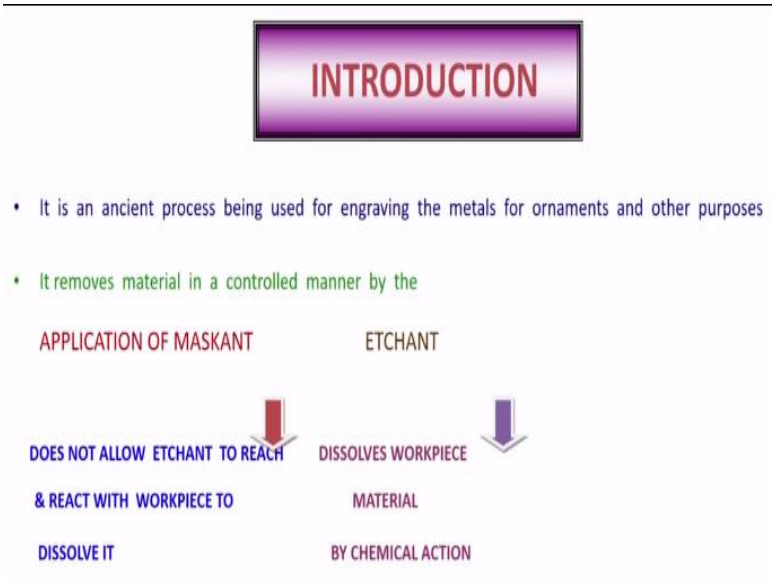
Advanced Machining Processes
Dr. Manas Das
Department of Mechanical Engineering
Indian Institute of Technology Guwahati
Module - 08
Lecture - 19
Chemical Machining (ChM)

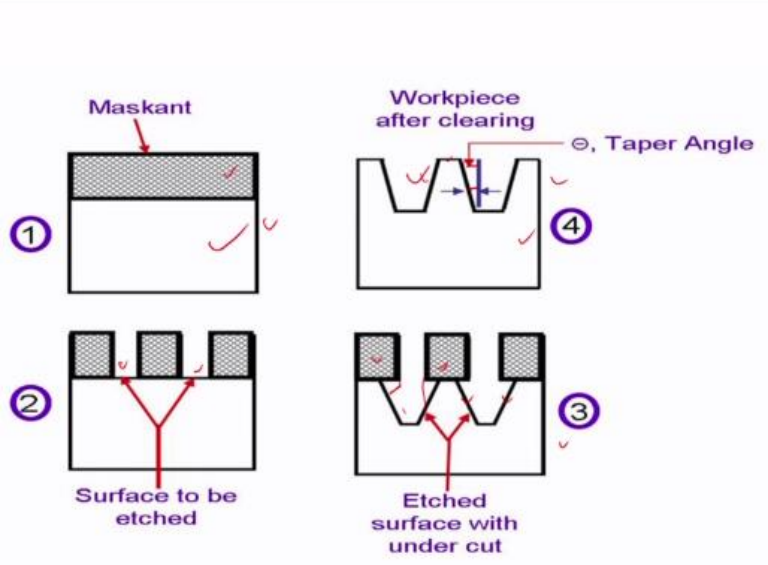
Welcome to the course on advanced machining process. Today we are going to discuss a new topic that is called chemical machining. So today we are going to discuss chemical machining process. So first we shall give the introduction.

(Refer Slide Time: 00:40)



So it is an very ancient process, well known process. It is being used for long years for engraving the metals for ornaments and other purposes. So it removes the material in controlled manner by the application of a maskant. So maskant is nothing but a it is a layer of a chemical resistant material which does not allow the etchant or chemical to react or reach with the workpiece surface and dissolve it. So this etchant, so etchant is used for dissolving this material for machining process. It dissolves the workpiece material by chemical reaction.

(Refer Slide Time: 01:27)



So this is the schematic view of chemical machining process. Here this is the workpiece. On this workpiece this chemically resistant material that is the maskant actually used, a maskant layer is used, deposited on the workpiece surface and this is the second one. After that this maskant from some selective area this maskant is actually scrapped or removed from some selective area.

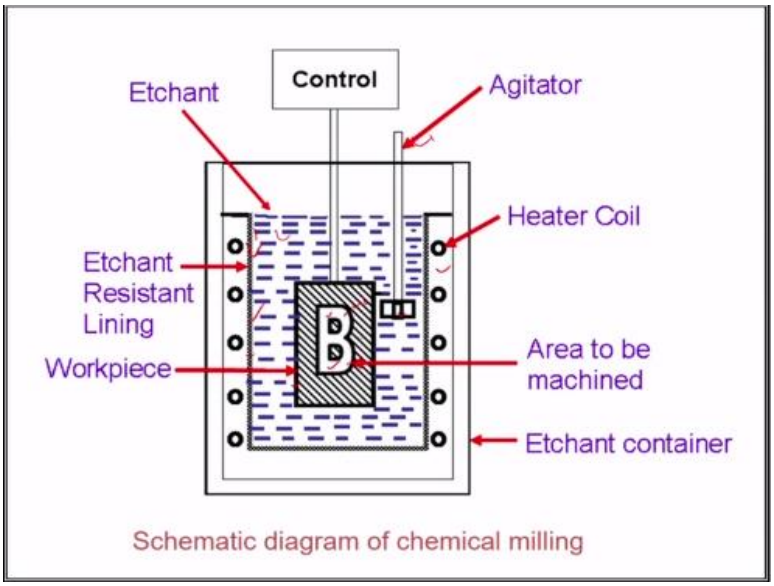
So it is exposed. That area is exposed this material of the workpiece is exposed in that area for machining purposes. This this is the area which are exposed where maskant layer is removed. Now this is the third step. In that third step this with that etching or from using the etchant or chemical etchant this chemical machining process goes on and after machining for certain amount of time to get the certain depth, machining depth into that workpiece that etchant actually this workpiece is removed from the etchant bath.

So you can see here this kind of tapered surface is made by using this chemical machining process. So this kind of tapered surface and here you can see overcut is there. So it should be perfectly vertical but this kind of overcut is there and tapered surface is generated by using the chemical machining process. So here you can see this maskant steel it is attached on the workpiece surface where we do not want any machining.

So in this area we do not want any machining so maskant steel it is attached. Now after that this maskant is removed from the workpiece here you can get the final machining machined surface okay. So from here this whatever maskants are there it is removed. So here this is the taper angle. So this is the disadvantage of this process, this kind of tapered surface is generated and here this kind of overcut is generated. So after machining this workpiece is cleaned. So before machining

before attaching or gluing the maskant on the workpiece surface this workpiece is cleaned. So initially it is cleaned and after that also it is cleaned workpiece is cleaned and you can get this kind of surface. So very intricate geometries can be generated from this machining process.

(Refer Slide Time: 04:05)



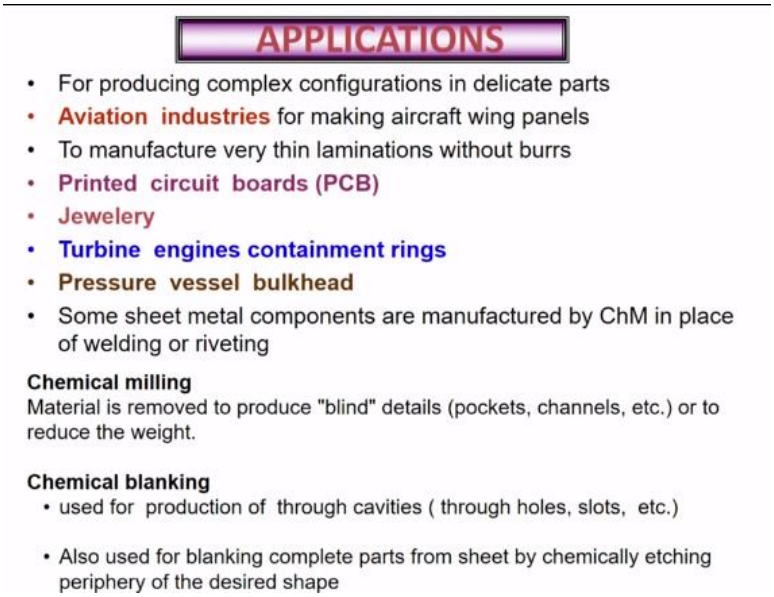
So here you can see this is the etchant bath. So this internal surface of this etchant bath you can see etchant resistant lining is there so that it should not make chemical reaction or it should not dissolve the bath etchant bath material by chemically dissolving it with the etchant. So this kind of etchant resistant material is lining is given at the internal surface of the etchant bath. So this is, this bath is actually it is filled up with etchant and this is the workpiece which is hanging with a rod. Now here you can see this portion we do not want any machining.

Only this portion actually we need the machining so other portions where we do not need any machining this maskant actually it is deposited or glued on the workpiece surface after that it is dipped into the etchant bath, so this area where machining is required. So this is the etchant container here and sometimes heater coil is actually required.

So whatever this etchant material is there it can be agitated by using a by heating this etchant by using a heater coil and sometimes this heater this etchant actually it is agitated by a agitator so here there is a rotating device is there. Using this rotating device this agitator or rotating device or agitator this whatever this etchant is there it is actually properly circulated inside the etchant tanker or etchant bath.

So this workpiece actually it is dipped into that etchant bath for a certain amount of time for getting a certain depth of cut. So for suppose this is the depth of cut here so this depth for getting certain depth from preliminary experiment we have to have information how much time we have to keep this workpiece inside the etchant bath so that proper machining can be carried out or proper depth of cut or exact depth of cut can be carried out.

(Refer Slide Time: 06:30)



So these are the different applications of chemical machining process. So it is used for producing complex configurations in delicate parts. So you can see that jewelries, different jewelries actually it is made up by chemical machining process, chemical engraving process. So these are the intricate components into that jewelry so it is made by this chemical machining process by controlling different process parameters it is possible to make intricate components into that workpiece surface.

So aviation industries it is used extensively for making the aircraft wing panels. So this aircraft wing panels it has certain curvatures are there and these are the very big panels so these big panels are actually made of by this chemical can be made by chemical machining process. So to manufacture very thin laminations without burrs. So this advantage is that if there is very thin components are there if it is made by conventional milling or conventional other processes so there is a chance of making burrs.

So these burrs are actually unwanted during fabrication process. So while in conventional machining process this burrs are actually made so it is unwanted but in chemical machining

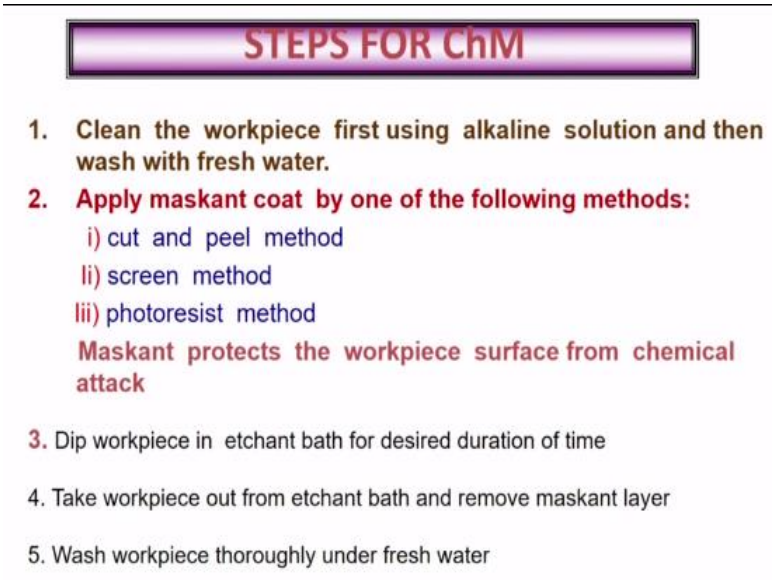
process there is no chance of making burrs okay so whatever surface you get that is burrs free. So this chemical machining is used for making printed circuit board. It is very famous in jewelry industries whatever this intricate components of jewelries are made this engraving process chemical machining process. So this turbine engine containment rings are actually made of by chemical machining process.

Pressure vessel bulkheads are made of this chemical machining process. Some of the sheet metal components are also manufactured by chemical machining process. So if you make this one by chemical machining process with a with a single sheet you can generate you can make a total component or product. So you can avoid this welding or riveting all such kind of operations where this strength of the base material is actually weakened.

So you can avoid this kind of thing by doing the sheet metal operations also you can do the chemical machining operation and you can make certain products. So there are 2 things are there. One is called chemical milling, another one is the chemical blanking.so in chemical milling process actually blank holes like blank pockets are actually generated. So material is removed to produce blind details, pockets or channels etc. to reduce or to reduce the weight.

So in milling process actually, chemical milling process blind details are actually generated. But in case of chemical blanking process through components with through details are actually generated, through holes. So used for production of the through cavities. So through holes or through slots which are generated by this process that is called chemical blanking. Also used for blanking complete parts from the sheet by chemically etching periphery of the desired shape. So these are the different applications of chemical machining process. So what are the different steps of chemical machining?

(Refer Slide Time: 10:24)



So first we have to clean the workpiece properly. So if you do not clean it properly what happens whatever this maskant materials it cannot be glued on the workpiece surface if some dirty materials are there on the workpiece surface it cannot be glued properly. So this maskant it will be debonded during etching process. So if it is debonded what happens there will be stray cutting will be there. So maskant actually it is given it is deposited on the workpiece surface to resist the chemical reaction into that area where this maskant is deposited.

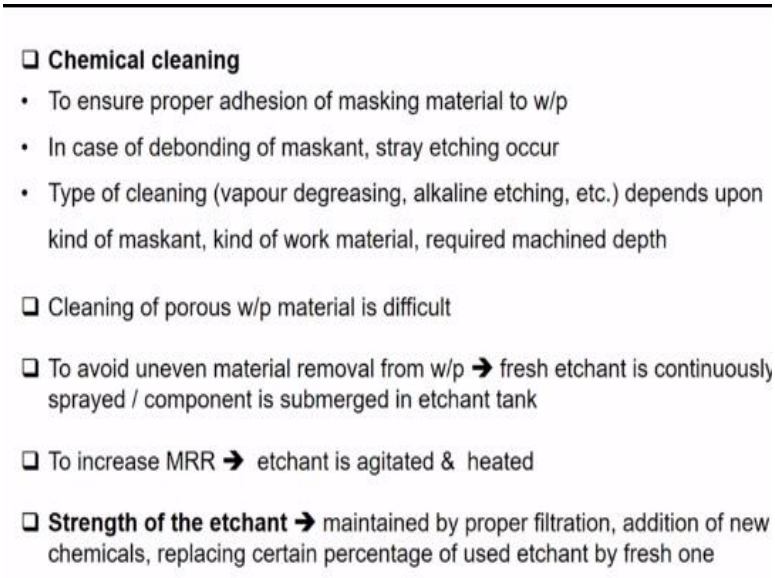
But this maskant if it is removed from that portion there will be stray cutting unwanted machining will be there from the workpiece surface. So cleaning of the workpiece is a must. So it can be cleaned it may be cleaned by alkaline solution or washed with a fresh water. So after that we have to put a maskant coat by one of the following methods. There are different methods are there for depositing this maskant on the workpiece surface.

One method is that cut and peel method. Second one is the screen method and third one is the photochemical method or photoresist method. Photoresist method it sometimes it is called a photochemical method also photochemical machining also.

So this maskants actually protects the workpiece surface from chemical attack. After depositing the maskant on the workpiece surface this workpiece is actually deposited dipped inside a chemical or etchant bath for desired duration of time for getting exact machining depth. So you take the workpiece out after this machining from the etchant bath and remove the maskant layer. So after removing the workpiece from the etchant bath we have to remove the maskant layer and

after that again it has to be cleaned thoroughly under fresh water. So these are the steps of chemical machining process.

(Refer Slide Time: 12:42)



So sometimes it is chemically cleaned also. Initially this workpiece it may be it may be cleaned by alkaline cleaning or it may be cleaned by water. Sometimes it is cleaned by chemical cleaning to insure proper adhesion of the masking material with the workpiece surface. In case of debonding of the masking stray etching will occur, already we have discussed. So there are different types of cleaning is there.

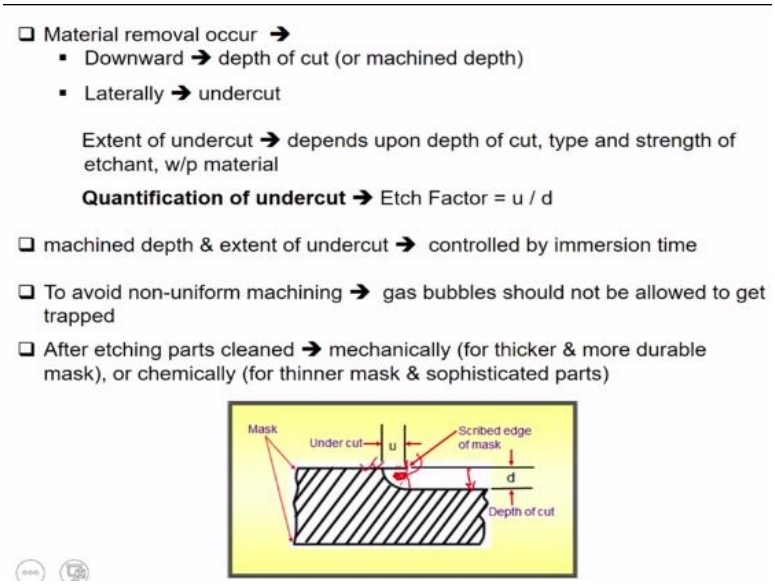
First one is the vapour degreasing. So whatever this oiling materials are there it may be removed by vapour degreasing process or it may be cleaned by alkaline etching etc. depending upon the what kind of maskant you are using. So this cleaning process actually depends on what kind of maskants you are using, what kind of workpiece you are machining, workpiece material and required machined depth, how much machine depth you are doing.

So this cleaning process depends on these parameters. So cleaning of porous material is very difficult because this porous material is because of this porosity. So it is very difficult to clean the porous material. So during machining to avoid the uneven material removal rate fresh etchant is continuously supplied into the etchant bath or certain portion of the etchant actually removed from the etchant bath and it is replenished with the fresh etchant or you can so either you can add etchant into that etchant bath or you can take away certain portion of the etchant from the etchant bath and replenished with the fresh etchant.

So to increase the material removal rate etchant is agitated and it is heated. Strength of the etchant maintained by proper filtration because whatever this chemically this material during machining it dissolves into the etching. So this is the difference between chemical machining and electrochemical machining. In electrochemical machining whatever this chemical reaction products are there it does not dissolve into the metallic hydroxide dissolve into the electrolyte.

But in case of chemical machining process whatever this reaction products are there it dissolves into the etchant. That is why this etchant should be filtered properly before recirculation. Addition of new chemicals or replacing certain percentage of used etchant by fresh one. So to avoid uneven material removal rate fresh etchant is continuously sprayed on the component or this component is submerged into the etchant tank.

(Refer Slide Time: 15:51)



So material removal rate either it occurs in the downward direction or it occurs in the laterally. So you can see this is the material removal rate in downward direction. So this is you will get the depth of cut and when so this is the maskant layer here. So this portion actually it was open and this portion and this maskant layer is there but there is a lateral machining is there. So because of this lateral machining undercut occurs.

So extent of undercut so this is actually unwanted. This much of material actually it is unwantedly it is removed from the workpiece. So it is not wanted. So this lateral machining is done due to the undercut. So extent of undercut depends upon the depth of cut, type, and strength of etchant and the workpiece material. For certain workpiece material this undercut is more and

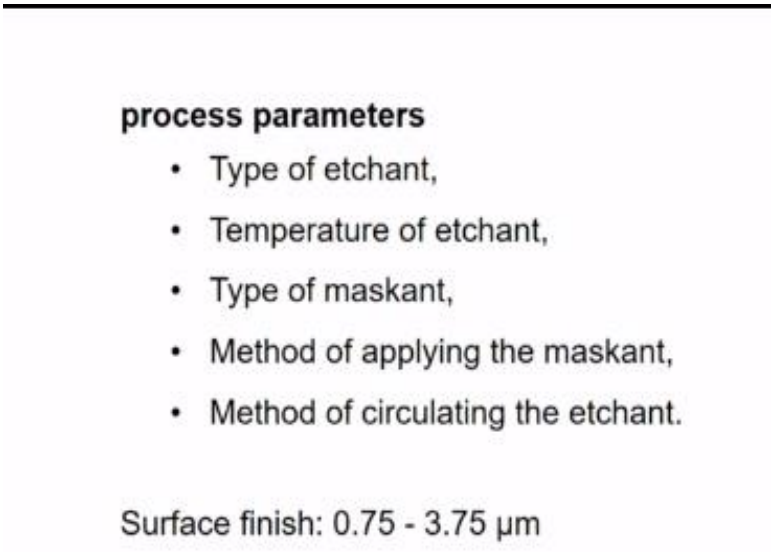
if you increase the depth of cut obviously your undercut will be more and type of strength this undercut also depends on the type and strength of the etchant also.

So how to quantify this undercut. Undercut is quantified by age factor which is u, this age factor is defined by undercut by depth of cut. So this age factor is defined by undercut u by d, d is the depth of cut. So machine depth and extent of undercut controlled, it can be controlled by the time of the workpiece it is immersed into the etchant tank. So to avoid non-uniform machining gas bubbles should be should not be allowed to get trapped into the under the maskant.

So this whatever during chemical machining, whatever this reaction products are generated at that time because of this chemical machining chemical reaction gas bubbles also generated. So if this gas bubbles are actually trapped inside the maskant material, maskant and workpiece then there will be less or inaccurate machining will be there. So whatever this bubbles or gas are generated it must be it must not be trapped inside the workpiece material.

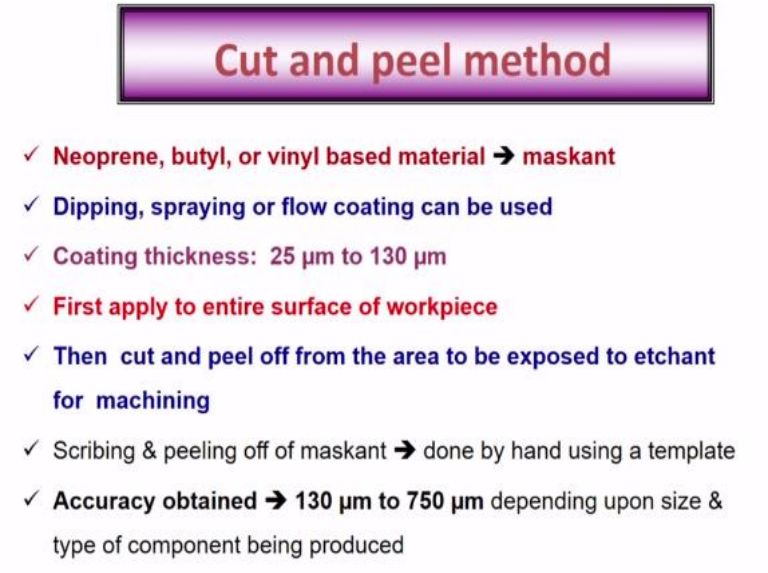
So after etching, parts is cleaned. For bigger material for thicker or more durable mask it is mechanically cleaned or for chemically or sometimes it is chemically cleaned for thinner mask and sophisticated parts it is chemically cleaned.

(Refer Slide Time: 18:51)



So what are the different process parameters for chemical machining process, type of etchant, temperature of the etchant, type of maskant, method of applying the maskant, and method of circulating the etchant on to on the workpiece surface. So surface finish generally obtained is 0.75 - 3.75 micron in case of chemical machining process.

(Refer Slide Time: 19:20)



So there are different methods for depositing the maskant on to the workpiece surface. So already we discussed there is one method, first method is the cut and peel method. Second one is the screen method and third one is the photoresist method. So this first we shall discuss the cut and peel method. So in cut and peel method these are the materials neoprene, butyl, and vinyl based materials are used as a maskant. Dipping, spraying or flow coating can be used.

So you maybe you maybe dip the workpiece inside this kind of materials or it maybe this maskant this materials, this chemicals may be sprayed this maskant materials may be sprayed or flow coated on the workpiece surface. So this coating thickness is 25 micron to 130 micron. So this coating is made on the entire surface of the workpiece because it is dipped into the coating tank or maskant coating tank so this entire workpiece actually coated.

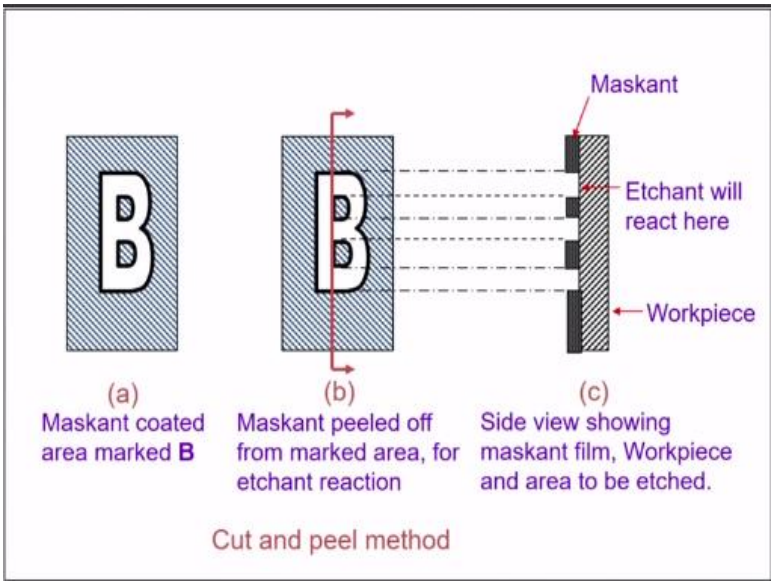
After that this maskant is cut and peel off from the area to be exposed for the etchant for machining. So then scribing and peeling of the maskant is done by hand using a template. So accuracy obtained by this cut peel method is 130 micron to 750 micron depending upon the size and type of the component being produced.

(Refer Slide Time: 21:05)

- ✓ Machined depth depends upon → etching time → usually tapered workpiece is obtained
- ✓ Good method for stepped component → Using re-scribing technique
- ✓ Good for large sized products used in chemical, aircraft, and missile industries,
- ✓ Good for batch size production and products with large depths (> 1.5mm) to be etched

So machine depth depends upon the etching time usually tapered workpiece is obtained. So this is a good method for stepped component using a re-scribing technique and good for a large sized products also this cut and peel method. Used in chemical, aircraft, and missile industries. So this is used for it is good for the batch production and products with a large depth generally more than 1.5 mm. If the depth of the machine surface is more than 1.5 mm then this kind of cut and peel method is used. It is good for the batch size production.

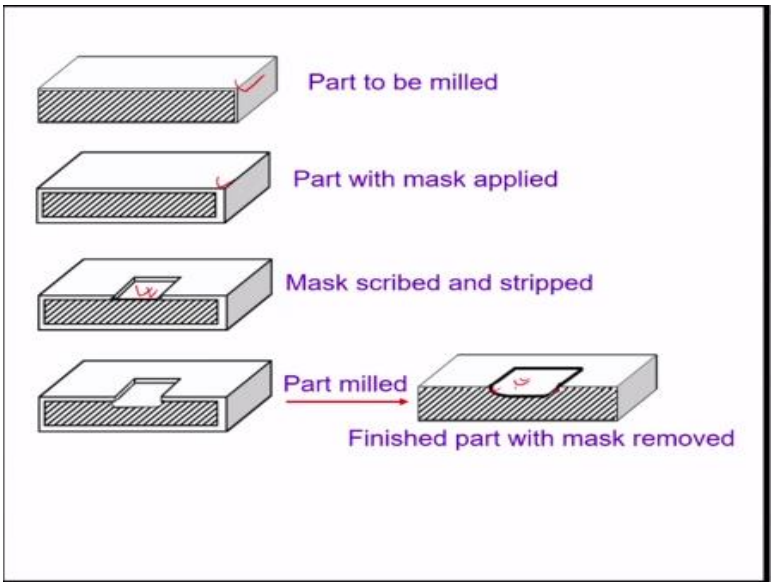
(Refer Slide Time: 21:52)



So this is the workpiece here, maskant coated already. So if you see the cross section of this maskant, if you take a cross section here along this line you can see so this is the workpiece material, here this maskant layer and this is the exposed area where we need the machining to be

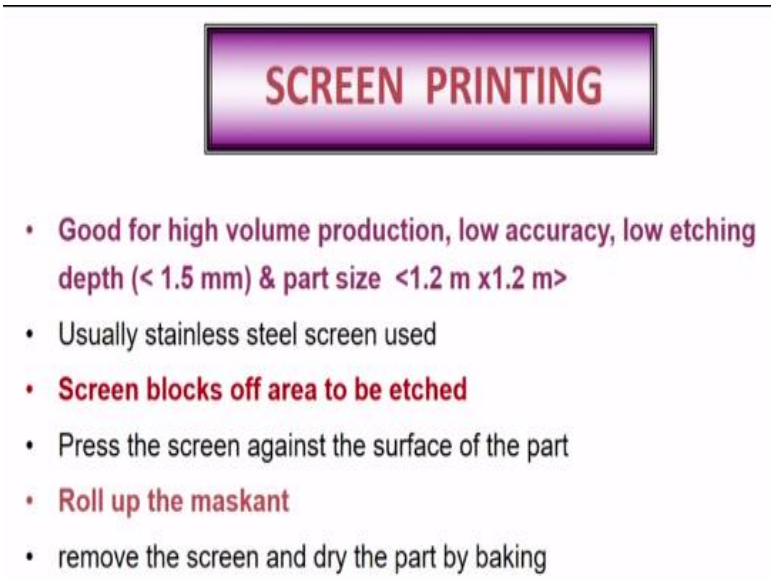
carried out. So these are the exposed area and this is the these are the maskant here. So it is deposited on the workpiece surface. So here this maskant is peeled off from the marked area for etchant reaction. So this is the schematic diagram of the cut and peel method.

(Refer Slide Time: 22:37)



So again so this part to be milled. So this is the workpiece. After that it is this part is actually it is coated with the maskant after dipping into the maskant coating material and then this portion actually cut and peeled off. This portion of the workpiece is cut and peeled off for the machining to takes place in this zone. So after machining you can see this is the part is generated and this portion there is a overcut is there, here you can see this is the overcut or undercut into the workpiece surface.

(Refer Slide Time: 23:23)



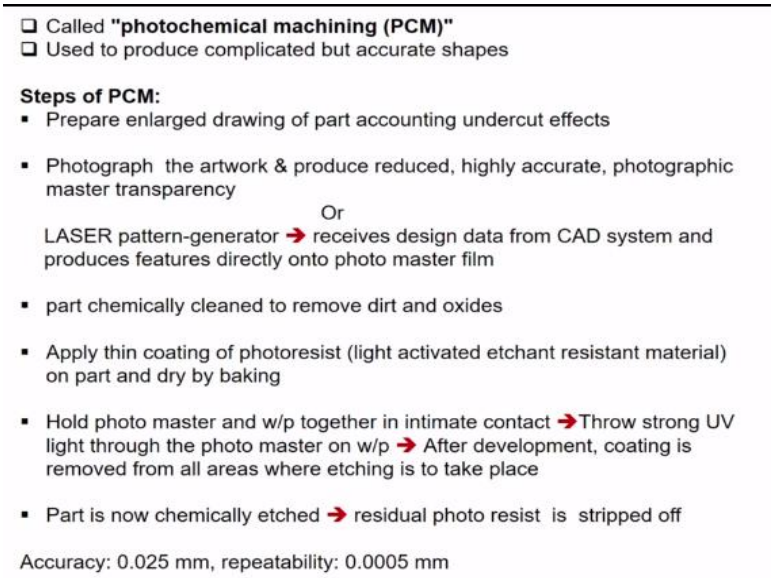
After that second option is the screen printing method. In screen printing method it is used for mass production where less accuracy is obtained. Here one screen is used. It is maybe made of stainless steel, stainless steel is one of the screen is used. This stainless steel screen is kept on the workpiece surface after that this maskant coating actually poured into the over the screen and in the screen actually where it is the screen is the impression of the workpiece to be machined on the workpiece surface so where this some blank portions are there on that screen there maskant is actually filled up and then after that it is baked and rest of the portion where this maskants are not there, there machining will be carried out. So it is good for high value production it gives low accuracy, low etching depth less than 1.5 mm and part size actually generally less, less than 1.2 to 1.2 meter. So within this range the workpiece size is there.

So usually stainless steel screen is used screen blocks of the area to be edged. Press the screen against the surface of the part and roll up the maskant and this maskant actually it is filled up where in the screen where some gaps are there and rest of the portion will be opened for machining. So remove the screen after that remove the screen and dry the part by baking operation.

(Refer Slide Time: 25:22)

So third method for generating maskant layer is the photoresist method.

(Refer Slide Time: 25:33)



So generally people call it photochemical machining. So it is used for complicated parts, for complicated parts this is very useful method for generating very accurate shapes this is very useful method. So these are the different states of photochemical machining or photoresist method of making maskant layer on the workpiece surface.

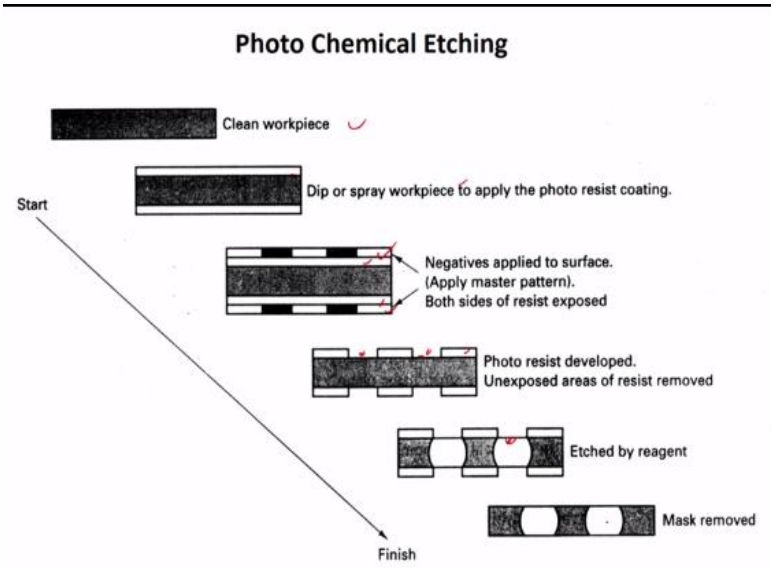
So initially this very enlarged view of the part is actually generated after considering the undercut generally one artist actually make the enlarged view of the part. So this after that that photograph and the artwork whatever this artwork is produced it is reduced to the original size which is highly accurate photographic master transparency, highly accurate photographic master

transparency is generated. Or you can make the master transparency master field by laser pattern generator. It receives the nowadays computers used a CAD model is used it takes the CAD model into the system and produces the features directly on to the photo master film.

In earlier days one artist actually generally will make this bigger size then it is actually reduced and then it is made on a photoresist or photo master film. So this part is chemically cleaned and to remove the whatever this dirts and outside layers are there on the workpiece surface it is chemically cleaned. So after that a thin coating of photoresist this photoresist actually light activated etchant resistant material, so a thin coating of this photoresist actually is deposited on the part on the workpiece and then it is dried by baking.

After that this photoresist, photo master film and workpiece it is made together, it is kept together in intimate contact and very strong ultraviolet ray is thrown through the photo master on the workpiece and after development this coating is actually removed from all the areas where etching is to take place. So now part is now chemically etched and residual photo resist is stripped off after that and by this process photochemical machining process 0.025 mm accuracy can be achieved and repeatability is 0.0005 mm.

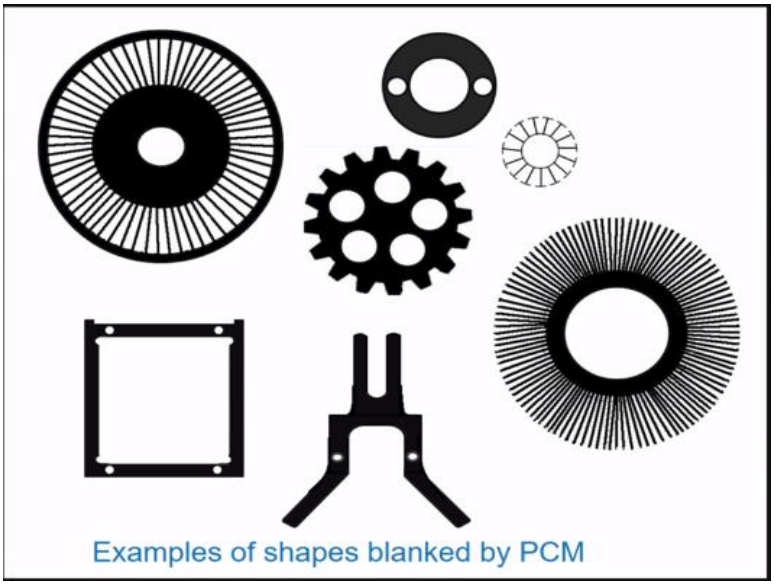
(Refer Slide Time: 28:34)



So this is the different method different steps of photochemical machining. First we have to clean the workpiece, dip or spray the workpiece to apply the photoresist coating, photoresist coating is deposited. So this negatives are applied to the surface, apply master pattern here over there both sides of the photoresist. So this is the master pattern, here this is the master pattern and this is the

photoresist material here and after that ultraviolet ray it is exposed to the ultraviolet ray so after exposing this workpiece under ultraviolet ray this photoresist develop over there and unexposed areas of the resist are removed. So these unexposed areas are actually removed. So after that this workpiece now it is machined by chemical etchant and after that this whatever this mask is there this mask is actually removed.

(Refer Slide Time: 29:39)



So this kind of complicated surfaces can be generated by using the photochemical method. This complicated details so these kind of complicated details can be generated by photochemical machining process.

(Refer Slide Time: 29:57)

Choice of maskant

- should be resistant to etchant,
- should be easily removable after etching,
- should not have any chemical effect on W/p,
- should be stable at high temperature of etchant bath

Etchant: dissolves metal by changing it into a metallic salt that goes into soln.

- $FeCl_3$ (for Al, Cu, Ni & their alloys),
- $FeN0_3$ (for Ag),
- HF (for Ti),
- $HN0_3$ (for tool steel). Other etchants: chromic acid, ammonium persulphate.

Factors to consider for etchant selection:
surface finish, MRR, depth of penetration, type of w/p, type of maskant, damage to the w/p by etchant, availability, and cost

So there are different choices of maskants are there. So these choices are it should be resistant to the etchant. This maskant should be resistant to the etchant. Should be easily removable after etching. Should not have any chemical effect on the workpiece and should be stable at high temperature of etchant bath. Etchant it dissolves the metal by changing it into a metallic salt that goes into the solution.

So there are different etchants are used for different materials for chemical etching of different materials like ferric chloride it is used for aluminium, copper, nickel and their alloys. Ferrous nitrate is used for silver. Hydrogen fluoride it is used for titanium. HNO3 is used for tool steel and other etchants are chromic acid, ammonium persulphate, etc.

So factors to consider during etchant selection, surface finish you have to consider; material removal rate you have to consider, how much material removal rate is required; depth of penetration; type of workpiece; type of maskant; and then damage to the workpiece by etchant; and availability and its cost also matters while selecting the etchant.

Thank you.