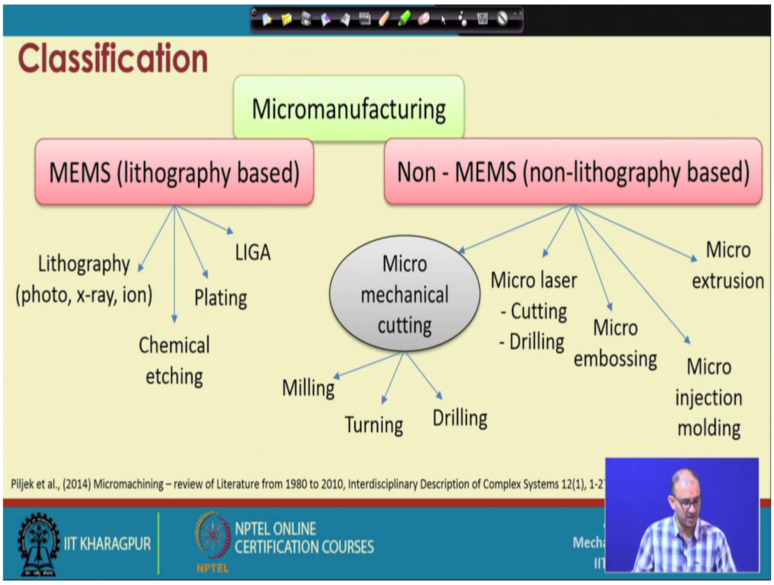
Introduction to Mechanical Micro Machining
Prof. Ajay M Sidpara
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 04
Introduction (Contd.)

Good morning and welcome to our course on introduction to mechanical micro machining processes. In the last class we have seen some of the classifications of the different micro fabrication processes, and those processes classification we have done in terms of the material, by which we can do different type of shaping, whether we remove the material from the workpiece.

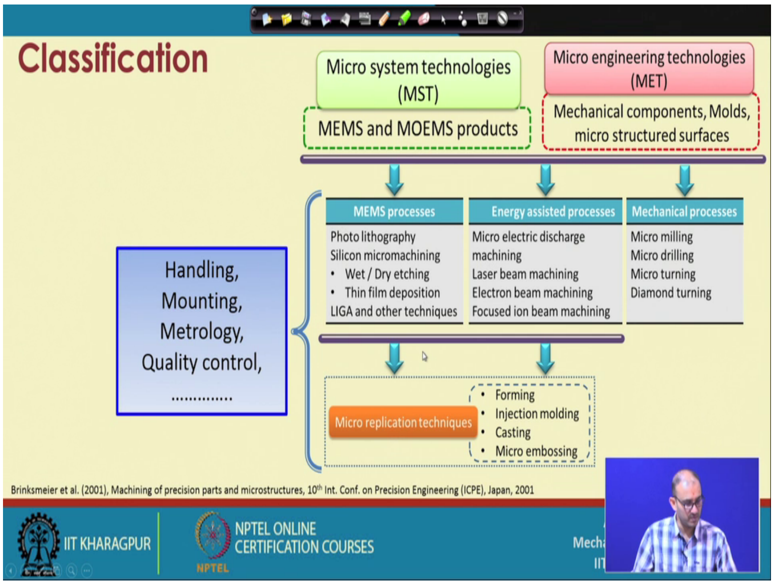
We add the material layer by layer, we contain the material mask and we deform the surface. So, that we can get different shapes by casting and moulding processes, or we join the different materials we have readymade shapes. So, these are the different classifications. And then we have classified this material in terms of the MEMS product or the lithography base, and non lithography processes, or called the non MEMS.

(Refer Slide Time: 00:55)



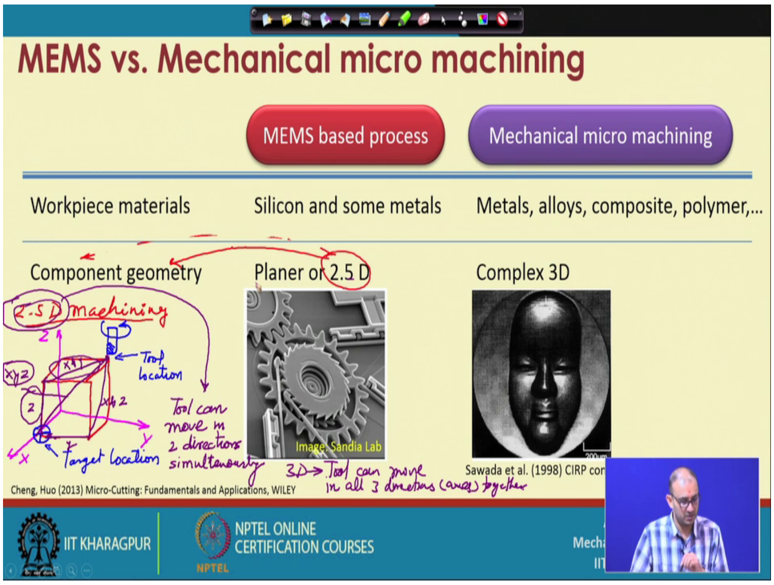
So, here also we have seen classification. And one category was related to the etching and lithography, and deposition. While in other case it was related to the casting, laser beam machining and the micro mechanical processes.

(Refer Slide Time: 01:18)



Third classification we have seen in the similar line, but there was a additional feature or additional component, was the handling mounting metrology and the quality control. So, these are the way we classified these different type of micro machining processes.

(Refer Slide Time: 01:33)



And then we started with the comparison between the MEMS processes, and the mechanical micro machining processes, then how these processes are different from each other. So, first one was the workpiece material. We have seen the silicon and some metals can be machined by the MEMS based; that is the lithographic processes or the etching processes, but here we have very var, last very vast range of the material, which can be machined by mechanical processes.

And then we have seen the component geometry. It is a planer and 2.5 D. Then we have seen the how to define the 2.5 D geometry; that means, your z height is very small or it can be neglected compare to the x and y dimension, and these are the some of the one components of 2.5 D, and this is the one component for 3 D part. So, this is the geometry. And other than that there is a one particular thing is 2.5 D machining. So, what is this 2.5 D machining. We know the 3 D machining, we know the 2 D machining also, but what is this in between these two.

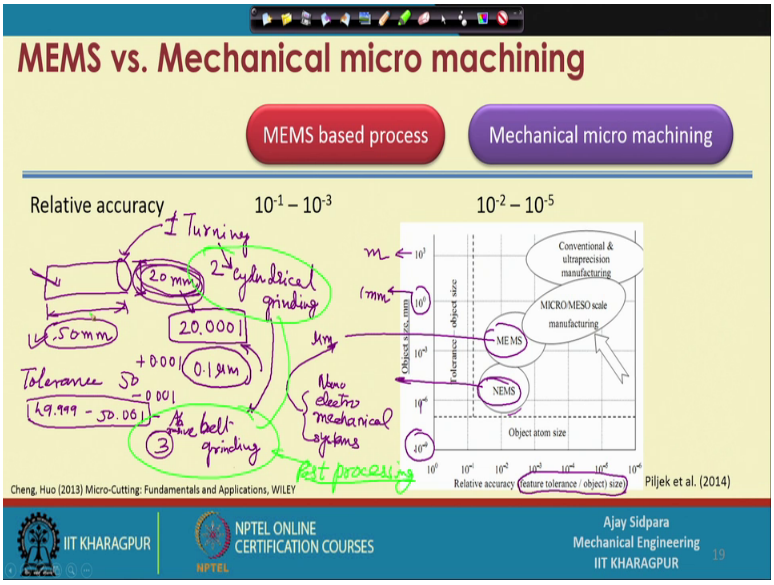
Now, if you consider, let us see that how we can define this 2.5 D machining . So, this is considered x direction, y direction and z direction. Now consider your tool is located here. So, this is your tool, it is rotating, it is a dislocation, and you want to go to this location. This is the tool and this is the target location. Now there are many ways by which we can go to that location. So, our tool will directly go from here to here, or it will go in this direction. So, first let us see what is 2.5 D machining. So, 2.5 D means that tool can move in two direction simultaneously. So, now, suppose our tool is here, then tool will move in this direction. So, when it is moving in this direction, it is moving in x and y, and then it moves in the z direction.

So, this is called z direction. In same way what it can do that it can move in this direction also. So, this movement is in two direction. One is in the, or a y direction is fixed. So, it is x and z direction. And the once it reach here then it will move in the y direction. So, in that way, we know that your tool is moving simultaneously in only two axis, either in xy or xz or it is in yz direction, but after once it reach then only it will move in the third direction. So, that is why it is called 2.5 D machining.

And now what is 3 D machining, that 3 D. So, now, our tool is located here, and if it directly goes from here to here, now you know that it is moving in all these three directions. This is moving in x y and z all three directions, because this is the shortest path by which it will reach to this location.

So, once it is moving in this direction, it is covering this path also. And once it is going down, it is covering z path also. So, when your tool is moving. 3 D machining means tool can move in all three direction or axis together. So, this is called 2.5 D machining, and this is called 2.5 D geometry. So, this is the difference between these two different terminologies.

(Refer Slide Time: 06:40)



Now, some other parameter related to accuracy. Related to accuracy is here 10 raise to minus 1 to 10 raise to minus 3, but here that range is little bit large. So, now, what is relative accuracy. So, now, here relative accuracy means, this is the tolerance divided by the object size, now if you see this particular graph, you know that this is the nano electro mechanical system, this is known it is micro electro mechanical system, and this is the our processes which we are covering here. And this is the conventional and the ultraprecision manufacturing processes. Now this is the object size and here this is the object size. Here you can see, it is very small it is in 10 raise to minus 9 millimetre size. This is in terms of 1 millimetre, and this is in terms of meter, and this is smaller in this particular direction.

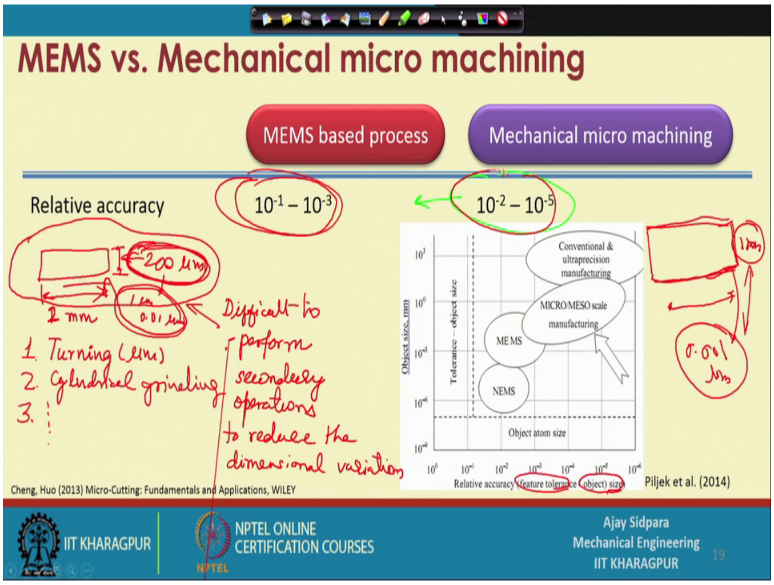
So, now, how we can define this thing now suppose you have one cylinder. Now these lengths consider 50 mm, and this is the diameter. And let us consider this is the 20 millimetre diameter. Now when you are telling at 20 millimetre diameter, and this actually you, it is difficult to fabricate with the same dimension. So, what we generally do that we give a tolerance. So, 50 plus minus, we put something like 0.001 or 0.001 something like that. So, it is something like that, if it is like that. So, if dimension is within 50.001 to 49.999; that means, this is a acceptable dimension with respect to the fabrication process.

So, now if you see this particular thing, this is called object size. So, now, if object size is this much, and you can easily get the dimension at the micron. Suppose it is a 50 by 20, then you consider, let us consider only the diameter that you need a length. Let us assume the length exactly perfectly you are getting 50 millimetre, but it is not the case. Right now let us consider it is possible. Now let us consider one dimension of the diameter. Suppose it is a 20 millimetre diameter, and if you can create a diameter, your requirement is 20 millimetre your machine is giving 20.0001.

So, it is in millimetre. So, here you can say it is a 0.1 micron tolerance you can achieve in this particular case. Now it is in millimetre to this one, it is possible only in the bigger size. Now when you turn it by turning process you cannot create a such a high tolerance. So, this is the turning operation first. First operation is turning, and once turning is over, then what you have to do. You have to do cylindrical grinding, and after cylindrical grinding, you main it some type of belt grinding to reach to this location; that is called abrasive belt grinding, and after that you can achieve this so.

Now, you can see that it has pass through many operation; one operation is this, second operation is this, and this is the third operation. Now you can see the dimension of this and number of operation, it is possible to perform a multiple sequential operation; that is dimension is in millimetre size. So, you can see the component, some type of post processing is possible. So, these all things are called the post processing. So, this is, and this particular process. So, these processes are the post processing. So, this post processing is only possible, because dimension is very large, and you can easily see, and you can perform different operation on the top of it, but here problem with this particular component is.

(Refer Slide Time: 11:58)



That means, you are able to do that dimension control in this case very easily, but if you see this particular part. Now consider we have a soft diameter of a 200 micron, and length consider around 2 millimetre. Now we have done a turning operation here. So, first operation is turning, similar to earlier operation, but it is in micro turning, and once it is over now, you cannot perform it is very difficult to perform.

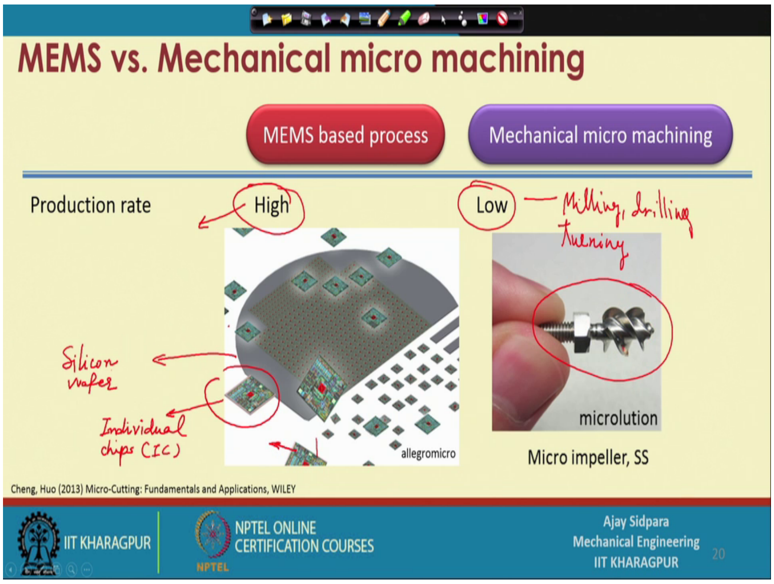
The third operation that is called cylindrical grinding and other operation like a abrasive belt grinding or some other processes, by which you can get the required amount of tolerances here. So, why this relative accuracy is very less in this case, because you will not get a second chance of improvement of the geometry or the dimensional accuracy, here we can write difficult to perform secondary operations to reduce the dimension variation right. So, this is what is happening in this particular case.

So, now, we know that our dimension is in 200 micron like this here. And suppose your tolerance is also in micron, because here maximum it can go with a sub micron level. So, difference between the actual dimension; that is what we are telling that, this is the size of the actual size of the object; that is a 200 micron and our feature tolerance is also in micron, or consider it is a 1 micron to 0.1 micron or 0.01 micron, but still everything is in micron.

So, if you take the ratio of this thing, it will be very small in this case, but if you see in this micro mechanical, our object components. Suppose we can easily get some component of a millimetre size. Suppose here it is a 1 millimetre is the diameter of this particular part, and you can easily get the different type of feature or different type of surfaces here, by finally, tuning the process, and you can easily get the from 1 millimetre, you can get 0.001 micron also.

So, in this particular case now, you can see the starting dimension is 200 micron here, but here starting dimension is 1 millimetre, and you can see the tolerance is in 1 micron 2 like that. Here also you can get 0.01 to 1 micron, but the difference is very large. So, that is why we are getting a very large relative accuracy compared to the MEMS product.

(Refer Slide Time: 15:22)

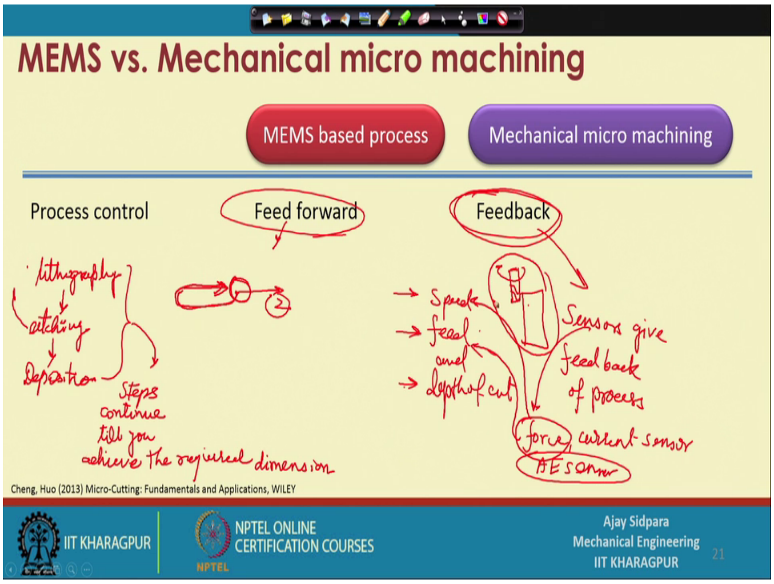


Now, another one the production rate, but production rate, it is very very high in terms of MEMS product, because now this all processes are cheap base. Now we can say that this is called, this is a silicon wafer, and these are the individual chips. Now it is called integrated circuit or IC chips. Now you can see the whatever the diameter of this silicon wafer, you can create a many chips simultaneously, because you do not need to do a single operation.

Now you can see this are the small components. Once all chips are ready, then you can actually cut this chips separately, and then use this chips for a separate processes. So, here the production, it extremely high, and this is the reason that our mobile phone and electronics items are, day by day their power is very high, and the cost is very low, because this is in mass production, but if you see your machine that we use a milling operation, then drilling operation and turning operation, and these all the operations can be perform in a sequence were; that means, you cannot perform both the operation milling and turning simultaneously.

To fabricate this component one tool will interact with the surface, and then once part is over, then only you can fabricate the next one. And again you need to spend some time in the setting of the component again the measurement and everything. So, that is difficult in this case; that means, the mass production is very low; that means, here production rate is low and comparatively very high in the MEMS processes.

(Refer Slide Time: 17:32)



Now, control is feed process, control is feed forward and it is a feedback control. Now what is this, because in MEMS product. Now we have lot of processes, it is a lithography then we do etching process, then deposition. So, these processes continue till you achieve the required shape or the required dimension of the features. So, this process is, this steps continue till you achieve the required dimension. So, here order will not be much problem, because etching may take place first. Also this may come first, this may come first like this, but it will continue, because in a single step, you cannot fabricate the process.

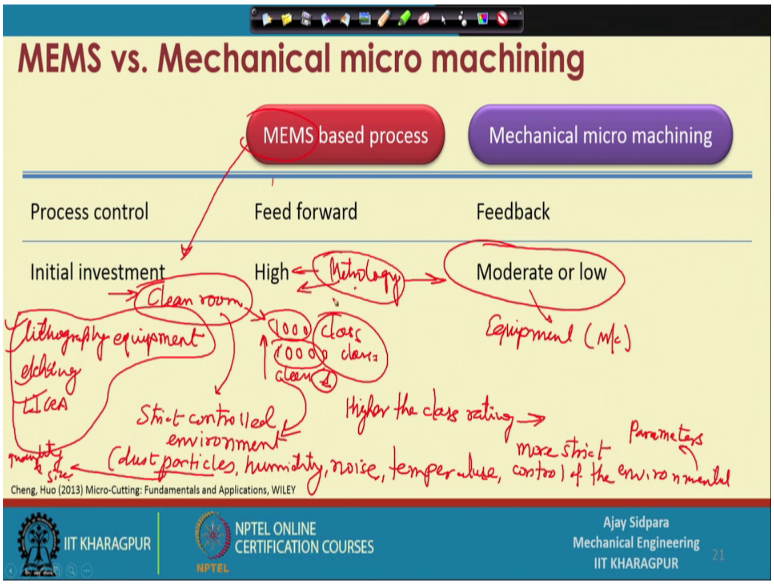
So, feed forward processes are that you can control the sequence only; that means, what it is coming out of this, you cannot actually regulate that particular thing that suppose your fabricate, your making one mass and you are fabricating one etching process here by etching process, you are fabricating some features here. And once etching process is over; that means, whatever process has come that whatever product has come that product will go to the next station. So, there is no way you can actually refine this particular process or earlier process.

So, that is why it is called feed forward processes. What is feedback processes. Suppose we are making one component, and this is our cutting tool, and it is rotating. So, we have in our hand speed feed and depth of cut, and we do this machining simultaneously, you are putting some sensors also. So, this sensors will give you the feedback, give feedback of process. So, this sensors can be a force sensor, then current sensor or some type of acoustic emission sensors.

So, once this sensors are there, at that time what here you can do that, you can actually fine tune this processes the. Suppose forces are very high, then what it will do. it will reduce the feed and increase the speed also. In that way you can actually control the process in a feedback manner. So, every time.

Whatever sequence is happening here between the cutting tool and the workpiece at that time, that signal will transfer to the input parameter. So, you can refine the para process during the machining, but that option a or that facility, or that particular feature is not available in the MEMS product, because there are many processes available which will process the component separately, but here we are using a milling machine only, and which is equipped with many different type of sensor, and that is the advantage of going with the feedback control.

(Refer Slide Time: 21:17)



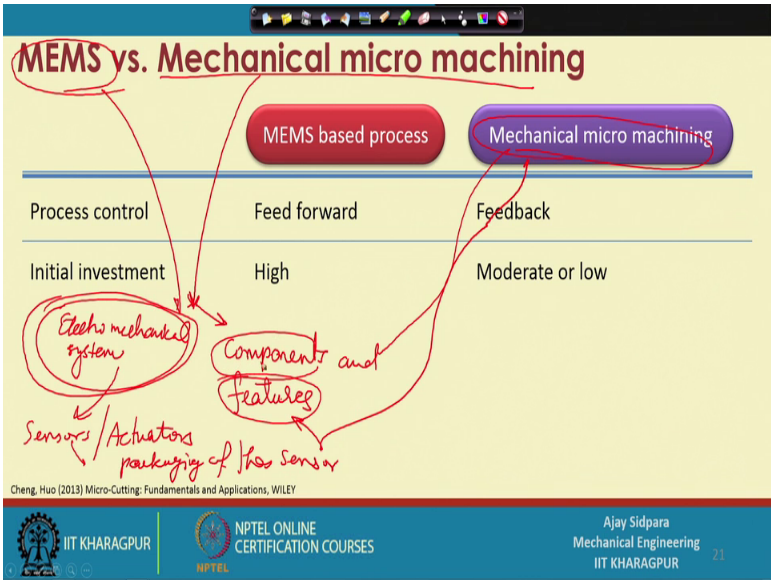
Initial investment is very high, and here it is moderate to low initial investment means here if you see this particular MEMS product. So, MEMS product needs many things; that is one is the clean room. So, clean room itself is very difficult, because you cannot operate this lithographic equipment, then etching, then Liga process. So, these are the particular processes, which need some strict environmental control. So, clean room is a controlled. So, it is a dust particles, humidity noise level temperature and many thing. This other than that, there are, you have to make sure that there is no large various in the temperature humidity, is also there dust particle, that how many dust particles are there. So, particles means quantity and size.

So, there are different clean rooms are actually rated in terms of the 1000 clean room, then 10,000. These are the 1000 class. It is known as a class 1000, then class 10,000 class one like that. So, higher this rating more strict is the control of this particular part. So, this class control higher the class, more strict of the environment, environmental parameters correct.

So, this is way if you see this, there are many processes available you have to prepare a clean room also, and that is why its cost is very high. Here it is moderate to low; that means, you have to spend more money in the process or the buying of the equipment; that is machines and then you need a metrology; that is in both the cases, because without metrology, because in, if you see both the picture size and all the things both things are in micron, but here you can go very small in the dimension; that is limited here, because we have limitation in the size of the cutting tool also.

So, metrology is required in both the cases. So, we are not considering the cost of the metrology, but here the metrology requirement is very little bit little tight here, because the dimensions of the components are also very small. So, resolution in all these things are very tight control, but here you can actually go with a moderate equipment of the metrology also, to make sure that dimension can be measurable.

(Refer Slide Time: 25:32)



Now, whatever we have discussed till now, that was comparison between the MEMS product and the mechanical product. So, here we have seen that these processes are mostly used for fabrication of the MEMS product; that is mostly electro mechanical system, and these products are. These particular processes are used for fabrication of different components, and features.

So, it has its own application, because here it is a complete package; that means, here you consider the sensors actuators etcetera, can be made by these processes, but here of this micro mechanical you cannot create a product, but here you can create a component and features, because suppose you want to make a sensors, and you want to create a one type of packaging of the sensors.

So, packaging of the sensor of the sensor can be fabricated by these particular processes. So, in that way, it has a different domain, and this one has a different domain. This is a related to the complete product, but this is related to the component and some of the features. So, let me finish this class here, and we will continue from the next slide in the next class.

Thank you very much.