Microsystem Fabrication with Advance Manufacturing Techniques
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Lecture - 2

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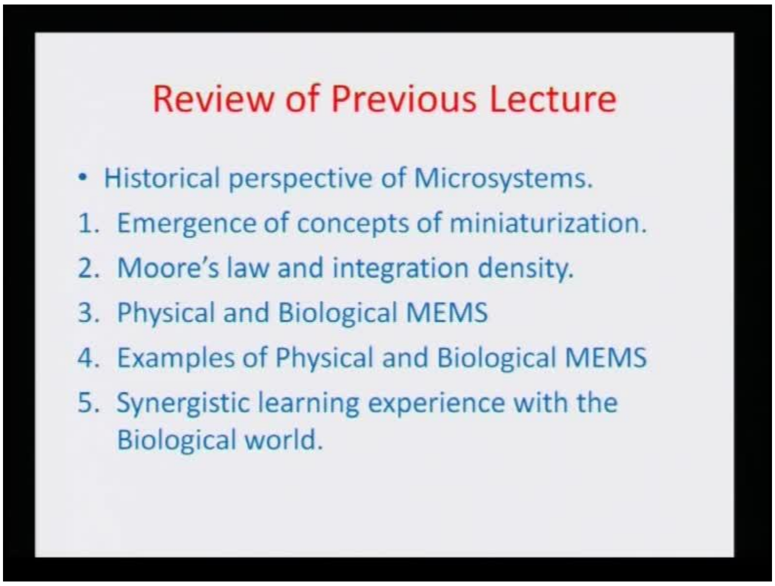

Welcome back, so, I would be now giving you an overview of advanced machining processes and this is about how you make the micro structure systems or Microsystems. So let us just briefly review what we did in the last lecture. So, we had historical perspective of Microsystems, we went into some concepts and the way that miniaturization drive had emerged starting from the very famous lecture of Richard Fame man in 1959, we talked about Moore's Law and the integration density and how Moore's law is increasingly changing from doubling in 18 months to doubling in about 24 months.

We also ah talked at length about physical and biological mems and discussed some very interesting examples, of physical and biological mems systems. So, the take of message for this particular lecture was really that, it is a synergistic learning experience with the biological world. So, there are lot of inspiration and material available from the biological world that can be translated to make Microstructured systems, Nano systems. And so, therefore, a vast majority of fabrication processes are really bio inspired as well. So, we will do this in details while looking into a historical prospective of how Parallely machining or Micro structuring evolved over time.

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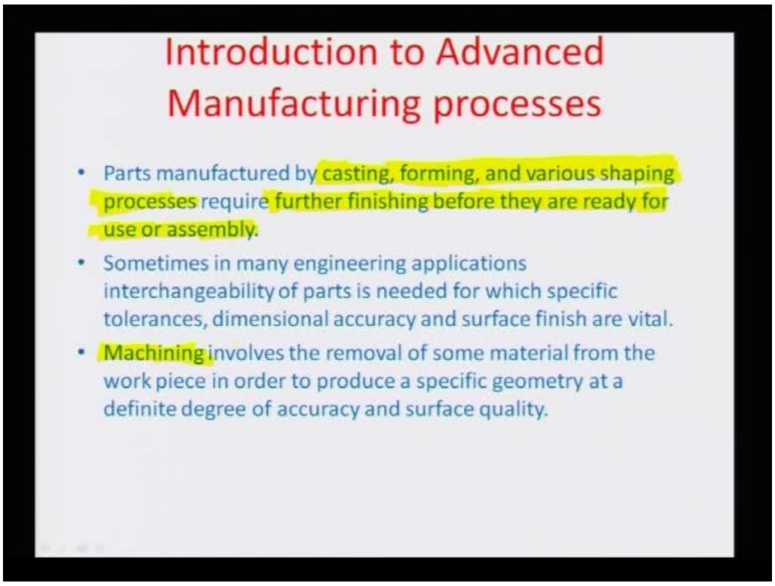

So, Let us get a historical perspective of some of these processes ah which are known, as manufacturing processes. So, we have already in our engineering lectures to this scene, there are lot of parts can be manufactured by some of these basic processes like casting, forming and various shaping processes and therefore, all these processes making parts really require further finishing, before they are ready. And to be used in an assembled form and these sought of high through put processes are further required to be fine processed. So, that whatever requirements of tolerance is dictated by engineering assemblies of such parts, can be realized.

And so, this is the 1 of the reasons, why initially advanced manufacturing processes were developed. So, that the tolerances up to the size of microns. Or even now a day's increasingly to Nanometers can be easily provided by the advancement of the process itself. Sometimes in also many engineering applications interchangeability of a part is a major issue, which needs this specific dimensional accuracy and surface finish. So, this again dictated the need for these advanced manufacturing processes. So, let us look at 1 of these processes machining, which involves the removal of some material from a work piece. In order to produce a specific Geometry and that too at a certain degree of accuracy and surface quality.

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So, with a machining into picture, 1 can really look into the History of Machining or where this concept of shaping objects started. So, 1 of the first examples, in the mankind of sought of machining comes from this most ancient Paleolithic stone tool industry the lowdown. It was developed about 2.6 million years ago, by members of the genus called Homo habilis or Homo sapiens and they were really, tools shaped out of stones choppers, burins and awls, as some examples, can be seen here. So, man really learnt to remove material in desirable manner, as far back as the Paleolithic age, further developments happened and the invention of Nets or bolas, were this big rock in a carved in a spherical manner would be tied up in a rope and thrown on to animals to make hunting possible or even spears, which would be something like what you saw here, tied at the end of a big stake or bow and arrows developed.

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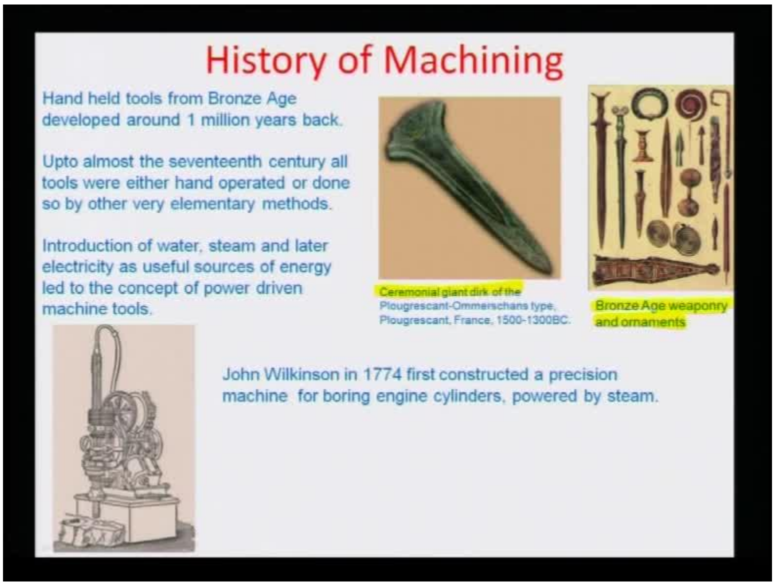

So, interestingly machining dates as far back as this period and slowly things changed and we went into the Copper edge where still hand held tools had lot of prominence, in the Copper as well as the Bronze Age, which was about 1 million years back. So, some example problems are illustrated again here, this was a Ceremonial giant dirk of found in France in the year 1500 and belongs to year 1500 to 1300 bc. This was some Bronze Age weaponry and ornaments, which were developed by people, who learnt some of the basic manufacturing processes by this time and still everything was really manual or hand held.

So, almost up to 17 century all the tools which men used for developing some of these fine objects were hand operated and the methods were very elementary until a little bit later of course, you know man human kind found out that. The power of water steam could be very easily used and of course, much later it was realized that electricity could be again another very useful source of delivering energy. So, that you could power drive some of the tools for creating different shapes onto metals.

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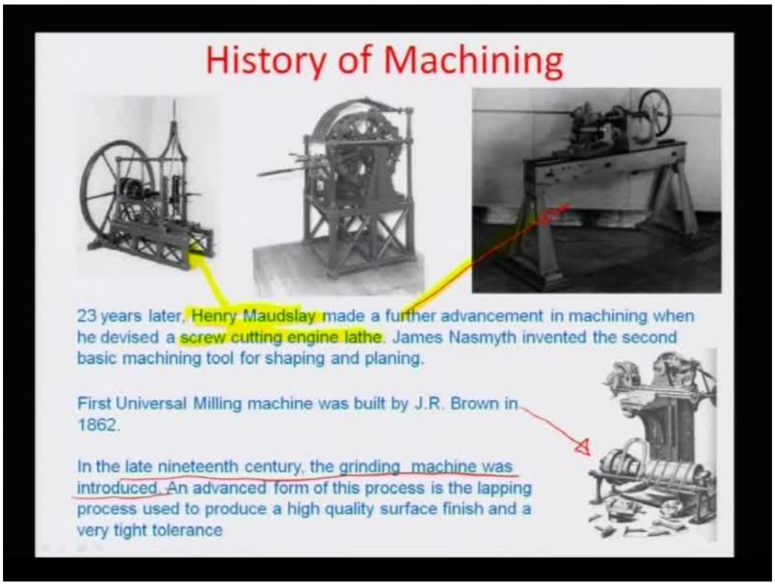

So, if you look at one of the first illustrations, it comes from this John Wilkinson in 19 in 1774. Who first constructed a Precision machine for boring engine cylinders and it was powered by steam. So, this is 1 of a earliest examples, of how machining could actually take place and increasingly go into the power domain from the manual domain. This followed a lot of other illustrations later on for example; 23 years later Henry Maudslay actually developed this screw cutting lathe as is illustrated, in this particular example here. And then of course, James Nasmyth invented the second basic machining tool for shaping and planning, which is again illustrated in this particular figure here.

Then the first universal Milling machine was built by J. R Brown in the year 1862 and these were all power tools, starting with John mill concerns first engine boring system, which used a steam for providing the power. So, after these basic machining tools were developed to have high through put processes or highly productive processes people realize that finishing was a very important aspect and so in the late nineteenth-century. The grinding machine was introduced for the first time, as a more advanced for this process later on changed to lapping and high quality surface finishes with very tight tolerances could be easily realized using a combination of a grinding and lapping processes, on the primary machining operations which were done by this powered systems as we illustrated before.

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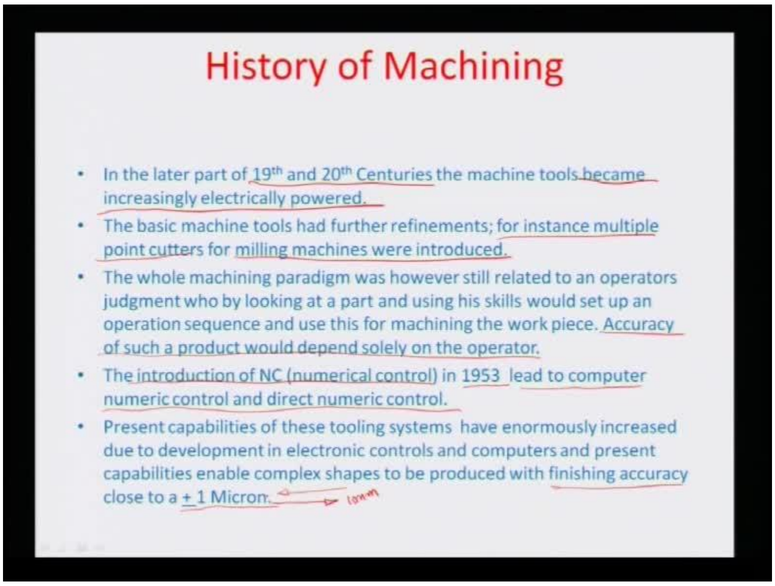

So, if we look into a little more of history the later part of these nineteenth and twentieth centuries machine tools, first became increasingly electrically powered. And they had many refinements for example, people shifted from single cutters to multiple point cutters and milling tool was introduced for the first time based on this concept. The whole machining paradigm although it was powered was still dependent on operators and human skill, who by their own judgment would look at parts and uses his or her skills to completely provide, the sequence of operations and therefore, on the work piece accuracy would typically depend on the operator.

So, as an increasing need for precision was felt rapidly in the industry, particularly because of complex systems like automotives etcetera. Which emerged on a commercial scale during this time, for the first time in 1953 the introduction to numerical control systems, where computers power would be used with the numeric logic for obtaining a good precision and repeatability of relative motion between a tool and a work piece was felt?

So, with all these capabilities integrated together the present capability of these tooling systems have really enormously increased up to the level of ,initially it was about a Micron, but then with the current technologies of chemical photochemical and you some high energy deem based machining it can go to the size range of a few atoms so it's about probably 10s of Nanometers that this limit has been pushed to increasingly. And not only that, it can it has tremendous capabilities of producing complex shapes with a kind of finishing precise, which can be as low as let us say Micron level finish.

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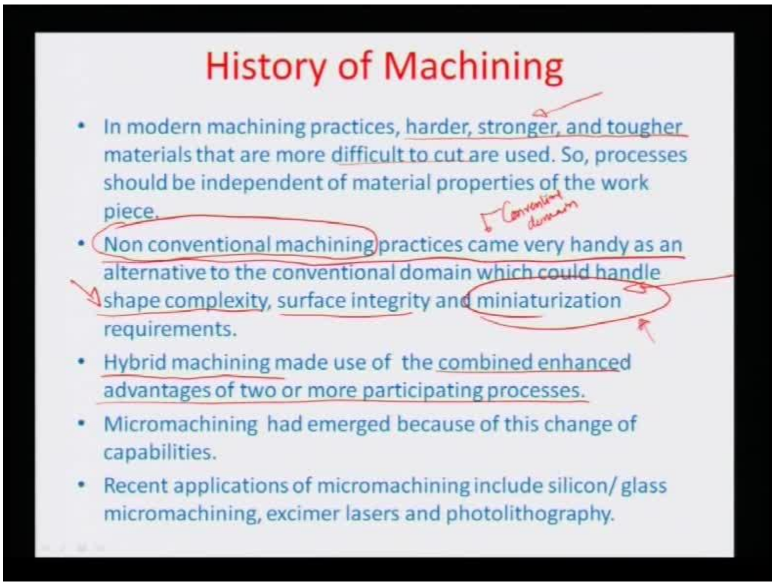

So, increasingly the power of machining industry has grown over on the various decades and up till now, you know this power can be really manipulated and maneuvered to even place of few atoms and molecules. So, that is what the accuracy level has slowly gone into in modern machining practices of course, 1 important aspect is to be able to remove material which is harder, stronger and tougher. And it is more difficult to cut and that is 1 of the goals of some of these modern machining practices and should be independent of…

So, the cutting processes should be really be independent of material properties of the work piece. As such increasingly from this so called conventional domain of metal to metal cutting increasingly the focus has changed in to some of these nonconventional machining practices, which has become very handy as an alternative. Particularly if you have to realize complex shapes with certain amount of surface integrity and most important aspect miniaturization or Micro micron sized requirements of the components.

So, in this course typically we would be more focused on to this nonconventional machining domain and the way that it could be used for creating some of or achieving some of these targets as machining complex shapes or going very small teeny tiny components, how that can be manufactured would be probably going through some material based on that. Of course, needless to mention is this concept of Hybrid machining, which combines the enhanced advantages of more than 2 processes, 2 or more than 2 processes.

So, that your objective of super high finish and high productivity or may be super high finish and complex shape both can be achieved together. So, because of all these domains which are now, increasing available in machining Science, Micromachining has emerged into a domain where really very small up to about 1 Micron or so feature sizes can be realized very easily combining some of these technologies as Hybrid machining technologies. So, recent applications of Micromachining could include silicon and glass Micromachining Excimer laser based machining photolithography these are the some most modern processes of nonconventional machining, which as used this particular domain.

So, machining has increasingly also come up from you know precision grinders where an accuracy of about plus minus 1 Microns can be melted using some noncontact mediated measurement processes, like interferometry or laser based instruments. And the future trends in Micromachining really include the power of beams of either photons or particles.

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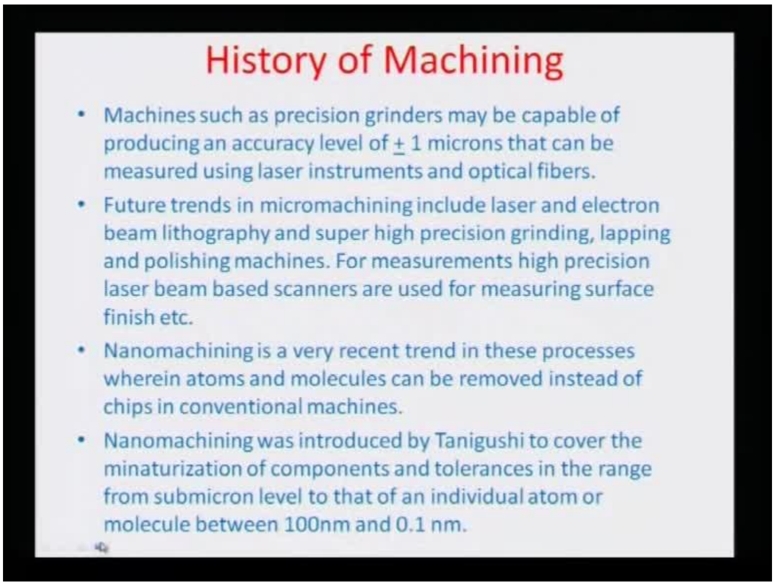

Processes like Electron-beam lithography or focus beam is increasingly being used to realize or Micro manipulate materials, even down to the atomic level in very précised manner. So, these combined with a few other processes, also are classified into the area of Nano machining. As a very recent trendand these processes are capable of you know, manipulation at the atomic and molecular level. And the Nano machining concept really was first introduced by Thaniguchi and it covered many authorizations of components and tolerances in the range of some micron level and also to the level of 100 of Nanometers or even as slow as 0.1 nanometers. In the various domains that was proposed by Thaniguchi in his model Nano machining.

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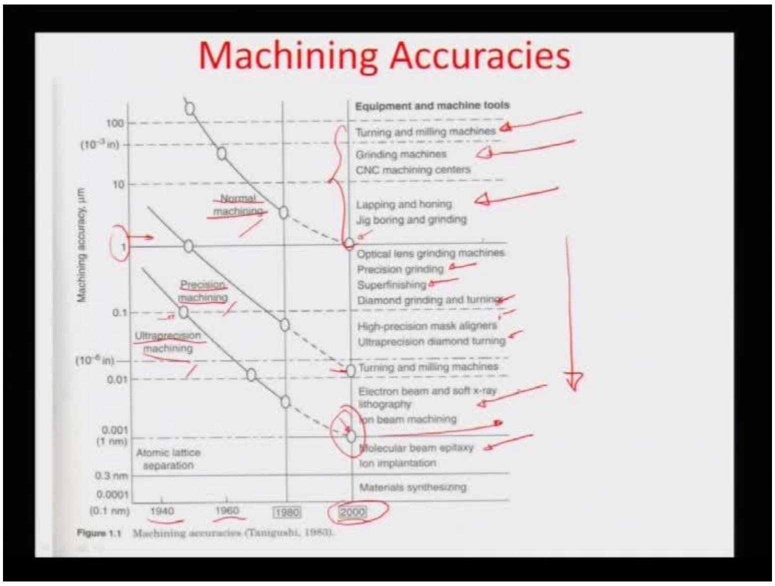

So, let us look at some of the machining accuracy with respect to the number of years as can be illustrated here in figure1.1. And as you can see these the different domains of machining like for example, turning and milling machines Grinding CNC machining centers Lapping honing jig boring and grinding so on so forth. So, these are the different equipments on machine tool classes, which are a grouped together in a order of how much machining accuracies they can produce.

And if you look at the way that this machining has involved no is evolved from as far back as 1942 you know the late 2000. You can see, that the machining accuracy really has changed quite a bit from about, let us say 0.1 inches to a 100s of Microns to about close to as low as about 1 Micron particularly few ah over to take into account these 3 conventional domain processes Turning milling, Grinding CNC milling centers Lapping honing jig boring and grinding so on so forth. So, this also is a normal machining domain and so you can achieve up to a machining accuracy of 1 Microns by the year 2000 as you can see here and this has really being achieved.

As indicated in this particular chart some of the other processes like precision grinding, super finishing diamond grinding and turning high precision mask aligners ultra precision diamond turning they come in the domain of precision machining. And here the machining accuracy really starts from 1 Micron and goes down on further to almost about 100s of Nanometers about 0.01 Microns and that could be roughly about 10 to the power of minus sixth of an inch. If you go little further down here, the electron beam soft x ray lithography ion beam machining molecular beam epitaxy ion implantation and will understand some of the basic machining principle and processes as we move along.

They can be classed into this ultra precision machining domain, where the machining accuracies as low as 100s of Nanometers of 0.1 Microns is the starting line and it goes all the way to about 2 out 2.001 Micron, which is road 1 Nanometer which is dad of even atomic manipulation, you know, at the level of lattice separation etc. So, you see that with increasing time wherein from 1940 to 2000, the machining pyridine classified normally as a normal domain, precision domain and ultra precision domain have gone from all the way from about 100s of Microns to as low as about 1 Nanometer. Which is that of simple lattice spacing between the atoms? So, such is the power of machining technology and its emergence over the number of years.

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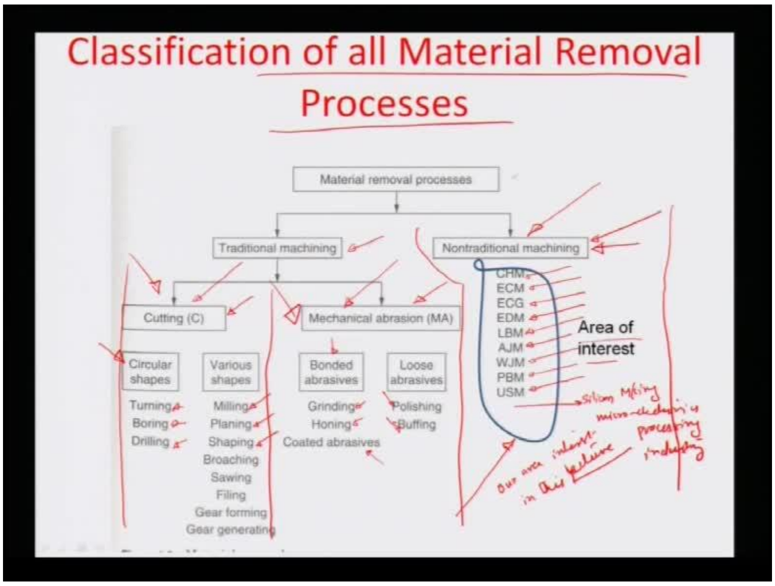

So, let us actually now at a broad classification of all the machining or the material removal processes. And here I would like to classify the processes as traditional domain and then the non-tradition or non-conventional domain. And of course this would be our area of interest for this particular course, although a brief mention would be made of the additional domain processes. So, in the traditional machining area if you look at the class and the subclasses of these machining you have a category of cutting processes, where these different you know processes can be classed as turning, boring, drilling these are all cutting processes, and this could be able to generate circular shapes.

Then some other shapes can also be generated by this other set of cutting processes or metal cutting mechanisms like milling, planning, shaping broaching, sawing, filing, gear forming, gear generating so on so forth. So, traditional machining has this 1 class or 1 domain where you are actually having a metal to metal cutting and then there is another domain which is used for finish machining operations on this cut pieces, which is mechanical abrasion based then it can be based on bonded abrasives like you often find in grinding or honing or coated abrasives technology a loose abrasive study often find in polishing or buffing.

Where the slurry really contains the abrasive and then the polisher of the 2 is really rubbing the slurry against the work piece surface. So, therefore, that is how traditional machining domain can be and of course, needless to say is that this is a high through put, low accuracy process and the mechanical abrasion is actually a ah relatively lower yield, but high accuracy process, so far as the traditional machining domain is concerned. So, we have already made a case before to illustrate that the these traditional domain processes may not be that useful than you comp to relies a machine increasingly, tougher or high strength materials with complex shapes and precision or accuracy to the level of even the atomic manipulation.

So, therefore, these set of machining parameters called the non-traditional machining techniques come into picture and they typically include chemical machining, Electrochemical machining, Electrochemical grinding, Electro discharge machining, Laser beam machining, Abrasive jig machining, Water jig machining plasma beam machining and absonic machining. So, these are some of the different illustrations of the machining domain, where very small surface finishes or even micro features sizes can be increasingly found and then there is a whole domain of silicon. You know, machining which also is borrowed from the Micro electronic processing industry which would be looking at great details.

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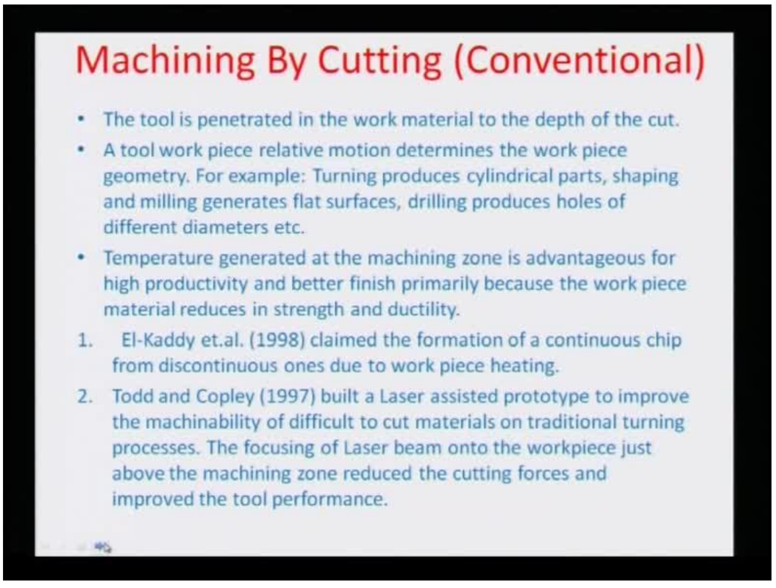

So, let us look in to a some briefly in to the conventional domain of the machining force starting. And so, typically in the conventional domain is we have realized that there is a tool and this tool is used for penetrating the work material to remove, certain amount of material up to a depth. And the amount of depth that the tool goes in to the material is also known as the depth of cut. So, there is of course a relative motion between the tool and the work piece and different geometries can be realized based on this relative motion between the tool in the work piece.

For example: look at turning the way it produces cylindrical parts. So, you have a single point cutting tool and there is a mask which needs to be machined and its rotated in a certain rpm. And the tool goes and scribes off, the material and increasingly goes deeper and deeper into the material. So that, the circular symmetry of cut can be generated in a cylindrical piece can be generated based on that. Of course, there are shaping and milling which generates flat surfaces, then there are drilling processes where you can produce holes up to any dimensions of different diameters.

Where again the relative motion between the tool in this case, the tool rotates and the work pieces fed linearly, it determines really how the shape of machining is going to be on the work piece. So, because of this regular scribing of material there is a temperature generated at the machining zone and that is advantageous for high productivity and better finish primarily because there is a slight reduction in the strength and the ductility of the material that we were cutting. And the preheating always helps to make the material softer so, you can at a very high yield and better finishing accuracies be able to cut materials.

So, there are certain illustrations found in literature, for example: a paper by I carry at all as you can see here in 1998 which claimed for the first time that formation of a continuous chip from discontinuous ones, were due to work piece heating and then of course, this Todd and Copley 1997.Who actually built laser assisted prototype to improve the mach in ability of difficult to cut materials on traditional turning processes, but preheating using this laser assistant system. It was focused the Laser beam on the work piece, just above the machining zone and reduce the cutting forces quite a bit and improved also the tool performance this way. So, some examples: were playing around the temperature of the material or to get better finishes or more amount of material removal have already been demonstrated by various people, using conventional machining domain.

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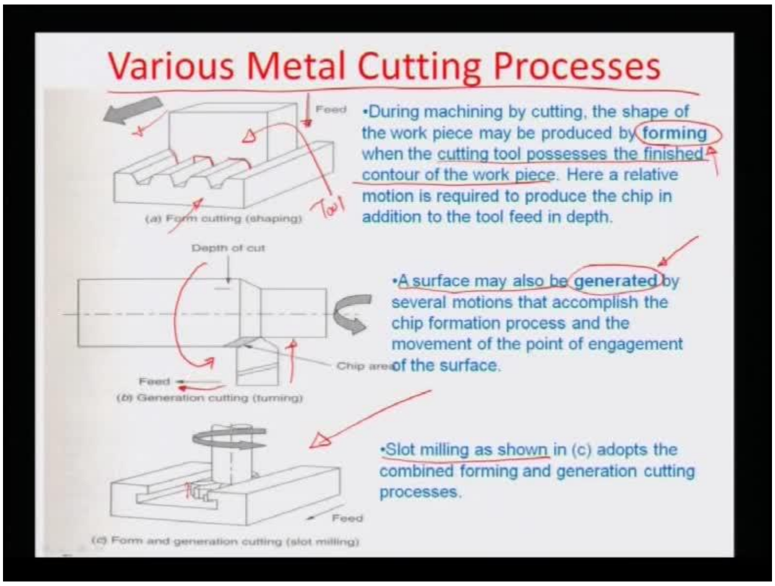

So, if you categorized the different metal cutting processes they can be either categorized into the forming processes or the generation processes and I would like to classify between the 2. So, a forming process typically is 1 cutting tool processes, the finished contour of the work piece. For example: Let us say, for example, in this illustration this tool here is having a inward contour, as can be illustrated here of whatever it produces finally on to the work piece surface. So, you give it a feed and then also give it a cutting motion and whatever contour is there on the surface of this tool is replicated in negative formon to the surface or the work piece over which this is moving.

So, you are forming the shape which was there on the tool, the negative of the shape which was there on the tool over the work piece surface. So, it is called forming, surface may incidentally also being generated. For example: Let us say, this single point cutting tool example in a Lathe where there is a movement ah of rotation given to the work piece and the tool is fed. In this particular direction also given a depth of cut so, that there is a circular symmetry, which is developed of the cutting zone resulting in development of a different shape.

So, these processes can be thought of as generating the contour or the feature relative motion of the tool with respect to the work piece. There can be combination of both the forming and generation processes, as can be illustrated in this particular example, which is a slot milling example. Where the forming can be thought of as provided by the thickness of this cutter in the milling can be thought of as relative motion between the tool and the work piece doing the machining operation.

So, another process these are all the metal cutting processes and the other processes that I was referring to is based on machining by abrasion. And Abrasion machining the machining allowances removed by a multitude of hard angular abrasive particles or cranes, which we also know as grids. And which may or may not be bounded to form a tool of definite geometry. So, in contrast to the metal cutting processes curing a Abrasive machining the individual cutting edges are randomly oriented and the depth of engagement is small and not equal for all the abrasive cranes.

And there is an average averaging effect of the cutting depth which results in a sought of surface finish, on the high yield processes like, some of these metal cutting processes forming or generation processes etc. So, it is really a finish machining operation and not all the abrasive cranes are simultaneously able to remove so, they come in contact 1by 1. And then they remove their own material by brutal fracture and therefore, the averaging effect also becomes more prominent. Because the chips removed are very minute and most of them are invisible because the temperature operation. So, high that they get oxidized and you can see a flame come out from the such operation or such rubbing action of the abrasive.

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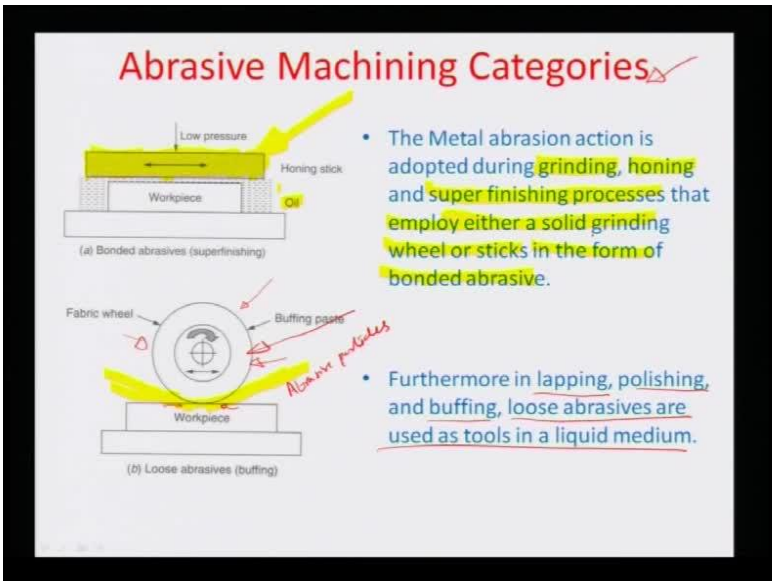

So let’s look at some of the schematics of how abrasion happens. So, typically 1 very interesting abrasion process is of course, mechanical grinding and then the some of the other processes are honing and super finishing processes that employ either a solid grinding wheel or sticks in the form of bounded abrasive. So, this i illustrated here in this example, where you can see that, there is a there is a stick for example: This is a honing process and this stick here illustrated by, this highlighted region is containing the abrasive grains or the grips, adhesively or bounded on to the surface by using an adhesive. And you apply a low pressure to this honing stick and move the stick with respect to the work piece.

So, there is gradual finishing of the work piece surface and you can use as a medium or something like oil, which carries of the material which is this large from the work piece because of this low pressure of the honing stick. Another interesting example of metal abrasion process is where instead of that as if being bounded as was grinding or honing. The adhesives are open and use wheel to rub the adhesive which is typically in the slurry. So, this slurry which is around this region really contains the adhesives or abrasive the slurry contains the abrasive particles.

The tool here is nothing but, a rubbing agent where it takes the abrasive slurry and rubs against the work piece and the tool can be rotary in nature as we can see here. And these are used for very soft applications like for example, when really high level of finishing like polishing or operations are needed. You can use some of these techniques like lapping or buffing or polishing, where loose abrasives are used in a liquid media and the tool as such is nothing but, a rubbing agent of this loose abrasive particles. So, that is how abrasive machining can be categorized into various ah different domains.

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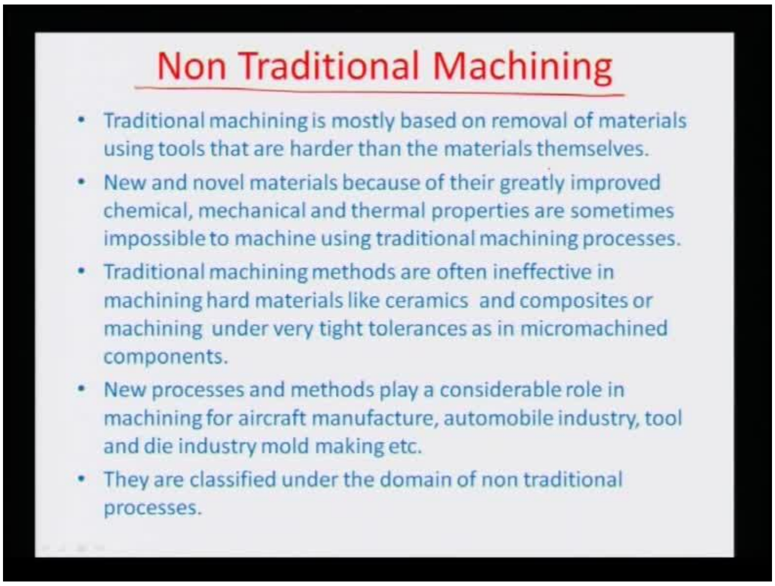

Now let us get into the domain of the nontraditional machining processes, as we have illustrated it so far many times. So, traditional machining of course is as you know mostly based on removals of materials, using tools that are harder than the materials themselves and increasingly the need for nontraditional is really felt because of the novel materials or alloys or high compo or high set composites which are being developed by material science time. So, that these techniques can become menstruate ah you know with such normal materials, which an increasingly finding engineering applications in even industries. So, what are those non-traditional processes or what is the domain of the non-traditional machining. So, we can actually have a closer look by going into this particular illustration or slide.

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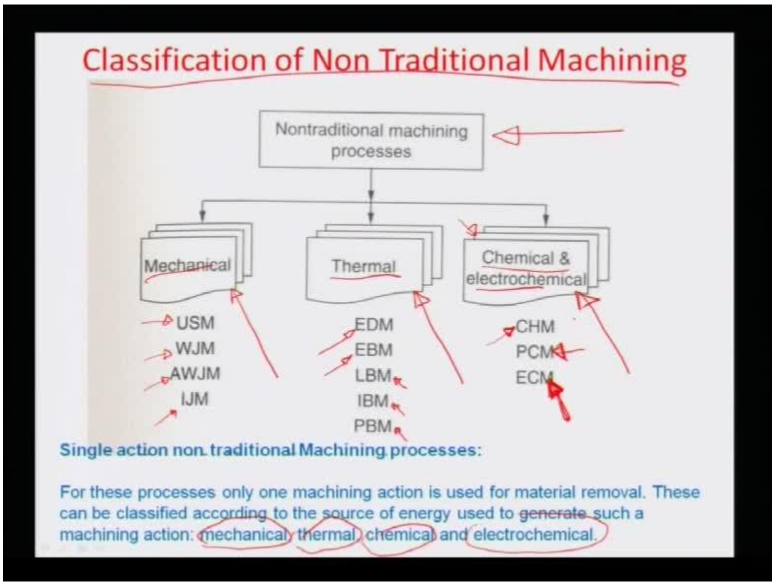

So, here I have tried to classify some of these non-traditional or advance manufacturing processes into different domains and there are 3 principle domains, that we can really classify these non-traditional machining processes, as there is a mechanical machining domain where you can again use mechanical removal of material as a means, of doing machining of course. In these particular cases, you will see ah the material removal will not be in a bulk state as turning or grinding processes, but in a very super fine state by use of abrasive materials in a very interesting manner.

There are thermal ways and means of removing material for example, what an electric discharge can do or a power of a electric beam can be used for machining or material removal. As a matter of fact power of laser beam or ion beam or plasma beam can be increasingly used for some of these thermal processes and then of course, there are this chemical and electro chemical machining processes, where things like lithography or even you know, where the power of a chemical called to be able to microstructure itself very accurately can be used for going smaller and do micro manufacturing with high surface finish and micro components micro systems as such so on so forth.

And then of course, there is this ECM or electro chemical machining, where ah particularly metallic domain materials in the metallic domain can be easily removed using ECM or complex shapes, in the intricate corners can be machined very easily and then ofcourse there is a huge domain of photochemical machining, which can be a combination between optics and chemical machining.

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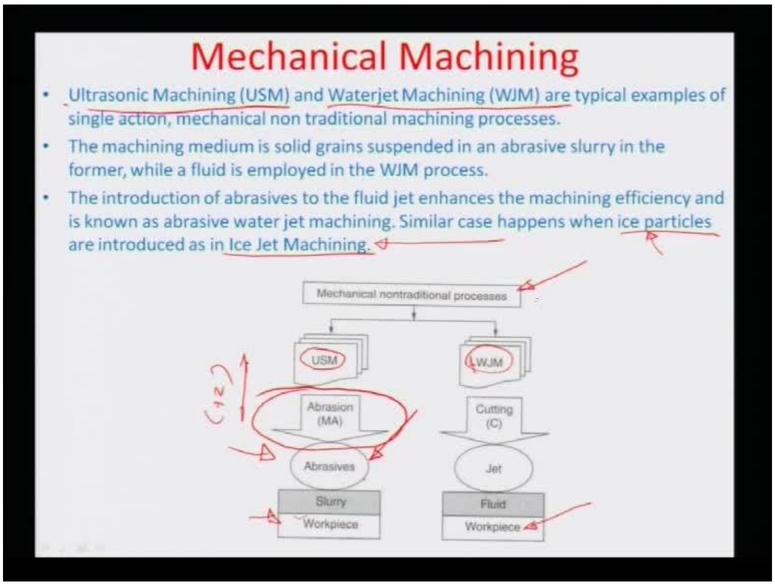

So, therefore, so the most of the nontraditional processes are classified only into this 3 kind's mechanical thermal and chemical or electrochemical means of removal and it is not necessary that only one process can be used. You can use hybrid processes here you can have the combination of more than one process and by the by, this classification is really based on how you are applying the energy. So, you can actually have the machining action using mechanical energy or thermal energy or chemical or electro chemical energy and they form the classification basis of this different material removal processes in the non-traditional domain let us look at these machining processes 1 by 1.

So, the first mechanical machining process, which comes to our mind, is Ultrasonic machining or as a matter fact water jet machining, which are typical examples of single action mechanical non-traditional machining processes. So, if you look at the schematically how this happens is that there is a mixture of abrasive grains. So, this mixture can be made up of medium, liquid medium into which these grains are immersed and these grains are all individually capable of moving and free to move. And the grain containing slurry is pressed on to a work piece, by means of a tool which vibrates at ultrasonic frequency.

So, essentially this tool head which vibrates. Let us say in this direction and the positive v direction at some above sonic frequency or Ultrasonic frequency is able to hit the abrasive grain on to the work piece surface and thus removes material in the brutal fracture mode. And so, super finishing process is again sometimes used these USM driven, you know material removal mechanism, where the feed or the depth of cart or even the tool free frequency can be adjusted in a manner. So, that different level of finishes can be obtained on the surface, for example: Another example of a mechanical machining process is what you can do with Water Jet Machining.

So, essentially here as the name sound there is a Jet of Water, which is realized with a high pressure and there is, you know a forced directed small jet area which is used to cut the work piece. Sometimes you have abrasives loading the water jet. And so, you will have these slightly the process slightly modified from WJM to AWJM Abrasive Water Jet Machining. So; therefore, use an abrasive material to actually perform the cutting action here and the jet provides the impact to the abrasive material to cause the brutal fracture. So, the machining mediums in most of these cases are solid grains suspended in cutting fluids and you can actually replace the abrasive frame by ice particles.

So, that you can subsequently a be called as Ice Jet machining. So, all these are mechanical non-traditional processes because the action that is applied here is really brutal fracture based mechanics of removal of the material and therefore, mechanical. So, we will look into the details of this process particularly the USM and the Abrasive Jet machining processes, a little bit later.

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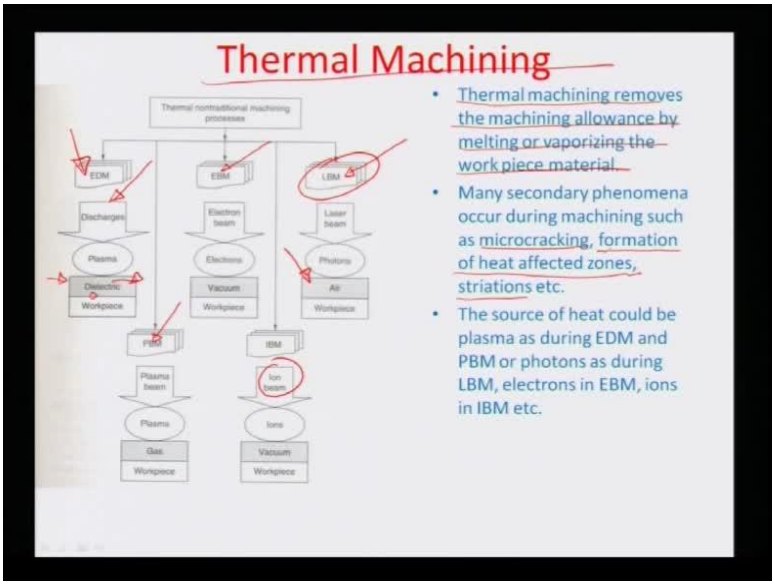

And let us come to the second modality of material removal which is also known as Thermal Machining operation. So, here really the modality is thermal, in the sense that you are trying to apply heat energy. So, that it can cause melting or vaporization of the work piece material thereby removing the material as a liquid or vapour state. So, there are many secondary phenomenon of course, which are occur when Thermal machining is been considered. For example, micro cracking, formation of heat affected zones, striations or banding phenomenon which can come during the Thermal machining processes if they are not very well controlled. And so therefore an important modeling aspect of such process come into picture which will look into great details as we go over some of these processes.

So, the source of heat could either in this case be that of from electric discharge as you can see here, in idiom. So, there is a plasma or discharge which is created between the work piece and the electrode and the diluted material inside in between the work piece and the electrode acts as an insulator really, where the plasma can be created in specific columns. So, whenever this plasma gets created the electron pressure is able to create a local temperature enhancement. So, thus taking the material the work piece material to wherever this plasma strikes to its melting point and whatever melt is withdrawn is removed by this circulating dielectric material.

So, this is 1 form of machining called electro discharge machining. The power of the Thermal power can be provided by a plasma beam and that then would be called plasma beam machining or let us say an electron beam. So, therefore, that can be called as e beam machining or electron beam machining or it can be any other form like an ion beam or Laser beam on. The mechanics of removal of the material here is more or less thermal but the conversions principles are different. For example, in electrons it is really the kinetic energy exchanged between the Impreditrating electrons. The Latus of the material whereas in laser beam machining it is a photon to phonon conversion or the conversion of photons into bun vibrations which results in the machining process. And so thermal machining also is very increasingly being performed in hybrid machining processes where some of these conventional formulated micro parts are given a secondary treatment using some of these thermal machining processes for issues like complex geometry is or even good surface finishers etc.

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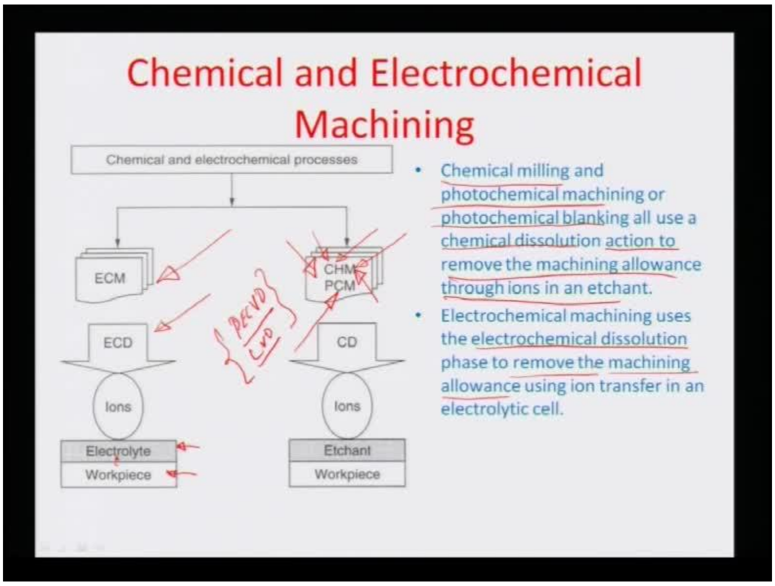

Now, third category of processes is the chemical and the electrochemical machining processes, as is illustrated here in the electro chemical machining process you again have the an electrode and work piece as another electrode and the electrolyte is flown in between the work piece. And the electrode in question and therefore ah there is always a ion transport which happens in between the electrolyte, where material is removed from the work piece. And the idea is that should not get deposited on to the electrode, but should get precipitated as soon as it gets removed from the work piece.

So, the electrolyte constitution is very critical so, that it is not only able to create a man movement from the work piece, but also be able to precipitate the material and move the material if you can circulate the electrolyte around. And so, that is what is meant by electro chemical machining and its governed by faraday's Principles and you can really calculate model the electrochemical machining rate based on some of these basic physics principles. The other processes chemical or photochemical machining process where again chemical machine would chemical machining would formulate the domain of edging, where edging is really nothing but, sought of engraving of metal structure or engraving of a certain area of metal or any other sub straight by edging it selectively with respect to a chemical.

So, that chemical can cause either a redox reaction on the surface or it can actually make state of atoms removed from the surface, which cannot dissolve very well and it gets increasingly carried away. It can also be gas based system where the same edging action is provided by a gas and not a liquid chemical. So, therefore, some of these processes increasingly used in silicon micro machining like PECVD plasma enhanced chemical vapour deposition or CVD chemical vapour deposition can be used increasingly to either Bulk micro machine or Surface micro machine some of these micro systems

Photochemical machining again is a very wide area of interest as well as the micro systems machining goes and this photo chemical machining typically includes photographic film called resist, and this resist is removed selectively with respect to mask and selective exposure to certain frequency light. So, therefore, if you can formulate the coat of this resistance selectively remove materials of it is surface then those can result in vias and crunchers, which can expose the sub straight the parent sub straight selectively for chemical machining and other different forms of machining.

So, photo chemical machining certainly is a very important area as far as the micro systems of fabrication technology goes and we will actually look into the details of some of these systems later. So, thus this chemical machining may include the domain of Chemical milling, Photochemical milling, Photochemical blanking chemical dissolution and the basically such actions are again used to remove the machining allowance through ions in an etchant.

And electrochemical machining of course uses electro chemical dissolution by the passage of electrons and ions from within the electrolytes and those machining allowances can be removed. You know the or the material can be removed it to formulate the machining allowance using an ion transforming mechanism in a electrolytic cell.

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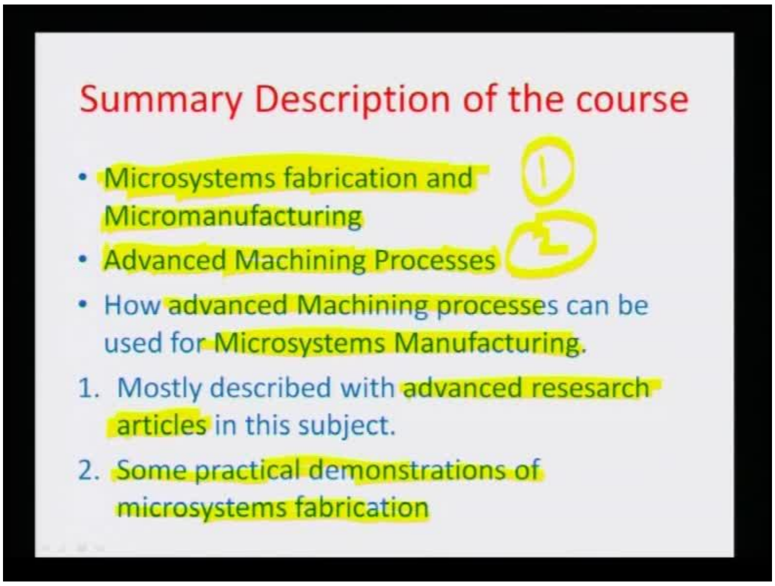

So, that is in a Nutshell is what is you know, brief description of what would be in the course contains on 1 hand we are actually going to learn this fabricating of Microsystems with an angle of micro manufacturing. And on another hand and so this would mostly include silicon based processes, processes where which can be increasingly applied to polymeric systems glasses from a standard point of microsystems fabrication. And then the other end of the course would actually del into this advanced machining technology is which have been indicated here that is a thermal mechanical and chemical electrochemical forms of machining and then finally we would like to integrate number 1 with number 2.

So, that we can use these advanced machining or non-traditional machining processes for making manufacturing micro systems. And so this section of the course would be dedicated to mostly some of the advanced research articles, which would focus on how MEMS can be created using non-conventional machining technologies. And then we would also like to demonstrate practically some of the micro systems fabrication protocols and processes, where non-traditional machining is actually realized, is actually used in practice to formulate a real macro system. So that is in a Nutshell, what this course is intended to be…