Technology of Surface Coating
Professor A.K Chattopadhyay
Department of Mechanical Engineering
Indian Institute of Technology Kharagpur
Lecture 22
Coating of Monolayer Abrasive Grain by Electro Plating

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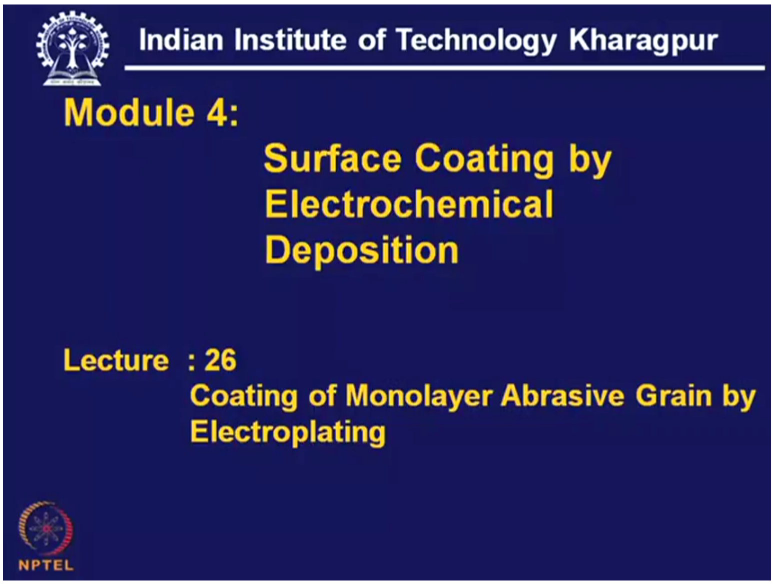

Okay, coating of monolayer abrasive grain by Electro plating and this happens to be a very special application of surface coating by Electro chemical deposition.

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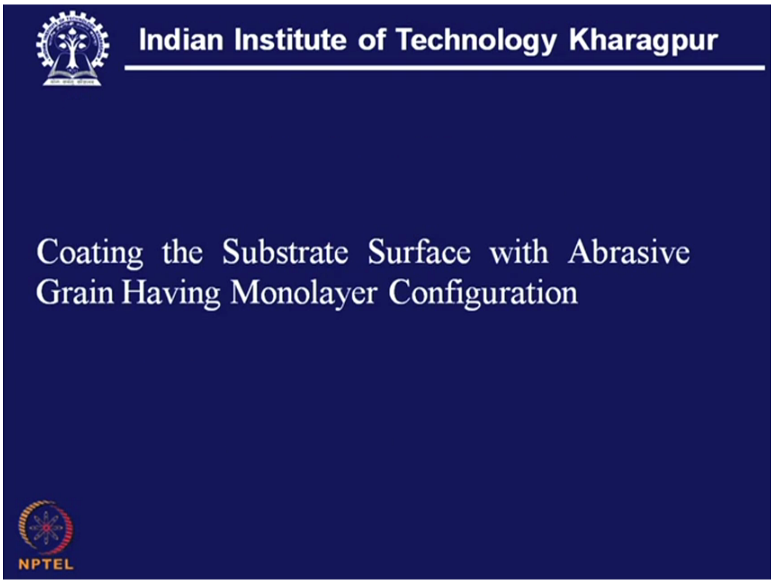

So it exactly means that coating the substrate surface it can be a metal or hard metal or even ceramic and in this case the grains are having a monolayer configuration and these grains will be anchored by an Electro deposited metal around each grain.

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Now the basic requirements come from the application of this abrasive in manufacturing and these abrasives are actually bonded abrasives, so they are held against a metal support with some bonding agent and this is required for the abrasive material in order that it can be very efficient and high performing. Now classically we know that this abrasive grains in order that they can take the task of material removal they are suitably bonded by conventional means and which are metal bond, resin bond or vitreous bond. So these are actually very old ways of doing this bonding to realize a abrasive tool.

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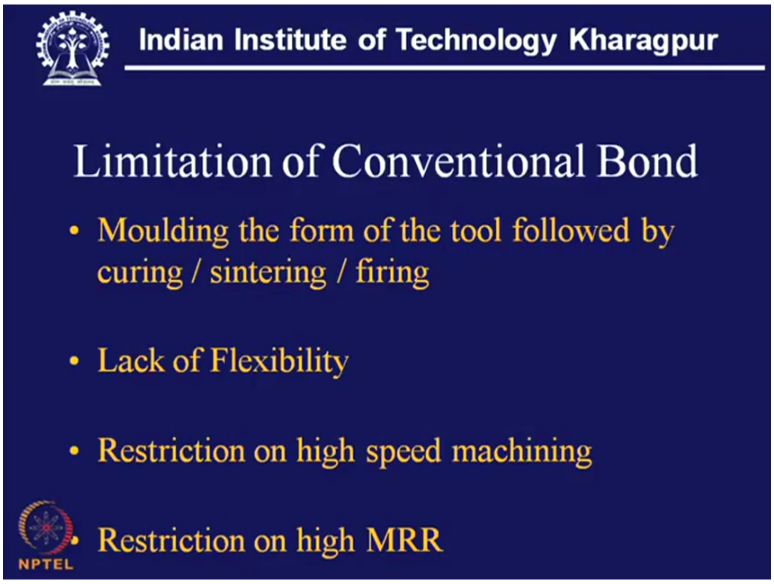

However the conventional bond their limitations are soon realized and these are few which are highlighted here, to make this wheel we need one mould and this moulding gives the shape of the form which should follow this what we call curing or sintering or even firing depending upon whether the bond is resinoid metal or vitreous.

So when we have to use a mould we have no other option than flexibility becomes rather small and this flexibility one can understand in terms of the geometrical flexibility on the wheel surface that means any form on the wheel surface cannot be so easily realized by this moulding process. So shape and size are restricted by this technique, now this particular bond also has some limit in that particularly for high-speed grinding this is true. In particular, for the vitreous bond where the material is brittle in nature and because of the high-speed there is a risk of bursting of the bond and there is restriction on the speed.

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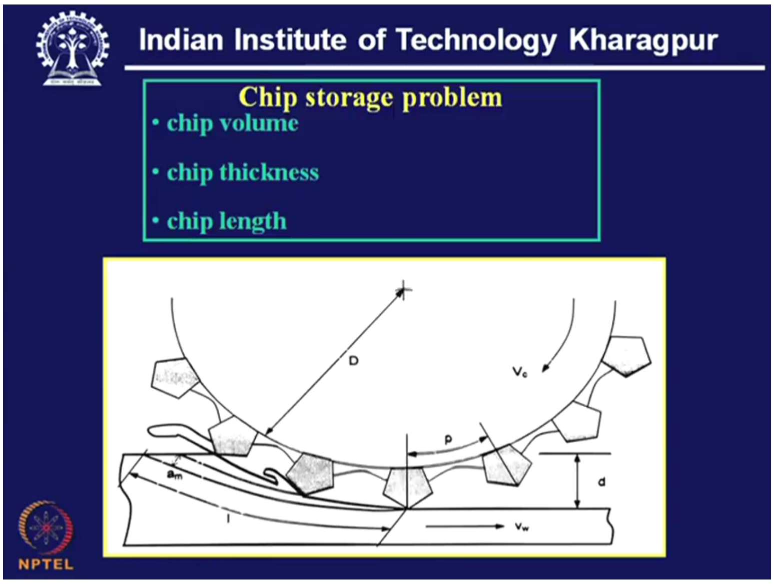

Then we also find restriction on high material removal rate and this can be understandable if we look into this figure. Now here we have the grits which are arranged over a periphery and this is the space available ahead of each grit or the cutting tool and this space must be adequate in order that this volume of chip which is shown here, this volume of chip can be well accommodated and once this chip pocket lips this workspace surface, then it will be thrown out by centrifugal action.

So from this starting point to this termination the material should be held with adequate chip storage problem. Now chip storage problem demand will become quite high when the material removal rate also become quite high, so these are the restrictions imposed by the conventional bond.

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However to overcome this difficulty one can go for a monolayer abrasive tool and it can offer say solution to the (()) (5:36) those problems which are just now highlighted.

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Now there are 2 ways of doing the thing either Electro plating technology or active brazing technology and by adopting one of these either plating or brazing, one can realize this abrasive tool with his monolayer consideration. Now each has its own merits and weakness.

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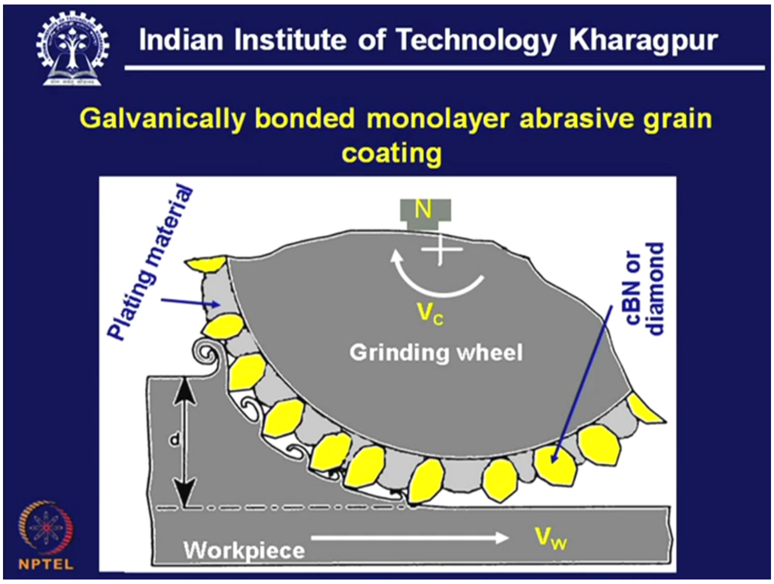

Now if you look to this process of making the wheel, one can see that these grits are actually anchored on this wheel surface which is a metal which is capable of working at a very high speed. So this material of choice is such that its centrifugal its capability to withstand the centrifugal tension or the stress is quite high and it is almost like a material which is chosen for the high-speed rotor of a turbine and this material can be well-suited to make a wheel, the abrasive wheel rotor and over this we have this bonding layer and in the bonding layer these grits are anchored. So this is just like a galvanic or electro plated bond around each crystal.

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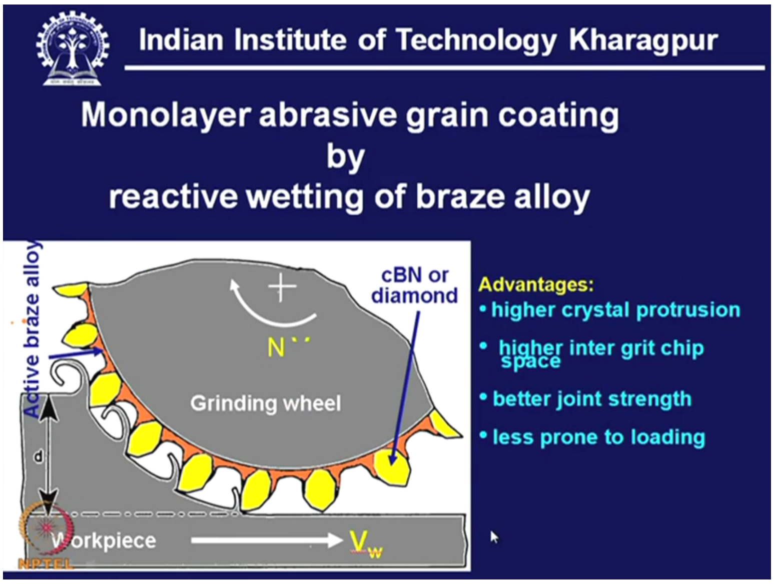

And we can also have a look on this brazed where the material is brazed over the surface. However though it has some of the salient feature and very special advantages which are unmatched by any other technology but still it is not free of limitations.

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And these limitations are number 1; we can immediately see that relatively high processing temperature. Now this high processing temperature means if the size of the wheel is quite large and having some non-symmetry in its geometry then holding the accuracy and precision of the geometry by the post brazing process or even during brazing it will be not a very difficult task and in that the whole brazing cycle has to be controlled with utmost care but still I mean geometrical distortion in the level of futants of Micron that cannot be just ruled out.

So this is going to be one of the major issue which has to be addressed and relative high processing temperature means that can be little bit meteorological damage to the wheel base that means the core material which needs also proper rectification that means grain refinement and some post brazing treatments.

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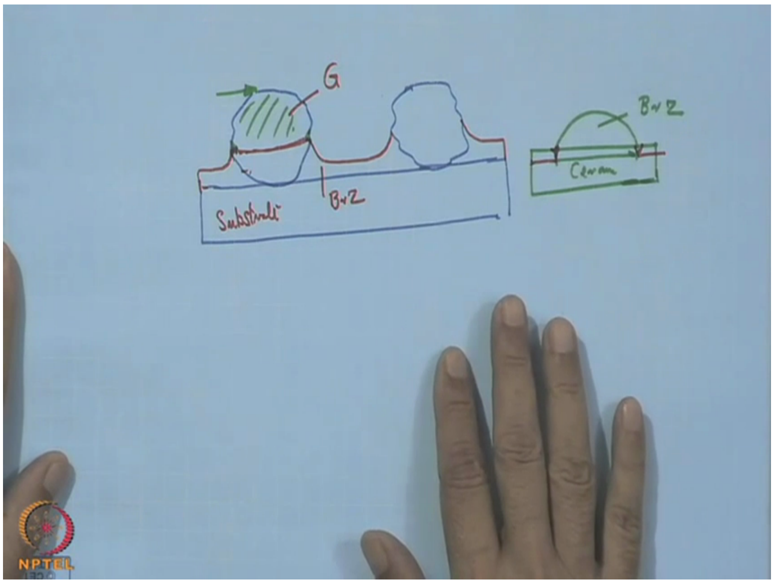

So this is just not free of any problem and then most importantly the thermal residual stress and this is very important issue but as to care for, say it can be illustrate by this simple sketch, this is one grit this is the second one and which are being supported by the substrate material and here we have the braze alloy and these base alloys by waiting effective waiting it will give this shape.

So that is one of the, I mean special feature of the brazing, so this will be actually shrouded, so this area will be covered by the braze alloy. So this part will be covered by the braze alloy and here this part is exposed. Now what happens during cooling of this brazing alloy this is the grit, this is the braze alloy and this is the substrate.

Now during cooling the base alloy because of its high thermal conductivity and thermal coefficient of expansion it will cool at of faster rate and the contraction will be larger in comparison to that of the grit material which can be diamond or cBN and what happens exactly? This material which is covered by the braze alloy that will be under compression occurs of this contraction.

However the portion above that, that will be free and as a result one may find out some kind of track here and this will lead to a disastrous failure and when some force is acting prevalent force than simply this part of the grit that will be separated living this path. So this is not the question of bonding or adhesion problem but this is just like an adhesion problem because of the thermal stress this can be also illustrated by another example.

So if this is the braze alloy and if it is the ceramic then also we see that when it is under solidification process that means after melting it is being solidified, in that case also the portion of the ceramic within this zone that will be under compression, however this part, this part will be under tension it is free, this part and this part as a result we may also find the crack. So this crack and this crack are very similar in nature.

Now why this has been raised? This is simply because of the reason that this is one of the major weakness of brazing and this electroplating as a rescue or come as a solution to this problem. So naturally one can find out that this low-temperature electroplating there is one of the greatest strength or greatest advantage of this Electro plating technique.

So this Electro plating technique will be used just for anchoring the abrasive grain and here comes the question which type of grain? What should be used as the cutting tool for making this abrasive tool? So what are those cutting points? What is the material of this cutting point which is the best suited for this abrasive tool application?

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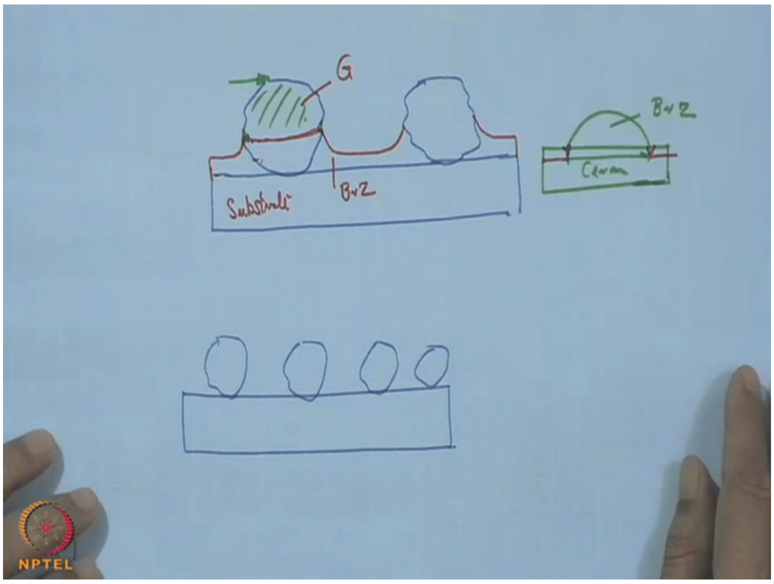

Now as we have already seen that this is going to be one layer configuration, so it is going to be one layer configuration and it is not very similar or identical to conventional wheel where you have more or less of composite mass. So when it is a moulding process or moulding practice, what we take normally it is a mixture uniformly mixed this combination of the Bonn material and the grit material that forms a composite mass.

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So it is a well dispersed mass of the structure but in this case it is a single layer formation. Now when it is a composite mass, it is not the abrasive wear resistance there is not a big issue because of the simple reason Aluminium Oxide, it is known Aluminium Oxide is inferior to Cubic Boron Nitride or Silicon nitride, Silicon Carbide is also inferior to diamond, so far as grinding ratio is concerned or wear resistance.

However when it is a composite structure, if one grain is worn out then there are several hundreds or thousands of grains which are within this composite body that will appear and that will start grinding action.

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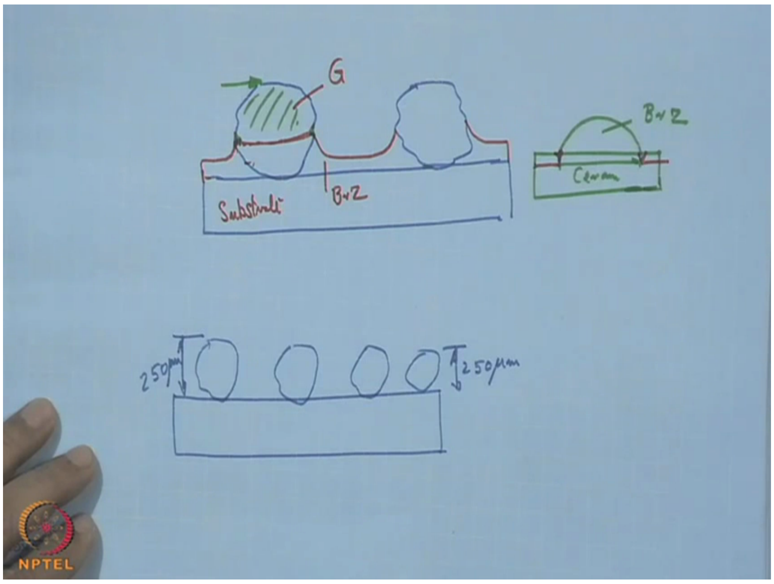

However this will not happen in case of a single layer configuration. It is only one layer, if say this grit is 250 micron quarter of a millimetre in size, average size and this 250 micron has to work without fail and reasonably and adequately to the satisfaction of the user and over this period a large amount of material has to be removed without damage or fall out of the grit that is the most important criteria that this grit should not have any kind of premature dislodgement or breakage and at the same time we must have adequate surface roughness I mean the surface finish and also the accuracy level on the work piece.

So all these we expect from this one layer configuration of the grit and in that case this electroplating will be one of the solutions. So considering this one layer configuration, one layer arrangement it is obvious that the grit material with higher grinding ratio should be obvious choice that's why this Aluminium oxide or silicon carbide they are not the first choice rather diamond and cubic boron nitride that means this cBN, these are the material of choice for this single layer configuration and we know that cubic boron nitride that is tailored it is a man-made material and that is tailored for all sort of high alloy steel, heat treated steel and very special alloy which are otherwise cannot be processed by grinding or machining.

Whereas we also know that diamond is one of the remarkable for grinding the nonferrous family of metal, it is metal metric composite or metal ceramic composite or even ceramic as such. So these are the 2, I mean member of the super abrasive family and they can be well used in the single layer tool, cBN and diamond.

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So it is the preference of super abrasive in Electro deposited metal bond just we have discussed this point.

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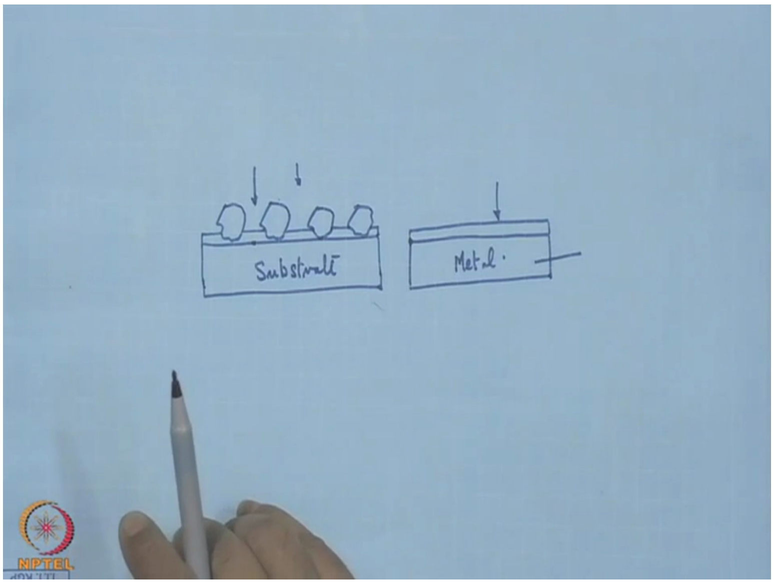

Now requirement of the abrasive material, now this material one point we should consider that this material is going to be in the metal bond and this metal bond is an Electro deposited bond that means this material of the substrate that should be electrically conducting the substrate material.

Substrate material should be electrically conducting an contact these grits will be placed or positioned or they will rest. So this is the arrangement one has to make and then what happens, this will be electrically polarised and then this metal ion which will be produced during this Electrolysis and this Electro chemical reaction this ion will be attracted on this side of the substrate.

And there they will be neutralised and become metallic in nature and this metal will build up around the grit and it should be reminded in clear terms that should not be, not even a single particle of this Electro deposited material that should arrive or deposit or it should not be collected on the surface then the whole purpose of Electroplating is lost. So when we say it is Electro plating, it is not exactly electroplating in conventional terms.

We know Electro plating that means here we have a metal and on this metal we have to put coating of another material to augment this surface and that we know and when it is electrically polarised we have cathode, anode combination and there is one electrolytic bath, electrolyte is there, so which should be a metal salt and then through this process of electrochemical reaction finally the metal ion will be collected on the substrate which should serve as a cathode, so this is electroplating, direct electroplating.

But here electroplating means, we have the electroplating in and around the abrasive grits which are non-conductor of electricity. So one condition that has to be fulfilled there has to be met that this material cannot have any kind of connectivity over their surface. However this may not always happen and that is one of the point one should remember. Now this happens because of 2 reasons.

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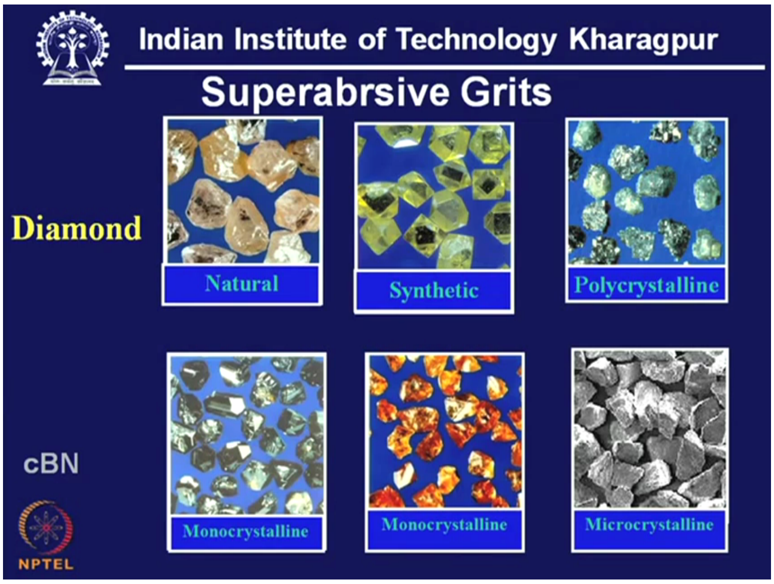

Here we see the super abrasive grit, look this is a natural diamond and it is mine diamond. So from the mine the non-gem quality of diamond that is separated and then through this use of the crushing technology they are properly screened and sized but each grit has a multifaceted appearance. Basically it's a fractured surface but then there may be some post crushing, polishing process which can little smoothen the surface.

But basically when it is a crushing we have a multifaceted surface by this what we mean? That we have several cutting points already available on this grit and at the same time this rough surface helps in Anchorage of the grit.

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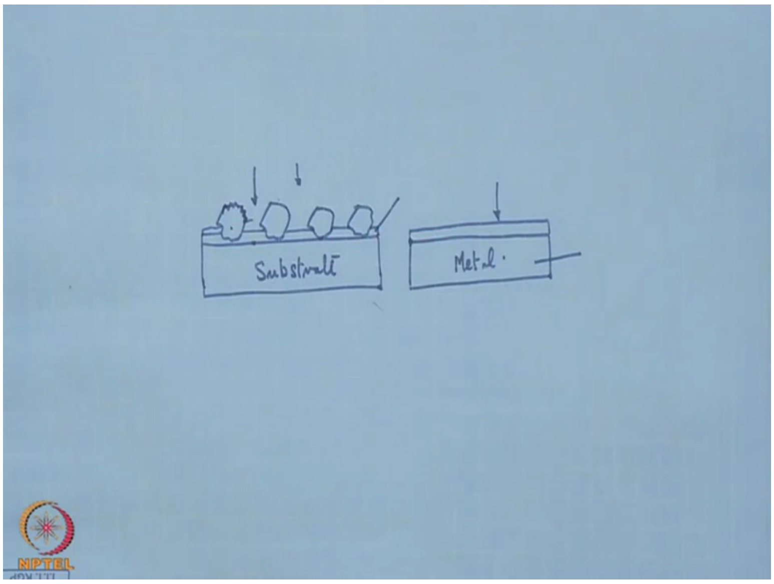

If we have just multifaceted surface then this will help in Anchorage of the grit in the bond. So this is natural diamond, so one requirement is that there should not be any electrical conductivity number 1 and number 2 if we have a rough surface that adds always to our advantage enhancing than Anchorage of this Electro deposited metal on the surface of the abrasive.

But at the same time we also see this man-made blocky single crystal, it is perfectly grown, it is used for a very difficult task when this difficult grinding task is assigned to this wheel then we have to have such kind of crystal. However in this case we have two fold problems number 1 is that during this growth of this diamond when you have the synthesis when it is undergoing the synthesis process, we use many metals as a catalyser like cobalt, nickel and many more.

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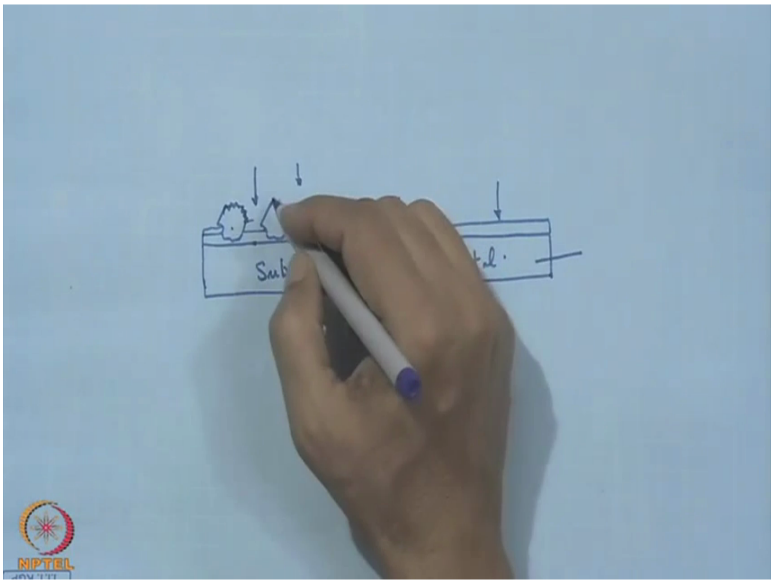

And if in unfortunate eventuality some of this catalyser like a solvent remain on the surface and that is not removed and it is overlooked then that can become a path or the source of conductivity and if this conducting path is created when this is placed on the substrate then there is every risk that this metal which is not supposed to sit on this surface that will deposit over and it may in certain extreme situation it can cover wholly or partly the grit and there will be heavy metal deposit.

Ideally metal deposit should be only in the space between the grits and not on the grits. So in this case what has to be done? A special treatment is necessary it is actually removing those metals which are remaining on the surface of diamond during this process of synthesis and that has to be etch out and this etching process becomes a part of the preparation or preparatory step to tailor this crystals for this Electro deposited anchoring.

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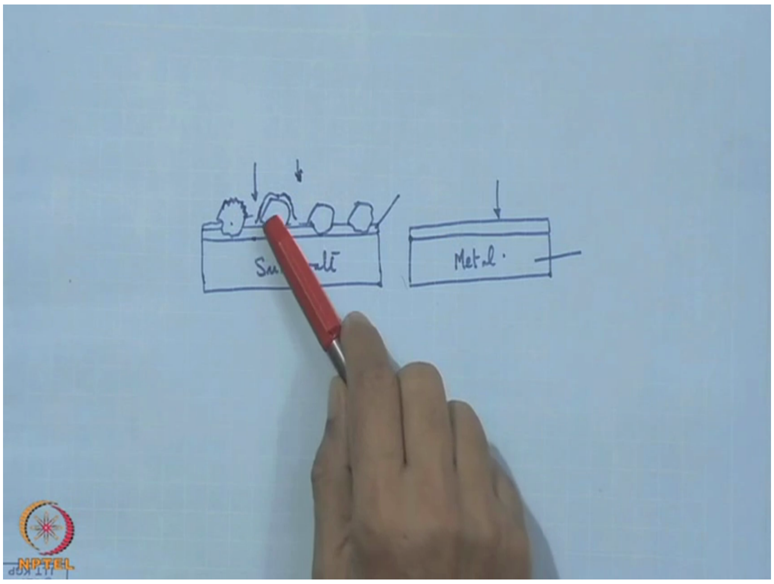

There can be another way of doing the thing that there are certain process which are practiced in industry that means these crystals are coated with a non-conducting coating like a plastic coating and then the so-called conducting grit may lose its conductivity and without any difficulty that can be used for anchoring on this surface. However the surface is smooth as we see it is perfectly grown crystal.

One thing we can see here that it is a mechanical Anchorage. So mechanical Anchorage means surface roughness plays a key role in augmenting the mechanical Anchorage and this mechanical Anchorage becomes automatic when we have a multifaceted appearance but just this is not possible because it is a well grown crystal with well-defined crystallographic planes.

In this case we must adopt certain process, method, technology that is how to roughen the surface? It can be thermal etching in presence of oxygen or it can be some chemical etching only to create some pitting micro pits, micro voids over the surface so it can have better Anchorage.

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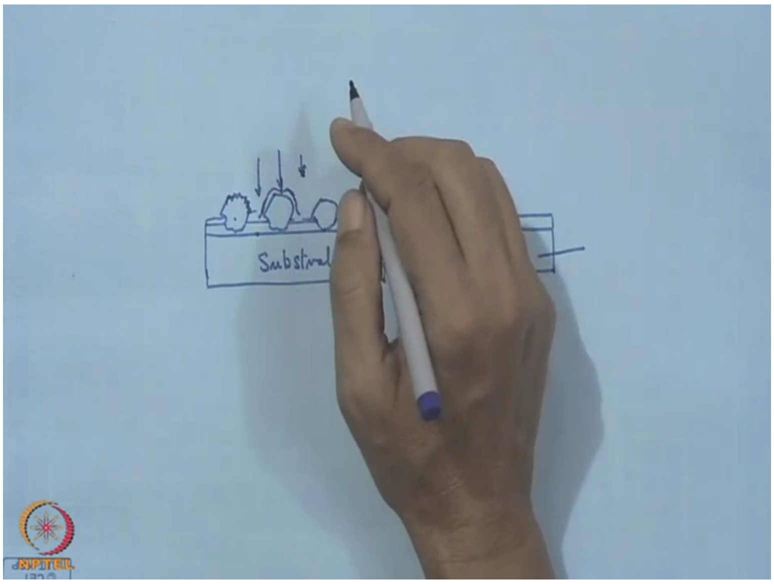

So we find that though synthetic crystals have many advantages but this user selection cannot be obvious and here utmost care has to be taken, so that this can be well anchored in this bond and at the same time there is no material deposit on this crystals surface because of some inherent conductivity and it is due to the presence of this catalytic agent which are used during the synthesis of diamond.

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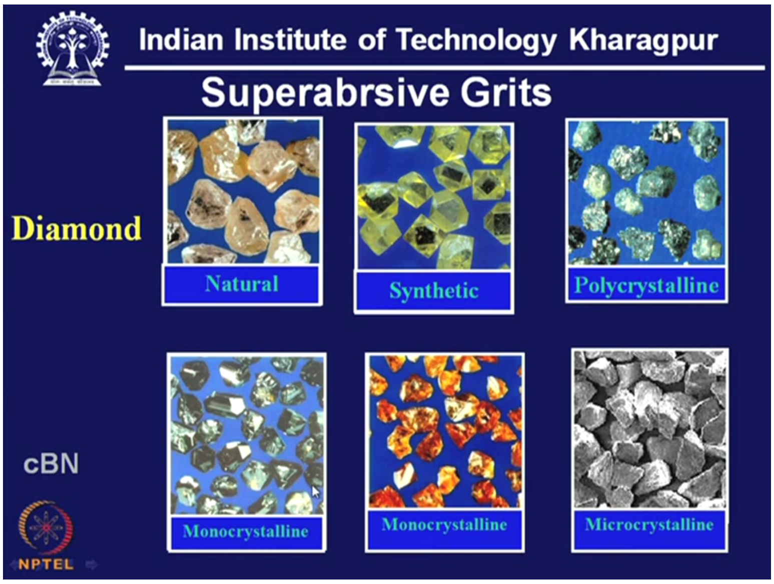

Now when we look at this cubic boron nitride, here also we have 2 type of crystals Monocrystalline and Microcrystalline and Monocrystalline this black variety is very strong, here boron percentage is retail more than that of nitrogen and here it is amber colour when nitrogen is little more in concentration than boron. However the most important and this is a Microcrystalline, so it has a better toughness average better toughness than this one but most important thing here is that whether we have excess boron on the surface of this crystal.

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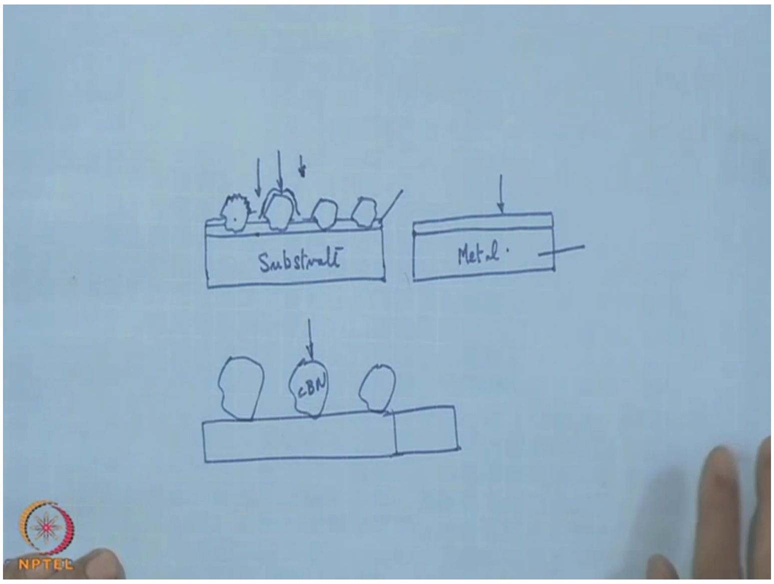

So on the surface if we place this cBN particle, cBN and if it has excess boron then that could become a problematic in that surface boron which is excess surface boron which can also lead to electrical conductivity and in that case also the position of this galvanic metal from this electrolyte that is that cannot be just ruled out. So what is to be done and what is done also in the industrial scale?

That if we find excess boron on the surface or the surface is rich in boron in that case what we do? something has to be done for chemical etching of this boron and with that also we can get a little bit micro groups or voids over the surface, this is good in both ways. One is that boron is totally removed, so surface conductivity is totally absent and when you have this micro pitting that can also help in enhancing mechanical Anchorage on the grit surface.

So this is the way one should consider the various aspects particularly the conductivity, electrical conductivity of the grit material and also whether the surface is roughen or if it is a smooth surface than whether it requires thermal etching or chemical etching for roughening the surface. Apart from that what is also necessary that is not from the requirement of plating or anchoring that is from the requirement of grinding that means ability of this crystal to breakdown in a very controlled manner that means auto sharpening.

So that the crystal always retain its (()) (32:00) whether it is the early stage of grinding or it is the terminal stage of grinding initial or final stage of grinding, the grit should always maintain the same level of sharpness and grinding capability, so that one layer can keep the same grinding behaviour starting from the very beginning to the end and this is not just a requirement for a grit which is used in composite field where the re-sharpening of the greatest is possible.

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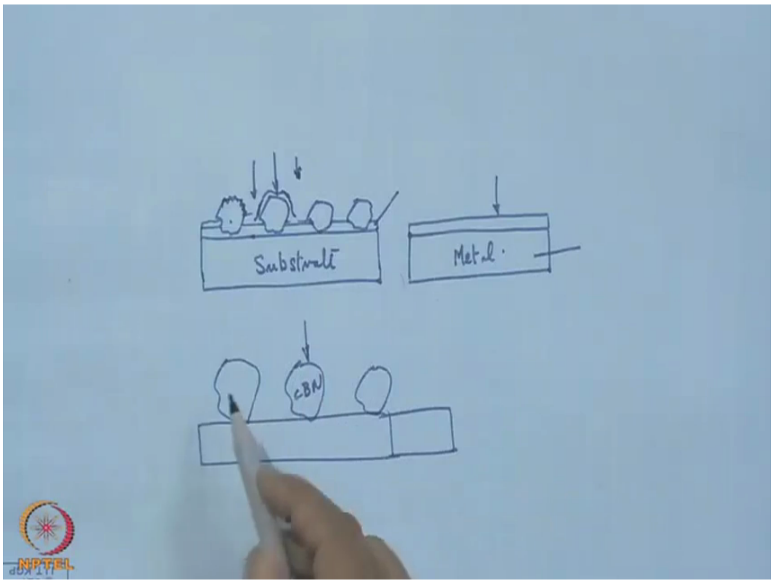

But in this case with one layer configuration re-sharpening of the grit is just not that easy and this single layer configuration that will keep on providing the grinding result which is more or less uniform throughout the grinding span.

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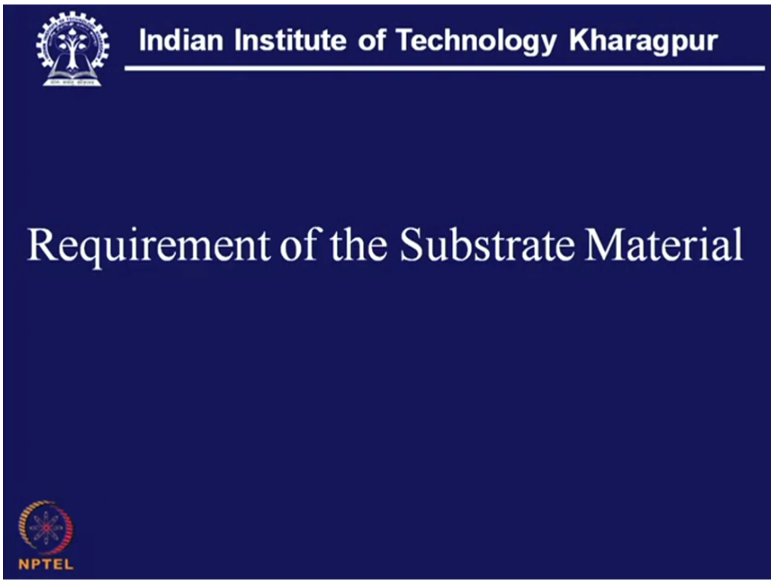

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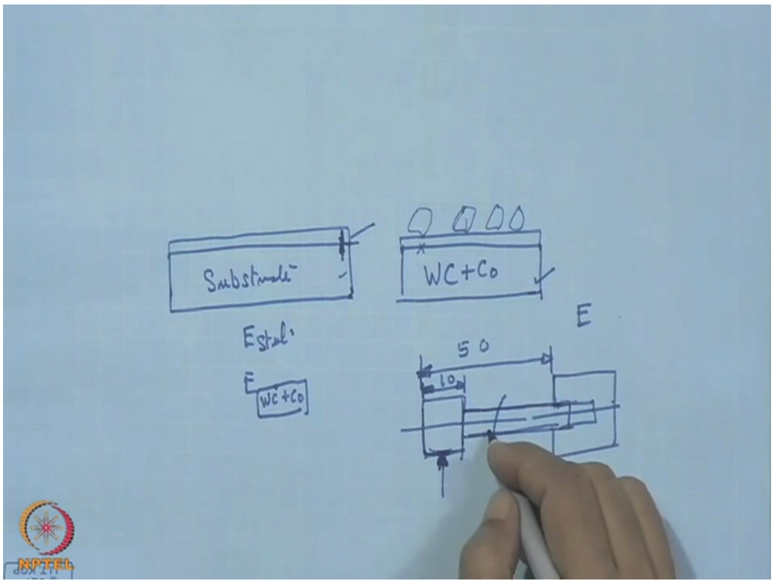

Now requirement on the substrate material, this is also very important issue in that as we know the substrate material, substrate. Now on that substrate what we like to have? The deposition of the galvanic material, so this substrate should be also electrically conducting and this bond is not just chemical in nature, so what is necessary?

That cleanliness and virginity of the surface is very important and it should be free of any oxidation, that should not be any oxide layer on the surface and at the same time the material of choice should be such that it is tough it can absorb alternating stress, it should not collapse at high frequency alternating stress and at the same time the material to be deposited it can have a good adhesion with this substrate material.

So when we apprehend that the surface can be contaminated by oxide then we should take appropriate care of removing this oxide layer and only after that, the material surface becomes compatible with the grit material with the bonding material. Now still is a normal choice for making such abrasive wheel but at the same time hard metal that means hard metal means here we know that it is Tungsten Carbide plus Cobalt there is also used as one of the material for substrate on which this galvanic material can be deposited and it must have a very good adhesion over which these crystals can be anchored, these crystals can be anchored.

Now why this Tungsten Carbide Cobalt is becoming so interesting for engineering application? We understand that if such a tool is used as a rotary tool, safer internal grinding or internal abrasive machining on a bore then this wheel this wheel which is a shaft like and it will be held in a (()) (36:11) on the machine spindle and this will have an overhang about say 40 to 50 millimetre overhang and this may be 10 millimetre that is the width of the working surface.

Now during the thrust force application, during this grinding action there will be a force at right angle to this working surface of the material. Now in this case what is going to happen? There will be some elastic deformation of this wheel surface and if we have a better E value young modulus then obviously deflecting can be reduced. So if we consider the E value of steel and E value of this Tungsten Carbide Cobalt it will be at least 3 times than that of steel.

So under the same level of force if we have a Tungsten Carbide Cobalt metric shaft and a normal steel shaft than with the same level of grinding force, we expect one third of the deflection then definitely that will be a good contributor in holding the precision or accuracy of the tolerance or on that dimension of the piece being ground or processed by this abrasive tool.

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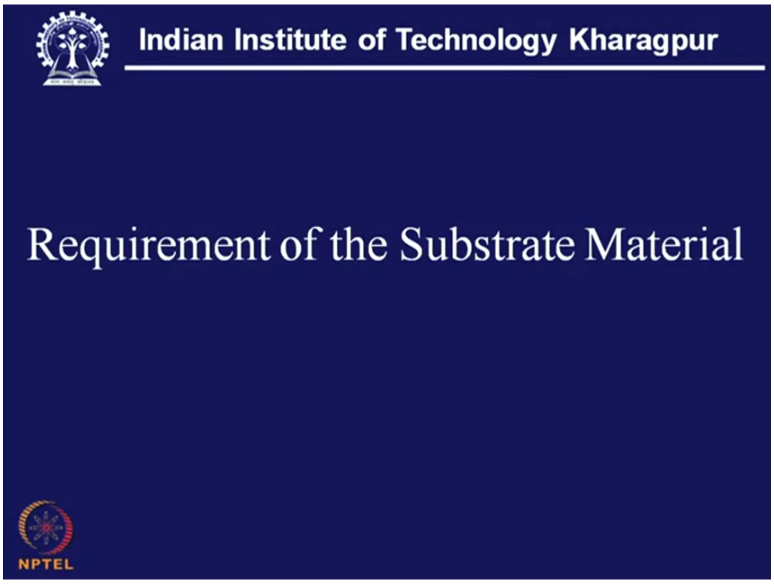

So requirement of the substrate material we understand that one should be that its strength and fatigue resistance and at the same time its adhesion with the galvanic metal which is being deposited and at the same time a high value of young modulus that means the material should be a rigid one.

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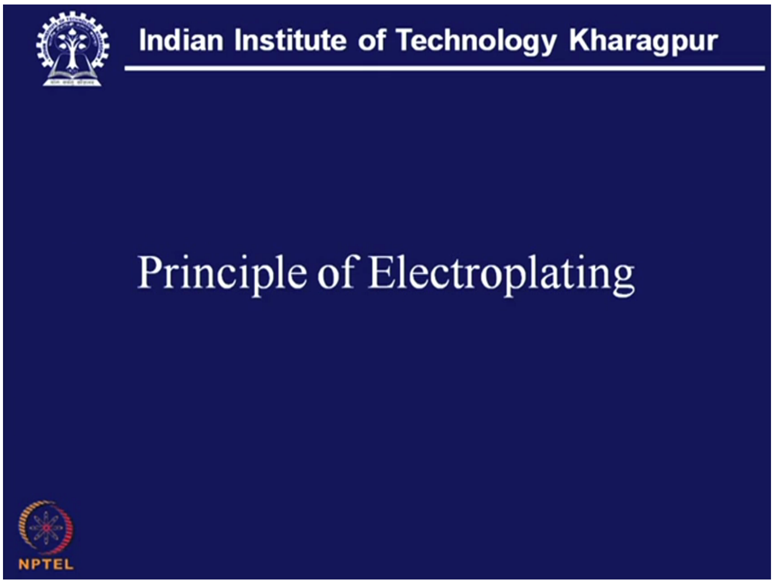

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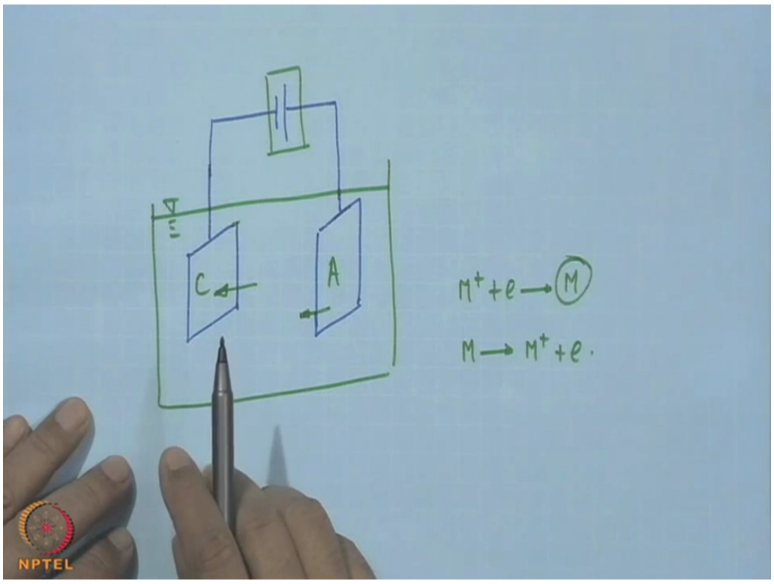

Now the principle of electro plating, we can have a quick look to this electroplating. So what is going to happen? Here actually we have one plate which is going to serve as the cathode and we can have another plate which is going to serve as anode, so they are properly polarised and these are actually put inside an electroplating bath. So this is cathode and this is anode.

So metal will be deposited to this cathode by the following reaction metal ion plus electron that will give to the neutral metal and that will go on this side and during this process the solution that will be deficient in that metal but this will be continuously replenished by this continuous erosion of the anode which is of the same metal as that of the metal in that salt solution.

So here it will be metal ion plus electron, so there will be anodic reaction that means electrochemical dissolution and here it will be electro chemical deposition, so this way the process will keep on going and here this power source that current density concentration of this electrolyte and these are the process variables which controls the growth rate or the deposition rate of the material.

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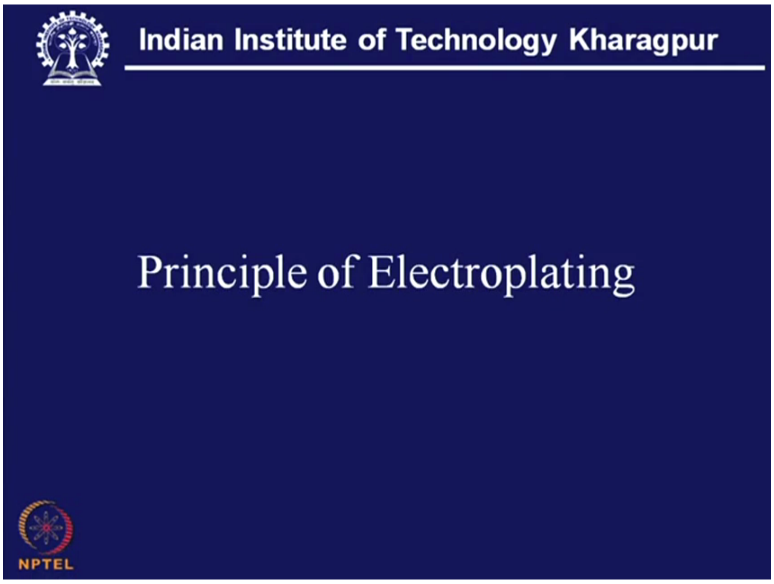

Now this is going to be used for realisation of this electro plated abrasive tool where in the crystals are anchored over a metal or hard metal substrate by depositing this galvanic material around each crystal.

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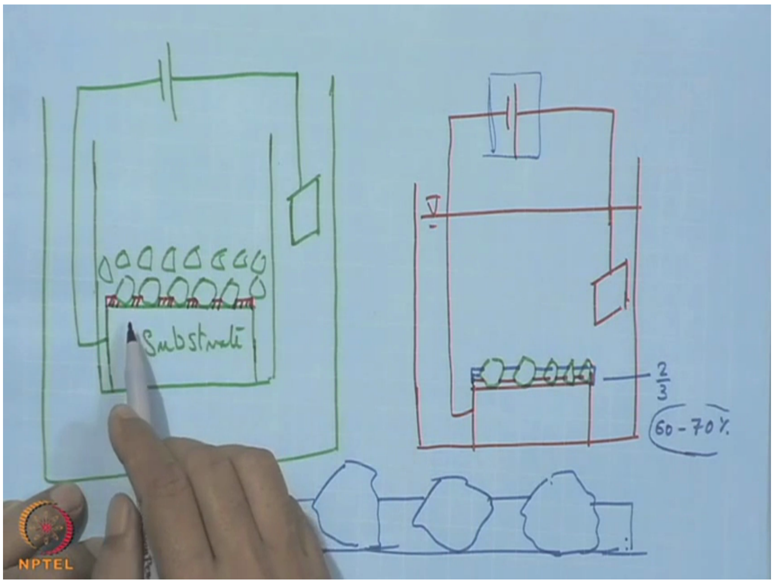

So there are actually 2 steps, first episode is called Tack down Step and this can be illustrated this way, if we consider one of the simplest cases it is a flat surface which is placed horizontally it can be also a vertical, cylindrical surface too and what we see here? That this will be, this will be the crystals of the abrasive and this is going to be a diamond bed. So that means there will be a container having pores, is almost like a strainer and over that we have one electroplating bath and this is actually submerged in this abrasive bed and here you have high concentration of this abrasive material.

And then this one the substrate will act like cathode and we can have another plate which will be the anode. So what is going to happen in this case? That this material with this electrolytic solution this material is going to deposit on the surface, so here what we see? That this will be just one cathode and this is going to be anode and this is the anode plate and that is the cathode substrate.

And here what is going to happen? That the layer of the grit which is touching this top surface of the substrate around that wherever we have the space there will be starting that there will start that will begin the deposition of this electroplated material or galvanic material like this. So we have large grit may be on the order of say 250 micron or say 125 micron or 90 micron these are the standard sizes which are used or it can be even low.

But the standard sizes which are used for grinding 250, 125, 100 or around 90 microns those are placed and through this capillary openings and space there will be continuous deposition of the material and when we find that a layer thickness is just sufficient to hold the grit, just holding them in position that is not at all a good adhesion, just by a finger touch or by little push we can remove these crystals it is just what we call tack down step only to position these grits in place and that means that on the substrate surface these grits are held and this is the tack down plating tank and after this it has to go to real plating.

So real plating means this one and here what we have this is the substrate where the grits are already anchored, however with a very weak holding force. So this is the level, this is the level of the grit, level of the bond material which is the outcome of this tack down process and now over that with this cathode, anode action, what we can have here? We have heavy metal deposition over this surface and that will be build up over this.

So this is actually the actual plating and it will grow and it can grow and it depends upon the level to which it has to be covered, say maybe it is two third of the grit height or 6 between 60 to 70 percent of the crystal height that we can cover. So from this concept of wage, if we consider these grits as the wage, so we can see at least more than 50 percent need to be covered to have proper wage action.

So it should be obviously around 60-70 percent of the crystal that is covered. So it is just now that how much energy is supplied? The concentration of this salt, metal salt in this solution and it is just a question of time how this material will build up? But in this case we have one problem that cannot be just overlooked or ruled out that means evaluation of hydrogen, this hydrogen also evolved and it is also collected at the cathode because it is an Aqua solution.

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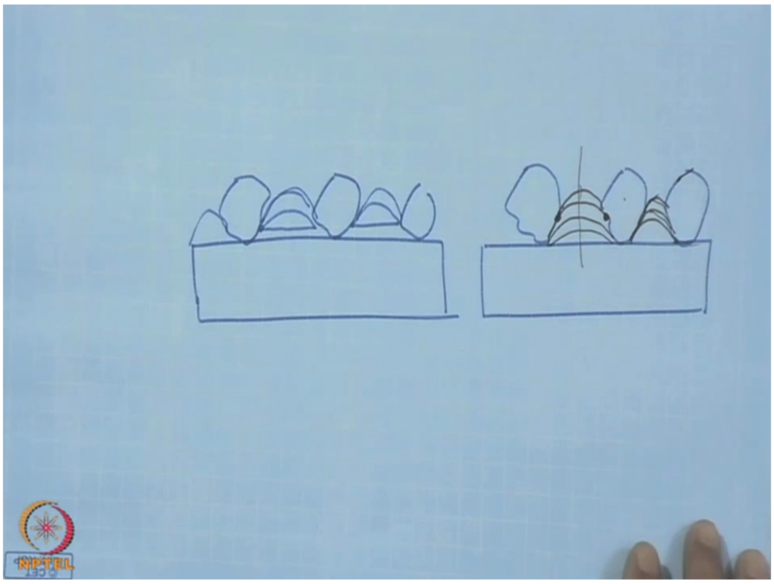

So hydrogen will be collected at the cathode and during this process, what we may end up? Instead of a plain surface we can also have around this grit, instead of this nice build-up material it can also be like a nodule formation and it can go like this it is also because of hydrogen entrapment and we have this global or nodule formation and this will have a negative influence in that, that if these are the crystals our aim is to hold this crystal with adequate bonding and with maximum available space but if the formation is like this.

The growth of the material like this that like a nodal formation than it is not going to serve the purpose because in this case what is going to happen, that at the root on the side of the crystal you have little metal and in the space in between the crystal we have high level of metal and it is just not going to serve the purpose of grinding. So this evolution of hydrogen and entrapment of hydrogen that should be also properly addressed how to remove or eliminate this problem?

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So this is actually the electrodeposition step, so with that we can grow the metal layer over this surface and finally the electrodeposited layer will be ready for any abrasive action or grinding action.

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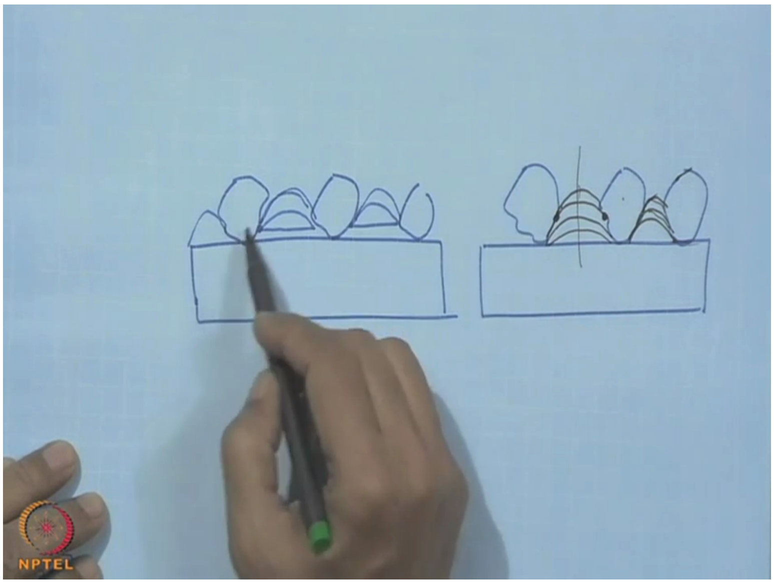

So here actually these are anchored this is just not a deposition what we understand by classical means but it is just the placement of crystal and then it is actually the deposition of the galvanic material and it is holding by proper Anchorage. Now here what we can do? Normally what we see that nickel is used as the plating material. So here we have the grit and this is the platable material, the nickel is known for its platability.

So this way we can have the nickel build-up after this tack down but there can be another secondary coating that means it is a multilayer that means a material say for example as chromium which is much more oxidation resistant and it's where resistance is still higher than that of chromium. So this layer will be nickel followed by a layer of chromium or other material which can be platable which is good platability that can be also become a material of choice, so that will give some kind of wear resistance.

In this case because of the simple reason that during grinding there can be erosion of this material and if it is too soft in that case this material will wear out leaving no material support and there can be undesirable fallout of the grit. So this kind of galvanic Anchorage, this kind of galvanic encourages suitable for single layer abrasive wheel for the wheel dressing tool or the wheel truing tool.

So dressing and truing these are 2 important process and in that case this dressing tool and Truing tool with high-quality diamond that can be also properly bonded and this can be one useful tool just not for grinding but for rectifying or giving the shape of conventional grinding wheel like the Ceramic wheel, Aluminium Oxide wheel or Silicon Carbide wheel. So this plating technology can be well adopted for Manufacturing grinding wheel or dressing wheel or truing wheel.

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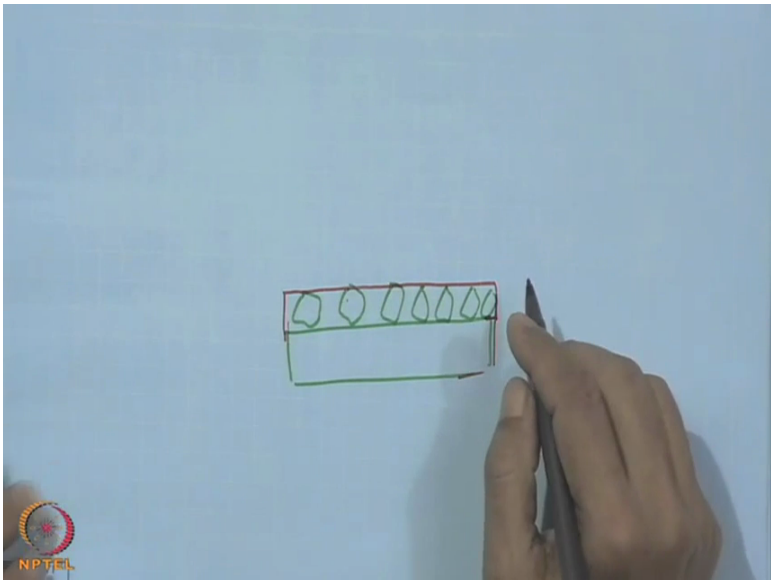

Now this can be also come as a dispersion of super abrasive grain in electro deposited metal matrix that means the whole thing can be covered. So these are the grits with a very high concentration and we can have a composite coating that means in this case the coating can go up to this point. So here we have a coating which is composite in nature that means we have abrasive grit dispersion with high concentration but that is very dispersed in metal matrix. So in this case the grits are not projected but that is totally covered. So this dispersion of super abrasive grain in electro deposited metal matrix.

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Now this is electrodeposited multilayer that also we have mentioned, that a chromium coating over a nickel coating that can be used for this purpose with a view to enhancing the wear resistance or some tribological property.

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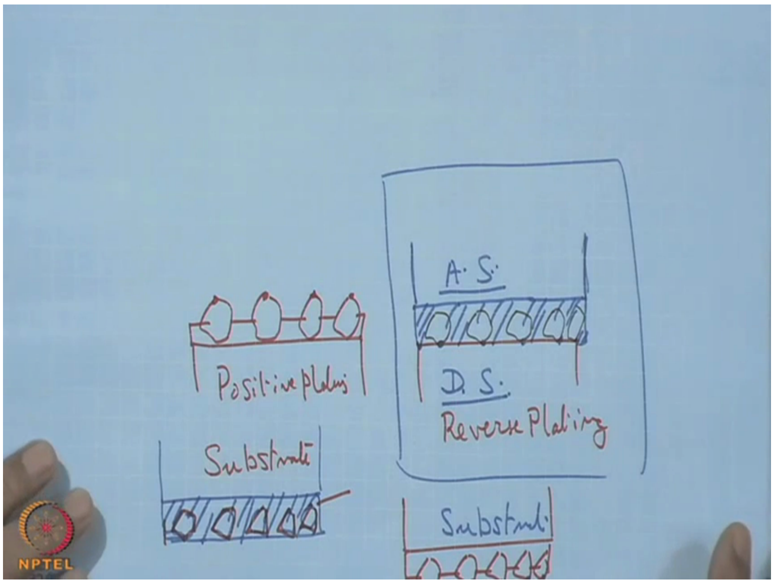

Now reverse plating, this reverse plating is important in that it can it facilitates making or Manufacturing of precision abrasive tool. So here we have to have a dummy substrate the basic principle like this in normal electroplating the grits are place like that and if this crystal heights are not same then these pick points are not on the same height. So they cannot have uniform cutting action.

So what can be done in this case? (()) (53:24) can also use, so this called a positive plating. So here this is the bond level and this is actually abrasive tool but this is actually the reverse plating. Reverse plating means we have to invest 1 substrate, so here the crystals are placed and then the actual substrate is brought from the other side, this is a dummy substrate. So this is actually the dummy substrate and this is actually the actual substrate.

So this is the dummy substrate and the actual substrate and in between the whole thing will go into the plating tank and then the entire area will be filled with this galvanic metal layer. Now the whole thing is filled in, now after that what is going to happen? That this dummy substrate will be chemically etched, so that we get a substrate surface where because in this case each point is now on this surface and they are at the same height.

So in this case we get this abrasive layer which is actually at the very beginning they were resting on this dummy substrate but after that the bonding is carried out by initiating this electrochemical deposition and this electro chemical deposition was continued. So it could cover the entire space between the actual substrate and the dummy substrate. So now the situation is something like this.

So this is a situation, so this is the coverage, okay. And what happens now? What we can do in this case? We can now, so these are the crystals which are embedded in this galvanic metrics and this is the substrate, actual substrate. So what can be done in addition that now we can continue etching of this galvanic material? So that finally we get in this form and where the bond material can be held like this and each points the pick points they are at the same height with respect to this substrate.

Now this type of materials with that you can cut uniform, you can provide uniform cut and this will be most important for making the forming form truing or the form dressing wheel which are used to give the form on conventional grinding wheel. So this reverse plating is one of the most precision processes for making precision wheel or giving precision form on the wheel surface.

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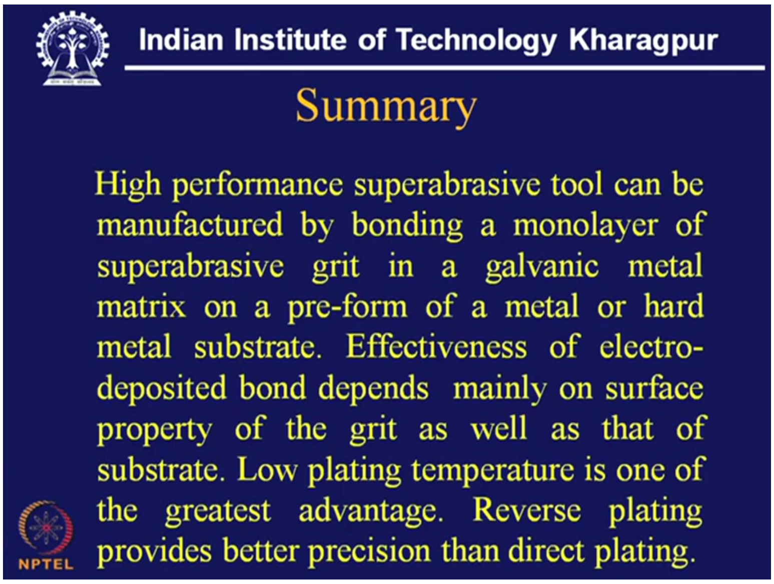

So with that we can make a summary of the discussion like this, high-performance super abrasive tool can be manifested by bonding a monolayer of super abrasive grit in a galvanic metal matrix on a free form of a metal or hard metal substrate. Effectiveness of electro deposited bond depends on the surface property of the grit as well as that of the substrate. Low plating templates is one of the greatest advantage of this process and reverse plating provides better precision than direct of positive plating.