Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Manufacturing Process Technology-Part-2

Module-02
Classification of Machining Processes

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Hello and welcome to this manufacturing process technology part 2 module two brief recap above what we did the module one of this particular course so we were talking about the various advanced fabrication processes which employ on different forms of energy including mechanical thermal chemical electrochemical so on so forth and in context of that we had looked into some of the basic processes like breasts of jet machining water jet machining laser machining electro discharge machining electrochemical machining so on.

So forth we also had a brief walkway for the various stages of manufacturing and how manufacturing evolved to the most complex form of the advanced manufacturing processes as on date let us look into a little bit details about these different forms of machining so mechanical machining for example the many types involved one is ultrasonic machining where there is a slurry composed of basically an aqueous solution of a bless of particles and there is a vibrating head which will give mechanical energy to these small abrasive particles.

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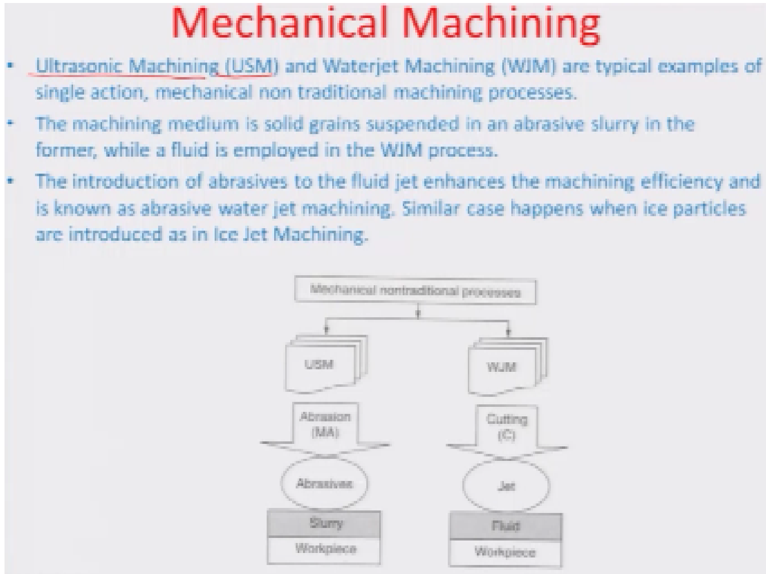

Which will actually embed on the surface because of the ham meaning action or because of the mentor that they possess towards the workpieceand it creates some kind of a brittle fracture typically this form of a machining is very highly preferred mode when we talk about ceramic machining or glass machining on things like that we have water jet machining where there is a jet of water at a very high velocity very high pressure as well which comes out of a small nozzle and it is mixed in terms with the brass of particles it is loaded with the brass of particles so there is always possibility of the abrasive particle being thrown upon a surface which would again create the brittle fracture process and that's how cutting is performed.

So these are typical examples of single action mechanical on-traditional machining processes sob typically as you are seeing here in the US and process there is abrasion there is an aggressive and the abrasive comes from the slurry right here which is actually in close proximity to the work piece and there is a vibrating head which will push similarly in what is it machining the cutting is through a jet and there is also a fluid work piece interface where this jet would typically strike and this kind of machining is typically done under water okay.

So therefore whatever jet emanates out with the abrasive particles loaded on goes through a layer of water before striking the work piece so the machining medium is solid grains suspended in an abrasive slurry in the in the in the farmer whereas in the later that is the blue gem process there is a fluid again but it really not a thick slurry but a thin slurry with the fluid loaded with some Garnett's or abrasive particles okay.

So you can do the same with ice particles replacing the abrasive particles if it is replaced by ice particles we call it ice jet machining so these are the different kinds of non-traditional mechanical machining processes there are also thermal machining processes typically which include EDM that is electro discharge machining electron beam machining laser beam machining plasma beam machining and ion beam machining .

So these are all different processes where there is interaction of a plasma which is typically superhot with respect to the surface the working surface and this plasma kind of melts away part of the surface makes a local pool and then there is a fluid or medium which typically carries out particularly in these cases like the EDM cases the depart Achill which is dislodged okay so there is a discharge and the discharges typically in a medium which creates a plasma and then you know the medium is typically a dielectric fluid.

Which breaks down to give way to this plasma and whenever there is an interaction between this plasma and the work piece it creates an erosion ok and so similarly in the eb machining again you know there is a beam of electrons which is actually guided over a surface and super focused in a very narrow zone so that the electrons traveling at Avery high acceleration typically would go through a vacuum where the work pieces placed and without ionizing anything in its path because of the super high vacuum this electron would actually work upon the work piece and create a thermal erosion.

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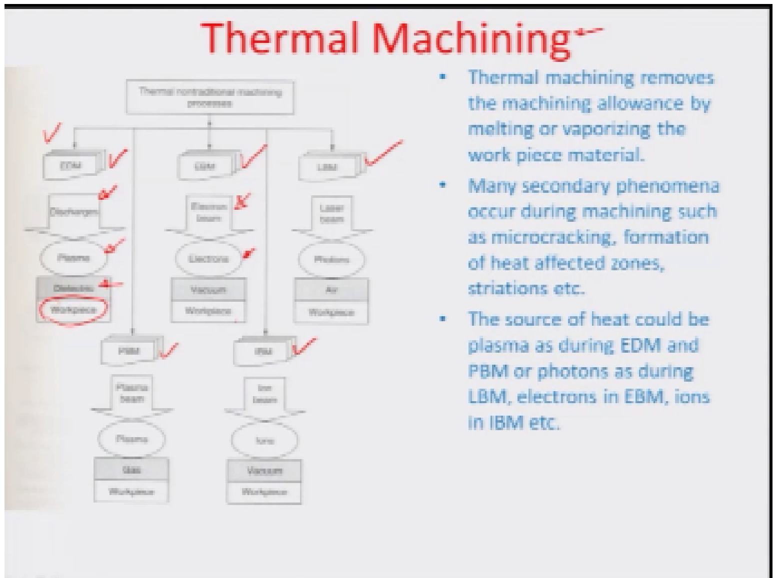

Again on the work piece so typically the electron doesn't really realize after it has crossed a few layers of lattices beyond which it starts to really share its momentum into the lattice and therefore there is a pocket which is created in a buried manner inside knee beam tool and it results in some kind of a sudden opening of the orifice and it creates some kind of energy transfer and the electron is able to depreciate material or create a melt pool down within the surface of the material.

Similarly laser beam machining again the same what is the chimp achieved here by a electron beam is done through a laser beam laser as we know is a very strong form of energy transfer which talks about beam of photons which are highly coherent in nature and generated by a laser source and these are actually thrown upon again work piece where there is air in-between the work piece and this laser beam and the photons typically hit the work piece and create a photon to phone on conversion so there is a sort of a lattice vibration which is created and which results in again some kind of local melting and also evaporation because the laser power is typically very high okay.

So the e-beam system deploys a vacuum which is actually shortcoming of the process which kind of limits the work piece eyes but in case of Woodley laser you could do really this kind of a machining over a very large or a wide area surface and that’s the reason why laser is used sometimes for wide-area texturing and various other applications you know which can you can feel you can think of in thermal machining similar initiatives are taken by if the source changes to plus source or an iron beam and for example the very common example in this area of the ion beam is the focused ion beam.

But there is a gallium source and it gives you a stream of ions which would actually deposit or strike with the work piece and create thermal erosion of the work piece so you can do really very fine machining using these processes but the means here is a sort of a thermal impact or a thermal shock to the material which causes the material to either vaporize or melt in Avery small area and thereby create erosion within the work piece okay.

So here are many secondary phenomena which occur during machining such as micro crack formation of the heat affected zones some striations etcetera because of remolding sorry Vida position or e solidification of the melt which has been created and therefore the surface really becomes a very critical issue and the finish of the machining process becomes a very critical issue when we talk about such thermal sources so and that tunnel machining.

So we have a similar kind of an alternate machining using chemical and electrochemical route okay so we talked about in this case for example the chemical machining process you have some kind of an etching or an engraving action so there is a an acid which interacts with the surface of a work piece and because of this interaction on a very selective manner in some selected zones there is a local erosion of the work piece material which results in the formation of an etch zone.

Or a edge area so there is literally dissolution of the material into the medium that is sentient because of which there is machining taking place we call that chemical machining we also have Avery interesting process called photochemical machining where some particular materials which are also known as photo resists or photosensitive or photoactive materials are used so there are films and layers of these materials which are created and then you selectively exposing some of the region to a beam of light.

Which is at certain frequency and it creates some kind of a bond breakage picker in this particular material cause of the high-energy photons which are pumped into the system and since the bonds are broken in one case or we formulated in another case it really results in either resolution of this area the bonds are broken or if the bonds are strengthened then it retains itself and the remaining area gets dissolved in a solution so there is an etching step after the photo exposure step in such machining and so these kind of machining where there is a light beam being used and a chemical material being used called resist.

It is also known as photo chemical machining okay so that is how you can actually think of these chemical processes electrochemical on the other hand are based on the Faraday's principle so you have some electron transport.

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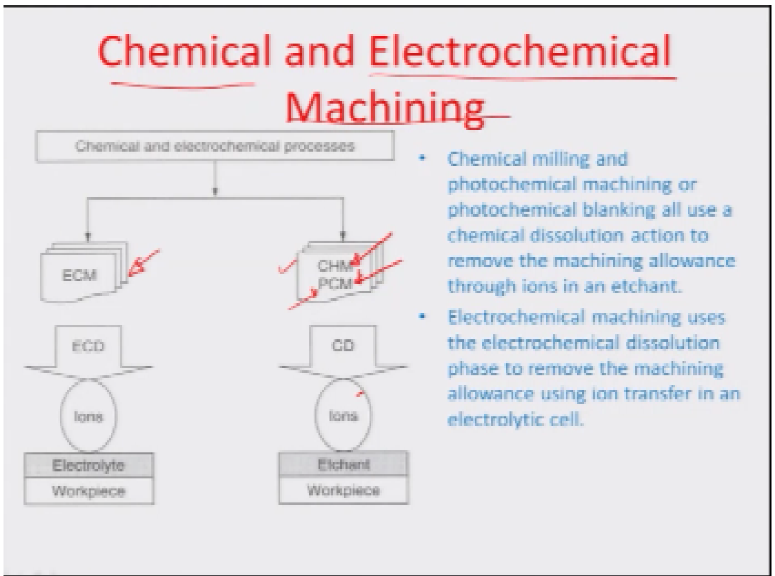

Going on with the chemical process and typically these are redo chemistry is where there is something which gets oxidized and some other material which gets seduced and there is some kind of a red o x couple being formulated between the two electrodes due to which there is a driving of either the metal going away which is known as electrochemical machining or the metal being deposited which is also known as electrochemical deposition.

So we can use either of these processes to really create a wide variety of machined surfaces using chemical or electrochemical means so there are many variants of such processes for example you have chemical milling you have photochemical machining a photochemical blanking all use chemical dissolution action to allow the machining allowance through ions in an etchant similarly in electrochemical machining it uses electrochemical dissolution phase to remove the machining allowance using ion transfer an electrically electrolytic cell.

So that is about chemical and electrochemical machining so let us now go into the first you know generation of the learning that we would I would really be emphasizing here and that is about the micro nano systems and how to some extent you know such machining processes as I have mentioned work out in the case of micro nano systems this is a very important aspect as long as far as the advanced machining processes go picket least you know half a dozen of such processes have been borrowed from the electronic industry and particularly those processes which are related to the fabrication of the microelectronic chips or semiconductor chips are really some of the advanced machining techniques which or maybe they are the first-generation advanced machining techniques which actually came out and they have really served through their commercial cycle okay.

So let us look into some systems for example that why the micro noon systems and then let us also look into some of the aspects of how to machine or how to fabricate such micro nano systems through variety of you know photochemical or chemical steps or even you know chemical deposits insteps so that you could actually realize very small micron to nanometer scale component.

So let us talk about these systems made up of very small components micron to nanometer scale which is actually these micro no systems they find a relatively high applicability to various fields but then you know they especially find a lot of application in the field of life sciences biotechnology and medicine although it is not really limiting because this you know if you look at difference you look at aerospace you look at you know cosmetics or you look at the variety of other areas of life you always almost about you know eighty to ninety percent of the times fine systems.

Which are very small and they are giving a very high resolution by virtue of their low inertia mass okay so it is really the very state-of-the-art technology that we talk about when we talk about such systems so let's look into some certain aspects related to such systems and I would just like to describe some examples here which talks about what these micro systems can do or what they are probably this you are able to recognize almost all of you this is actually one of the cornerstones of today’s so-called nano fabrication or nanotechnology.

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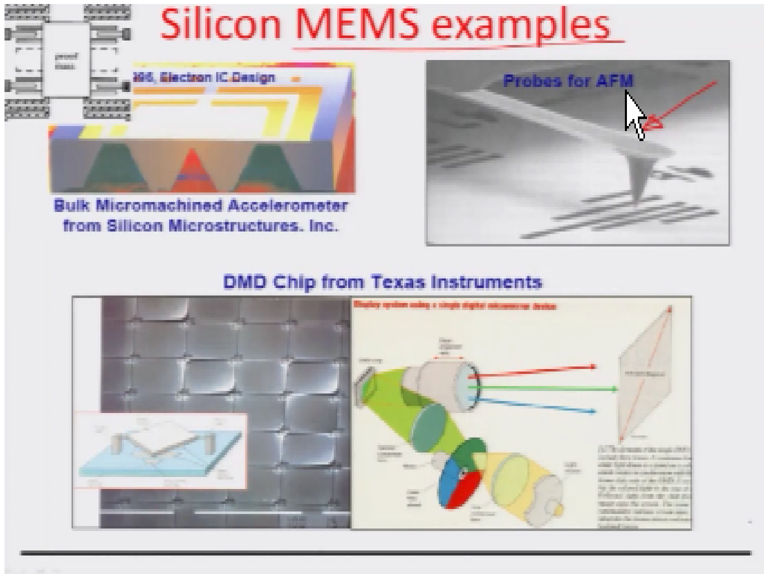

This is the atomic force microscope of the AFM so this actually right here shows a cantilever tip which is actually meant for such an AFM this may be something like about let us say300 to 400 nanometers thick and if you look at this particular length right about here this may be a few tens of microns so that is how small these things are and then if I again look at the sharpness of this particular tip here this is completely atomically sharpened okay.

So this is atomically sharpened tip so such a an object is Avery important tool for scanning of surfaces where if there is a let us say some kind of hills and valleys on the surface and there is some surface roughness you can merely scan this over the surface and from the deflections that it suffers may be able to reconstruct the surface over which it is it is being scanned.

So obviously there are two different modes in which this can be scanned over there is a sort of as the you know the AFM you can actually operate through two different modes that is the touch mode or the or thetapping mode and this is a very important example where you can see how micro system plays a very critical role because its own mass of this particular tip is so small that its own inertial effects are quite negligible okay.

Similarly let us look at this particular example here which is a bulk micro machined accelerometer which is actually sort of you know this image has been borrowed from silicon microstructures incorporated where we talk about a small proof mass so this mass right here in the center is actually a proof mass and there are certain you know there are certain sort of patterned metallic structures which are actually a part of this proof mass and this proof mass is pivoted over small you know it is like let us say as mall post with some kind of a spacing in between.

So this is actually a sort of pit you can say this is a pit and this mass is being projected outside the pin and on the base which is actually this particular area this is the base okay the pit is actually what is you know illustrated by these vertical lines and the incline lines show the base so there are different structures which are carved on the base for example there is a there is a structure which is actually an electrode like this there is another electrode and there is again a third and a fourth electrode and these two regions right here.

So the idea is that the proof mass is positioned in a manner with these sort of extended wings you can say of the proof mass that as the proof mass to Sun turns based on the overall motion of wherever whatever system is carrying this small unit of the small chair so this is a capacitative change between the post which is actually on the base you know this is shown by this sorted you can say the post which is are the electrode of the post which is on the base right here.

The marketed or classified as one and the wings which are let us say the wings two and the wings three okay which are actually hinged to the proof mass and they are subjected to sort of movement with respect to this electrode one so it is like a finger plate or interdigitated capacitative unit that we are talking about where there is a you can say change in this sort of you know the vibrating wings and the post electrode and because of which the fourcapacitative changes at the four corners can be calibrated with respect to the total amount of roll or pitch or your you know.

Let us say when acceleration the acceleration so on so for these values can be measured accordingly and so you have a very good idea about such bulk micro machined accelerometers again very interesting example used in our day to day life is this DMD digital micro mirror voice chip which is manufactured by Titian instrument so what happens here is that the there are a series of these micro plates which are you know a cross-section of which is shown right here.

So these plates are hinged over two posts and these are all micro machine the setoff electrodes which are at the base and the idea is that you know with electric field between the plates shown by these lines and the base you can actually deflect the plate between one corner another okay so you can actually rotate the plate by some degrees either way of about the hinged axis and the idea is that if supposing there is a light beam which is falling on this DMD chip you can see right here through you know it is passes through the RGB filter for example and it is passing and formulating an image on this particular DMD chip right here.

And let us say there is a beam of light which gets reflected off such a plate you know so let us say this plate one is reflecting a beam of light so by twisting and turning the plate around its hinge taxes there is possibility of either sort of focusing array to the focus of the you know the sort of you know aperture lens which finally magnifying lens which finally magnifies the image onto the screen another words it can be deflected so much that the beam goes out of focus and so.

It is no longer there in the in the aperture of the projection okay so in away by manipulating these various small ships through electric fields you could transfer a pixel-by-pixel information of an image and you could formulate an image with the dark pixel or a bright pixel and that is how things are projected and the lens would actually help by magnifying the particular image from a small scale as is obtained in this DMD shape all the way to the wall.

Which is at a probably a higher version so there is an ass that is a resolution involved of the size of which is defined by the size of these mirrors which is actually about how much would be really the pixel size so if we talk about let us say you know 50 micron by 50 micron mirror or even a little bit lesser let us say 10micron by 10 micron mirror so there is possibility of sort of you know focusing the light and getting that kind of resolution of an image.

So these are some examples from the silicon MEMS we also have other examples for example this again shows a single chip a kilometer from analog device.

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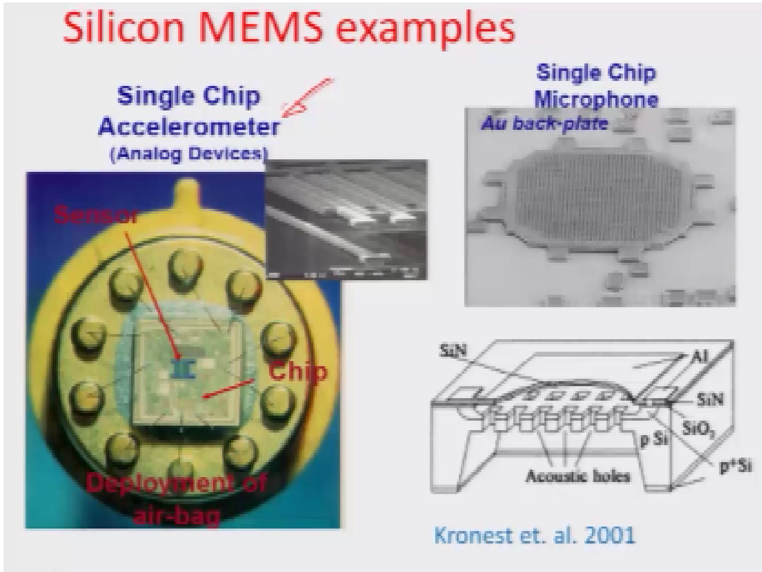

There is a microphone this is very interesting so there is perforated plate as you can see herewith some kind of a pizza resistive material and so therefore whatever acoustic waves are encountered by this perforated plate it changes those acoustic waves into electrical signal which can later on be amplified and sent into speaker so that is how a small microphone you know is made out of these memes-based structures so there are several such examples also in the area of medicine and biology.

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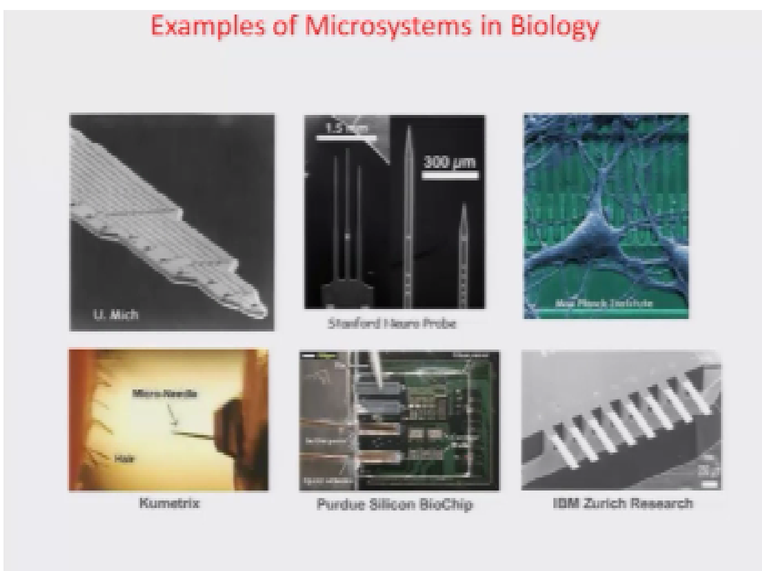

For example these are set of electrodes microelectrodes which are sore you know it is used to do you know is used to monitor the electrical activity of the brain tissue okay so electrical activity of brain tissue there are other examples here this is a slender electrode very tall electrode which is actually a neuron probe you know it is used for sometimes feeding by you know by a method called deep electrical stimulation des these are again set of neuron cells which are growing on you know an array of MOS transistors.

And definitely the way that these cells would talk to each other in terms of its surface protein expressions would be related in form of a differential electrical signal between these arrays of most justice a very interesting example is this micro needle which is several microns several hundreds of microns tall which is maybe about 180 microns or so tall with the diameter of something like about close to 20 microns and this actually mimics the mosquito needles.

That whenever there is it is used to inject a drug inside the skin it does not damage or deflect the pain receptors because of which there is a possibility of leasing drug without inflicting any pain on the particular subject these are some bio chips which are used for or made in silicon and are used for various detection purposes like detection of maybe microorganisms to all the way to about you know different million cells and finding out their healthy state as opposed to unhealthy or you know even like screening off harmful or virulent forms or stains of microorganism.

So on so forth these are set of cantilever arrays again which are which are which are made with an intention of you know biomoleculardetection so the idea is that if I had sequence of molecules which are immobilized let us say if there is at here is some kind of a single-stranded DNA molecule which is immobilized onto these surfaces and they bind to some other molecules which are target molecules there's going to be some deflection.

Because of the change of the surface energy which is actually given by you know something called stones equation where the surface energy change between both surfaces of small cantilever would result effectively in deflection so such are some of the such are or such or many other numerous examples are available where you can use these micro systems in various walks of life as you have seen.

And so we let us now sort of go back into how you process these using the first generation microelectronic processes and for that you would like to just point out about the different materials which are used to formulate such you know architectures there are silicon mostly and other microelectronic materials is most popularly available microelectronic material there is glass in quartz wherever there is need for optical transparency.

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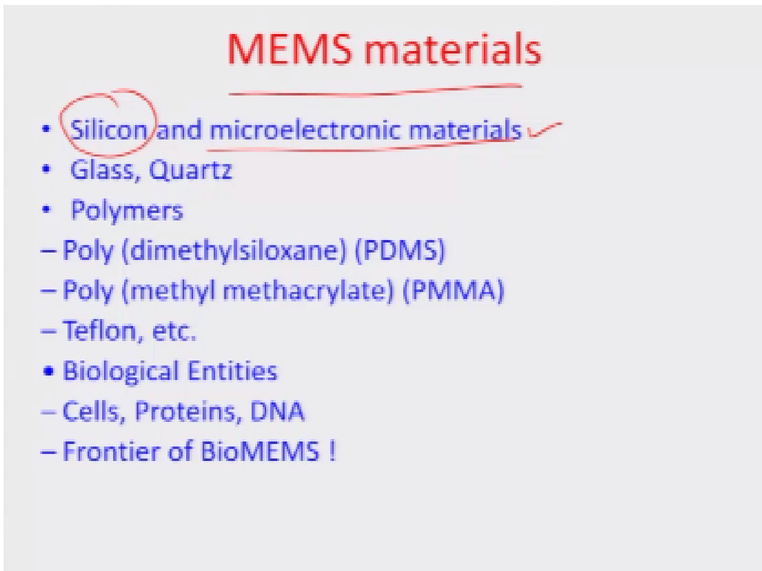

Because of some signal monitoring issue particularly in a sensor design these are employed there are polymers again very huge area is coming up about polymer manufacture in fact some of the processes associated with polymers have now attained the status of being on the road map for the International semiconductor technology and it is used for again very imprinting very small feature sizes so polymers like let us say poly diethyl Sloane or poly methyl methacrylate or Teflon it is a very hydrophobic material are very often used or employed for making these structures these small structures.

Then we have in fact the most recent forms of advanced machining which are in terms of the entities themselves so there is also a possibility of you know building chips or building these micro architectures by deploying some of the biological entities you know in such materials so these are sort of the different generations of materials which are used for micro systems planning or Microsystems designing and let us now look into the first material which is silicon.

And the various associated processes associated with this microelectronic industry which has been translated into formulation of the micro machine structures or features so silicon by and large is the most popular MEMS material because of its background and you know because obviously the Misprocesses or the micro system fabrication processes started as an offshoot of the fallout of the microelectronic industry so some processes became obsolete in the microelectronics and they Were picked up by the by the MEMS or the Microsystems industry.

So silicon and its compounds for example oxides nitrides poly silicon can be categorized into three classes based on the amount of the range of order these can be single crystallinepoly crystalline and amorphous materials think I had Illustrated about all this when we talked about the materials are the basic you know properties of the engineering materialism the module one of the manufacturing process technology in the part one.

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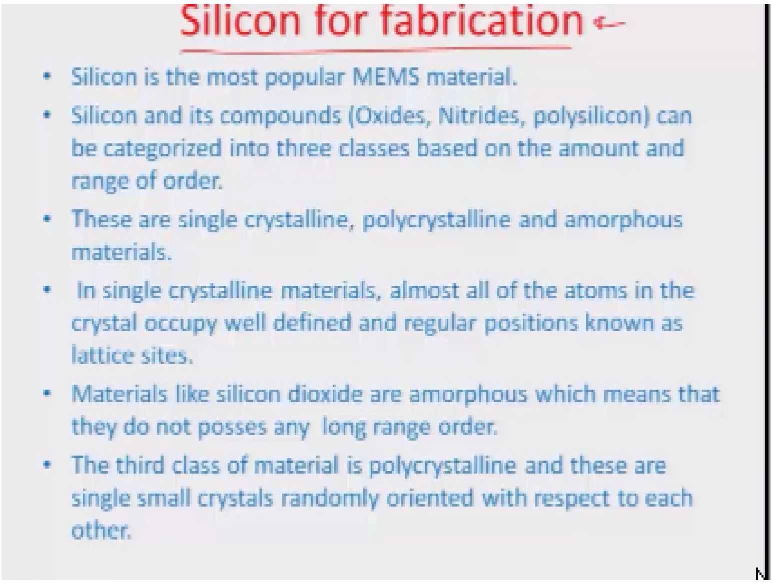

Of the manufacturing process technology and we all know that in single crystalline materials almost all of the atoms in the crystal occupy well-defined and regular positions known as lattice sites materials like silicon dioxide are amorphous which means that they do not possess any long-range order and then there is a third class of materials which is poly coastline and these are single small crystals randomly oriented with respect to each other in fact almost all of you who have done my course on you know the first mod the first part of manufacturing technology.

Have probably gone through all this and how crystal formation takes place what are the kind of defects which are therein Crystal's so on so forth here we would be focusing on a little bit you know different aspect and that is related to how the crystal structure of silicon can be really envisioned and how you can represent this and then play around by introducing chemical machining like etching processes or even like you know some kind of employing some physic-chemical etching processes or only a chemical.

Or physical etching process through a beam and so therefore we need to study about this crystallography and some crystal structure aspects of silicon.

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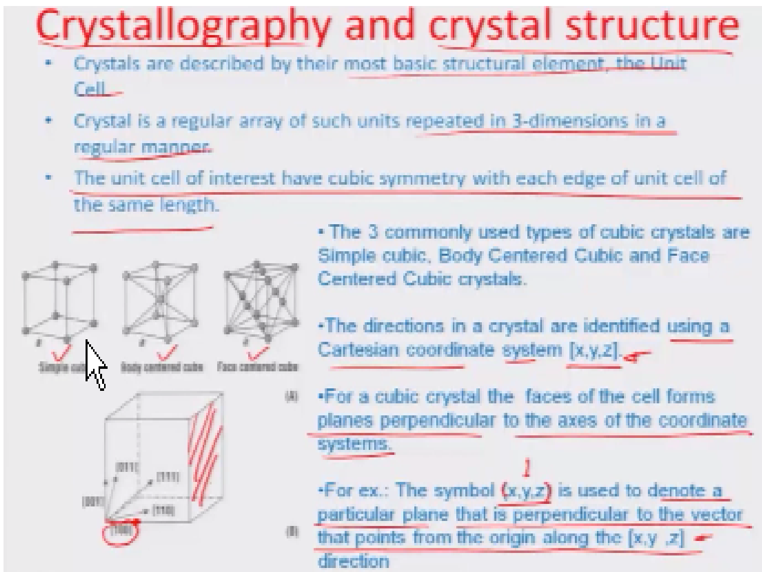

So obviously as we all are aware that crystals are described by their most basic structural element that is the unit cell and a crystal is regular array of such units repeated in three dimensions in the regular manner and the unit cell of interest have cubic symmetry with each edge of the unit cell which is of almost the same length and there are three different structures which are there I think this we had earlier illustrated as simple cube body centered cubic.

And face centered cubic also there is a hexagonal close pack structure which we do not need in the case of particularly describing silicon systems so the directions in a crystal are identified using a set of Cartesian coordinate system XYZ okay and for a cubic crystal the phases of the cell forms planes perpendicular to the axis of the coordinate system for example the symbol round bracket XYZ.

It is used to denote a particular plane that is perpendicular to the vector that points from the origin Along the X Y Direction so if I say that this vector right here is the 100 vector the plane which is perpendicular to this vector would be known as 100 circular bracket plane okay and further I mean all such planes together could be signified by this third bracket 100 so therefore all such planes of the type which are perpendicular to the direction 100circular bracket okay.

It is given by this third bracket 100 and that is how you represent the directions of a crystal so I think we will probably close this module here and in the next module we will look at some of the basic processes related to the chemical photo chemical etching or even for the deposition of photo lithography through which we can micro manipulate these silicon structures so that you could actually be able to create layer by layer into what is known as a micro systems or micro scale structure thank you as of now.

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