Technology of Surface Coating
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Lecture 21
Electro Plating, Anodizing and Electro-less Coating

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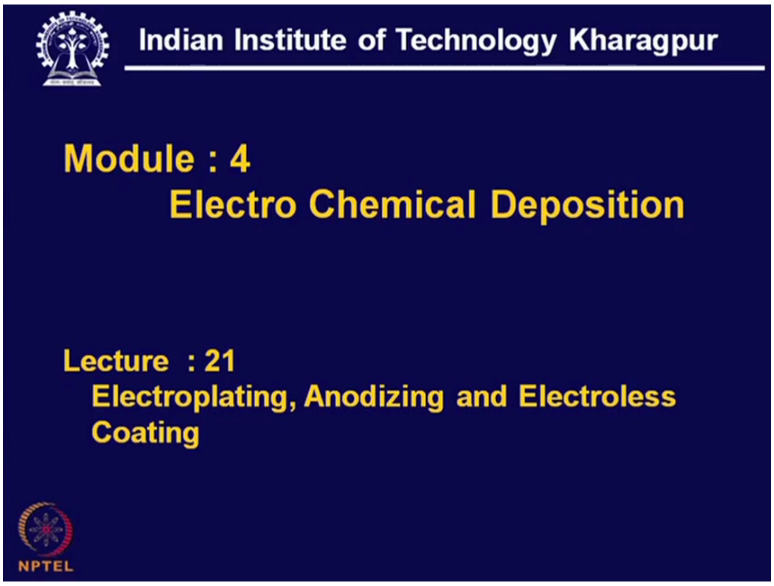

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Module : 4
Electro Chemical Deposition

Lecture : 21
Electroplating, Anodizing and Electroless Coating

Electrochemical deposition, now this electrochemical deposition it includes electro plating on what we know as galvanic deposition then also it is anodising plus there was another process where we don’t need any electricity and that’s why it is called Electroless deposition. Now all these techniques of modification of surface through layering of the surface of the substrate these are actually this take place in atomistic level that means if we recall those processes like CVD, PVD which also occurs in atomistic deposition in that term we have some kind of similarity.

However in this case what is done? It is actually a chemical reaction augmented by the supply of electricity and exactly that’s why we call it electro chemical reaction.

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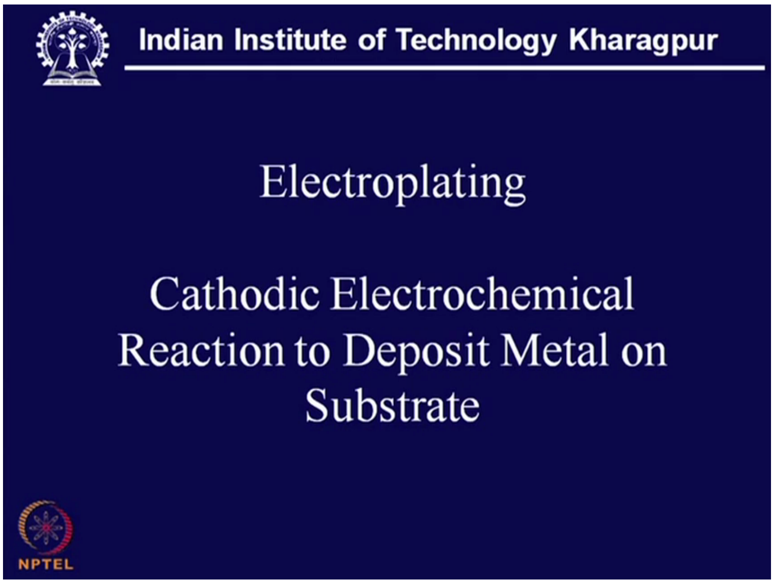

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Electroplating

Cathodic Electrochemical Reaction to Deposit Metal on Substrate

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Now what we see in this case, this electroplating that is number 1 and this electro plating what we see? It is actually if we consider a galvanic cell or a cell with a vessel full of electrolytes then we have 2 electrodes and in these 2 electrodes, one is going to be the cathode and another is going to be the anode. Now what is of immediate interest to us? Those on the cathode we like to have deposition of the material from this electrolyte.

That means electrolyte could be the source of metal and it will donate the metal and that will be accepted by the electrode that means the cathode and its growth will keep on going and that's why we call it Electrochemical reaction that is taking place on the cathode surface and this is actually the reaction for deposition of the material but we can also have anodic reaction.

In that case what is going to happen? That is actually the removal of the material from the anode surface or it can be a reaction layer that can also form on the anodic surface and with the result of surface modification. Now in fact, if we see that this deposition on the cathode surface that means a reaction takes place on the cathode and that is also accompanied by another reaction on the anode and in this case the anode is the sacrificial electrode that means it is a consumable electrode and this way this electroplating can be done and we can have one illustration to have further understanding.

However what is the engineering significance of this process that also we have to understand? Just like any other process it is basically surface modification to improve or to augment some of that capabilities of that functionals surface and number 1 which is very common in place that is actually the resistance to corrosion. So by this electro plating technique perhaps we can get one coating, a coating of a metal which can offer a remarkable resistance to corrosion of the bare this substrate.

Say for example it is low carbon steel and if we can have a deposit of chromium definitely corrosion resistance will go up. The number 2 that is also where resistance of the coating, in that case we can also have hard electro plated coating. So that can be also possible but there are certain metals which itself can give relatively higher hardness compared to the soft one that means the ductile 1.

So that is also one thing one like to achieve then say for decorative purpose, decorative purpose aesthetics for that also we need certain kind of coating, say for example silver coating or gold coating and all say the palladium coating these are all the noble metals, costly metals and these are very well used for aesthetic or for decorative purpose then we have also another type of coating, say electroplating of the solder, solder material particularly this is used for making this all electronic circuit and in the leads of those electronic component or other places we can have a Electrodeposition of this solder.

So that means those terminals are coated with this solder, so we need not apply externally any solder with the soldering iron and when this terminals are held, pressed against another element and heated up then that coating itself will be the bonding layer and that can be used for bonding purpose. So this is another very special application of this electroplating.

However Electroplating is also used to say for increasing the wettability of a surface, some of the surfaces they can be quite inert and maybe set or prone to oxidation in that case to increase the wettability for some surface we can also put a coating of some of those strategic material by this electrodepositing technique and thereby we can get the job done as per the requirement.

Now all these processes, the greatest advantage of electroplating process is its simplicity, it’s not a very complicated process and additionally we get further leverage from this process, so it is actually a liquid, so we can immerse any substrate of any geometry and the liquid is going to cover this external surface anyway. Now after just upon switching the battery on that will be continuous flow of ions, metal ions on the surface of the substrate and this ion has good accessibility over the entire surface and thereby the deposition can be done, so this is one of the greatest advantages.

Now we have to weigh between amongst the processes, compared the processes say for example we can take this example chromium can be deposited by PVD, CVD and say by this electrodeposition technique. Now accordingly depending upon the geometry than the coating thickness, the structure of the coating, its roughness, it's podocity8:45, adherence with the substrate, the growth rate, coating deposition type and many more things which are in the objectives, objectives of deposition or making this coating from that we get the answer which one should be the best process handle.

One of another advantage of this it is the low-temperature operation; hardly the deposition temperature crosses even 50 degrees. So naturally most of the elements or metals those are can be used for this electro plating process; however what is very important in this case? The conductivity of the material that is only one condition but nowadays we have other processes, so by that say Electroless we can have a pre-coat and then that can follow this electrodeposition.

So even on plastic it is not uncommon to deposit any metal by this electrodeposition technique. So these are the some of the consideration concerning this electroplating technique that means the substrate, the growth rate, thickness, adhesion and it's ultimately the functional requirement that should be also taken into consideration.

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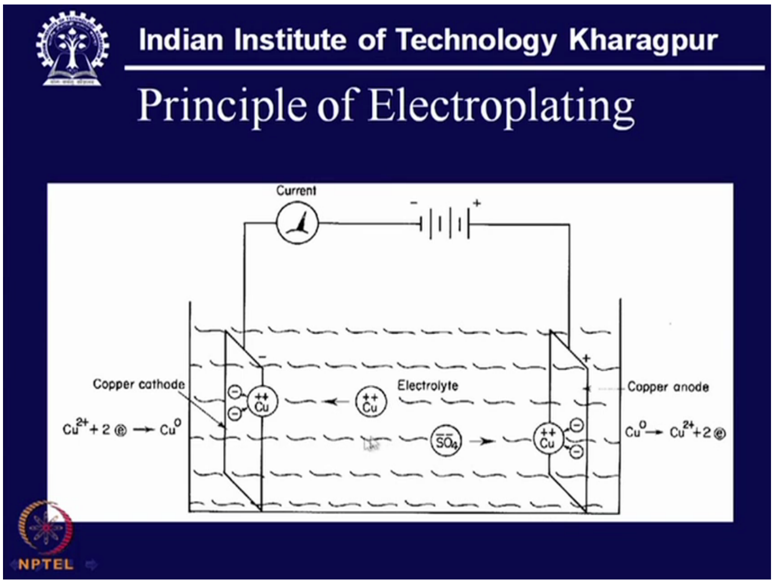

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Principle of Electroplating

Now this is actually a basic principle of this electroplating and what we see here? That it is just a most simplest possible and one of the common example one can cite so this actually the electroplating tank consisting copper sulphate, so it is an acidulated copper sulphate solution and what we have? Just like 2 electrodes this is actually anode it is made of copper and here that is the cathode that is also made of copper.

Now since we use these as cathode, naturally we have to connect this negative side of the power supply. So it becomes negatively polarised and this one that is positively polarised, now what is going to happen in this case? Now because of this negative polarisation copper ions that will collect on this surface and then this electron from this path that will move on the side because it is actually this copper ion and this will be going to be neutralised by this electron and this become a neutral copper that will be collected on this surface.

However this electron will flow on this surface and at the same time as electron this moves, we have released of this copper ion because of the release of electron and that copper ion that goes into the solution to combine with the sulphate radical and in this case what we see? That with migration of this copper ion towards this cathode surface there will be a deficiency of copper in that solution and that will be continuously replenished.

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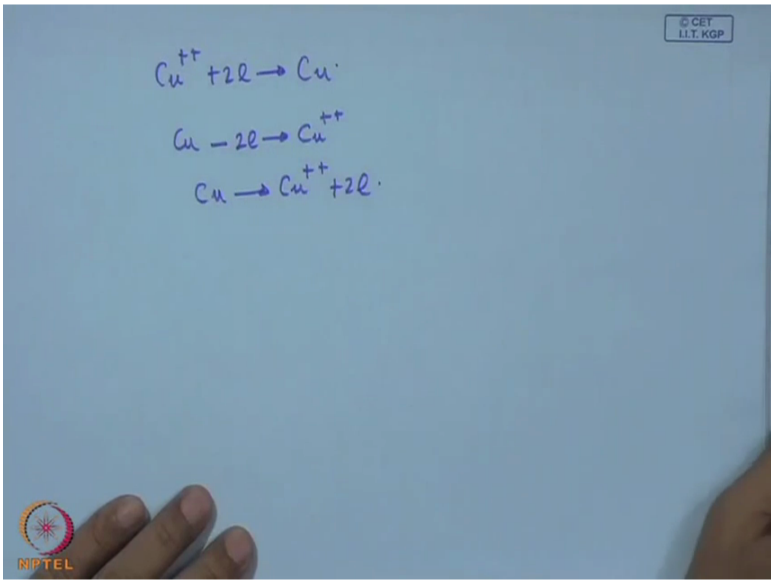

$Cu^{++} + 2e \rightarrow Cu.$

$Cu - 2e \rightarrow Cu^{++}$

$Cu \rightarrow Cu^{++} + 2e.$

So that means on this side, we have here it is actually what we can show on the cathode we have this plus plus 2e and that gives you neutral copper but on this side, what we have it is actually minus 2e that gives us 2 plus plus. So this is or we can say that this is also ion plus electron. So there is actually the thing, so this electron’s which are released from this anode side that is going to actually neutralise this copper ion which collects on the cathode side.

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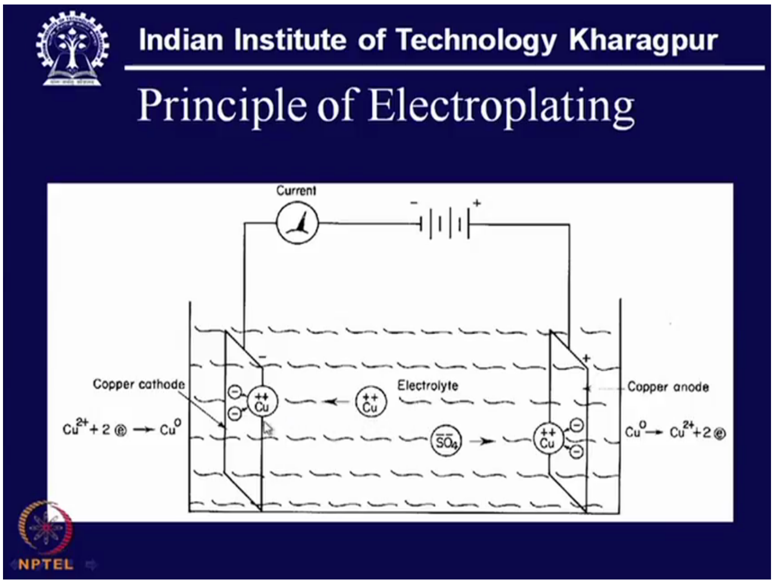

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Principle of Electroplating

In this way there will be continuous flow of copper ion on this side which will be neutralised and there will be erosion. I think we should say it is electrochemical dissolution, so what we see?

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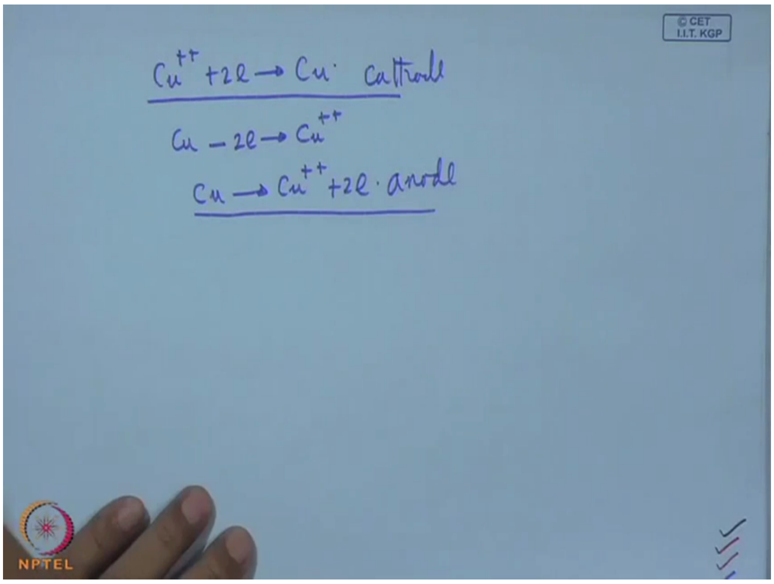

$Cu^{++} + 2e \rightarrow Cu$ cathode

$Cu - 2e \rightarrow Cu^{++}$

$Cu \rightarrow Cu^{++} + 2e$ anode

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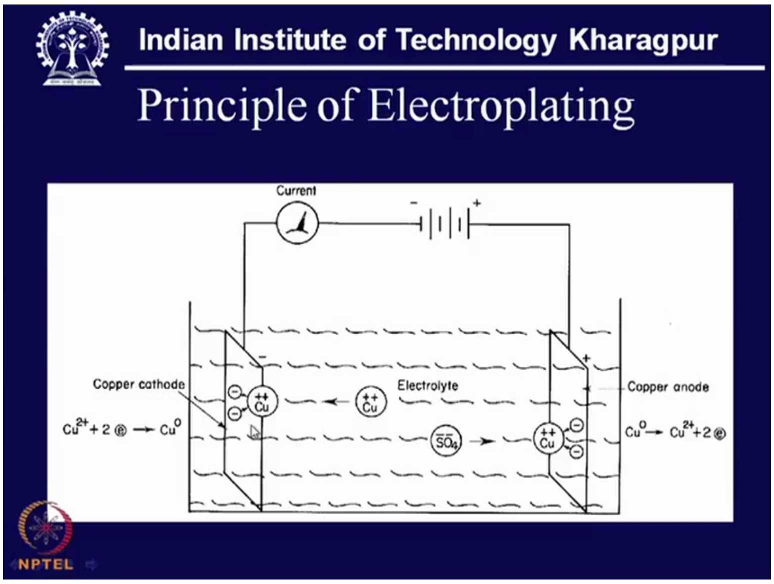

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Principle of Electroplating

So this is actually on cathode and this is on anode, so both the things, so here what we see? So this is a reduction reaction and this is an oxidation reaction, so both are taking place simultaneously and this way we can have electrodeposition over the surface. So this is in fundamental, in principal the deposition that means same metal can be deposited just by transferring from this to the electro plating solution and then finally on this cathode surface, so this way this process will keep on going and we have a metal build-up on this surface.

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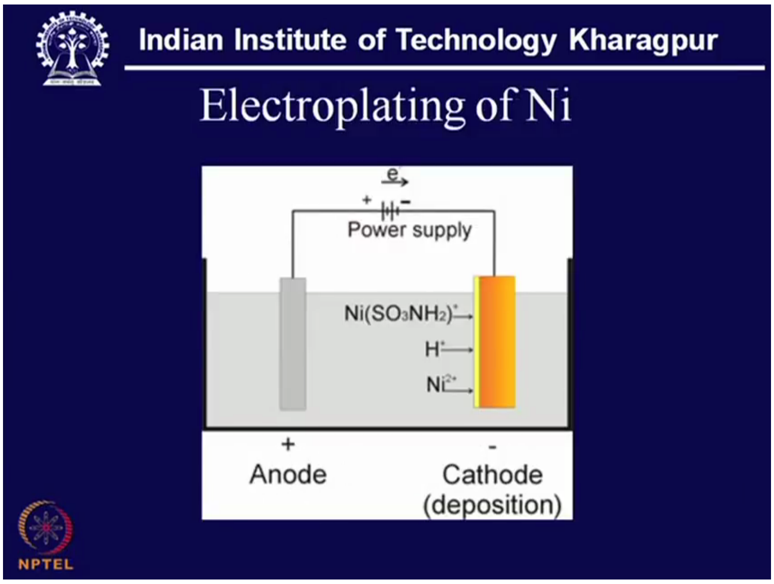

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Electroplating of Ni

This is another example of nickel; in fact we have material say like copper, nickel, cobalt, silver, gold and Palladium these are the metals of immediate interest for deposition over the substrates surface for augmenting their performance. In we can have a particular reference to this gold and silver apart from from use as decorative coating giving that attractive colour these are also used in the pins of all those electronic or electrical goods and products the pins which are connected to the socket and these pins are not just made of copper, so these are coated with silver and gold only to have minimum contact resistance and those contacts should not have any contact problem at all, so that's why we know that these are the material of choice.

Now here what we see that this is actually the nickel sulphamate solution, so what we have? In general actually just like any coating process what we like to have? Just the source material that means in this case we have nickel sulphate, nickel chloride and also we can have ammonia and with that we have nickel sulphamate solution and what happens in this case? This is actually the nickel anode and this is going to be a substrate.

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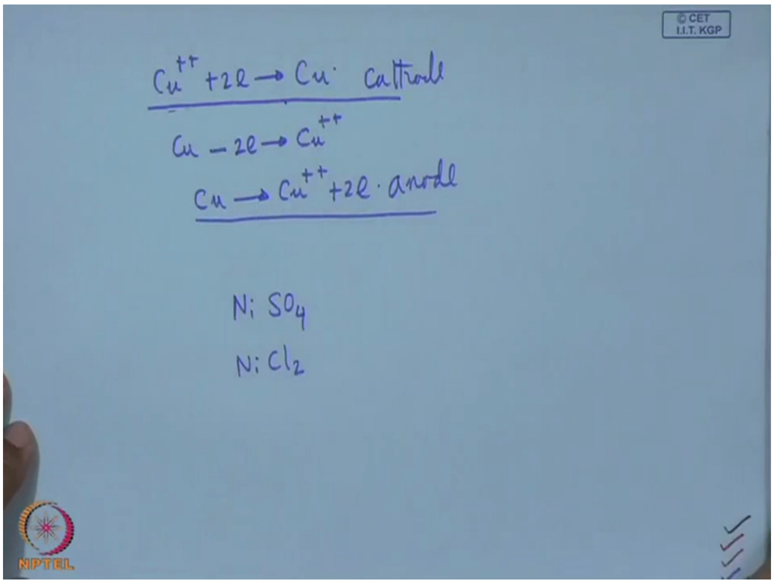

$Cu^{++} + 2e \rightarrow Cu$ cathode

$Cu - 2e \rightarrow Cu^{++}$

$Cu \rightarrow Cu^{++} + 2e$ anode

$NiSO_4$

$NiCl_2$

Say for example a low carbon steel and from this nickel sulphate we have this splitting of the nickel ion which will be collected here and it will be neutralised just by the cathode reaction what we see here? So instead of copper here we have to write nickel, so that will be the neutralised nickel. Now one thing also we must look we cannot ignore that because of this we have here this H2O and that will be slated into hydroxyl ion which is negative and hydrogen ion which will be positive.

Now this hydrogen can create some kind of problem in the coating of nickel, the reason is as follows if we see this illustration then this along with this nickel ion hydrogen we will also collect here and this hydrogen can be trapped at this point. So there we must have sufficient arrangement, good waiting agent, so that this hydrogen can be removed and this waiting agent will create a surface for immediate absorption of nickel ion and not the hydrogen ion.

So if for unfortunate eventuality hydrogen gets in, we may not get a structure desirable structure and it is going to be the global form with entrapment of hydrogen and that type coating cannot be useful surface will be very rough, it will be hollow, it will lack strength and all other mechanical qualities. So there we have to pay attention.

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Mechanism of Coating Formation

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Now mechanism of coating formation, the mechanism of coating formation what we can see?

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Growth Mechanism

Layer Growth
3D Crsytallite Growth

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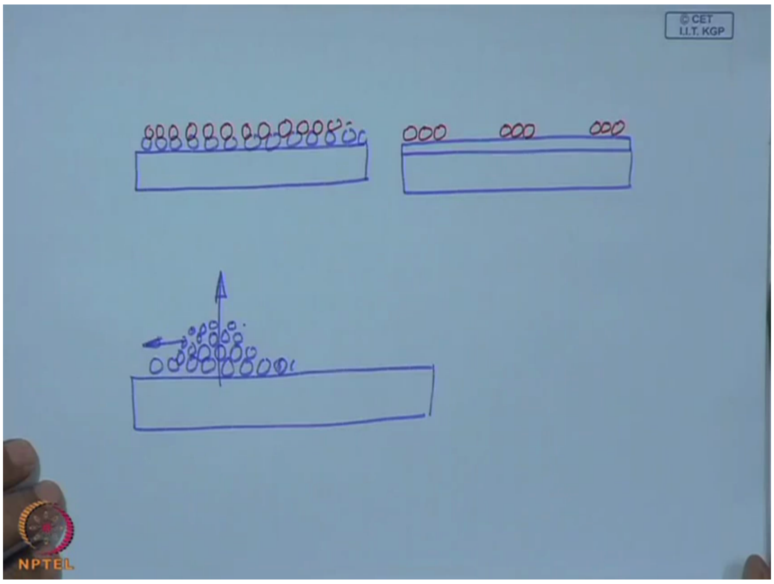

Say for example how this coating is formed? Now it can be just like one layer formation. So if we have the substrate, now here we have first layer which gets absorbed on this for example and over that another layer will keep on growing of the same metal. So another layer will keep on growing like this, it is layer by layer this growth and it can be also in discrete position.

It can be so that we have a continuous layer the first layer of atom which we have shown here and we have say over this, we have little bit here, little bit here too that is also possible. So this is called layer by layer growth but it is also possible to have 3-D Crystallite growth that means three-dimensional growth that means every direction and it will be we can illustrate it like this.

So this is the substrate surface and we have say growth like this. Now what we have? We have a growth in this direction and like this also it is growing. So that means as it is going on this side it is also growing that means it is the vertical direction growth and it is also lateral direction growth, this way also it can grow.

So these are the 2 ways it can grow but obviously if we like to have uniform growth then definitely it should be uniform growth add-on process not just selective sites where this add-on will keep on going. In that case we cannot get a uniform coating but we may end up with some out growth at different locations, so this is one has to consider.

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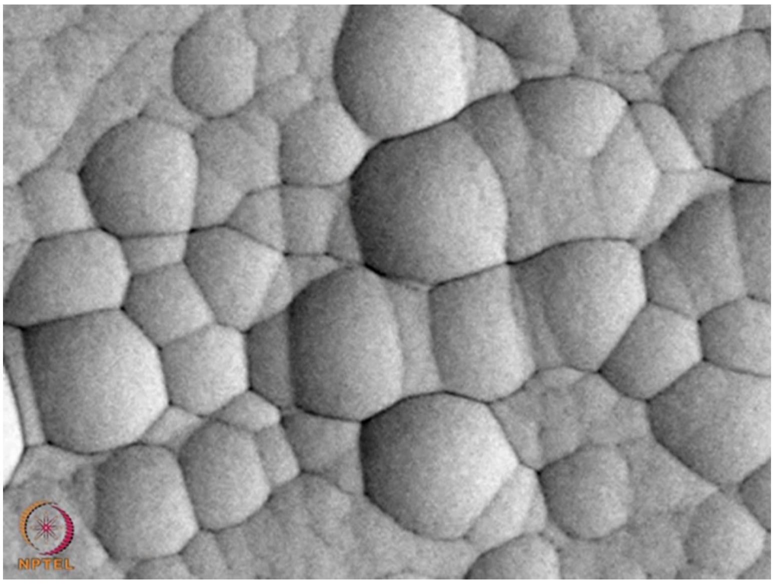

Now this is one example how this coating grows. So ultimately this is the top layer, so if we consider this is the top layer, one thing we have to see it is actually spear like. So we can illustrate this point here.

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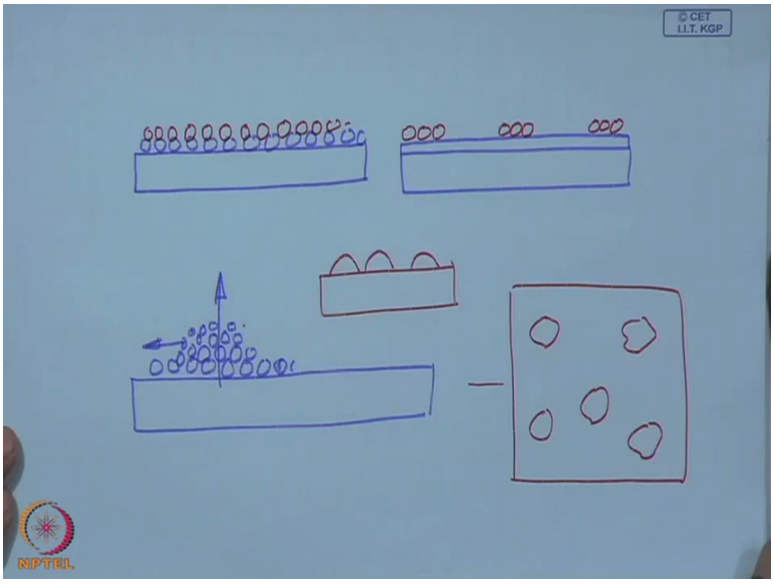

So if we consider this is a surface, so on this surface we have some formation in some sites. So these are the preferable sites and ultimately this will grow and get jointed. So it was originally small but it will keep on growing because this is already embryo is formed and finally what is going to happen?

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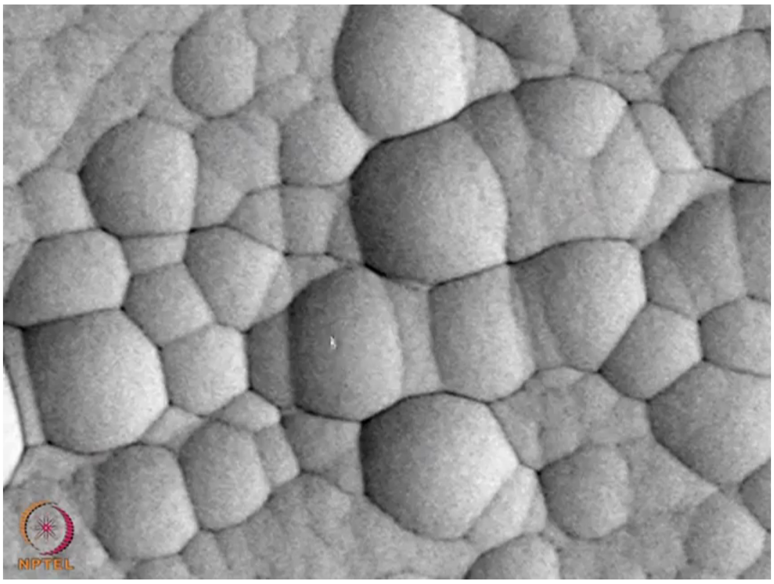

Just what we see here, it was originally rather small and it is growing and another is coming from this side and they are jointed. However during this joining process, we have a lot of surface defects and flaws for example this is one pore, so with such we have I mean so many pores it can be easily detectable without any difficulty and here we can say it is almost like a sphere like thing and we understand this is just not like a wetted surface.

When it is a wetted surface properly wetted, we should have a flat but is almost coming like the global, so here we can show on this surface, so it is almost coming like a global and it is not very waiting in nature. So these are the things one has to also looking that how to get a coating with a better uniformity better flatness and also good surface finish.

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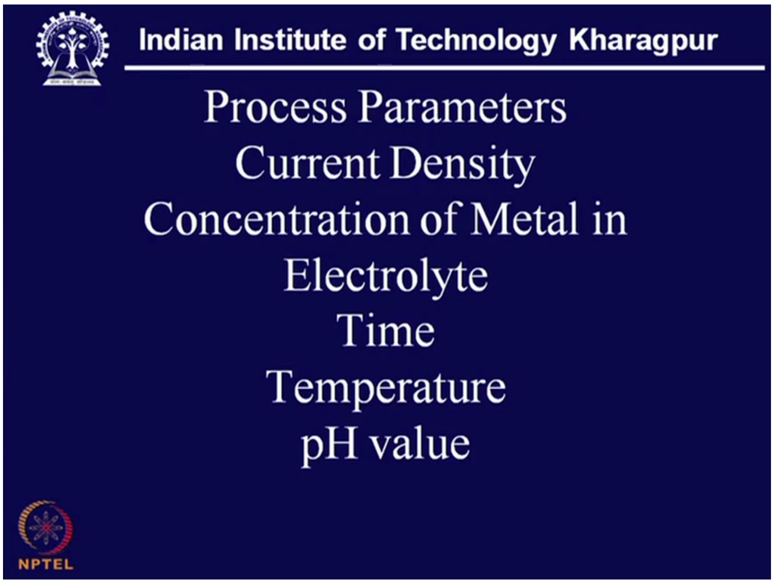

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Process Parameters
Current Density
Concentration of Metal in Electrolyte
Time
Temperature
pH value

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Now one thing we have to also look, that what are the process parameters of this electro plating technology. Now here one is definitely the current density, current density means on the electrode surface this current is collecting and the area over which so much of amperage is supplied that gives the current density. So par you need the area, what is the current density?

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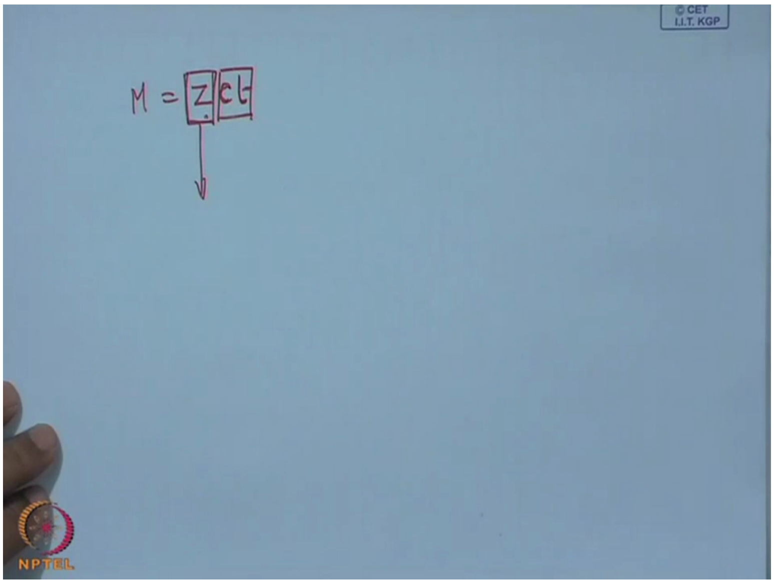

$$M = \boxed{z}\,\boxed{ct}$$

Because it is simply the material deposition that will be given by this is this according to Faraday’s law of electrolysis that will be given by z into ct and that is we call it electrochemical equivalent and then this is actually the current c and this is the time. So this c into t that is the electric charge and this is called the electrochemical equivalent and this is the characteristics of a particular material.

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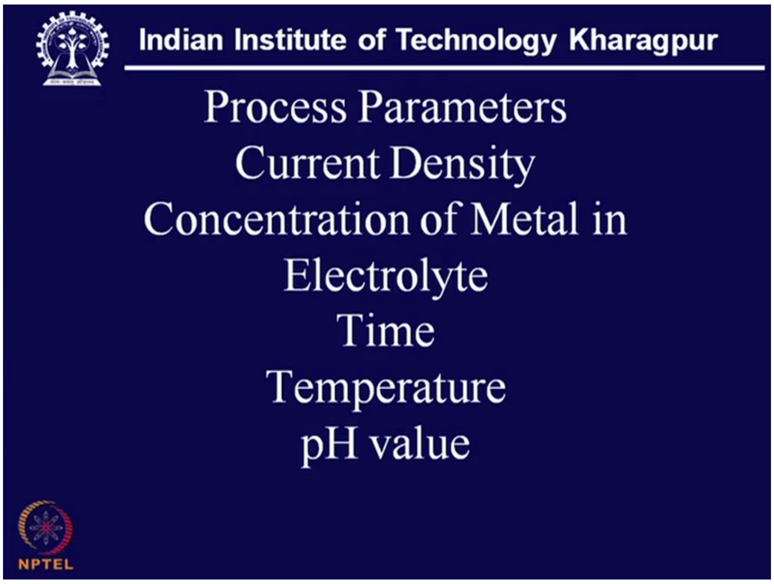

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Process Parameters
Current Density
Concentration of Metal in Electrolyte
Time
Temperature
pH value

So here par unit area the current density that is definitely one of the determining factor then comes the concentration of metal in that electrolyte that means it is mostly acidulated acidic solution or alkaline solution but if it is acidic solution say we at H2So4 to have increased the conductivity of this particular solution and in that how much material has been added per litre.

Say for example that is going to be another issue that means the rate of growth that depends upon the concentration of the salt say sodium, nickel sulphate or copper sulphate or nickel chloride. So that strength of that solution that is also one of the parameter then time function definitely if you're interested in the growth rate it is also the time function with what time, what is the thickness of this coating? That's what we are interested in.

Then comes the PI value, definitely it is actually whether it is acidic or it is a alkalinity of the solution that is also influencing the deposition rate and this one routinely look into that then also temperature little bit variation one can expect with the temperature. However the thing is that plating the versatility of the plating is because of its very low temperature deposition this capability that makes these processes very versatile. So this way one can look into the various properties that which can be controlled by controlling this process parameter.

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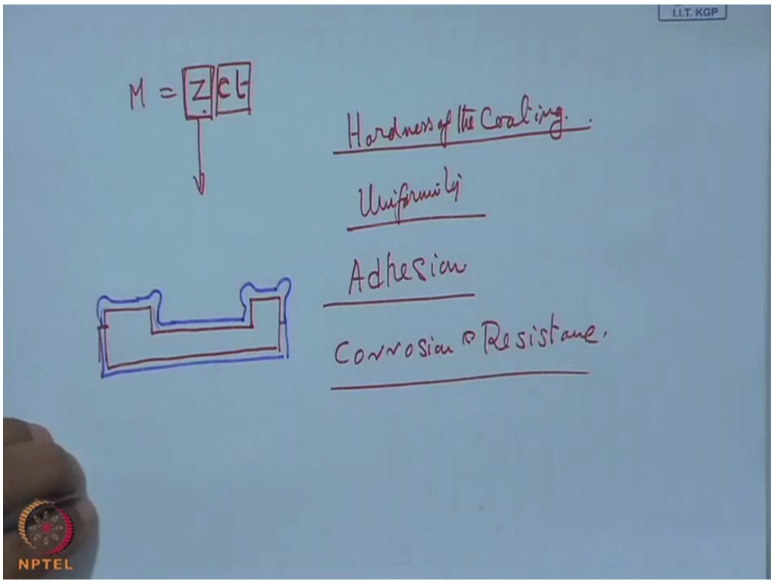

Now what are those properties one has to look in? Let us see number one, hardness of the coating this is one, uniformity, adhesion then of course corrosion resistance. So simply one would expect this thing to be properly controlled hardness of the coating means where resistance of the coating corrosion resistance and uniformity of the deposition, it is also one of these aspects one cannot ignore that suppose if we have such a thing and we like to have and say this side, this side we put a lacquer to make it passive.

Now we expect this coating to deposit on the surface, so this is the area where we expect this coating to deposit; now what we may expect? It will be something like this because of this sharp edge. So this is going to be something of this nature, so it is a non-uniform deposit and this is unlike of any PVD, CVD process. So here because of this sharp point we have large current density.

What we have shown here? This large current density and accordingly we may end up with such thing. So this is one point, one should look into that this uniformity of the thickness. Now so far adhesion is concerned, this is also one issue how to prepare the substrate? So here also just like the PVD process we should be extremely careful in the preparation of the surface number 1, it is just not a chemical reaction but it is physically attached to the surface.

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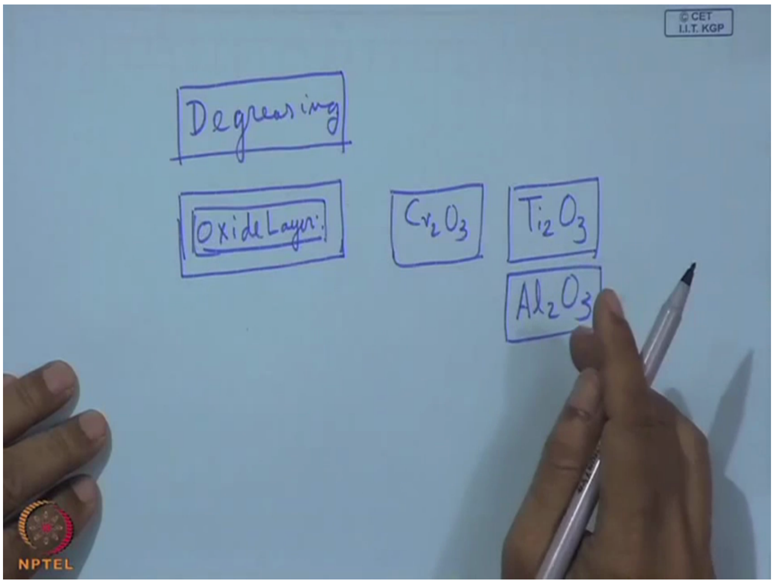

So substrate surface what we need? Say degreasing, so degreasing, so by alkaline solution we must degrease the surface then it should be treatment with some acid, so pickling bath that means it is oxide layer to be removed that has to be removed and these are the 2 basic things one has to achieve to get a virgin surface to get a reasonable attachment with this particular surface. So these are the some key points in the preparation of the surface if one has to get a good coating.

Say for example on stainless steel it will not be a very easy task because of the reason on the stainless steel it is Cr2o3 for example and then deposition will be extremely difficult say if we have some titanium alloys it can be also Ti2o3, if it contains aluminium then also it can be Al2o3, so this if it is present in some atomic level then this will become a non waiting surface and we will end up with this global formation.

However in certain cases these coatings, these oxides are not continuously formed, so it is partially ruptured and that’s why it is also possible to have some kind of galvanic deposition even on these 2 surfaces.

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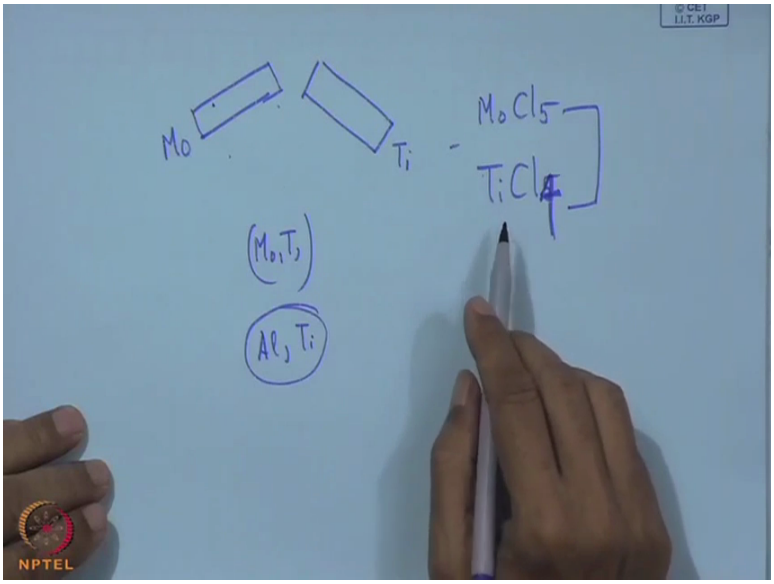

Now co electoral deposition, co electoral deposition means say for example we like to deposit say we can give this example say when it is spattering we can have 2 targets, so it is actually 2 targets for spattering say Molybdenum and Titanium, so with 2 targets we can have Molybdenum and Titanium or it can be Aluminium, Titanium co-deposition is possible. Even say by CVD we can have MoCl5 and TiCl5 but can be TiCl4 tetrachloride what can be brought to the reactor we can add something more and with that we can have co-deposition of this coating over the substrate surface, so that is not uncommon.

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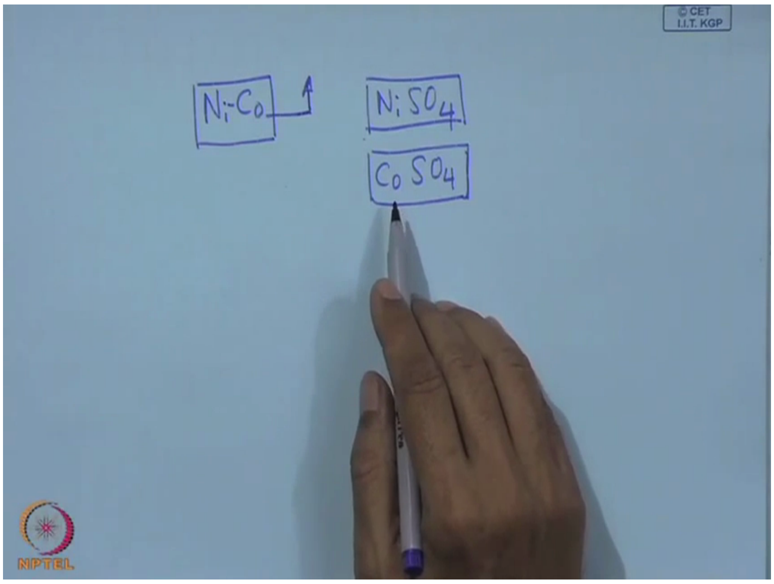

So in this case say for example nickel and cobalt, so there is one very promising pair and we find immediate use in industry because of the elevated, augmented capability given by cobalt. So this cobalt actually increases the surface property in terms of hardness, resistance to scratching strength also. So in that case the reasonable thing would be to have NiSo4 nickel sulphate and CoSo4, so these are the 2 salts which can be put in the electrolyte solution and then we can have a co-deposition of this thing and there can be other combinations also.

So wherever we find a combination that will be useful and when there really compatible than this co-electrodeposition that is also possible and in that case definitely this current density, voltage across the electrode than the temperature these are the few things definitely that will affect the deposition rate or the composition of this one.

So it depends upon the definitely the electrochemical equivalent of nickel and cobalt and also their respective concentration and accordingly we have the deposit with certain variation in their percentage but in principle co deposition by this galvanic technique that is also possible.

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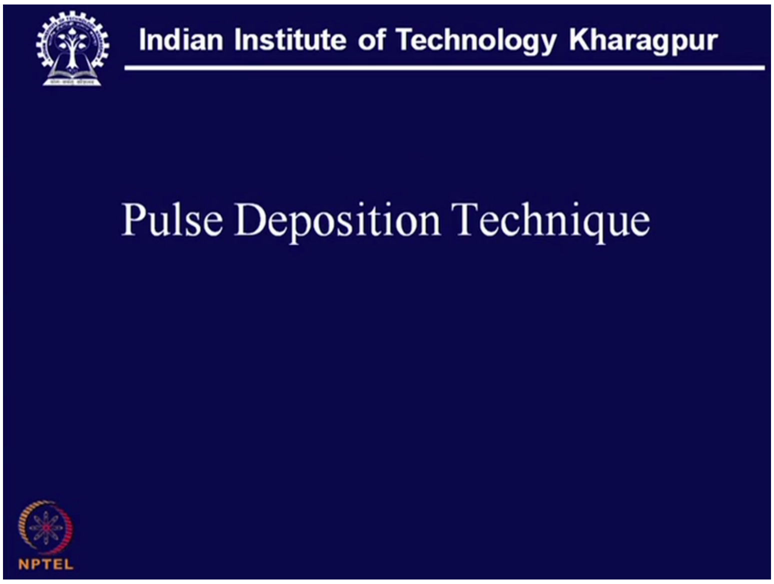

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Pulse Deposition Technique

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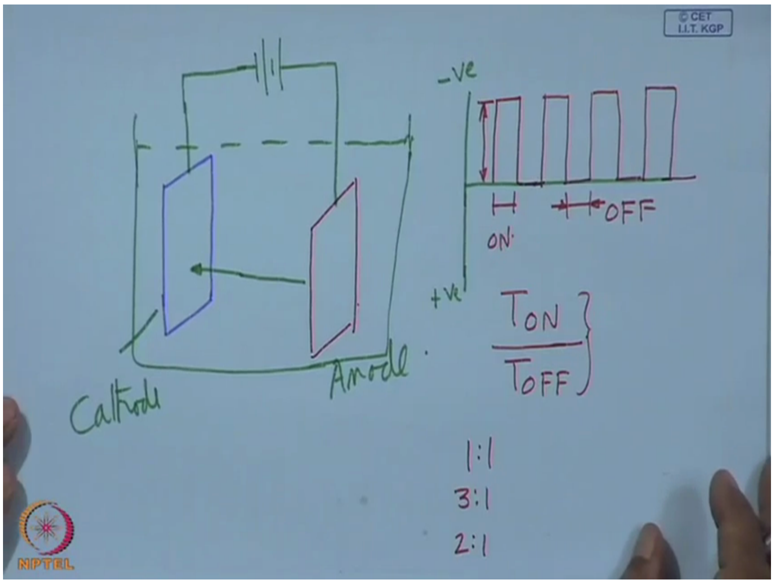

Now think very interesting and important that we call pulse deposition technique, so what is this pulse deposition technique? If we have seen this electroplating then say this say is the cathode and here we have one anode and the whole thing that is put inside in electrolytic tank, so this is normally the connection cathode, this is anode. So this is actually covered in one electrolytic tank.

Now obviously here we have the electrolyte which is filled with this and hear continuous migration and deposition on this site, so this is because this is cathode but what can be done in a very intelligent way that we can have a pulsing? Now this pulsing means this process is actually interrupted, so we intentionally interrupt this process and this can be explained this way, say this is actually say voltage or current distribution and that is negative and this side is positive and what we have?

We have a pulsation like this; it can be something like this it goes on, now this is just by way of illustration. Here what we see? 2 issues are there that means what is the level of this voltage or current which is negatively polarised? So this is actually the cathode voltage, so this is the cathode voltage and this is over a period of time, what we call ON? So this is ON and here this is actually OF time OF time.

So we can say it is T oN and T oFF by this interruption, what we see? That this material which is deposited sometime this unwanted or the coating sometimes there is some contamination or oxidation that can be removed or interrupted an in principle we can recall this pulse DC type supply in spattering thereby this positive we clean the target that means the target is cleaned by this positive pulsing.

Similarly what we do? This is one way of doing, so here it is on and off time that one has to find out it can be 1 is to 1, it can be 3 is to 1, it can be even 2 is to 1 on and off type.

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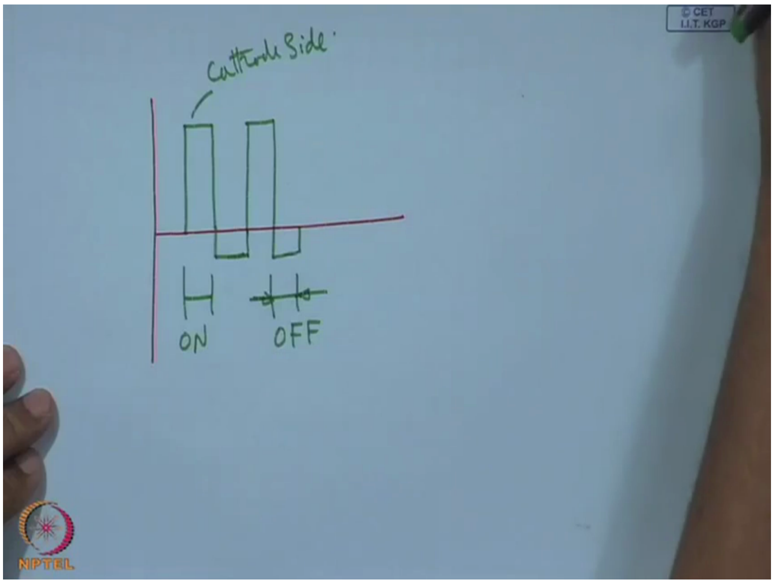

However we can do further to this, further illustration is possible just by having a variation here, so this is negative that means on the cathode side and we can give little bit on the positive side and then again it is negative and this is positive, what we mean by negative? It is actually on the cathode side. So let us say it is on the cathode side, so cathode is this we consider negative.

So cathode is negatively polarised for this period of time ON, that we call ON and then it is positively polarised that we call OFF period. So that means what we see in this case? The processes just not stop, the processes not stop but what has been done in this case? It is rather it is now; this cathode is now used working like one anode.

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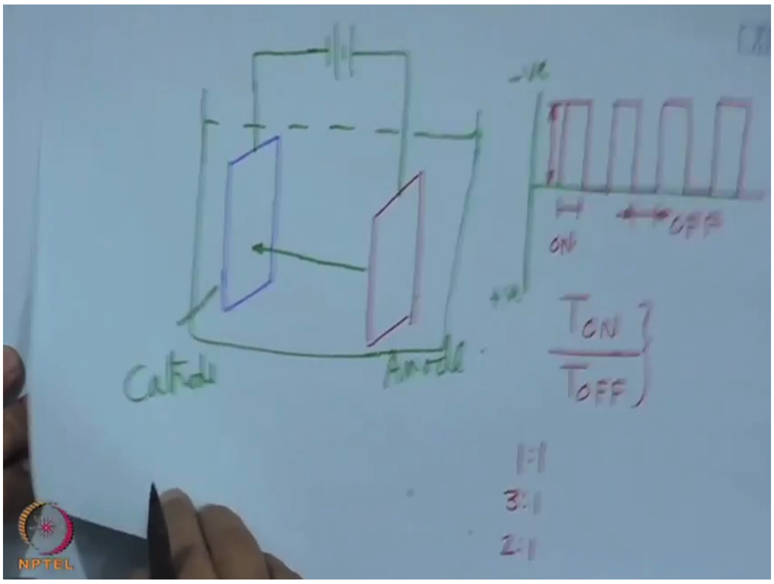

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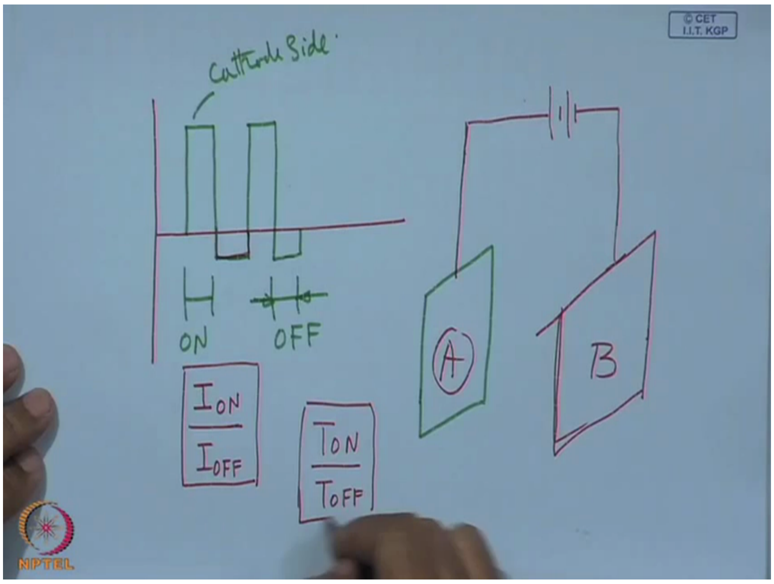

So re-calling this figure if we see is a we can draw immediately another picture, so this which was used as cathode, so now it is no more cathode, so it is polarity is reversed. So with that now is going to be just like one anode. So with that what was going to happen? That this material will be sometimes dislodged and removed.

So by that process cleaning or removal of the contaminated material or sometimes if there is some oxidation or removal of this entrapped hydrogen listing will be possible by this particular process and here 2 issues are there that means this current that means current during this ON period and this OFF, so this is one of the parameter that means how much we have to have this positive side of this cycle of this curve on this side?

That means cathode will be positively polarised and here this plate, say this is plate A and plate B, plate A is acting like cathode for this period here we have little bit on the other side, so it is working like anode here. So this T ON and T OFF that is one of the parameter and this is I ON and I OFF that is the current and also T ON by T OFF.

Now it is also reported that by this process of this pulsing technology it is possible to have remarkable improvement in the quality of the coating, this nickel coating or nickel cobalt coating's or similar materials which has all the required properties as a metal but when it comes like a deposit there we lose their property as they have already mentioned that a pora structure with hydrogen embrittlement, we have non-uniformity, we have a global formation, lot of imperfections are incorporated and last but not the least, enlargement of the grain.

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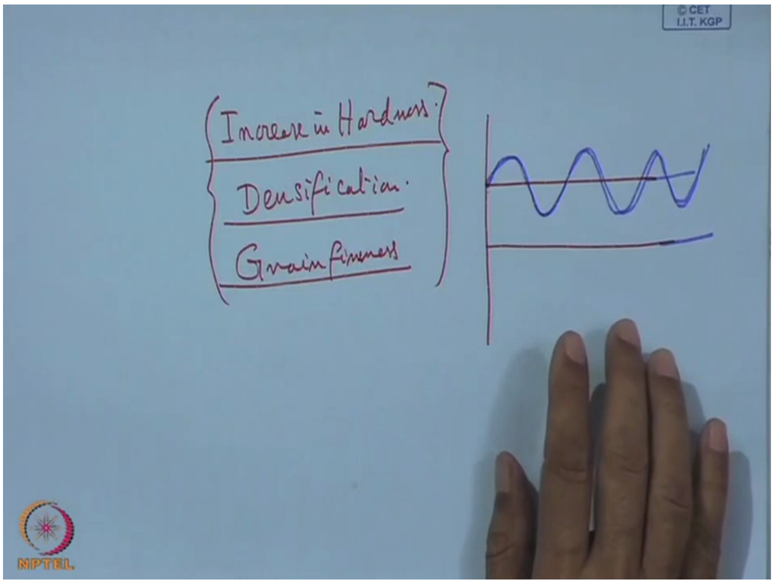

So it looks like all discrete materials are put together with lot of air pocket in between, now to get rid of that if we have this pulsing, in that case what we have seen? Increase in its hardness, Densification, Grain fineness, so these are the immediate things one can look into also improvement in adhesion.

So this is one of the upcoming technology, so people are more interested in looking into various aspects of this thing and to get one of the optimum value with this pulse frequency and in certain case also there has been some attempt that normally if we consider this is a DC from the cathode side over that also one AC can be superimposed, so this is a DC over that it can be like this.

So finally what we get? It is actually this is the, so that means this voltage is continuously changing and by that change some results, good results are expected. So a DC biased with a sinusoidal AC which is superimposed over this polarised biased DC that is also being used for this pulse deposition mode.

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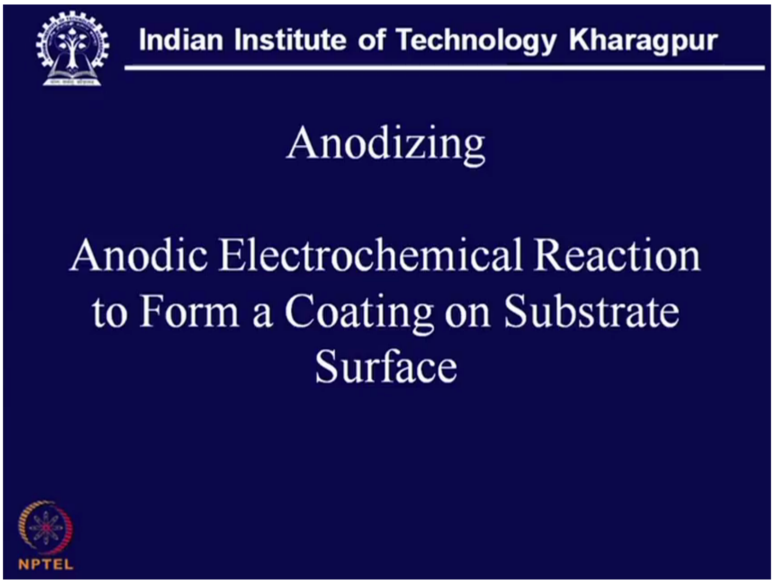

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Anodizing

Anodic Electrochemical Reaction to Form a Coating on Substrate Surface

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Now we have to consider this anodising, in fact anodising means it is actually what we call electrochemical dissolution? That means the reaction on the anode side that is not add on the material is being continuously donated and anode will lose its mass that’s what we understand but here anodising means it is also a surface modification process. So in this case we don’t have a cathode to accept anything, so it will be a passive cathode, so it doesn’t interact with anything within the electrolytic tank or the container but it is actually the anode which is going to be attacked or affected.

Now the whole purpose here is to have a surface modification, now we have surface change in surface property or surface characteristics. What so far we have seen by this galvanic deposition? It is an add-on process but when it is anodising that means it is also a reaction on the anode side and it is just not electrochemical dissolution. It will not be continued or it will not be allowed before that the whole reaction will stop.

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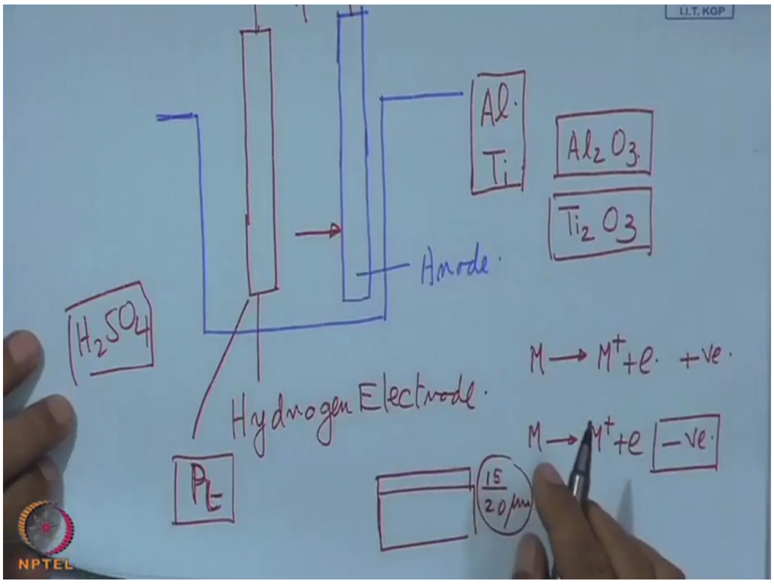

So let us look into this basic principle, say this is one electroplating bath and here we have one anode it may be a rod circular or plate form, so that is anode and on this side what we have that we call, this is called hydrogen electrode that means its potential that means this electrochemical potential of this one that is at 0.

This we know that materials can be arranged according to their electrochemical potential and the electro chemical potential with high negative value means materials are anodic in nature that means they are prone to this anodic action and the materials with high electrochemical potential that means high-value, those are Cathodic in nature that means they are inert to this reaction and accordingly we have a scale and accordingly we have a scale and on the scale we can see that on the extreme we have all electrode positive element those are anodic in nature that means they have high negative e electrochemical potential.

And on the other extremity we have say gold, palladium like material which are inert to that, that they cannot be used so quickly and they remain unaffected and in that scale in the intermediate, in the central position that is the location of hydrogen and platinum that is actually it's electrochemical potential is actually at the 0 level. So that is a standard electrode that we have to use for measuring the electrochemical potential of any material.

So that means if we see a metal and that goes like this plus e, so this is if it is a that electrode change in electrochemical potential, if it is positive that means it is anodic in nature and it will easily release the electron. So if we have a positive electrochemical potential but if we find a metal and we can write similar thing but here we find it is negative it means that this material is not at all electropositive rather it is electronegative and it is Cathodic in nature that means this material cannot so easily release the electrons.

So this way we find that there are certain materials say for example Aluminium or Titanium these are the metals which needs some kind of attention, and attention means protection against environment or atmosphere. So in this case what is done? We have this aqua solution of H2So4, so that is the electrolyte in this case. So in this case it will be filled with this aqua solution and then what is going to happen?

If we switch on the battery in this case than what we find? That this is going to be anode, so here we have this oxygen that will come in this, in this side and that will try to have anodic action over the surface leading to a formation of this oxide. It can also go with titanium with Ti2o3 but interesting part of the whole thing is that this layer will be immediately passively layer and with this passivity, no further reaction will occur on this side.

So we can very easily get a thickness of say 15 to 20 micron over the surface of this thickness that will become this oxide of Aluminium and that is called the process of anodising and this can be also with some addition of dye in this solution, we can also have some colouration of this anodised film and it can have blue, yellow some kind of colour according to the choice that can be also done. So basically it is forming one passive oxide layer by this anodic action and which makes the thing passive it becomes non-conductor of electricity.

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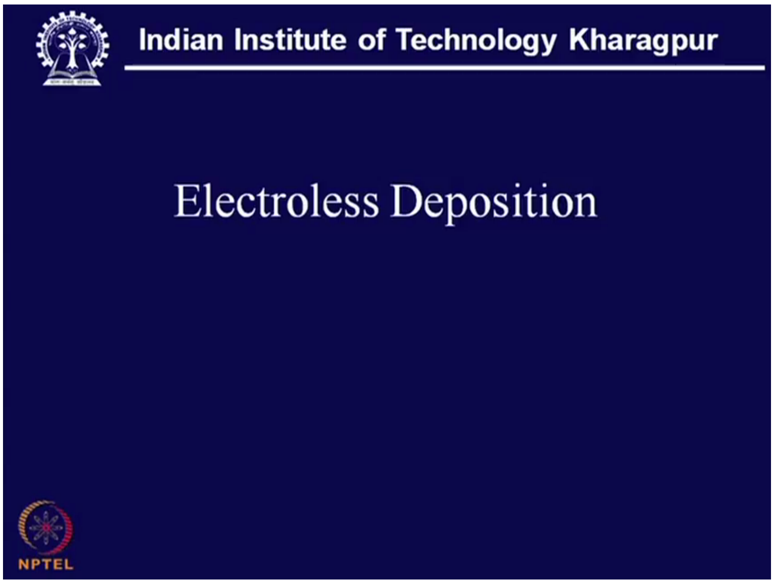

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Electroless Deposition

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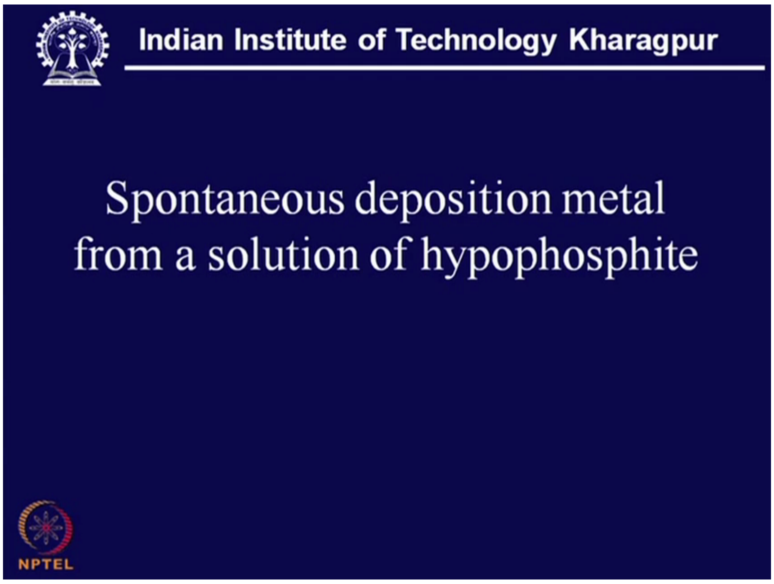

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Spontaneous deposition metal from a solution of hypophosphite

No here we have Electroless deposition, so this Electroless deposition means in simple language it is actually spontaneous the position of metal from a solution of hypophosphite, so what is their speciality?

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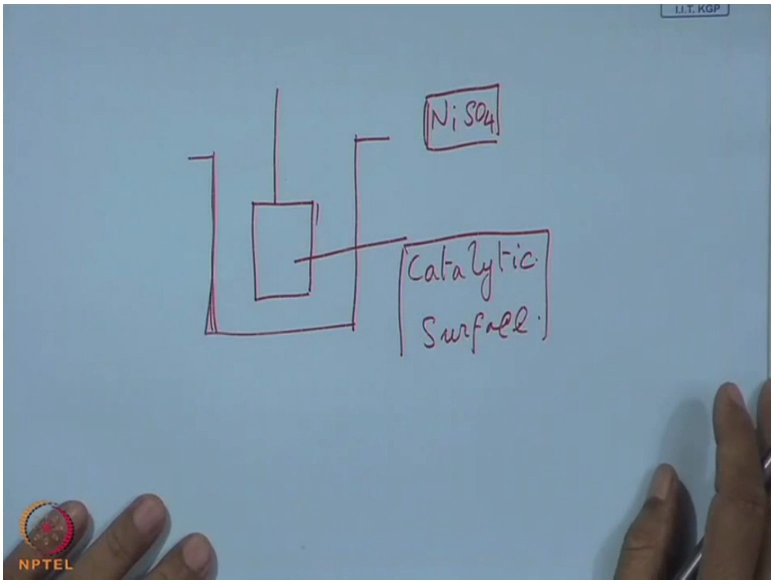

This in the plating tank what we have? We have just one solution of metal and this one here we have that substrate, now this substrate itself the surface will be catalytic. It is called a catalytic surface. So here we don’t have any electrode, no supply of electricity that is necessary and what we have? We have actually said here, we have the nickel sulphate solution or nickel hypophosphite.

So basically it is sodium hypophosphite plus nickel sulphate that is added and this nickel that will be put here but what is? This is actually a reducing agent, so this nickel will be reduced the sulphate and this nickel will be attached to the surface, this will become a wettable surface and by this catalytic action over this. So here what we find?

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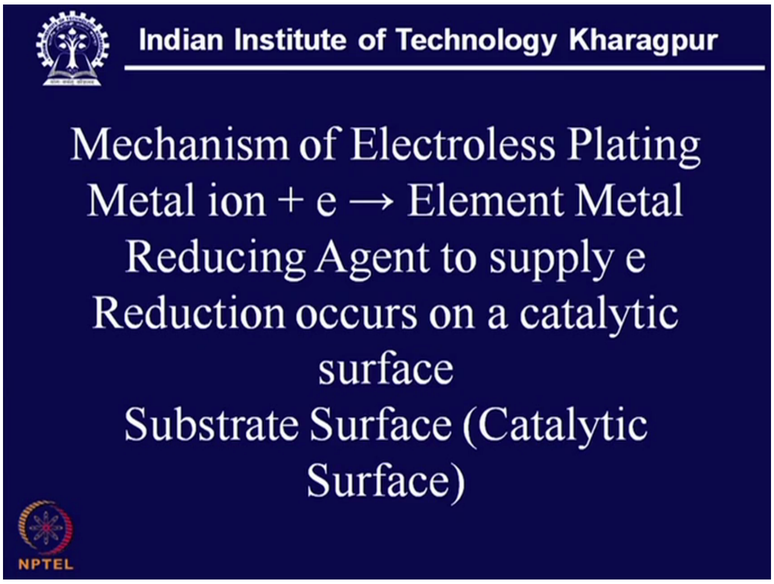

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Mechanism of Electroless Plating

Metal ion + e → Element Metal

Reducing Agent to supply e

Reduction occurs on a catalytic surface

Substrate Surface (Catalytic Surface)

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That mechanism of Electroless plating, we have generation of metal ion and this metal ion will be released neutralised by electron and who will supply this electron that means there is one reducing agent and this hypophosphite that is going to release this electron and by addition of this electron on the surface we get one of the element metal. So what we see here? That metal ion plus electron that gives that means this is reduced by this e electron and we get this metal element. So from this we expect this nickel to come over the surface it can be still very easily it can be handled and reduction occurs on a catalytic surface.

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Advantage over Electrodeposition

So this uncontrolled autocatalytic chemical reduction process this way also we can describe this electro it is autocatalytic, auto adjusted control process. And advantage of this electrodeposition over electro this Electroless over electrodeposition is that in this case we don’t need any electricity, you have a better uniformity of the position, a substrate need not to be conducting and we can have a densification of the coating. So these are the few advantages one can immediately expect from this Electroless. Only one limitation is that the surface of the substrate should be autocatalytic in nature.

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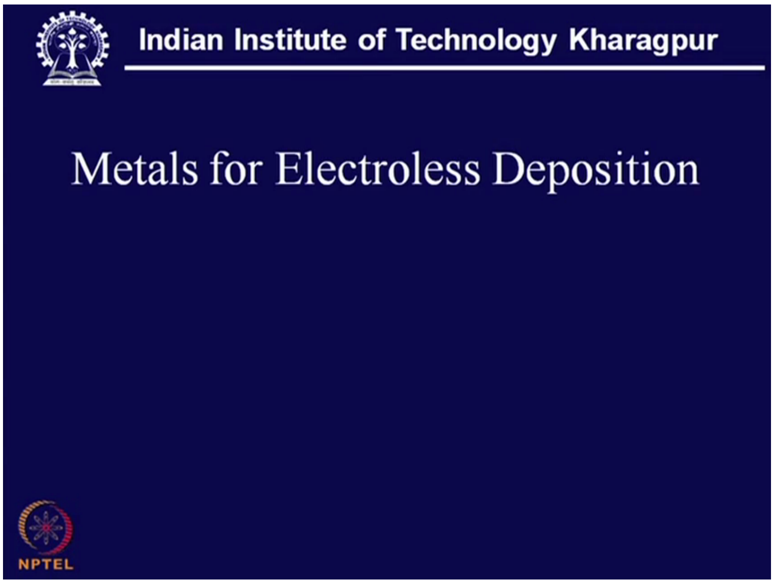

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Metals for Electroless Deposition

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Now metal for Electroless deposition we have all the metals nickel, chromium, Cobalt we can have also silver, copper, gold everything is possible, but what is advantage? Yes, we find along with nickel we have little bit of phosphorus also coming from this hypophosphite and that nickel phosphite that with little percentage of phosphite that adds to the hardness.

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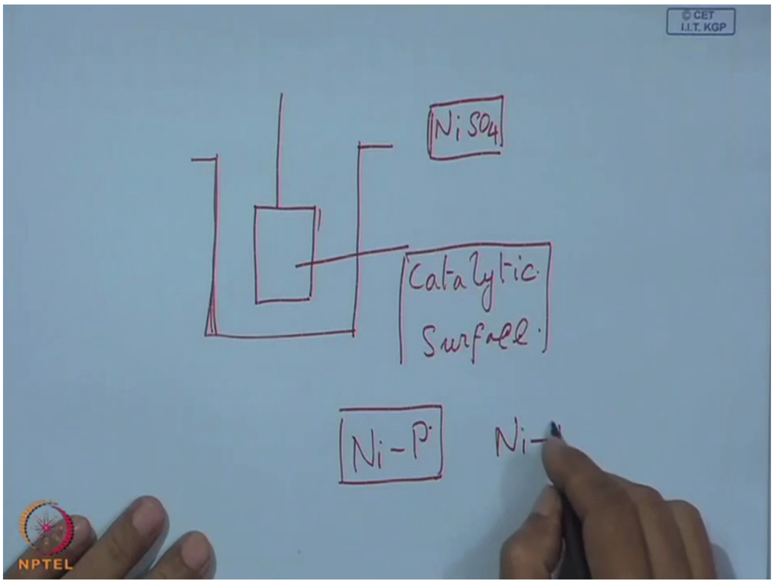

Similarly if we have some this reducing agent continuing Boron, it is not difficult to have also nickel boride and in this case that reducing agent is not a phosphorus containing aliment but it is a Boron containing aliment and as a result we have also Nickel Boride.

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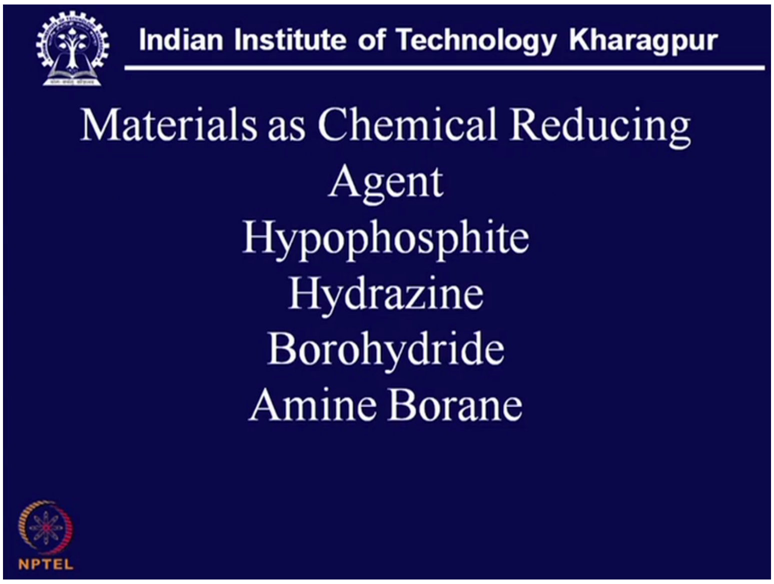

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Materials as Chemical Reducing Agent

Hypophosphite

Hydrazine

Borohydride

Amine Borane

So materials as chemical reducing agent it is hypophosphite that we are mentioned Hydrazine, Borohydride and from that we get this boron for this Nickel Boride. It is also Amine Borane that is also a source of Borane.

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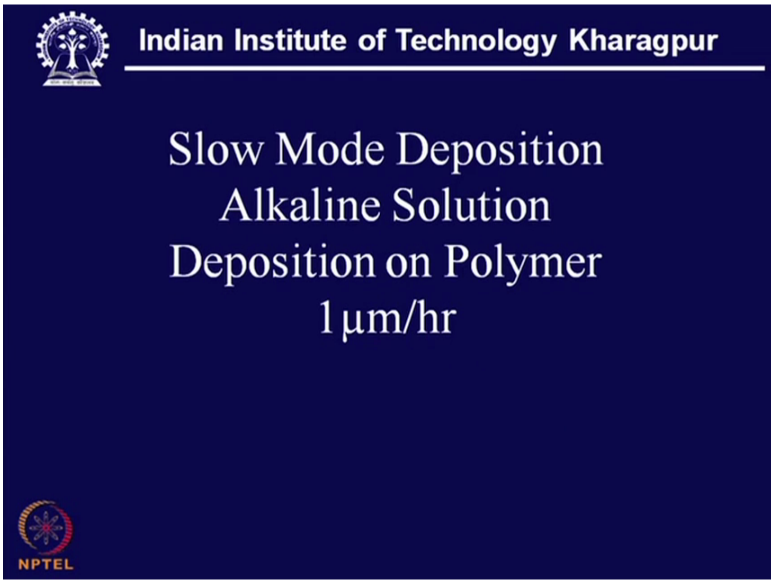

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Slow Mode Deposition

Alkaline Solution

Deposition on Polymer

1 µm/hr

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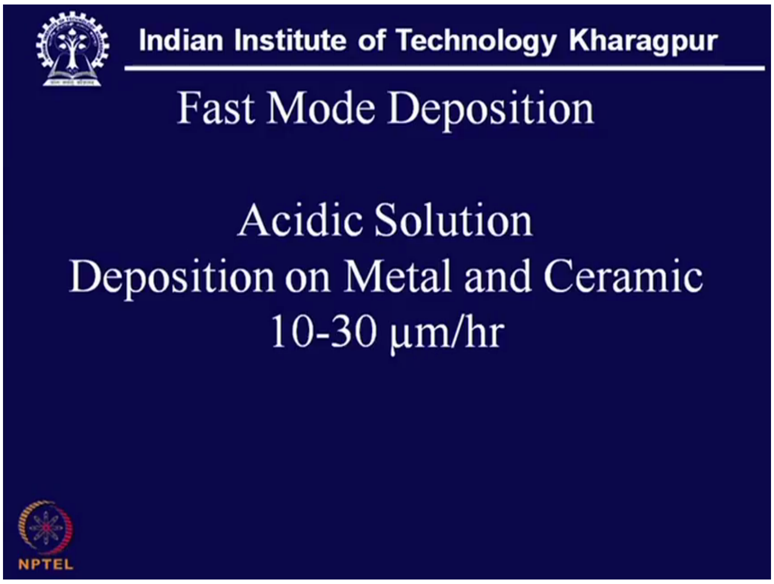

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Fast Mode Deposition

Acidic Solution
Deposition on Metal and Ceramic
10-30 μm/hr

Now we have 2 types of deposition, one is called Slow Mode deposition here the growth rate is about 1 micron per hour and this is one alkaline solution and this alkaline solution that is good for coating on Polymer but when it is a metal or ceramic surface we can go for a faster rate and then the solution is acidic in nature and this 10 to 30 micron per hour that is not a very difficult task.

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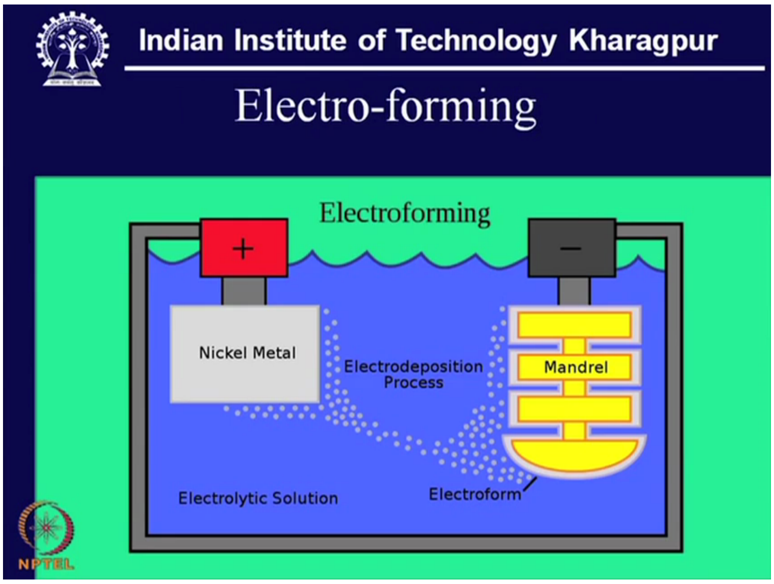

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Electro-forming

Now here we have some examples of Electroforming that means this electrodeposition can be also used for making a form over the substrate and then this Mandrel can be withdrawn and we can have a freestanding shape over this. So this electrodeposition it not just forms only for covering the metal but it is also for getting a freestanding surface.

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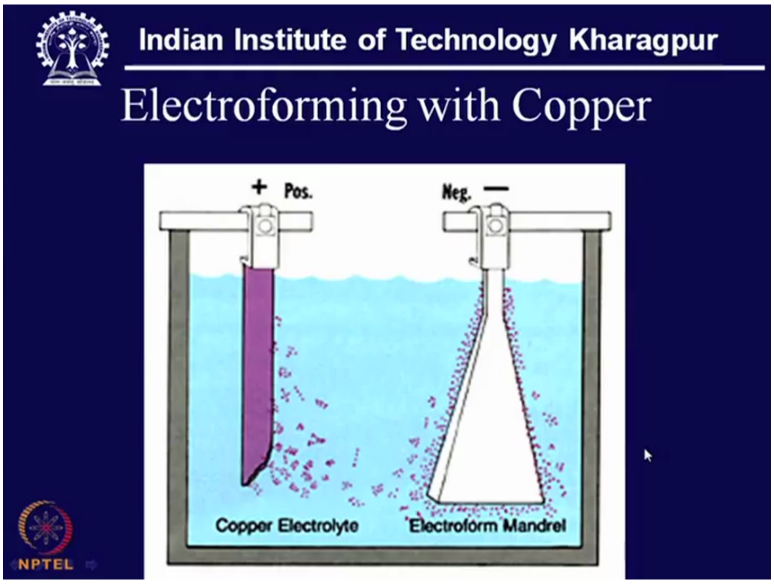

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Electroforming with Copper

So this is also another example with a different shape, it's like a taper and it is deposition on copper that can be also done.

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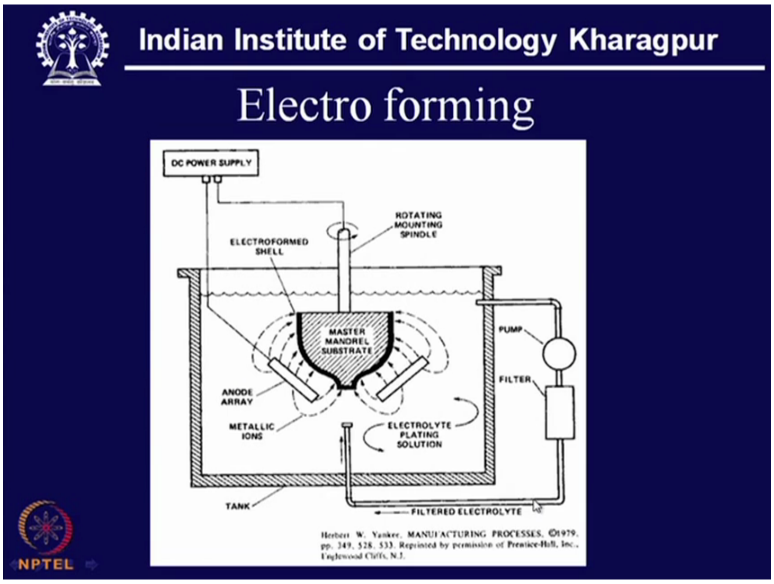

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Electro forming

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This is also industrial application that Electroforming of a vessel having this surface and thereby all this anode array we can have flow of the material and as a result of that weekend get a very uniform surface over this mandrel.

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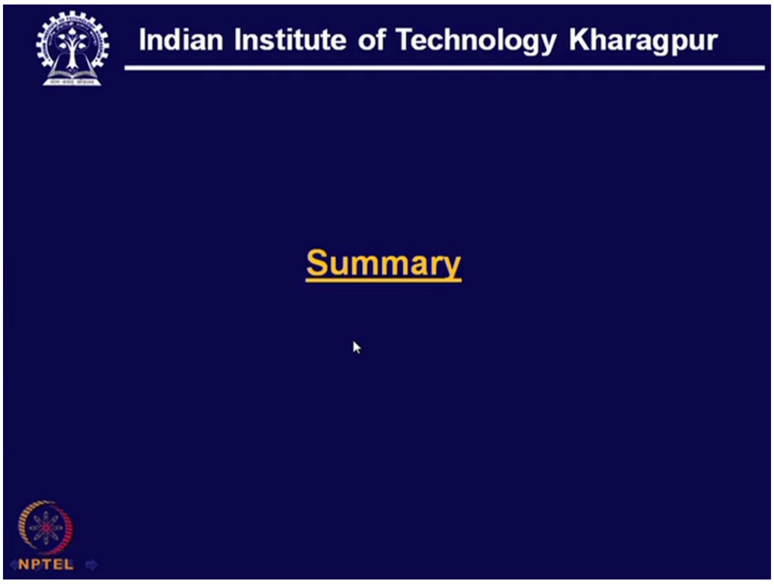

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Summary

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Now, with that we can summarize today’s topic that is Electrodeposition that is based on the Cathodic deposition, Cathodic reaction on the surface of the cathode which is one electrode, and here it accepts the electron and thereby the material is neutralised and it is collected on the cathode surface. So it is actually the acceptor of the metal ion and on anode side this electron is released and that is (()) (57:35) to the cathode side. So thereby this ion that goes into solution of the electrolyte and that is continuously replenished.

Now in Electroless what we see? That in this case we don’t need any electric power or the substrate need not to be conducting but only we need one reducing agent for reducing of the metal salt in the solution and only one condition is imposed that means the substrate surface need to be a self catalytic to have this deposition on that surface and it can be a slow process or a fast process depending upon the substrate and accordingly we can have alkaline solution or a acidic solution.

So this is also possible to have Anodizing the surface by proper surface modification, so we can have a ready passive oxide layer on aluminium or titanium protecting against it for any environmental damage. Now this electrodeposition process can be industrially skilled up to make freestanding shape it is just not on a substrate and this can be used for making various vessels, containers or having different geometries.