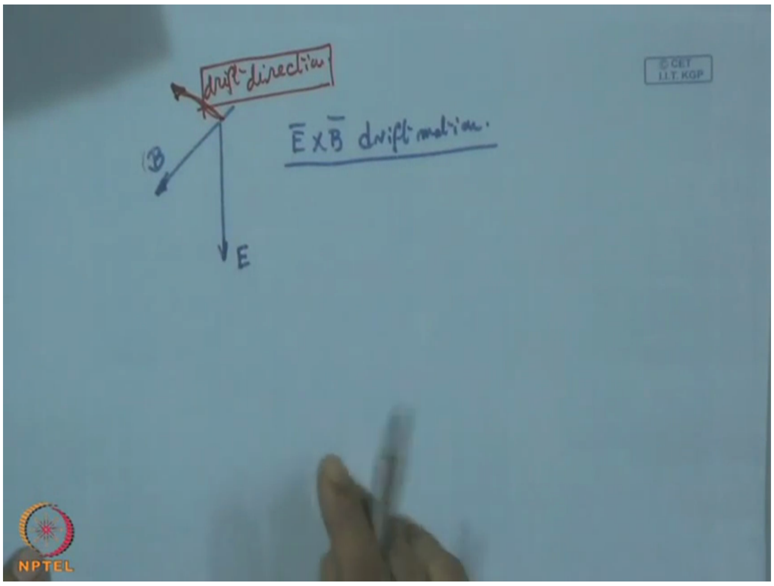
The Electric and Magnetic Fields are at right angle

- The drift motion is at right angle to both the fields



Now drift motion are at right angle and exactly what has been shown here that when they are at right angle, so with this line with this mark with this marked we are showing that drift motion and this is magnetic and this is the electric field.

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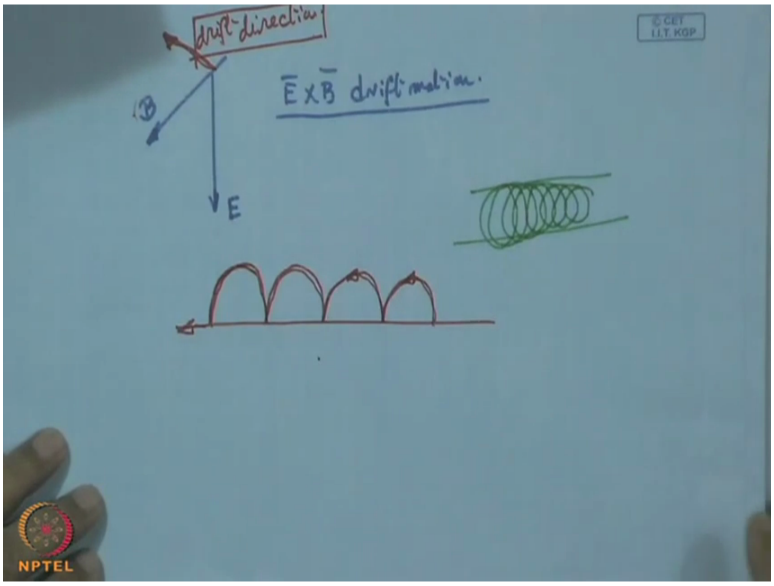
Form of Drift Motion



Now form of the drift motion now form of the drift motion is also very important, it can be there are 2 situation 2 extremities we would say, one can be a circular motion that means this drift motion will be very close to that of a circle, so it will follow it will follow almost like a circle, so it is moving in this direction but it is also almost following orbiting and other same time it is moving, so this is a drift motion so it is almost following however another extremity will be that where we have what we called a cycloidal motion that means it is something like this, so it will be more or less like a cycloidal motion.

Now this happens because of the situation if the energy gained by this charge particles because of the very presence of electric field, if it is larger than the initial energy then it will be a cycloidal motion but if it is just the contrary to that that means the energy gained because of this presence of electric field that is smaller compared to the initial energy of the charge particle then that will be more or less like a circular motion. So one is cycloidal so it will move like this, so it is the drift direction but it will also have this trajectory, so this is actually the trajectory but it is directed in this in this along this line which is at right angle to this B and E, so cycloidal and circular.

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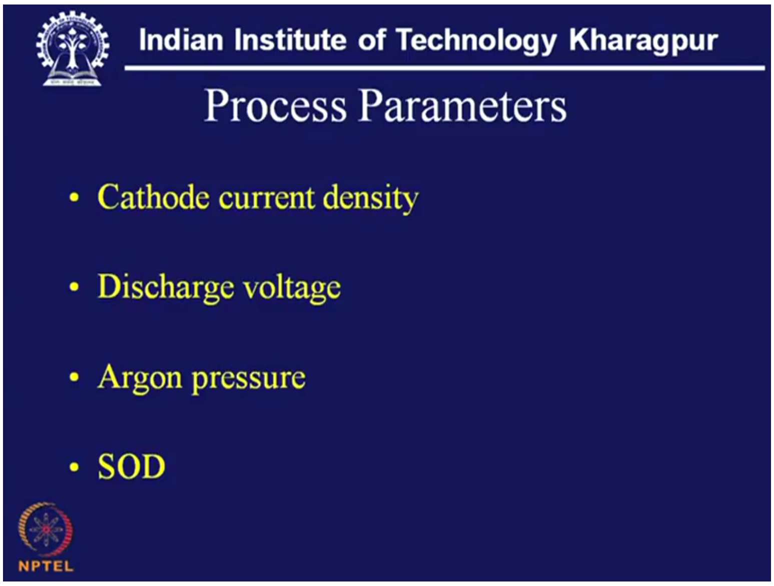

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Process Parameters

- Cathode current density
- Discharge voltage
- Argon pressure
- SOD

Now process parameters, now one would like to understand and know and that will be the immediate interest centred around the centred around this values cathode current density, discharge voltage, argon pressure and stand-off distance, so these are there few metres which will be of immediate interest to anyone who will be interested to operate this sputtering device to get a coating having all the required properties.

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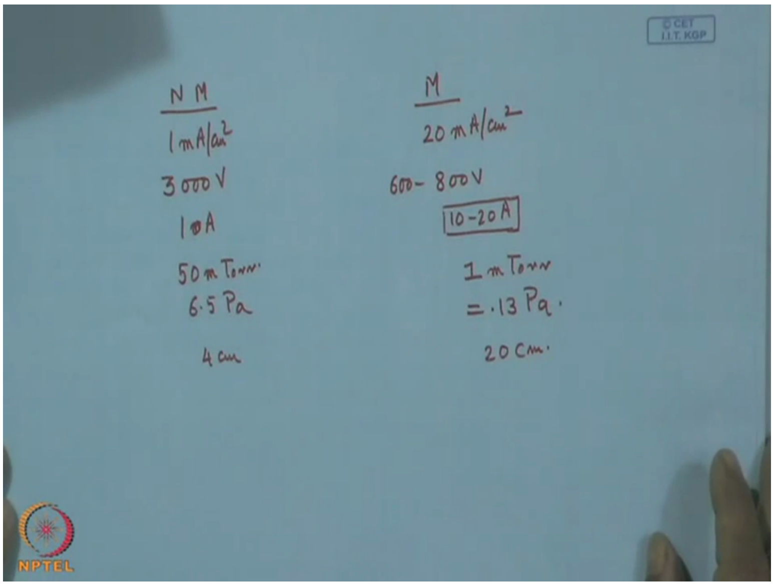

N M	M
$1\,mA/cm^2$	$20\,mA/cm^2$
3000 V	600 - 800 V
1~~0~~A	$\boxed{10\text{-}20\,A}$
50 m Torr.	1 m Torr
6.5 Pa	= .13 Pa.
4 cm	20 cm.

That means if we have non-magnetron on this side and this is magnetron, so here cathode current density straight way with a magnetron a cathode current density of Millie 20 milliampere per square centimetre it should not be a difficult task to attain whereas on this side it will be just limited to 1 milliampere per centimetre square of the cathode surface. Discharge voltage, the discharge voltage on this side it is say an indicative value not at all exaggerated it is 3000 volt but this can be achieved with a voltage say 800 or say between 600 to 800 volt that is not at all a difficult task.

So on this side one can get just 1 ampere maximum and on this side 10 to 20 ampere can be very easily achieved and then the argon pressure what we have already noted, this is, this millitorr that means it is above 6.5 pascal and on this side we can just get down to 1 millitorr which is equal to 0.13 pascal and then stand-off distance that can be quite high here it is about 4 centimetre it can be as high as 20 centimetre, so if we compare this to without going into any detail one can immediately recognize the capability, the efficiency and the productivity of this magnetic field assistants, magnetically enhanced sputtering and which we call the magnetron sputtering, so this is the advantage one can very easily recognize with the addition of this magnet in this along with the electric field.

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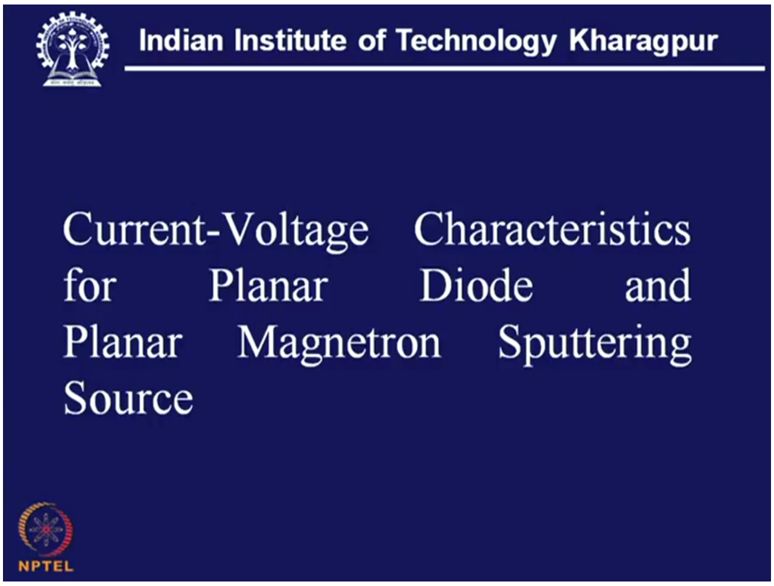

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Current-Voltage Characteristics for Planar Diode and Planar Magnetron Sputtering Source

NPTEL

Now current voltage characteristics for a planar diode that means what we mean here it is a non-magnetron and a planar diode and it is also DC but provided with a magnetron, so we have 2 sources here one with an ordinary without having any magnet and the other one which is backed up which is having a backup of a magnet. Now with this let us have a quick look in this diagram and this is also another reason how efficient this magnetron his so one would be very much interested not only in the magnetron, how good or how efficient the magnet, it is geometry, design, its field strength, what should be the best value? So far as this current voltage characteristics is concern that means this current voltage characteristics is a true index of the whole process. This discharge and there are magnetron or no magnetron that picture will be totally clear if we just try to illustrate the whole thing with this graph.

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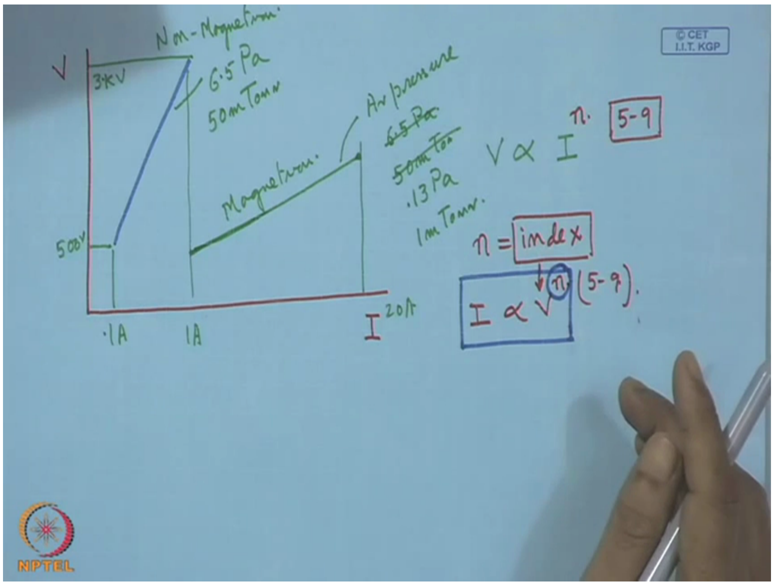

So this is the characteristic feature on this side we have the discharge voltage and that is the discharge current and when this discharge voltage and discharge current naturally one would be interested to have the line that means less voltage and more current that will be the objective of the sputtering or this user of magnet. Now here we can see 2 graphs one may be something like this, this may be one graph.

Another graph we can find this is on this side, now here we can just have some by way of illustration some indicator value maybe this is around 3 KV and this is around say 20 ampere and this is just around 1 ampere and this is say few hundreds of volt 500 volt and this may be around 0.1 ampere. So from this one would like to one would expect that this graph, this graph should prevail and this is this is the characteristics of V I and this is possible only with the use of a magnetron and this is without a magnetron, we must mention here what was the pressure argon pressure. Argon pressure in this case it is of course by way of illustration this is 6.5 Pa which gives us 50 millitorr.

This is actually 0.3 Pa that means 1 millitorr and this is actually 6.5 this blue line 6.5 Pa pascal and that is actually 50 millitorr, so what we find immediately the difference between that means this is this blue is non-magnetron, this is non-magnetron and this is with the magnetron. So the use of the magnetron that is immediately felt and realised just by looking at this V I characteristics and this V I characteristics we can also put in this form that this is actually proportional to I and here we should put…now when it is ohmic conduction, we can put the value of N as 1 however V is proportional to I in ohmic conduction and this is one but however in this case it is just not one, so we should put a value, we should put one index that is n, so this end is n index and that n that shows the performance of magnetron.

So n is an index showing the performance of the magnetron, so normally it is our experience that it is varying maybe with from 5 to 9. Now this value one should look for a higher value that means what we get here this can be can put all also in this form also because here it is voltage and current we can also put in this form I is proportional to V that means here it is the voltage which will be applied and to get the cathode current, so if we can put this way, this is also valid and this is actually the index here what we can see and this is actually 5 to 9 that means from this relationship, from this relationship what we understand that to get a level of cathode current, we need certain impressed voltage.

Now what should be its value whether it will be in the kilo range a few thousands or it is in the few hundreds range, so obviously our choice considering all technological constraints and limitations one would be interested in a lower value of V and that is why to get that same value of current one has to increase the value of n and exactly this n means this is the role played by the magnetron that means better the quality of the magnetron more will be the value of higher will be the value of n and this n will be showing the performance of the magnetron.

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Planar Diode Magnetron Sputtering Source

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Now planar diode magnetron sputtering source, how it is made? Let us have a look, we can have planar magnetron or we can also have a cylindrical magnetron.

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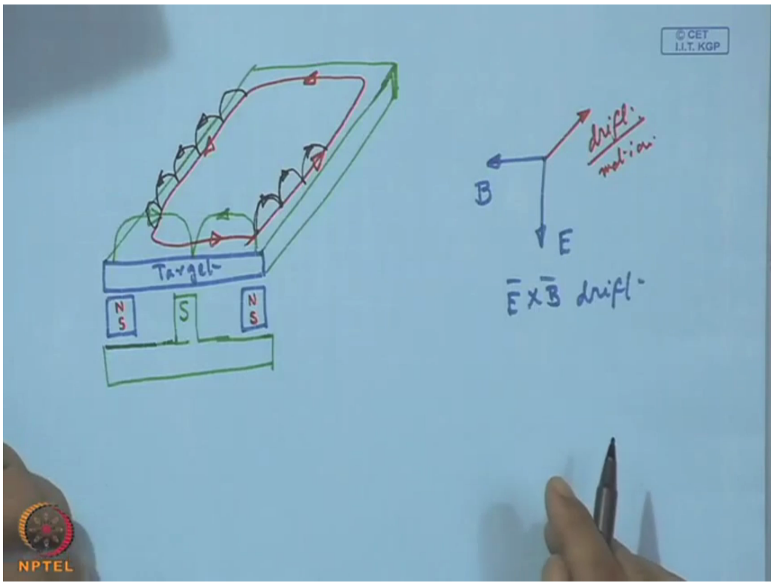

Now in this case we can have say for example a planar magnetron a rectangular piece like this and here what we can have, these are the magnet, these are the magnet with North South poles and this is a central pole piece, this is a central pole piece which is kept like this, so that is why this becomes South, so naturally what we see, this is a rectangular plate and here we have north and this is South, so lines of force that will flow like this, so this will be the direction of lines of force and this way we can have one such configuration.

So this is a rectangular that means this can be like this, so this is one rectangular piece and here we can have this is actually the cathode or the target material, this is actually the target material and beanie this we have such a configuration of the magnet and then we have the electric field in this form. This is the electric field and then this is the actually the direction of this magnetic field and has a result of this with this EB drift we can have this EB drift, EB drift motion and that drift motion this will be like this, so drift motion will be in this direction, so that will be the drift motion.

So here we expect one drift motion that means this electrons are actually locked, this electrons, secondary electrons in close proximity of this target, those are locked and those are trapped and they are forced to orbit following this drift motion that means we can expect a drift motion like this, so this will be the drift motion that will be the direction, so the electron will keep on orbiting this part and that is locked and trapped however over this we have to superimpose this cycloidal motion, cycloidal path, so it will be something like this. So this will move in this form.

So it will have this motion and that is directed in this direction and from this side when it is on the other side it will be in this way, so one thing we observe immediately that this electrons are actually following this path at the same time it is also moving along this cycloidal and thereby it is actually following a longer path, it is just not the initial of electron from the cathode and arrival at the anode, so this electrons are locked, they are trapped in closed proximity of the target and the have such kind of motion this orbiting and the cycloidal motion thereby the chances of collision with more number of argon neutrals will be more that means one electron has now the possibility of splitting more number of argon neutrals into argon ion.

Thereby what is going to happen? We have now a densification of the plasma with a heavy ion flux density that is the bombardment or impingement over this get surface, so in this closed proximity of this target material because of this locking of the electrons in in this near the surface, we have now concentration of ions which will be generated by this collision as it follows this path and more number of ions will be generated by one single electron and there will be densification of the plasma and that will have a cascading effect that means that will lead to larger ion flux that means ion current density will be more and finally it will lead to high sputtering yield, more number of ions per unit time, sputtering yield, erosion rate and then also the deposition.

So this way one can consider the effectiveness of this magnetron and how it is making the secondary electron more and more efficient in that it is now capable of splitting and ionizing more number of neutrals than ever before when it was not trapped or locked by this magnetic field where it has a free axis from moving from this cathode surface to the anode surface and like that. So this is one planar target instead of this, we can also have cylindrical one, it depends upon the flexibility of a process or to simplify a process or to make the sputtering technology rather an easy option for doing the coating.

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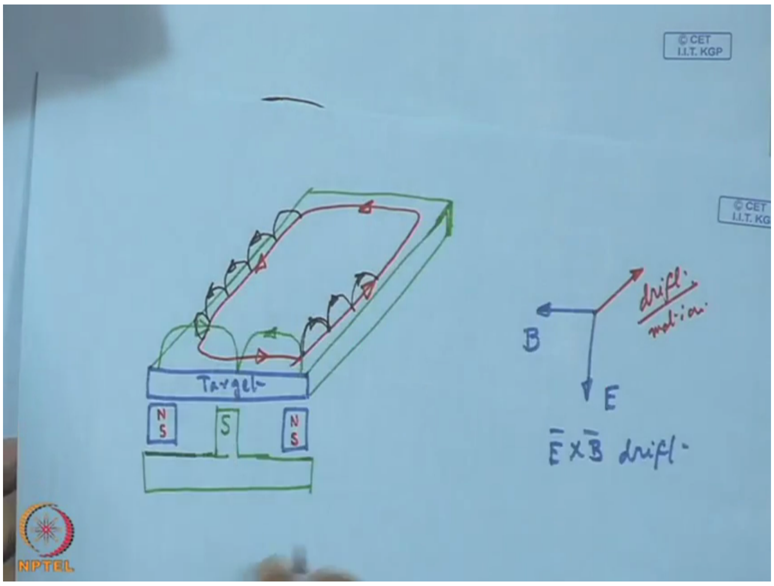

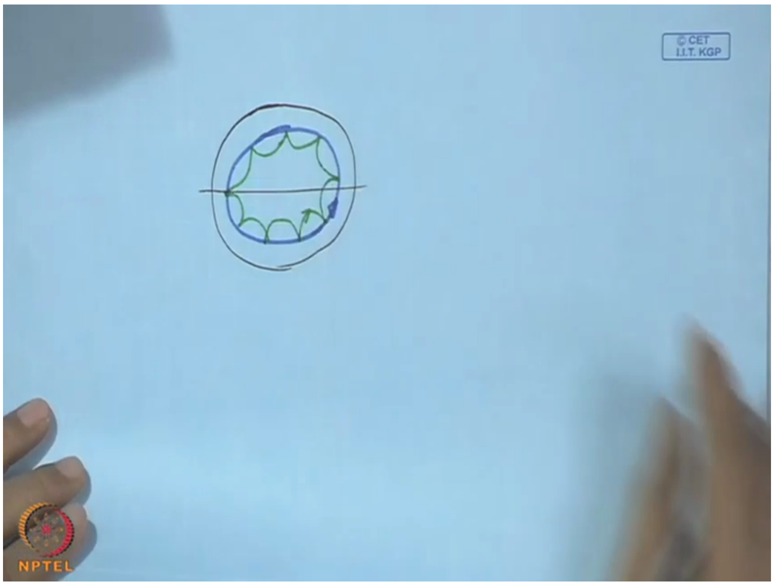

So in that case if we have a circular target then also what we can see it is going to be a circular target if it is like this, so here also we have this kind of trajectory, so this will be exactly the way what we have shown here by this red line that is the track that is the drift motion here what we are showing by this blue line that is the drift motion and over that we have to superimpose by this cycloidal path and it will go like this over the surface and it will be just following this longer route and as a result it becomes more efficient and chances of ionisation of this neutrals will be more. So this is just one circular plate but we can also have a cylindrical magnetron.

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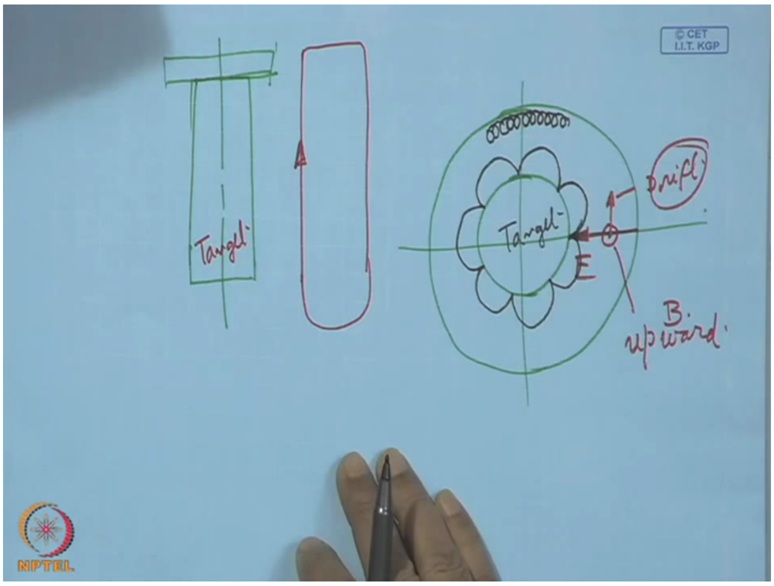

It is a cylindrical it is almost like a look like a shaft, it looks like a shaft and it can be placed inside the vacuum chamber and this is the topside, so there will be suitable fixture and this is inside the chamber and here also we can have the magnetic field, it will be like that and it can be an electromagnet, so inside we have this direction of this field and then this is target, that means that is the cathode and if we just have the top view of this whole the system then what we can see? For example this will be the cylindrical target looking from the top and then we have the chamber somewhere here that is the chamber valve, we can have a very quick look and then this is the valve.

So field will be electrical field will be directed in this way, this is the electrical field and then this is the magnetic field, so magnetic field is like this, it is normal to this paper, so as a result of this what is going to happen? It is EB drift and according to this EB drift will be a drift motion, so if this is vertically now here we have the magnetic field which is actually upward, vertical upward, so B it is vertically upward this is the direction of E and as a result we have at this point E and B, so that will be the drift motion, so at each point this will be the drift motion so that will be tangential, so we have a drift motion which is also circular but over that we have to superimpose this cycloidal motion, so it will be something like this.

So this will be the actual path followed by this electron and it is close to this target or the cathode and this way it can also shifts the track and when it is near the valve will be more circular in nature that means here it will be more circular in nature though it is also following this path, it is also the drift motion, so this drift motion is like a circular motion and over that we are actually superimposing a circular form or a cycloidal form, so this is also another way of sputtering and in this case the material will be sputtered and it can be sputtered on a in a hollow tube because it is a cylindrical solid target, so it can be used for this purpose for coating this internal surface of a tube, so this way what we see, now this magnetron that is actually helping in getting a low discharge voltage, high discharge current, high deposition rate and the requirement of low-pressure.

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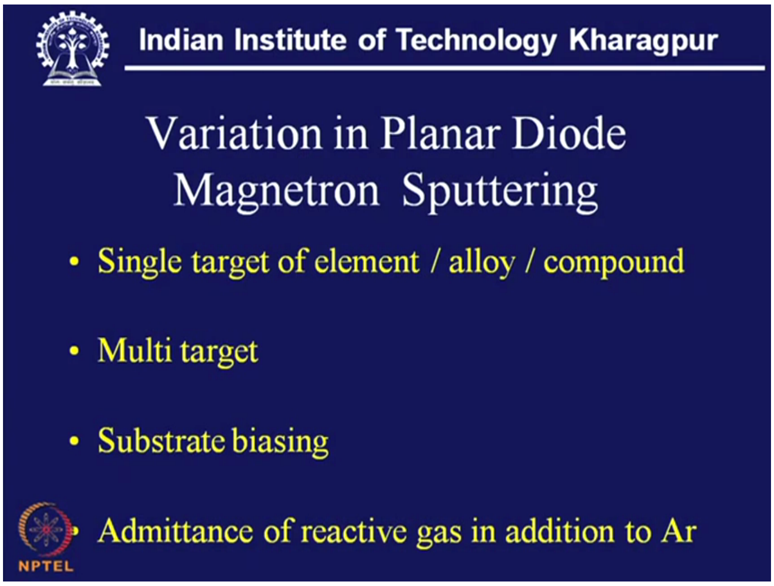

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Variation in Planar Diode Magnetron Sputtering

- Single target of element / alloy / compound
- Multi target
- Substrate biasing
- Admittance of reactive gas in addition to Ar

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So with that what we can see, we can also have a look in this, what we call this variation of planar diode magnetron sputtering that means a normal non-magnetron planar diode system can be converted into a magnetron sputtering system keeping all the basic features of this without deviating from the basic features that means it can be a single target magnetron, it can be multi-target magnetron, it can be also a multi-target magnetron with substrate biasing, it can be also magnetron sputtering with reactive gas, so it can be reactive magnetron sputtering. So all the variations are possible just with incorporation of the magnet and the machine or the apparatus becomes much more efficient than the case where we do not use the magnet.

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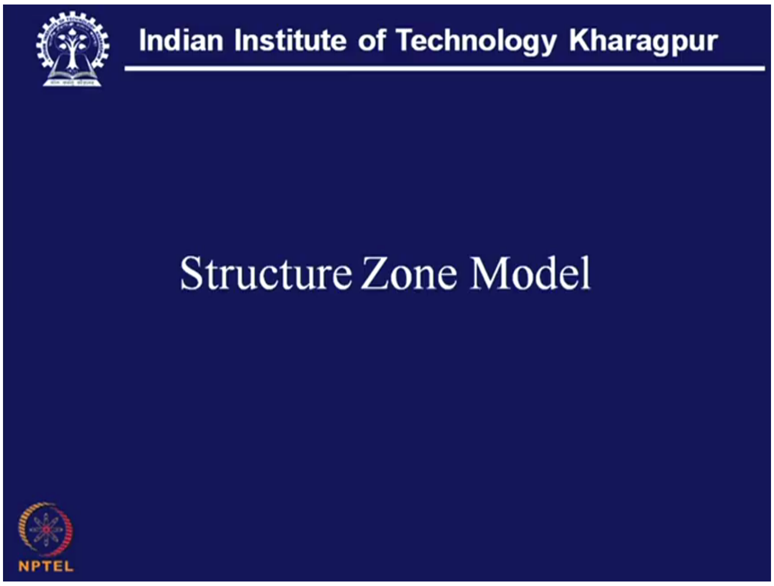

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Structure Zone Model

Now structures own model, this is one we can say this is just like a map, this is just like a map of the structure which is the outcome of any sputtering process.

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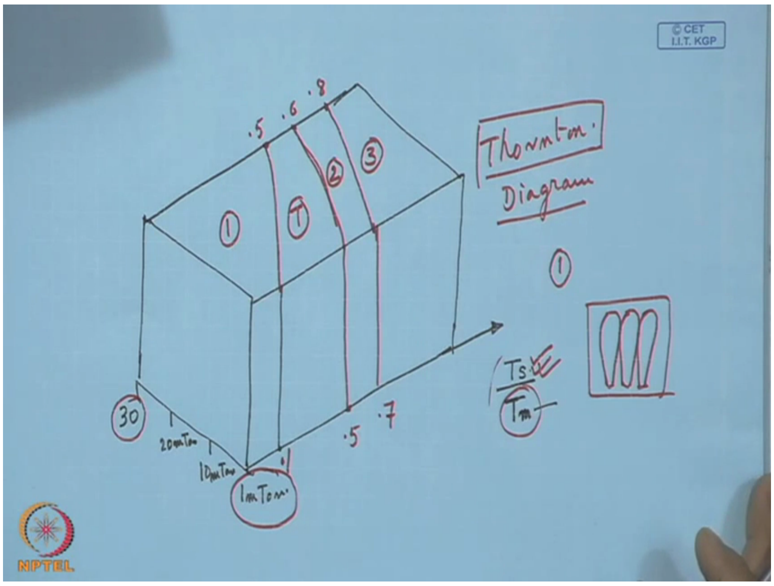

So let us try to illustrate this point here just by drawing this blog diagram, so this is just like rectangular block, this is a rectangular block, this is just a rectangular block and in this rectangle a block we have few variables of sputtering. For example along this direction we put this notation T by Tm. Now this T is actually temperature of the substrate Ts by Tm and Tm is actually the melting point of the target, Tm is the melting point of the target and this is the temperature of the substrate and on this side we have the process pressure and let us put say this is 1 millitorr this is 10 millitorr and this is 20 millitorr and this is 30 millitorr and here we can now have segmentation of this block to show the structural features of sputtered coating that means a layer is developed by this sputtering process and let us have a quick look here, say this is about 0.1, so this 0.1 means actually 0.1 means Ts by Tm 0.1 and this is about this zone.

So this is one zone we find and then we have another zone which is which comes around at 0.5, so this is another zone and this we can also show like that, then we have another zone around say 0.7 and here it is around 0.8, so this is 0.5, this is 0.6 and this is 0.8, okay. So let us have some discussion on this, so this one what is the physical meaning of this diagram? This is actually called Thornton diagram. Thornton diagram this is actually the mapping, so here what we see that if we like to have a structure and this is called zone 1 this is a transition zone and this is zone 2 and this is zone 3.

Now zone 1 that is characterised by a porous columnar growth, so in sputtering it is mostly columnar growth in the vertical direction it is a growth like a broomstick and in this side we have a porous structure and it comes like almost like this, it is a domed and it is with a back tipper, so this is a porous structure which is growing and that is here, so physically what does it mean let us try to understand. If we increase the pressure then up to 0.5 Ts by Tm we can expect such a structure which is very undesirable but if we like to have structure with a small temperature range which is actually 10 percent of this cathode melting point then we have to give down with the process pressure of 1 millitorr.

So from this diagram for one thing we understand immediately the significant or implication of this low-pressure operation, we can have high pressure and we can ignite the discharge that means to initiatives sputtering that can be done with high-pressure with much ease but in that case we will be always left with such a undesirable structure or growth architecture of the coating and that can prevail even if we increase the substrate temperature even to 50 percent of that of this cathode material or the target material but if we like to lower the substrate temperature which is one of the significant point of sputtering, then if we like to have a deposition with a low temperature then we must also reduce the process pressure here.

So this way we understand that at one on one side it is the temperature of the substrate which should be at the low end considering temperature sensitiveness of the substrate and other same time capability of the apparatus to work with low-pressure. Now here what we have this is a transition between 1 and 2, now what we have in zone 2, these are also sticks but finer in size and densely packed and it is also densely packed, so a transition from this porous to densely packed that starts within that and in this case also what we see? If we work at 30 millitorr, it can go up to 0.6 of Ts by Tm but if we can reduce this pressure then it can be done with 0.5, so this is zone and which will continue up to 0.7 of this ratio with 1 millitorr but which can be extended with up to 0.8 of Ts by Tm if we increase the pressure and in this zone 3 what we have? As we increase the temperature it is actually the diffusion and moment of the mobility of the other term which are being which are received from the sputtered flux.

So it is actually this mobility of this other terms and the lateral movement that makes a structure what we call (())(56:56). It is very grainy it is like a (())(57:00) like structure in that zone 3 and zone 2 broomstick with highly packed broomstick very dense structure, it is open structure and it is a transition that is changing, so what we understand from this is that this effect of pressure is extremely important and if we like to work with low-pressure then obviously the significance of this magnetron sputtering is immediately felt and immediately understood and in that case we can work with a low substrate temperature provided we have the possibility to work with a low-pressure and that is possible by this assistance from this magnet and that is called magnetically assistant sputtering or magnetron sputtering.

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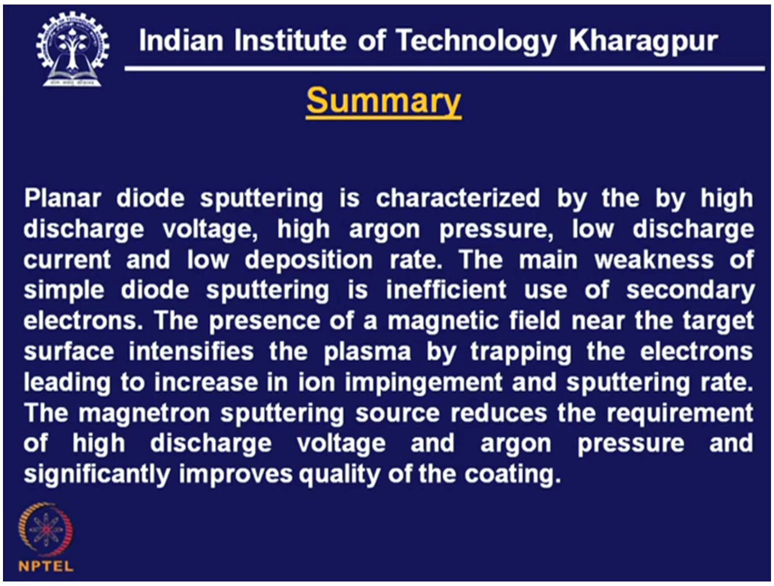

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Summary

Planar diode sputtering is characterized by the by high discharge voltage, high argon pressure, low discharge current and low deposition rate. The main weakness of simple diode sputtering is inefficient use of secondary electrons. The presence of a magnetic field near the target surface intensifies the plasma by trapping the electrons leading to increase in ion impingement and sputtering rate. The magnetron sputtering source reduces the requirement of high discharge voltage and argon pressure and significantly improves quality of the coating.

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So with this we can summarise the discussion that planar diode sputtering is characterised by the height discharge voltage, high argon pressure, however low discharge current and low deposition rate these are the limitations however the main weakness of simple diode sputtering is inefficient use of secondary electrons, so these are not properly utilised in the system.

When we present, when we bring a magnetic field near the target surface and we have also seen that this magnetic field line is parallel to the target surface immediately it intensifies the plasma by locking and trapping the electrons and it is along a trajectory and that is called the drift emotion, so it has to follow, particularly guided motion and it cannot be a stray electron and that will lead to an increase in ion impingement and sputtering rate, so we also find that magnet on sputtering source reduces the requirement of high voltage, high discharge voltage and high argon pressure and significantly improves the quality of this sputtered layer or the coating.