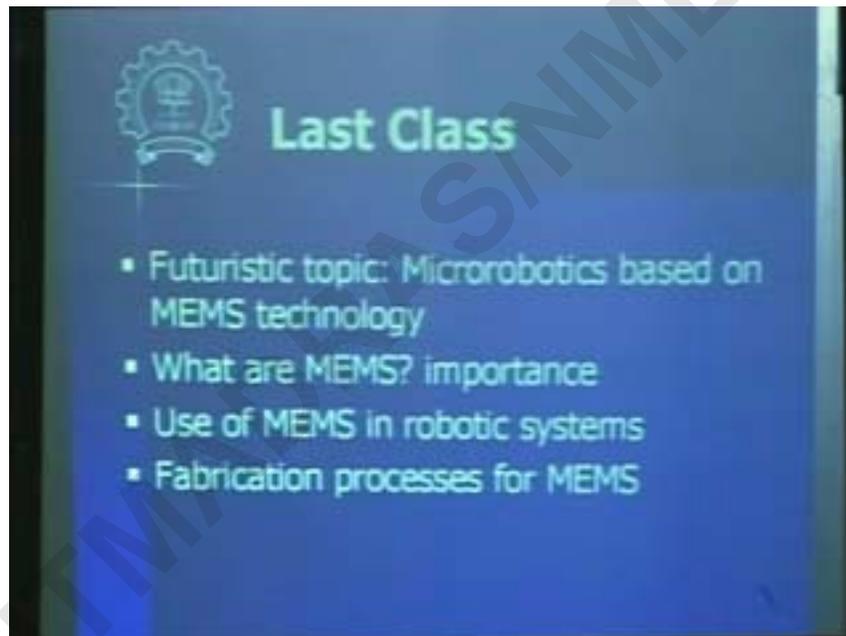


ROBOTICSProf. P.S.GandhiDepartment of Mechanical EngineeringIIT BombayLecture No-40Futuristic Topics In Robotics : Lecture 2

Good morning this is lecture number two of the um module futuristic topics in robotics okay

In the first module um in the first lecture of this module we studied micro electro mechanical systems MEMS is the futuristic topic and some technology what is MEMS what is what is it important for like why it is gaining in importance then some issues related to how the fabric how the MEMS based devices are fabricated what are the different fabrication procedures involved in that (refer slide time 00:01:52)



And then we had a little bit look at use of MEMS in the robotics

So in the today's class we will have likely to more introduction on some other unconventional MEMS fabrication methods and their use in actually building the micro robots okay

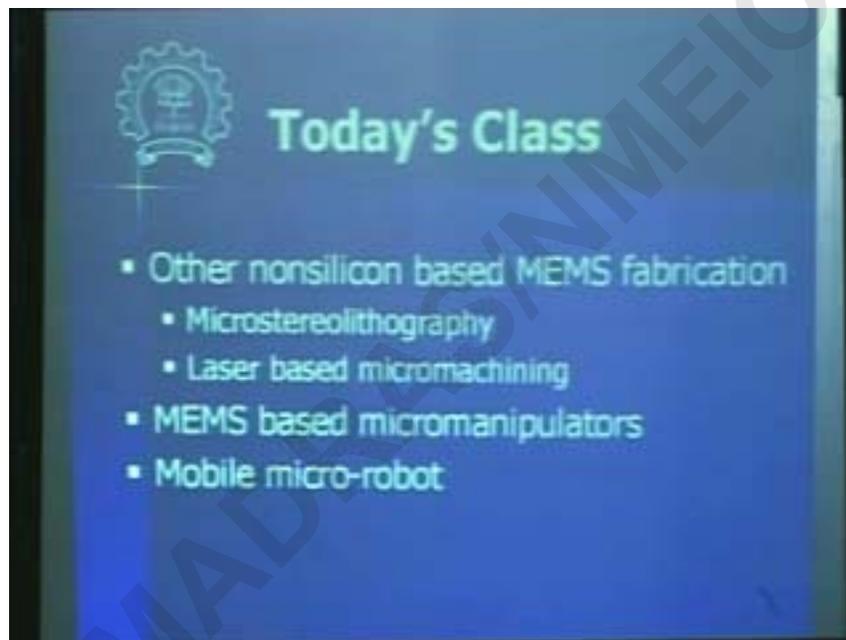
So we will have a look at that and then there are technologies where you don't have right now any applications in robotics but they are very very much potential for applications in robotics okay

So these technologies we will study first and then we will go on to applications in robotics with um with the technology which we have we have studied in the last lecture okay

So two D based a silicon based VLSI based MEMS fabrication technology that technology we will apply for some um micro robots micro accelerator micro manipulators

we will see how these ro these these devices can be fabricated by using the two D fabrication or VLSI based technology okay

So what we will study is basically unconventional fabrication processes like micro stereo lithography okay (refer slide time 00:03:17)



i will explain you what is this process and what are the important aspects of this process why is it different from your conventional MEMS or the silicon based or VLSI based fabrication

and then um laser based micromachining we will have a little bit look at this laser based micromachining technology okay

why it is important again like what are these advantages and things like that and then we will move on to MEMS based micromanipulator okay or or application of these technologies for robotic purposes okay

the main the main important application the most widely used popular these days is micromanipulators

may this micromanipulators is important for like um bio-cells want to manipulate bio-cells you want to move and study their properties and things like that

so it is very important for bio applications and in bio surgery where you have to manipulate very accurately very precisely some location in your brain surgery or whatever okay

in those applications these micromanipulators are very important okay

and then we will study one mobile micro robot it is very recent development but we will have a look at and see how like what is the domain in in the micro domain how things are different from the conventional domain okay so we will have a look at that fine

that is that we will conclude our today's class and this module on futuristic topics on robotics okay

then also we will um have a look at some other topics which are not covered in this course but you should be aware of that there are some other topics related to um futuristic they are they are more futuristic kind of a application okay

so let us start with the micro stereo lithography what is the motivation for studying or for going for this process micro stereo lithography

basically the limitations of the conventional MEMS fabrication are like basically it has capability to fabricate only two dimensional micro components okay or planar kind of a components

you can have multiple planes but essentially they are planar components you can have one level two level three level processes for micro fabrication but they are essentially half planar in nature okay

so each each level will have a planar structure okay but you have we can have like multiple planes but in in many applications one may need true three D type of components okay which doesn't have planar laser but it is like true three dimensional nature like lets say for example um you can imagine flower pot kind of a structure okay

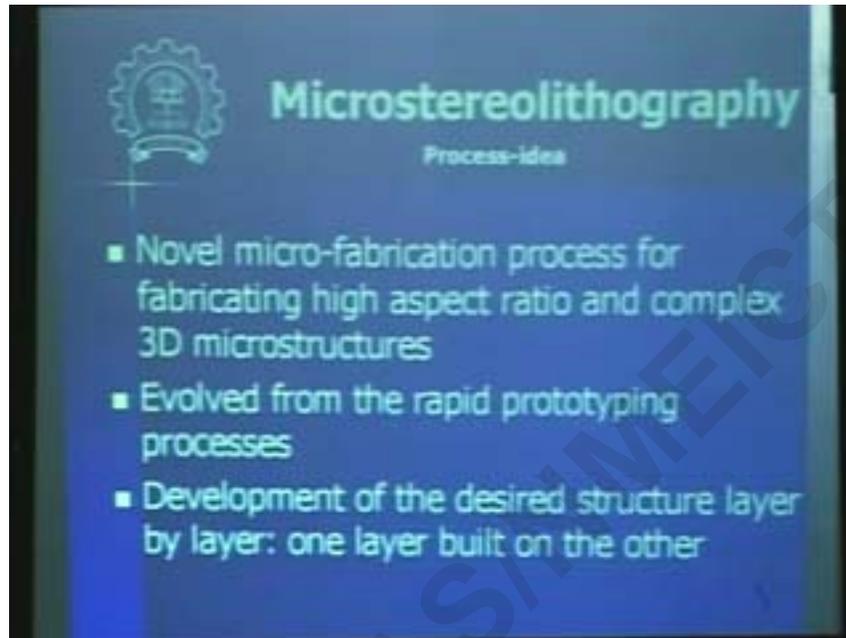
it's a true three D structure so how to fabricate those kind of components so so that is a basic motivation for going for the micro stereo lithography

other important um motivation is basically a limitation on the number of or number of materials that can be processed in conventional MEMS processes okay

micro stereo lithography gives like more um number of materials or more um wider choices for materials being processed okay

you can process ceramics you can process metal powders or you can process polymers in micro stereo lithography okay

polymer and ceramics entering are very widely used for micro stereo lithography okay fine (refer slide time 00:07:20)



now what is what is the idea um how micro stereo lithography works okay it's the idea based on the stereo lithography which is a rapid photographing process okay

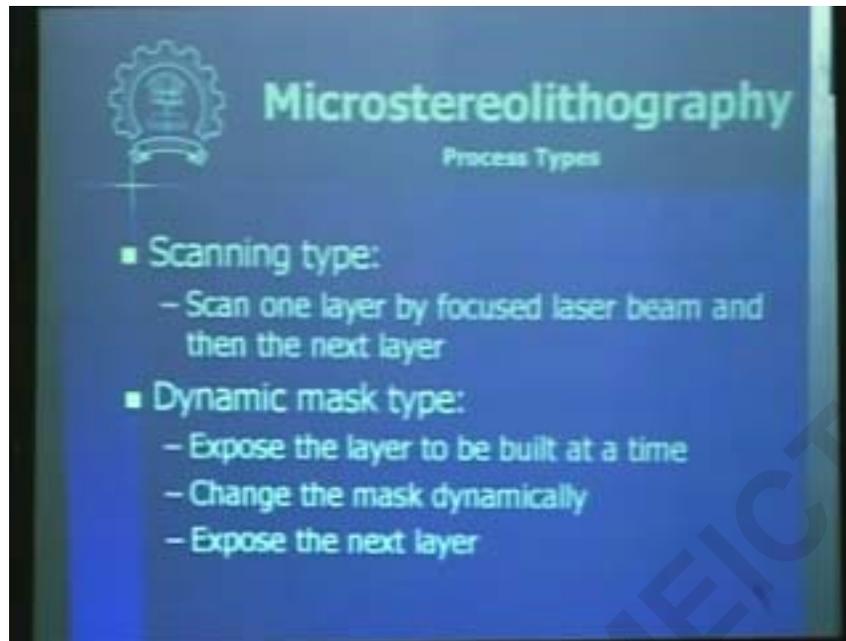
so so it is like you build it a component there is a liquid and then you use that liquid photo polymer it will get affected like this liquid will get turn into solid when you expose it to light okay that is the photo polymer liquid okay

and then the idea is like to generate one plane planar section on the surface of the liquid and then you have other planar section built on the top of this planar section okay

so section by section you go on building the component okay so let us we will we will see in a minute what is how this process will look like in animation

so but that is the basic process that you build components layer by layer so if you have a say say for example flower pot example if you take you first divide the solid structure into six planes different levels of planes okay and then you have each planar structure or each plane or each section built level by level okay

so first you will have a first lower level section built on the top of that next section will be built like that you will go on building the component level by level or layer by layer okay (refer slide time 00:08:57)



so there are different types of these processes first is the scanning type process in which you scan a section by lines okay

so you have a plane on which you will have different lines drawn okay we will i will i will show you again in the animation how this scanning process work but you don't expose the entire layer at a time to um light okay

you scan one line okay by a laser which is pointing on the surface okay

so that that line like then you scan a next line like that you scan different lines and then go on building the section okay that is a process will will come to that again in the animation i will explain you that but that is the scanning where there is no exposure entire of the entire sections at a time

in the dynamic mask process you have a mask which is changing its shape dynamically automatically okay so in these process like how how it changes and all we will go into little more detail um um in the slides to come

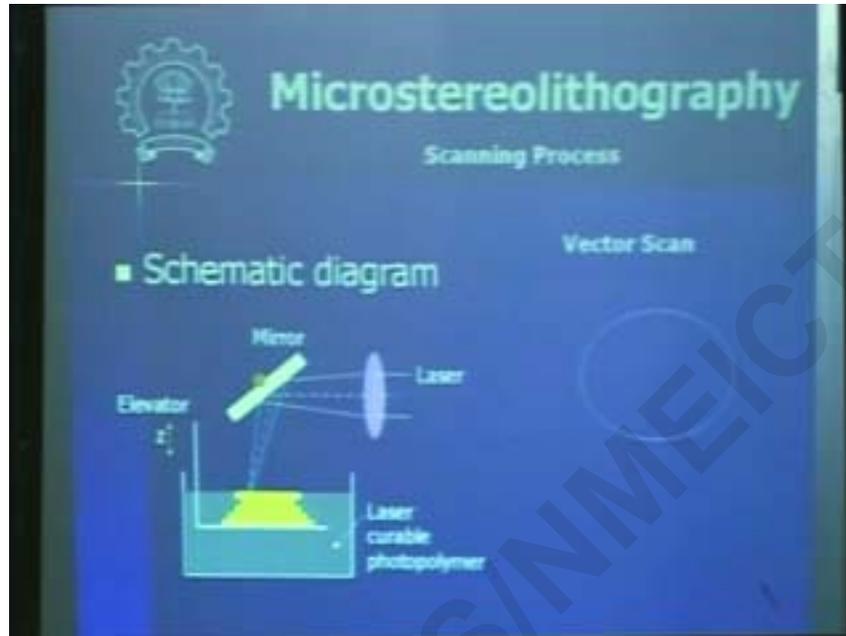
but its basically you have a mask which is changing continuously okay so you expose at a time one section okay then change the shape of a mask and expose the next section

so like that it is the process of building components there is there is exposure at a time for entire section okay

again i will come to that when i will explain you in detail how this process is actually work

but these are the basic two differences like in the scanning type process and dynamic mask type process okay

now let us see the scanning process in little more detail (refer slide time 00:10:50)



okay what you see here is this laser curable photo polymer liquid which is kept in this tank and then there is this lens which is used to focus the laser light on the surface of this photopolymer

you have this g elevator okay which will move this stage into the liquid once the one of the sections is completed so that next section can be built on the top of this section okay

and then you have this mirror actually these have shown here only one mirror but it should be two mirrors actually if you want to scan in both the directions okay

so i just for simplicity sake of simplicity i have shown only one mirror but um you will typically have a scanning system which is um which is similar to what you have in a you know on the tv's monitor okay

but in this case the difference is like this deflection of this laser beam they are happening because of the movement of these mirrors okay

so will will will see what are the different types of movements and how we can achieve that but um essentially there is this mirror which is moving and then it is scanning the particular section in the surface okay

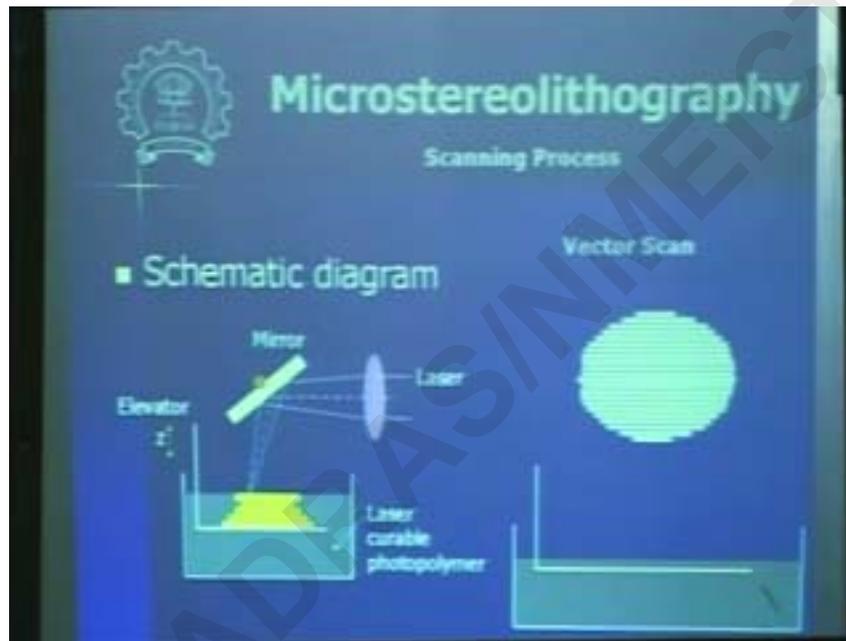
now let us see how this scanning happens

like you have this again this photopolymer and then elevator what is done is this elevator is first dipped into the photopolymer and then it is brought up okay

so that a particular thickness of the liquid is there on the top of this surface in the elevator okay

now you want to scan one of the sections okay say the section is of this shape and now you can see the way the scanning is done okay

the line by line the entire section is covered okay so this elliptical shape you wanted here is drawn line by line okay (refer slide time 00:12:56)



so you can obviously see there are some errors that will occur it will not be exact section okay there will be slight error because of this kind of a scanning okay

but they are they are well within your limits um their accuracy may be about ten or five five to ten percent okay

if you are scanning like a bigger section okay then it will be much better because scanning very small section then you will have a little bit lesser accuracy in um in in terms of percentage okay

so i mean you can see a the limitations again with these because of these kind of effects we will not be able to build very very tiny sections i mean the very tiny micro components which are of sub micron dimension it is not possible okay

so this is this kind of a technology is used to to build components in the range about like say um thirty micron all over or twenty micron all over okay

you cannot really i mean you can go below that but then like it will be very costly process in the first place and then um i mean it will have that accuracy problem in terms of [] like wise okay

so so once you do this scanning the section will be built on the surface here okay so this shows the top view and this is the section view of that okay

so now once this section is built again the process is repeated you dip again into the liquid photopolymer so that surface tension effect is gone and then that um polymer photopolymer comes on the surface of on the top of this section and then again you raise it to have a appropriate level of the photopolymer on the surface okay

the thickness can be controlled by controlling the c movement or this movement of the elevator if you bring it to the top it will be lesser thick okay

of course it will have some some additions like addition effect or some kind of a um thin layer of the liquid always will be there and you cannot have zero over thickness or there will be some depending upon the viscosity of the photopolymer you will you will have the limitation on the thickness

so you raise the elevator elevator is independently controlled see all these movements this c direction movement of the elevator and then see scanning movement they are controlled through computer okay

so they are synchronized with each other and controlled through computer okay see your laser laser light intensity it goes up to a certain depth only it will not go full depth i mean

so it will go up to a certain depth because the focal point or the laser focus is only at a one one particular point so up to certain depth only the intensity of the light will be sufficient to acquire the photopolymer okay

so if the solidification will take place in the small thin layer okay

so they are these factors as we discussed affecting the resolution of the component first is the laser intensity (refer slide time 00:16:45)



how much intensity you have um then motion of the beam okay how fast you move the beam if you move beam very fast like it will have like lesser thickness of the line

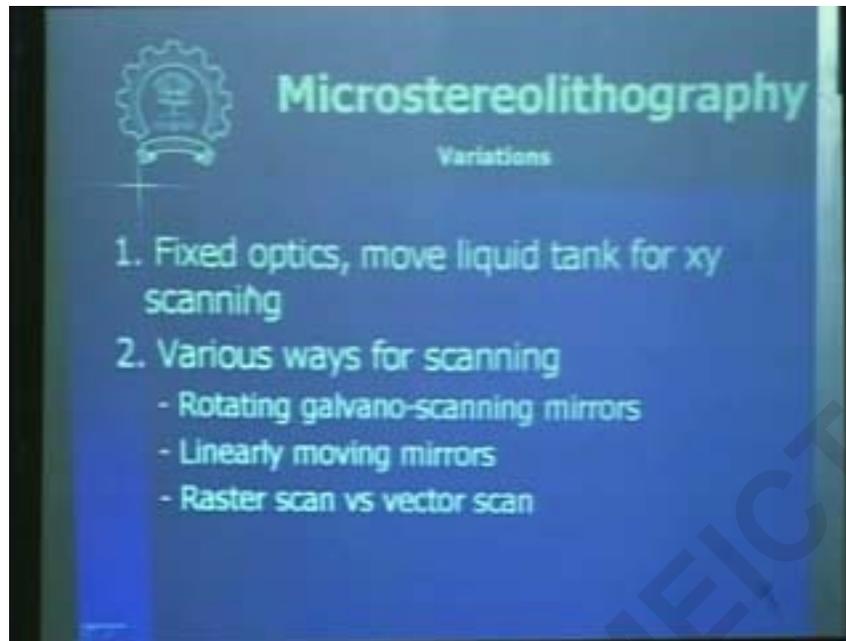
if you have if you move beam slowly you will have a better thickness of that bigger thickness of that so you can control that to have accuracy good accuracy

then um what kind of photopolymer we use for this purpose then what is your focusing how accurate is your focusing or optics that you use for focusing and then exposure time okay

that are these are the factors um on which um resolution or accuracy of the component if will be dependent

and then in case of ceramic materials you use a ceramic powder and then you use a laser based sintering of this powder okay instead of like having kind of a liquid photopolymer okay

now there are several variations like you can have fixed optics and move the tank okay (refer slide time 00:17:50)



in a in animation which which we saw the the tank was fixed and the mirrors were like moving

so there there was a moving laser beam okay with the problem is that that the focal point doesn't remain um see as you tilt your focal point is changed now it is not on the surface of liquid any more

it will be either inside or outside the surface of the liquid so that to avoid that problem this is another one variation which people track is like you keep the optics fixed and move the tank okay

of course you will have the c um c direction movements but x and y are scanning will do by moving the tank okay

then there are various ways of scanning one way we saw was galvano scanning mirrors like rotating mirrors then like um you can have linearly moving mirrors okay

so the mirrors will move in a linear fashion the advantage here will be like um you can have your focal point at a fixed level with the linearly moving mirror okay

we will not get into details about optics about how we can have and all but it is possible

then you can have raster scan versus vector scan what we saw was a vector scan okay so what ever the section limits are the laser beam it changing its direction at a limit of the section

but in the in the raster scan the say if even if you want to have certain kind of a circular section we will move the beam to travel in the rectangular section and then you will switch on and off the laser light at a appropriate points okay

so for example if we go for a this thing for this section i will decide the limit points for for this particular line okay

actually the mirror will be moving to take the laser beam from this point to this point like a in a rectangular fashion scanning

but the laser will be switched on at this point and switched off at this point okay so this movement from here to here this kind of a not very efficiently used okay

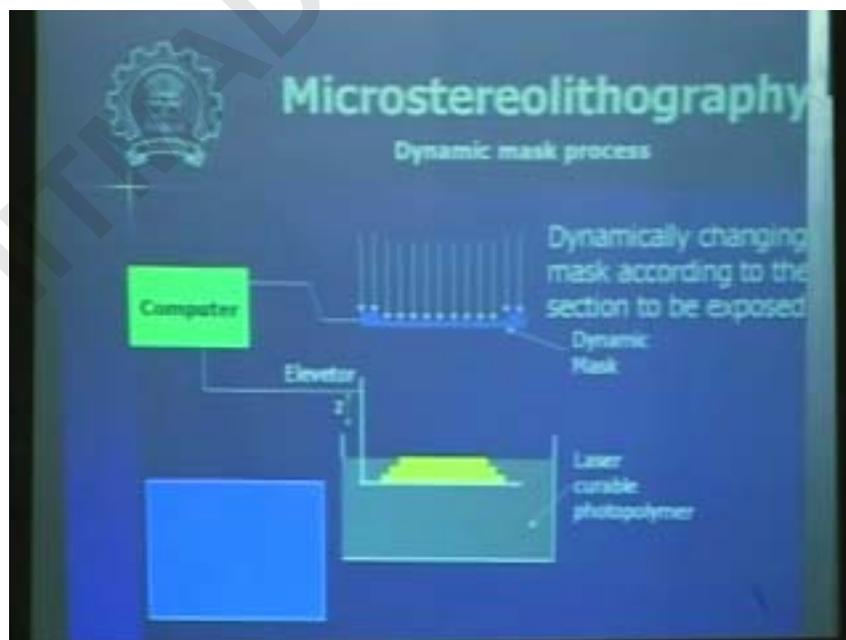
so raster scan is not not required okay vector scan will be like kind of much much faster kind of a process okay

there are other issues regarding like where you will have velocity reversal and so so you will have wherever you will have velocity reversal um there like exposure time will be more

so it is again like um your balance between how much accuracy you can sacrifice to have and because of like more um time of exposure will have like little thicker sections there

so it it depends upon like the way the way you have designed your control system to basically control all these parameters okay anyway

now this is a dynamic mask process (refer slide time 00:21:15)

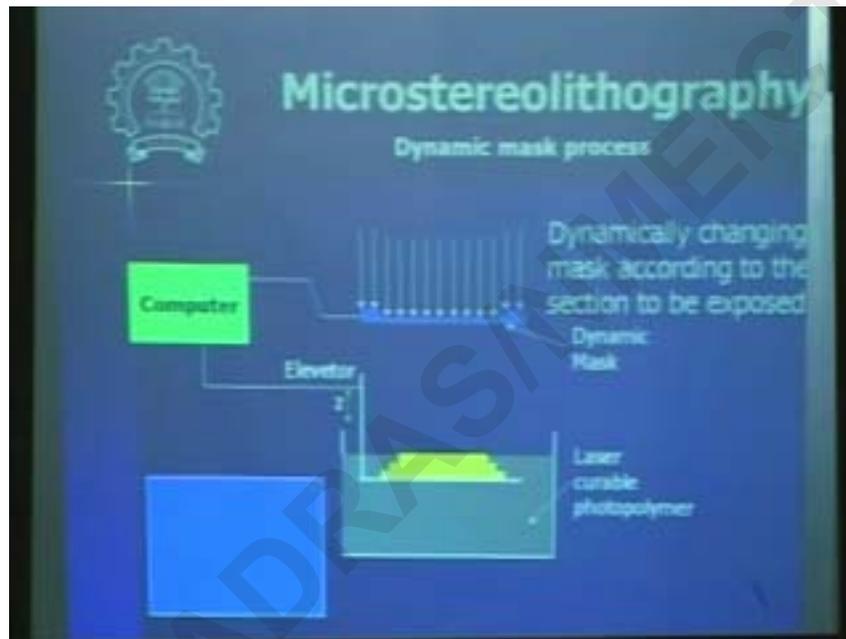


so you have this mask which is controlled by computer which is dynamically changing

you have seen this um watches with lcd display right so there the this dynamic mask is something of that sort you have this pixels which are like um either made to have a dark point or to have a transparent okay

depending upon this pixel um like whether it is dark or whether it is bright or it is transparent this mask will be produced okay

so say for example this is a whole of your lcd type of a screen in which like if you want to have this kind of a section (refer slide time 00:22:04)



then you will all these all the other points will make dark and then this part will make bright so that it is now transparent okay

so that is the kind of a philosophy used in dynamic mask okay now the inherent um disadvantage of this thing is like you cannot have like um a higher power of the laser for exposure because it will damage this mask itself okay

so you usually you need to use the moderate power of the laser and then you need to expose entire section at a time in this process okay

then again this other process other part of the process remain the same like you have this see elevator here which will lower in a photopolymer tank and then you will section by section you will read the component

but now this section is exposed at a time okay entire section is exposed at a time so it is faster process this entire section is getting exposed at a time it the process is faster

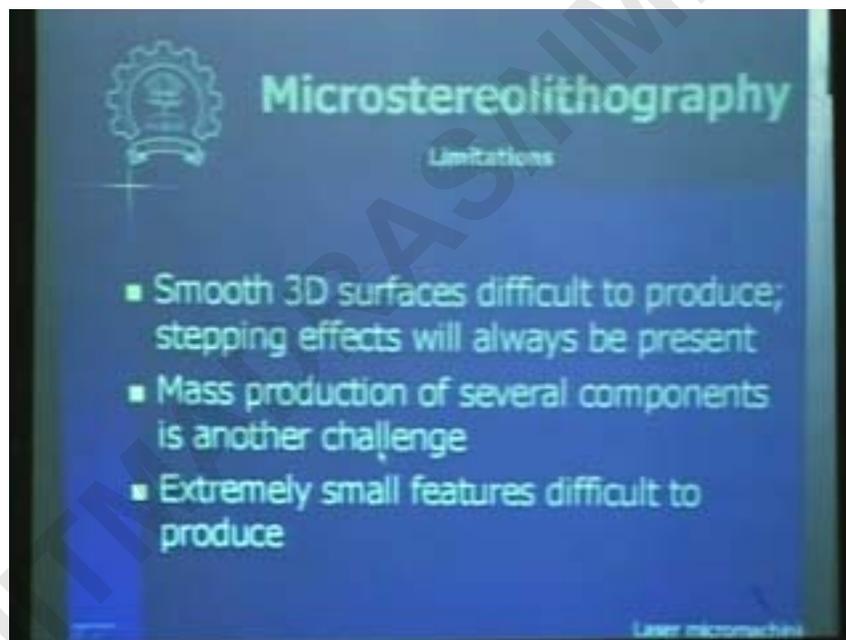
so so you have this first section then like you will have second section of different size or dimensions then you will have the third section like that you will go on building section by section okay

so this is dynamic mass process now you can see that since here the section is exposed at a time like μm and there is no line by line writing of the section here the accuracy of the contours of each section will be better than the scanning process okay

but you will still have in the c direction accuracy the same that as in the previous case

because in the c direction you will have these steps as there you cannot do away with that only thing you can reduce the μm each section size okay

and then may be improve upon accuracy in both the processes but always you will have this stepping nature okay in the third dimension okay
(refer slide time 00:24:24)



so these are the limitations that i as i mentioned the smooth three D surfaces are difficult to fabricate

stepping effect will always be there and then mass production this is another problem or challenge is that mass production of the several components at a same time is difficult in this case

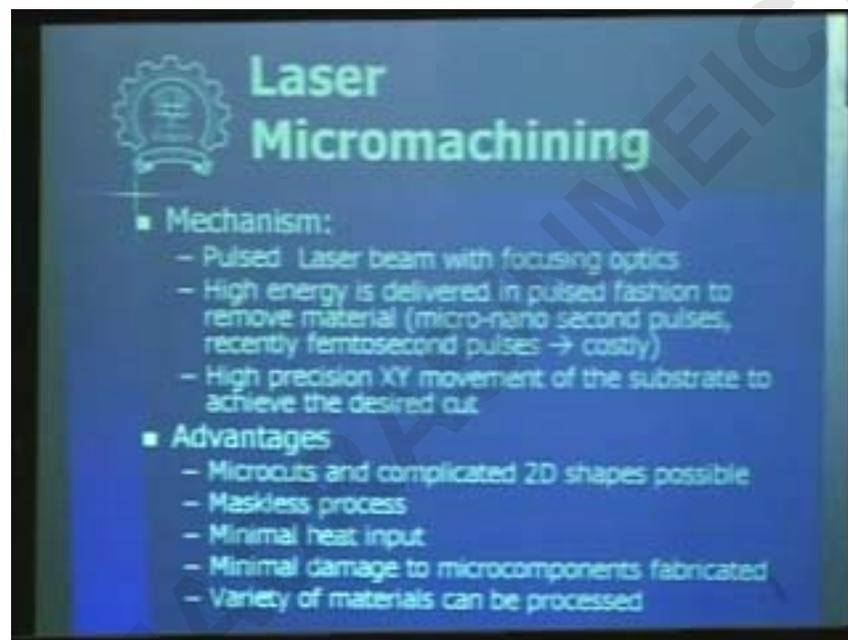
because you you can have like see for that if you want to have the mass production done then you will need to have multiple laser beams working at the same time okay

so far that is i mean that some people have tried i mean that in producing multiple sections at a right time it is not it is technological challenge actually okay

and then extremely small features are very difficult to produce like you cannot go to sub micron kind of a dimensions okay

so ten twenty micron onwards accuracy is reasonably good to achieve with this micro stereo lithography process okay

now lets next we will go for laser micro motioning okay we will have just a brief idea about what is micro motioning and why it is useful what are the advantages and things like that okay (refer slide time 00:25:43)



so what is the mechanism for laser micro motioning is like you have you have a pulse laser beam like you have a laser beam but it is not exposed directly it is given in the pulses okay

switching on and off kind of um so you will have this short pulses of the laser beam okay

and then in each pulse there will be very high energy delivered to the material that you are processing okay

so these pulses they will be focused like you have the laser beam it will be focused on the surface which you want to machine

and at a focal point like you will have this surface kept so that entire energy in a very small location it gets concentrated okay and then it is the energy is delivered in the fraction of these pulses okay

the typical pulse time for these pulses will be about micro second or nano second okay that kind of a pulses we are talking about okay

in some cases like um like most advanced lasers which are say he has a fire that time is a femto laser they are giving the pulses in a femto second period okay

so like lesser is a period more is the accuracy that you get because like in a short time you are like giving this high amount of energy to the material okay

because of that like it doesn't get a chance for the material to spread that energy okay since it is delivered in very short time there is no spread of that energy and that results into very localized like um affect thing of the material that you are processing so very localized effect will be there

so like shorter the time more localized is the effect okay and because of that like more will be your accuracy of the machine or more shorter will be like um the scratch or the cleavage that you produce on the surface of the machine okay

the main advantages of laser micromachining versus the conventional machine processes are you have micro cuts on complicated two dimensional chips

so any complicate two dimensional shape can be machined very easily of course you will need x y stage movement you have that shape possible but inherent accuracy of the laser machining will allowed you to have very complex nature of two dimensional features cut out of your material okay

and then this is a mask less process there is no mask which is expensive process like if you want to compare now these with um the material removal process with etching that we have seen in the conventional two dimensional MEMS processes then um this process doesn't require mask okay

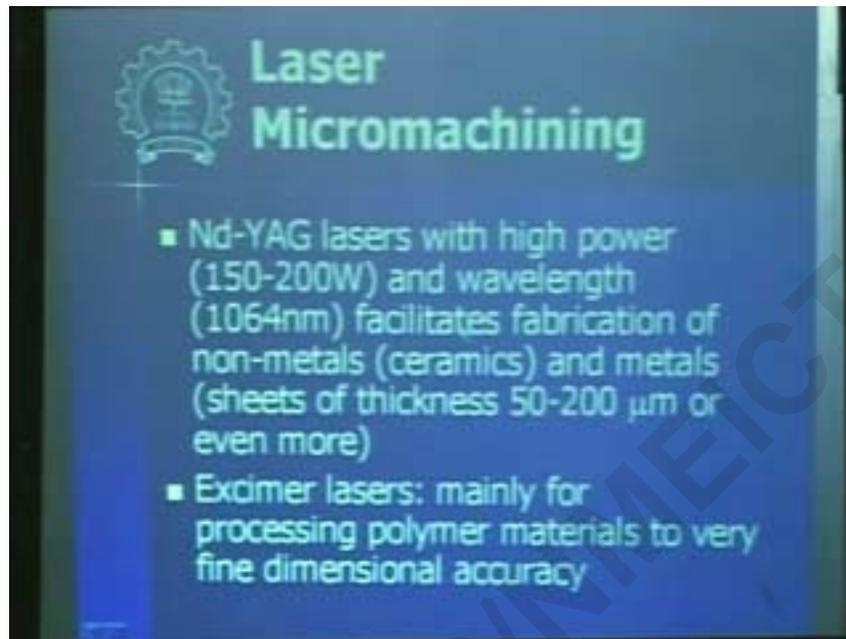
so that brings down the cost okay then it has a minimal heat input or minimum energy input that goes into the laser micromachining okay

and then um this is other very important advantage is that there is a minimal damage to the micro component which is getting fabricated because the energy is very much localized which is not spread onto entire substance okay

because of the local nature of the thing the area which is getting affected around this local wherever you are having a cut is very short very small area is getting affected

so heat affected zone for the laser micromachining is much lesser okay

and then you can process variety of materials okay i will give an example like say for you have a Nd-YAG laser with power say one fifty to two hundred watt um this has wavelength of one zero six four nanometers okay (refer slide time 00:30:16)



and it facilitates fabrication of nonmetals like you can process ceramics and metals all all sort of metals you can process

for example the sheets of the steel thickness fifty two two hundred microns or even little more they can be processed like point five mm or five hundred microns upto five hundred micron is um very easy to process with one fifty to two hundred watt kind of a Nd-YAG laser okay

but now this since Nd-YAG this power is considered to be little on a higher side or moderate side so if you try to process now a polymers with this power it will be difficult

because they will have like more heat effect i mean more kind of a energy delivered it they don't require that much of energy and if you are delivering more energy then the kind of cuts or kind of the process machining accuracy that you will get is much poorer okay

so we will be able to process um but it it um accuracy will be poor so for that you go to excimer lasers okay

these are lasers mainly for processing polymer materials okay you cannot metals are difficult to proce process to these lasers and then these um lasers have wavelength of order two hundred to three hundred or four hundred that order nanometers

because of that you will have a much better accuracy on the surface okay so its like higher the wavelength lesser will be the accuracy okay

but we are talking accuracy in terms of a some few nanometers or micrometers okay

for excimer lasers it will be very good for i mean from accuracy point of view okay but it can process only polymer materials okay (refer slide time 00:32:15)



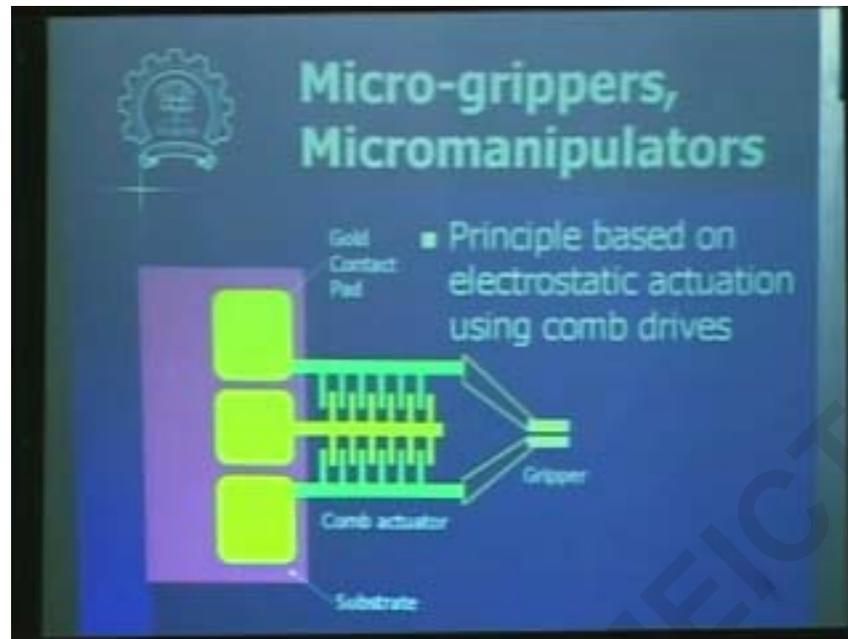
now we will see how these um fabrication processes were used for the purpose of robotics applications okay

we will have a look at this micro grippers or micromanipulators okay then we will have a look at several micro actuators which can be used for picture robotic applications okay here we will see mainly the actuators which are not currently in use for micro robots but they will be they have high potential to be used for micro robotic applications okay

and then we will see one very um particular very nice design of this mobile micro robot okay

so it is called scatuator so why it is called at and all those things we will we will see in the next slide to come okay

let us first start with micro grippers okay (refer slide time 00:33:16)



so you can see here the principle here is dependent upon the electrostatic actuation using comb drives okay

so comb drives are basically you have this kind of a comb like structures here you can see these are the tips meshing with another set of tip on this part okay

now when you apply a voltage to this gold contact pads okay then there will be electrostatic force of attraction between teeth on this side of the comb and other side of the comb okay

and then because of that electrostatic attraction we will have these manipulator movement or gripper movement okay

that is basic principle of operation okay in terms of fabrication now you can see that these are freely moving structures which are anchored at these point okay

so this is similar to the cantilever fabrication process that we saw okay only thing that the shape of the cantilever is different instead of the same simple rectangular shape they have this comb like structures protruding out of there okay

otherwise the process is exactly the same okay or you have like multiple options available to fabricate this like multiple based in which we saw a two ways in which the cantilevers can be fabricated so you can use either of them or you can use another process also

you have this cantilever's structure in the comb shape form realize okay and then you can do this gold contact pads okay this usually the contacts which give the electrical signal to your structure okay wherever necessary they are made out of gold okay or its conductivity okay

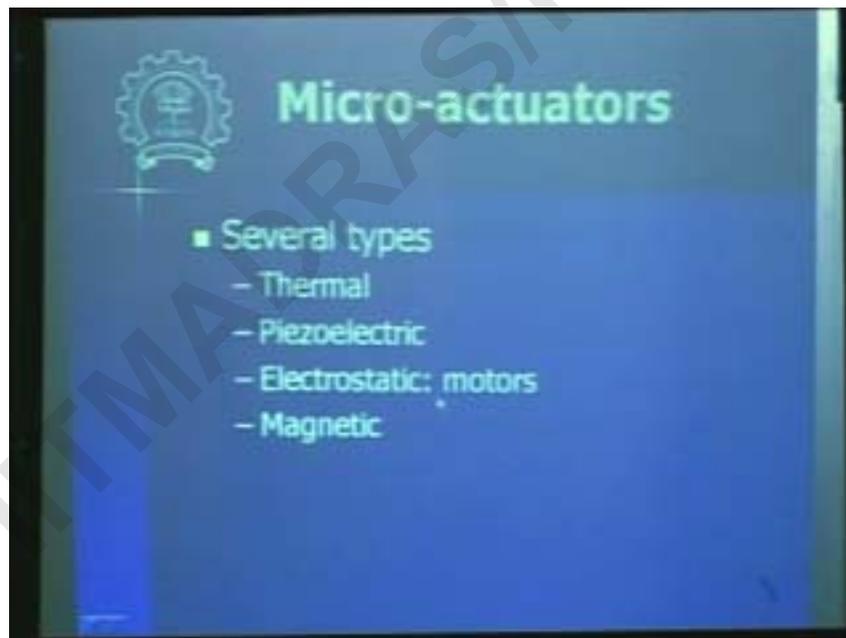
so you will have this big gold pads on which will have some some sort of a wire which will finally connect these things to the pin that you see out of your IC structure okay

so in inside IC that you see conventionally okay whatever pins you see outside they are connected to the point where your actual processing electrically is happening by very thin wire um by a process called wire bonding process okay

so see we are seeing only one end like its um this is the whole thing which is going inside chip or this this part like whatever part you see up to this point that will be inside the chip and wha what will see outside is only this part and some contacts okay pin contacts

so there is there are processes these are only the fundamental concept or structure there are many thing that go behind like packaging issues and other issues okay which which we are not going into details so this is this is the principle on which this micro grippers will we are are there based

and then um these can be fabricated using conventional processes conventional MEMS process that we have studied okay (refer slide time 00:37:08)



now next let us go on to the actuators there are different types of actuators possible at the MEMS level see if you think for conventional robots what are the actuators possible electrical motors electromagnetic principle basically okay and then may be hydraulic principle

so these are the two major types of actuators which which you have for a conventional robots

now when you go for micro domain that you have multiple possibilities like you have thermal actuator possible okay

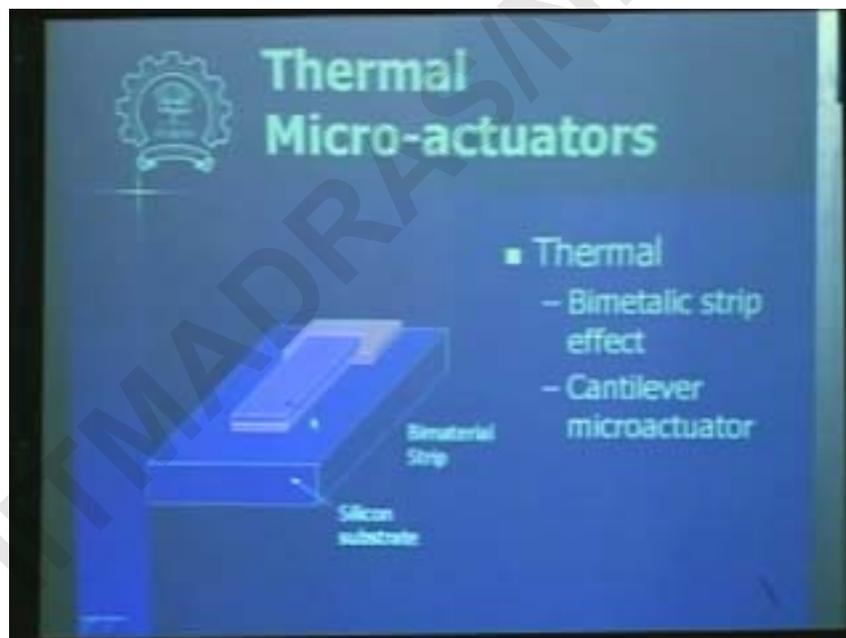
so i will explain how this this basically on principle of bimetallic strip kind of principle okay

then you have piezoelectric actuators possible then you have motors but based on electrostatic principle okay

people have not used for MEMS devices a magnetic type of motors a lot i mean you will not see in the literature any magnetic motor um motor based on magnetic principle at very micro scale okay

this we are talking about a scale of like say few hundred microns okay that that smaller size we are talking about okay

and then we will see some cantilever type of a magnetic actuator okay
(refer slide time 00:38:39)



so let us start with thermal actuator so as i said it is based on the bimetallic strip effect

see it is very easy to have multi multilayer kind of a structure built with the MEMS technology that we have seen okay

so you have a cantilever on the top of the cantilever you have one more layer and then your bimetallic strip is in place

so now you can have this this structure heated okay now there are multiple ways like you can have localized heating possible you can just run some kind of a conductor on the surface of this liquid um on the surface of top surface of this layer

and then you pass current through that you have $i^2 r$ type of a heating there okay so that is the resistive heating and then that heat will delivered to the structure will expand upper layer or contract or whatever depending upon what what are the coefficients of thermal expansion for these two layers

and then it will have this actuation possible okay because of that differential coefficients of thermal expansion okay fine

that is the way this thermal actuators behave okay they are used for switching i mean currently if you see in the technology they are used for um switching in the sense like you can have some mirror attached at this end okay reflecting surface

and then you want to deflect the light from coming from one fiber to other fiber okay

so there this kind of switching between two like whether you want to deflect the light or you want to not to deflect the light okay

that kind of thing you can achieve by using this type of mirror based switching so it is it is basically switching of the optical signal you you know the optical fiber that are used to transmit the signal so you want to speech that signal you can use the mirror an array of mirror for this purpose okay

so that is the current use but um then you can see that say this this can be used as well for the robotics in the applications okay

now piezo electric effect is basically you when you give there are some materials when you give voltage to them they will expand okay or stress strain will be produced in that

so these materials um they are very compatible very much compatible with the MEMS based fabrication okay

so you can incorporate very easily these materials one of them is Si O two silicon okay or quartz material okay

so this materials if you have on the top of your cantilever now you apply some current to this they will expand they will have a piezo ele electric effect because of which they will expand okay

so this is called a piezo patch you apply on a surface of a cantilever and then this will bend when when you apply the voltage trapezopad okay

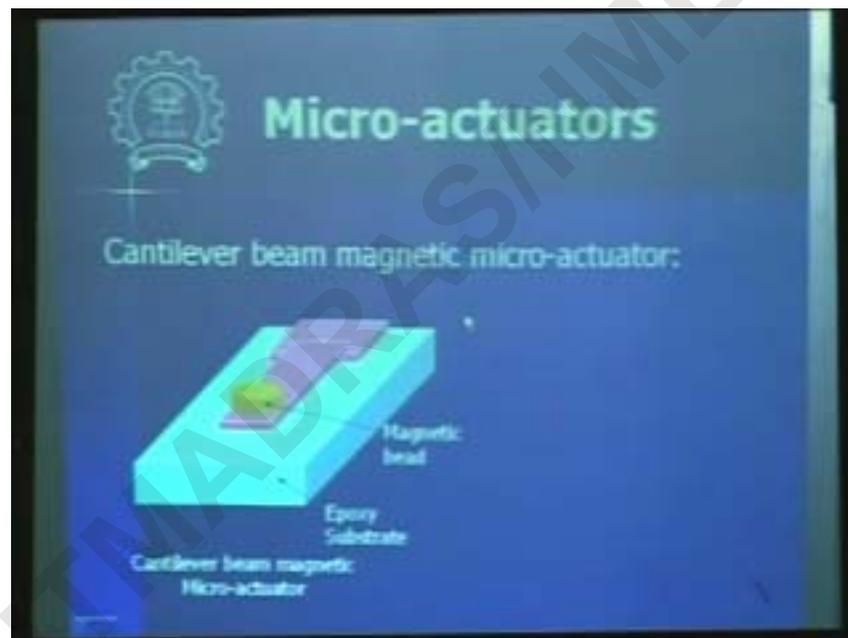
so that is a piezo electric actuator these type of actuators are already in place in many micro manipulation um basically for something called AFM Atomic Force Microscopy okay

that is the very popular application of this kind of a thing okay

so there is no um i mean you can use this piezo actuation in different ways in micro structures i mean you can have this piezo actuation done on the substrate and keep the cantilever fixed or keep the probing see in in AFM its basically a other way wrong

you have a cantilever very micro or very thin cantilever okay which is which is having a probing tip at a at this end that is very thin probing tip at the other end and then you give micro movements to the base or substrate by using piezo actuator okay

so that is one of the applications of the piezo actuator okay
(refer slide time 00:43:18)



next we will see this magnetic actuator it is cantilever beam type of a actuation here the principle is like this you have this magnetic bead placed on top of the cantilever substrate

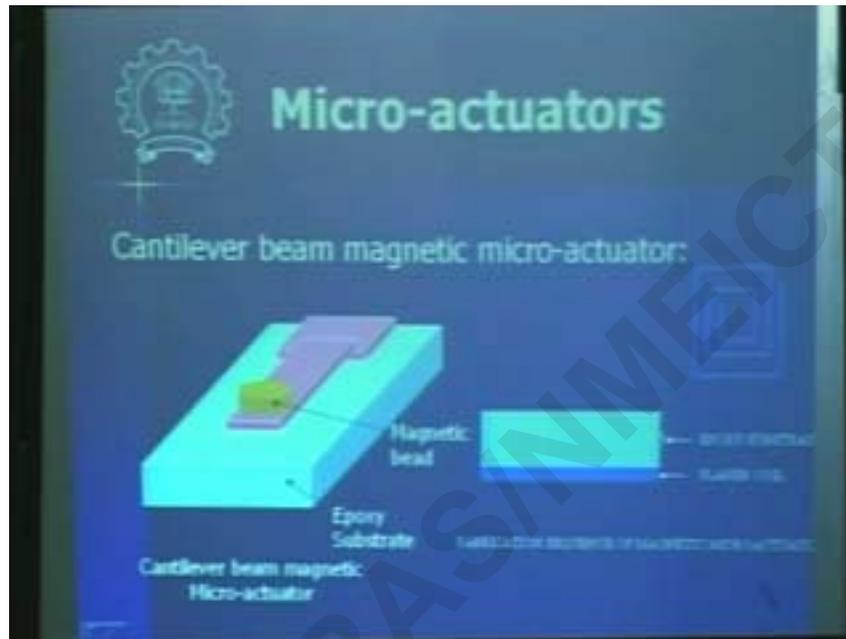
and now there is a copper coil below the substrate we will see how that is fabricated okay we will see the animation of the fabrication in a minute but there is a copper coil which is on this side the lower side of the substrate okay

and when you now pass current through copper coil because of the magnetic field this bead will get attracted below okay this is the magnetic bead so it will get attracted below and then you will have that kind of actuation

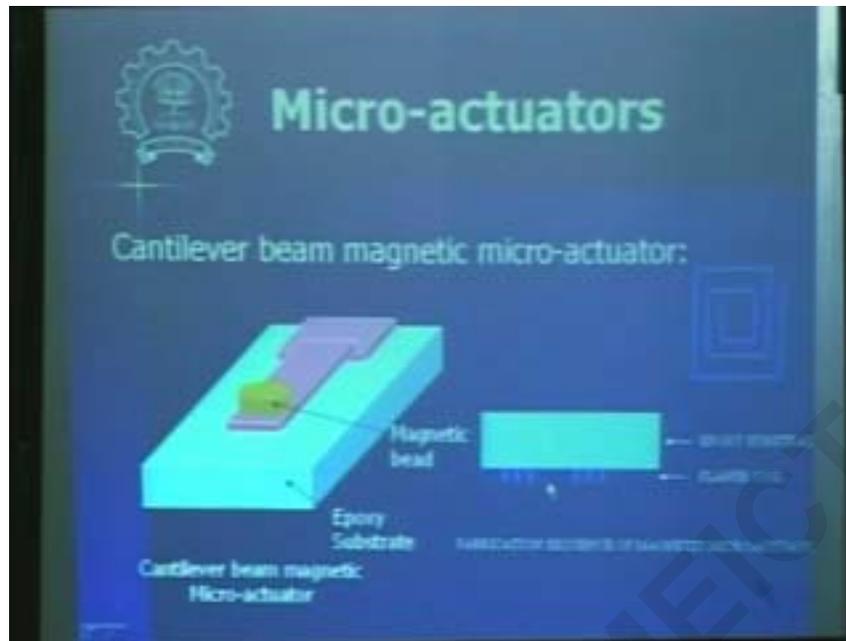
more the current you will have more the effect so let us see how this fabrication is done

so you have the substrate which they have used epoxy substrate here then you have this kind of copper deposited okay

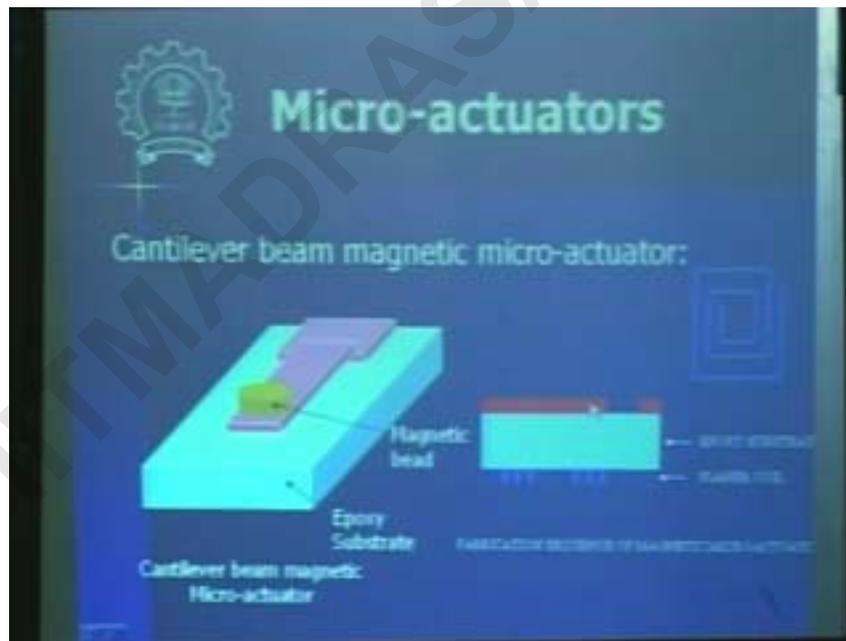
you pattern this copper and then produce a coil out of this okay this planar coil is of this nature okay (refer slide time 00:44:36)



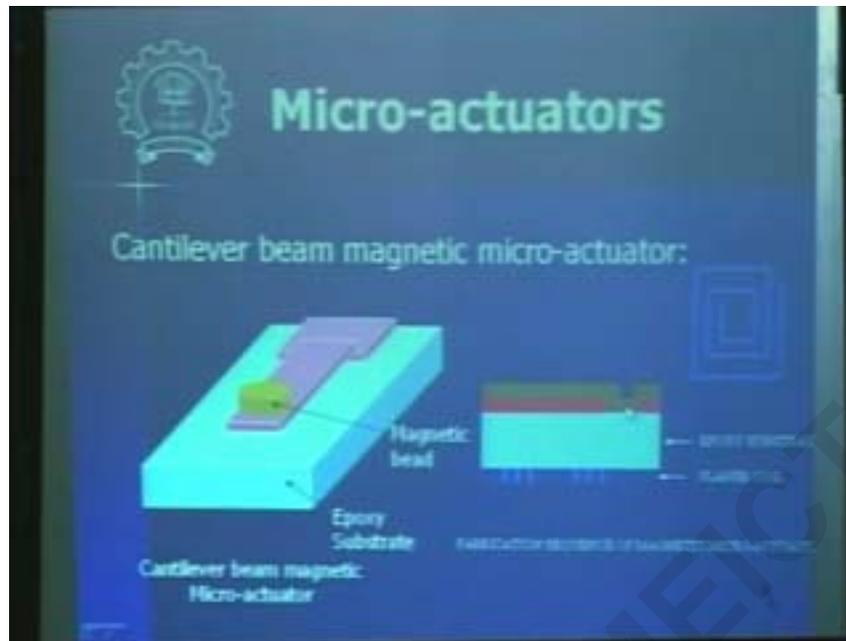
so you pattern or you have the mask which will produce this kind of a structure on the surface and then you expose it and do your etching and then you will get planar coil over here okay if you take the section it will look like this okay (refer slide time 00:44:56)



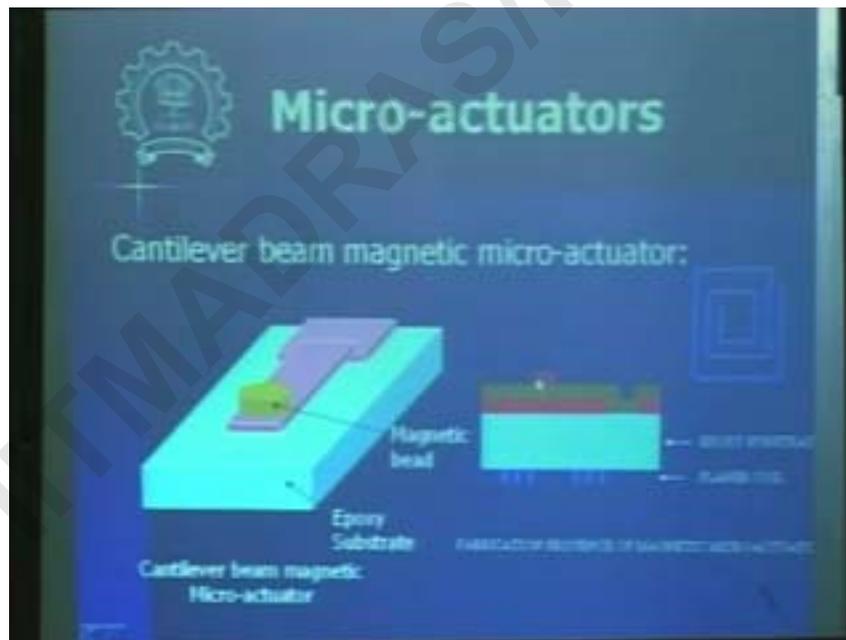
now on the top you again have this window open
(refer slide time 00:45:08)



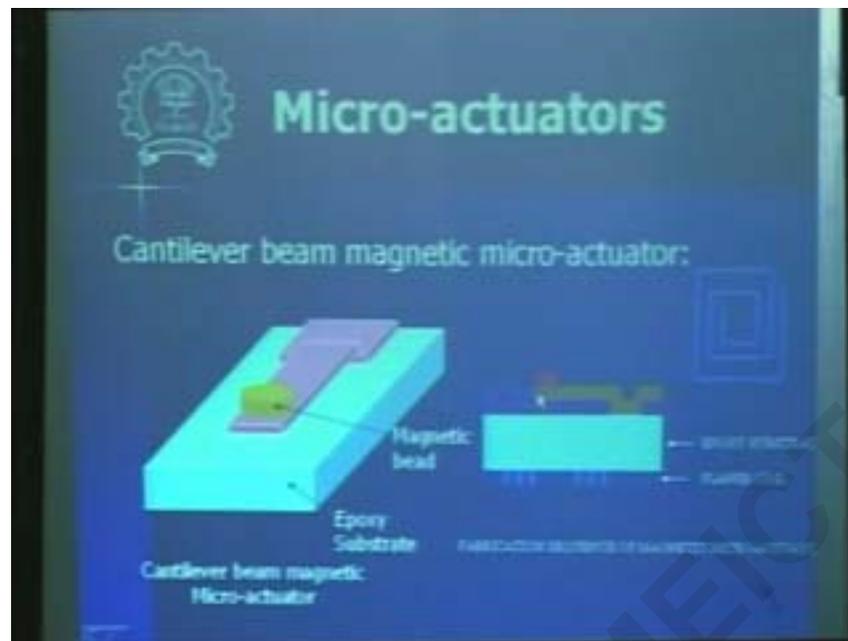
in which you will deposit whatever cantilever material you have okay
(refer slide time 00:45:15)



on the top of that now you will have another deposition like another window will be opened and in that you will deposit this bead okay (refer slide time 00:45:24)

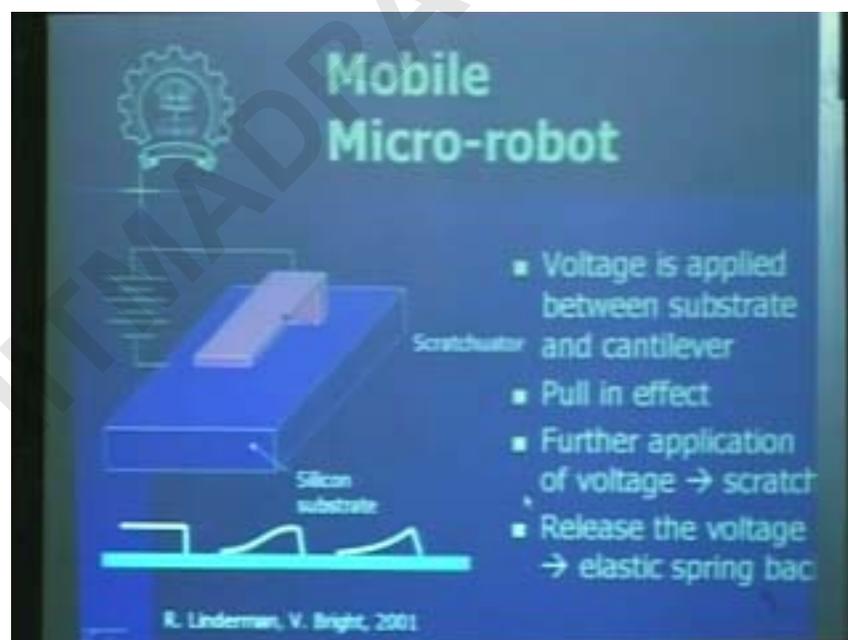


now once these bead is in place then you can like etch the entire material to remove this part okay (refer slide time 00:45:36)



so and release your cantilever in this side so so this way your structure of magnetic micro actuator will be ready

now you now you pass the current through this coils and then will get a actuation okay (refer slide time 00:46:00)



now these these are whatever we saw were all the actuators now let us see one very elegant structure which is used to as a mobile robot okay

so essentially you have these type of a cantilever structure which is free it is what attached to the surface okay

so it will look something of this sort when you see from this side okay

now you apply the voltage between these and the substrate because of the electrostatic charges here between this gap there will be a electro electrostatic force of attraction and this will bend down like this okay

so now you increase the voltage then this part is going to a scratch on the surface and move little further okay this part is fixed since it has larger surface of contact and then see if you see here there is just a line contact okay

so this part this is a surface type of a contact here and you are applying more voltage more electrostatic force this has to bend little more

so you can do that by scratching the surface there is a line contact at this point it will just scratch on the surface and then it will move by a small amount on the surface

now you release the voltage okay this will become structure of this kind and then it will slide slide to this this part which slide a little bit on this side okay

so like that you do multiple times in pulses and then you will you will actually the movement of this type of a structure on the substrate okay

that this kind of a very crude kind of a mobile robot i mean how to change the direction of the motion is an issue

then how to change the orientation like if you want to take a turn how to do that these are different issues like how do you modify the structure to achieve that kind of a thing they are the issues

but this is a principle or basic idea that people have tried for um that will have this the there will be wires connected for this contact to substrate and this robot

so this wire also will have its own effect on the robot okay

these are the issues that one needs to deal with but this is a very innovative kind of an idea to try out for mobile action or the micro robot okay

so these are these are the two gentlemen who tried this idea and it is very recent like two thousand one the they have a paper which will find this electro micro robot okay [noise]

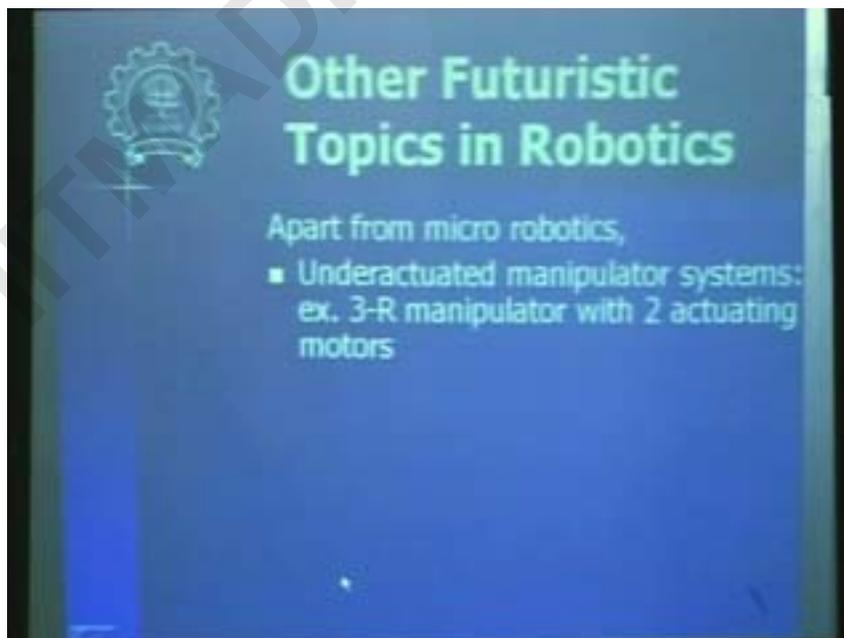
so it can be made of anything actually the material they they i think used um silicon poly silicon um material for the thing

now let us see some other topics which are of futuristic nature in robotics
(refer slide time 00:49:37)



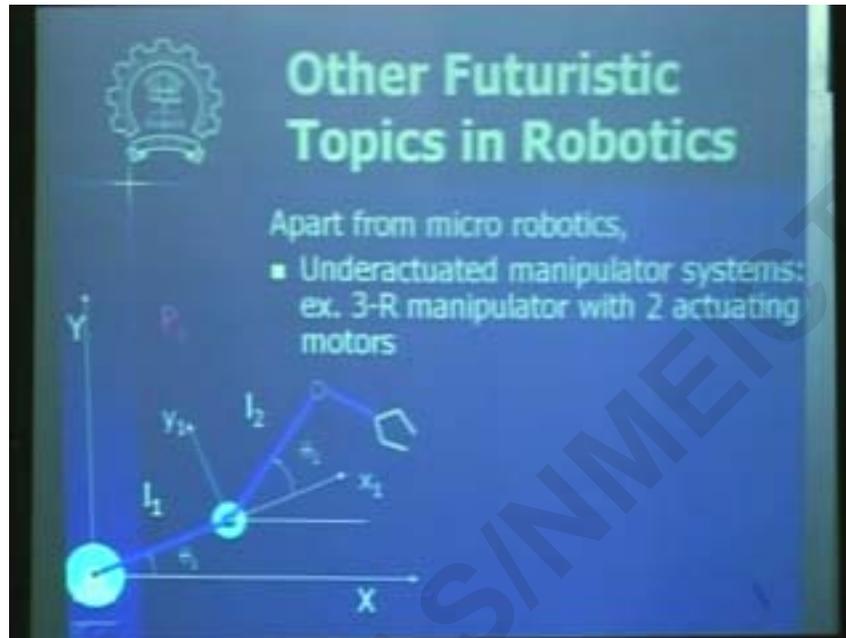
and um which we have not gone into de depth of that but these are ag again these are the topics were people are carrying out research

so one of them is um under actuated manipulator systems okay
(refer slide time 00:49:47)



so the essential idea here is that you have a manipulator which has number of degrees of freedom more than number of actuators okay

typically these kind of problems like for example you have this (refer slide time 00:49:06)



or conventional like that the example that we are looking at we were looking at in this throughout is force is this two D or two D of freedom two degree of freedom manipulator it is two R manipulator

now you attach one more link at this end this is link is attached but there is no motor which is actuating this okay

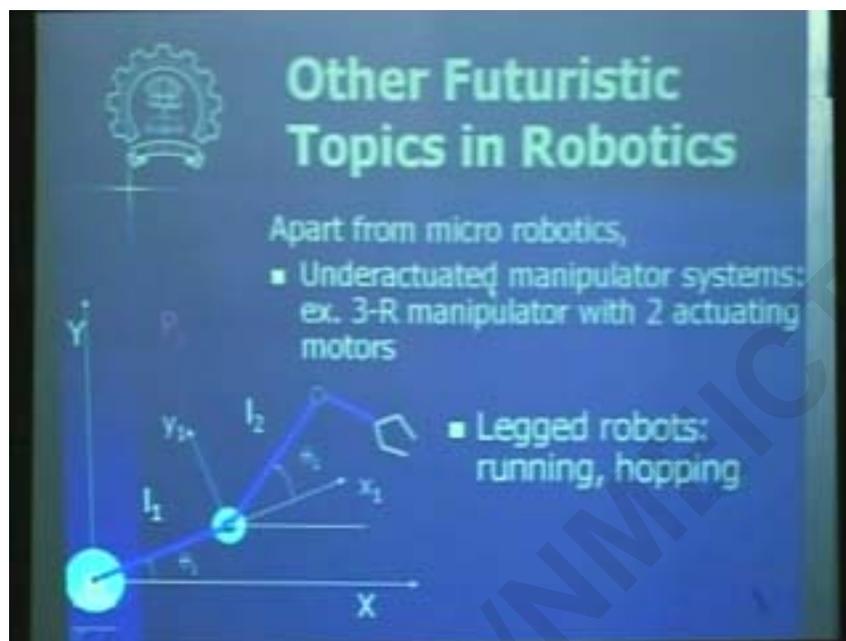
so now the problem is like how how do you control other two motors such that these link goes from safe example for example this desired position this initial position to some other desired position okay

say for example if you have this in horizontal plane okay no gravity effects are there how do you do that okay

so these kinds of um area mainly related to control of this under actuator manipulator okay control is big issue in such manipulator like it is not as trivial or as easy we have seen for some pd control kind of cases okay

so um here you will need very sophisticated complicated control algorithm which will try out this link from one position to other position in a specific manner

so like we have actually such manipulator in one of our labs and some research is going on on this manipulator in this direction
 how to do this control okay (refer slide time 00:51:50)



now okay other thing to other point to mention about this under actuated systems like see this is the big domain actually if you see under actuated manipulator or under actuated system its it's a big domain of systems um the the very simple example is um your aircraft

it has number of degrees of freedom more than the number of control surfaces based on which is operated okay

so that technologically the problems in the aircraft they are very similar to problems in under actuated manipulator and typically for tackling this kind of systems like you will need um good amount of physical understanding or physical inside into what is happening in the system okay

the system behavior how the system behaves so that kind of a understanding if they have very good understanding of that kind so that like you will develop good controllers to control these systems okay

then you have seen this example already which is um legged robot okay so you have seen one of the example of natraj which is six legged robot and then in that in in legged robots you have many possibilities like you have a running in robot or hopping robot

so if you have a single leg it will be a hopping kind of a system um it will just bum bump or bounce so as to stabilize itself and then if you like say if you change the direction of

the link which on which it is hopping then it will start moving in a particular direction okay

if it is vertical it will just bump at the same point same place it will not move but if you tilt it little bit it will start moving in a direction which is opposite to that tilt okay

so that is a very ah very much studied i mean um people have like over the years developed many different types of hopping robots and many different strategies to control the hopping robots

so so this is their typically dynamic in nature like their um all these they are continuously moving so the it is not that you have a fixed position that um they will achieve okay

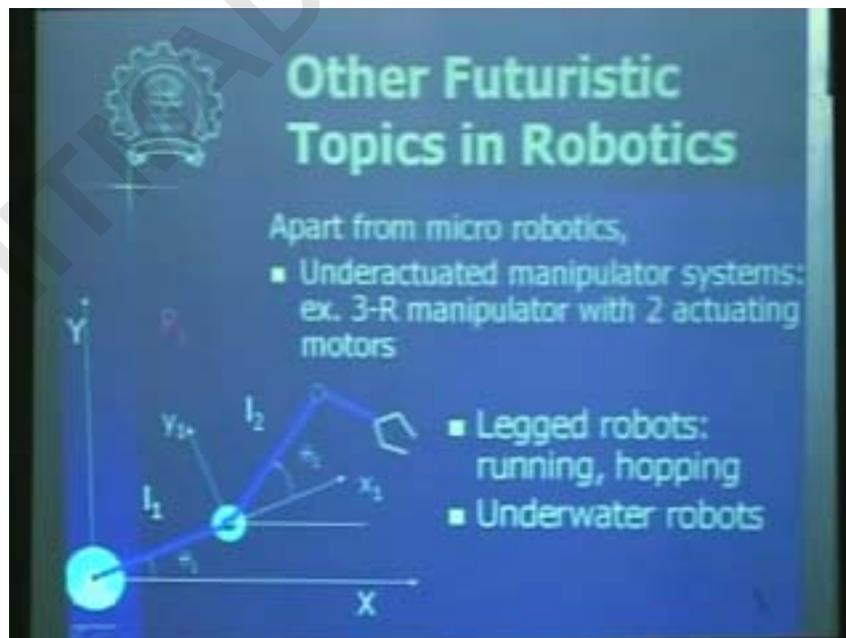
so they are continuously in the dynamic equilibrium so you can go from one dynamic equilibrium to the other dynamic equilibrium okay

so it is hopping at this place now i want it to hop at some other place so how do i move it from this place of robot to that place

but i can do that but it will be always in the dynamic equilibrium like at final position also it will not be it will not be kind of stopped it will be having the dynamic equilibrium at that point

so that is the main difference from the point of view of control in what we have seen what control we have seen and what is this type of a strategy okay

and then next is under water robot right (refer slide time 00:55:03)

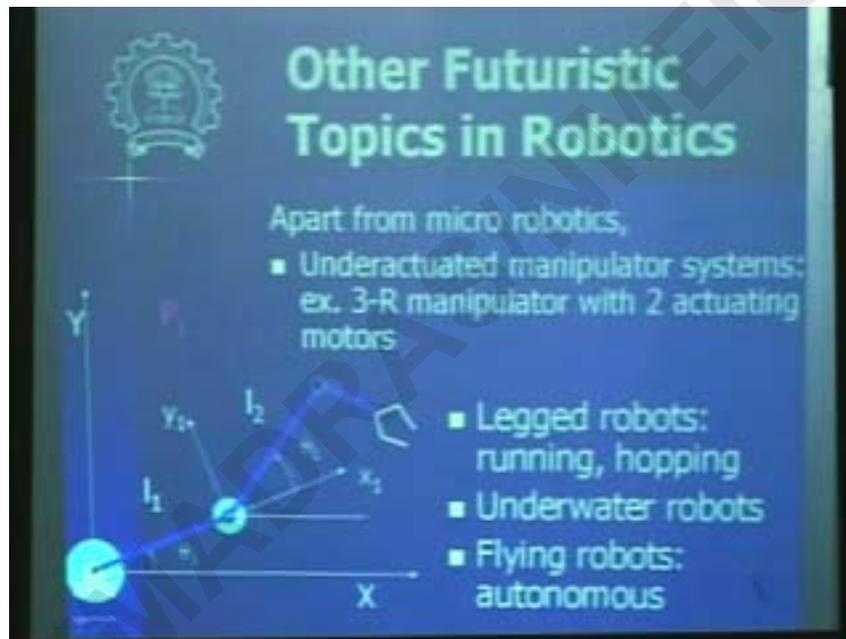


you have robots for underwater applications okay

so they are similar in nature technologically to aircraft kind of a structure they will have a control surfaces they will have a propellers will propel them in the liquid or in the water and then like the problem is to control this surfaces such that you achieve a particular type of a motion or particular it goes to a particular place and thing like that okay

and then in addition to that you have to control a buoyancy so that it moves with respect to the water level okay

it goes deeper or it goes towards the surface for that there is there is a different mechanism you to have that kind of a motion possible okay
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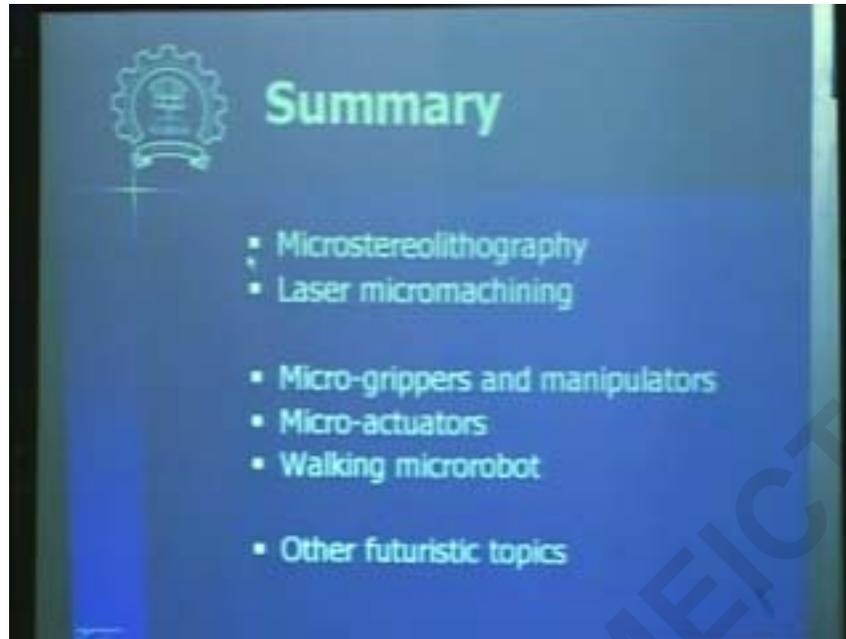


then you have flying robots which are again similar to aircrafts but much smaller in structure so tech there are many technological issues regarding what kind of um lifting force they will have and things like that

so so that is again technological challenge like and then converting this flying robots into an autonomous flying robots is another challenge okay

these are the other futuristic issues in the robotics area okay

so we will conclude this lecture now (refer slide time 00:56:36)

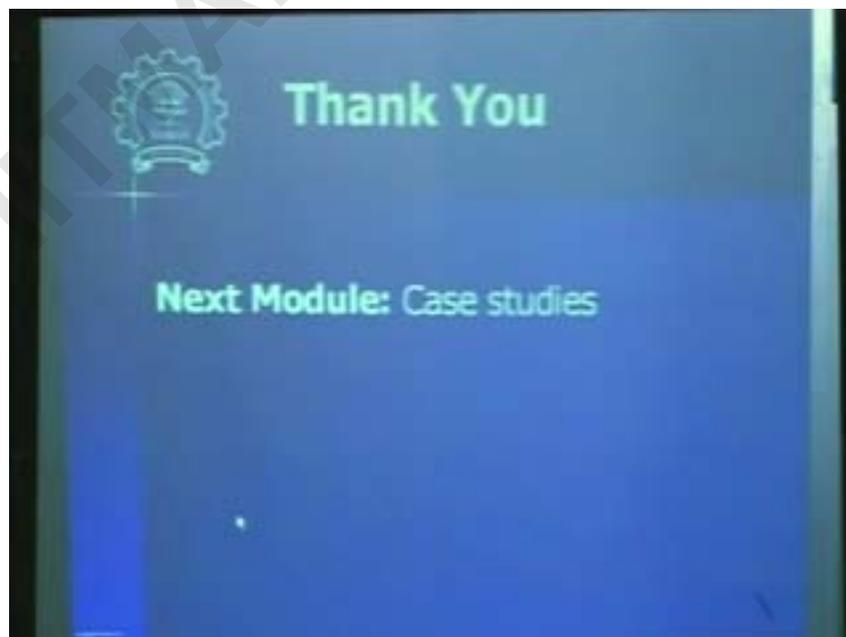


what we have seen is basically micro stereo lithography laser based micromachining process okay these are the processes like for fabricating micro components but it there it there based on the unconventional kind of a process okay

then we saw some micro grippers micro manipulators then one example of walking micro robots and then couple of micro actuators okay

and then some other futuristic topics okay

with this we will conclude this lecture (refer slide time 00:57:16)



and then with this i think we are concluding the entire course okay right

this case study modules you have already seen in the previous class so may be we will have some more case studies and then we will conclude okay fine [close]

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