Electronic Systems for Cancer Diagnosis

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Lecture - 09
Micromachining Techniques

Hi, welcome to this particular class. This would be a series of modules that you need to go through. And the idea is to explain the importance of micro machining. Now, when we talk about MEMS, what exactly MEMS are? MEMS are Micro Electro Mechanical Systems right. So, electronics when we design electronics using a micro technology, we can understand what is the mechanical right, micro electromechanical, where is mechanical things comes into picture.

So, if you know right we perform machining in mechanical workshop right, we have seen we use lathe machine, we use other drilling machine and we perfom machining right. So, you take a material, you etch the material right, you can form something similar to etching of this particular material right. So, you can we can create this machining in a bigger surface, bigger area. What about you want to perform machining in a smaller dimension in a micro dimension, that will be your micromachining right; machining at a micron scale micromachining.

So, let us learn, let us see why this machining knowledge is very important for us to understand, and how we can use it to fabricate some sensors right. So, when you talk about machining, there are two types of machining; one is bulk machining and second is surface machining. So, bulk micromachining, surface micromachining. So, let us see what exactly bulk micromachining is and then we will see what is surface micromachining, and then bulk surface micromachining, and we will take few examples right.

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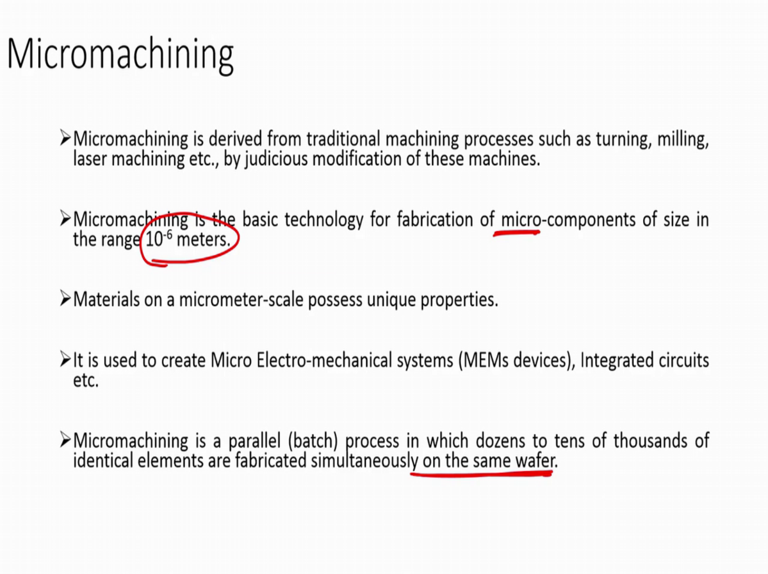

So, let us see what is micromachining. Micromachining, micromachining is derived from a traditional machining process like I said such as turning, my milling, laser machining etcetera by judicious modification of these machines correct. Then micromachining is the basic technology for fabrication of micro-components. Micro, what word micro means 10 raise to or 10 to the power minus 6 of a metre micrometer right; components of size in the range of 10 to the power minus 6 meters. Materials on a micro meter scale possess unique properties. Micromachining process is used to fabricate MEMS based devices, integrated circuits, etcetera.

Also micromachining is a parallel that is batch process in which dozens to tens of thousands of identical elements are fabricated simultaneously on the same wafer right. So, if you see machining technology, then you will understand that we can have a batch processing where thousands of identical elements can be fabricated on a single wafer at one time that is simultaneously.

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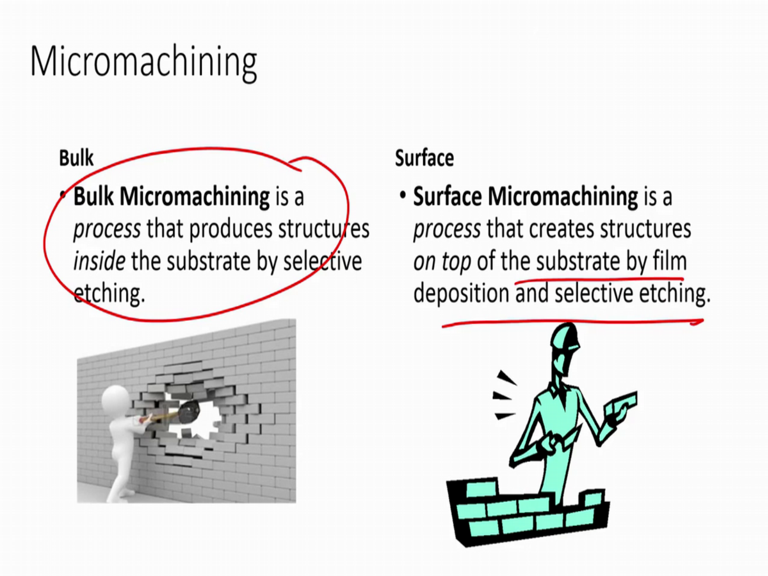

So, now let us further see bulk and surface micromachining right, bulk and surface micromachining. Bulk micromachining is a process that produces structure inside the substrate by selective etching. You see he is only etching this part right, he is only breaking this part, this parts are intake remaining parts are intake. So, selectively breaking something or etching something right within a substrate, we can we can define as a bulk micromachining right.

We will see a better example while in case of surface micromachining this is a process that create structure on the top of the substrate by film deposition, and selective etching right. We can deposit a film and selectively etch the film. So, there is a fundamental difference as we can see between bulk micromachining and surface micromachining technologies.

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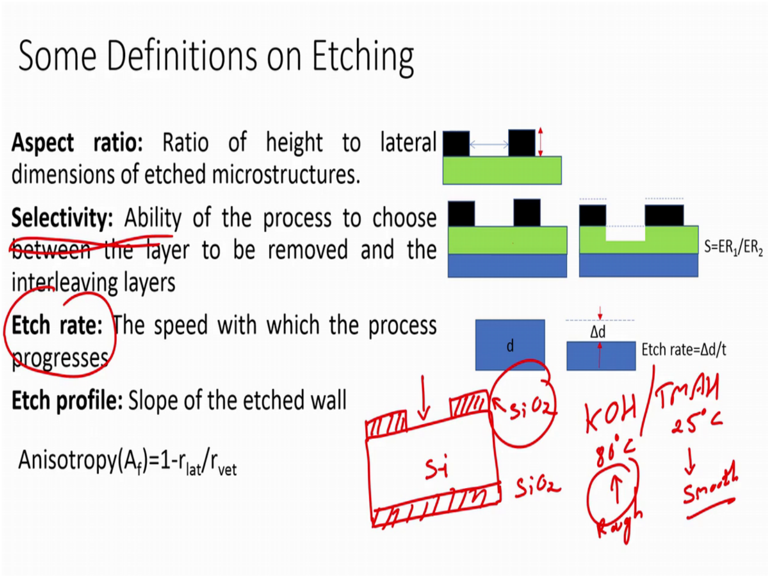

So, let us understand very important definitions on etching. You can say parameters, you can say properties right. What are these properties? First property is aspect ratio. What is aspect ratio? Ratio of height to lateral dimensions of the etched microstructure, you can see here right height to lateral dimension is a aspect ratio ok. Ratio of height to lateral dimension of etched microstructures.

Second is selectivity. What is selectivity? Selectivity is the ability of the process to choose between the layer to be removed and interleaving layers. So, if you see in this particular case right, if you see this example right, in this example what we are doing we are selectively etching only this surface, only this surface, you can see here right this is etched this green section is etched without affecting any black section without affecting the black section, we are selectively etching this area this is the selectivity, selectivity.

Next, what is next? Next is etch rate. Etch rate is the speed with which the process progresses. Suppose, I want to I have a silicon dioxide. Let me just try it once again ok. I have a oxidized silicon wafer. What is oxidized silicon wafer? Silicon, silicon dioxide, silicon dioxide right.

Now, using photolithography I have created a window and etched silicon dioxide right. Now, I want to etched silicon. So, how fast I can etched silicon is my etch rate right. So, I have we know that for etching silicon using wet etching, chemical etching we have potassium hydroxide and we have TMAH right. And if you remember potassium hydroxide we perform etching at 80 degree centigrade, TMAH at 25 degree centigrade, KOH is faster etching TMAH is slower etching. KOH surface reference is poor right surface roughness is poor; TMAH surface roughness is smoother so better right. This is coarser; this is smoother. This is smooth; this is rough right advantages disadvantages.

Now one thing that we have seen is the etch rate for KOH is higher that means, the silicon can be etched faster that is what etch rate means that is what etch rate means right. Now, when I am dipping this wafer in KOH or TMAH, only silicon will get etched and silicon dioxide will not get affected, silicon dioxide will not get affected. So, silicon dioxide is not affect getting affected only silicon is getting etched that is our selectivity, selectivity right.

So, just quickly wanted to show you one example. Now, next would be etch profile. What is etch profile? Slope of the etched wall, slope of the etched wall. And it is nothing but etch rate 1 by etch rate 2, also anisotropy. What is anisotropy? Anisotropy is 1 minus r lateral divide by r vertical, rate of lateral etching divided by rate of vertical etching right. So, these are some of the definitions when we are talking about etching right. Etching like I said very important. And you can create several structures using bulb micromachining and surface micromachining.

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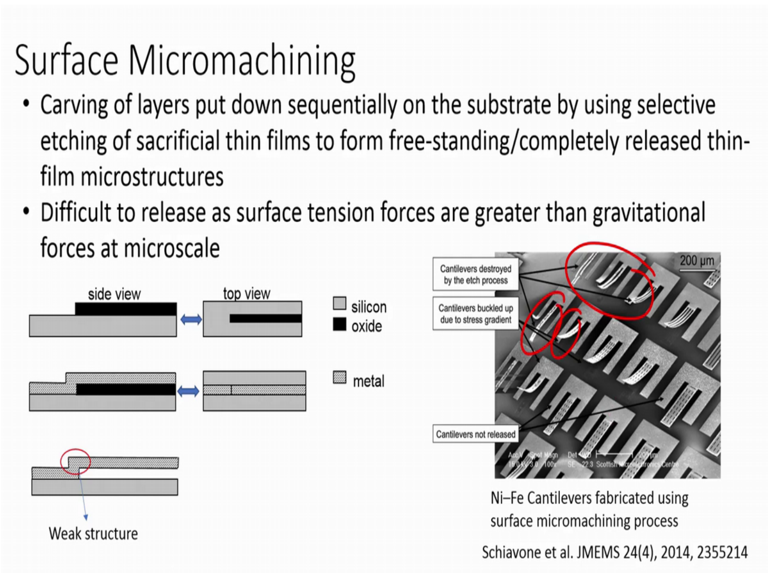

So, let us see what kind of structures we can design or we can fabricate using surface micromachining. So, you can see here this is an example of surface micromachining.

And if you see this example the grey colour is silicon and black colour is oxide. So, if you see the side view right, we have oxide and silicon. Now, we are depositing a metal, we are depositing a metal, and then we are etching oxide we are etching oxide. What will happen, we will have a cantilever right we will have cantilever of what, we will have cantilever of metal right. So, this is how we can create a cantilever.

Now, carving of layers, carving of layers put down sequentially on the substrate by using selective etching of sacrificial thin films to form free-standing completely released thin film microstructures that is wall surface micromachining does right. What it does? Carving lay of layers put down sequentially on substrate, you see here, we have silicon dioxide on silicon, we deposited a metal right, and then we have etched the silicon dioxide. So, silicon dioxide here would be a sacrificial layer; it will sacrifice itself, sacrificial layer. So, when I sacrifice silicon dioxide by etching silicon dioxide in buffer hydrofluoric acid what I will have, I will have a cantilever made up of a metal.

Next is it is difficult to release as surface tension forces are greater than gravitational forces at micro scale. So, at micro scale you should understand that the gravitational forces are less compared to surface tension forces and that is why it is difficult to release a cantilevers. Now, you can see here there is a nickel-iron cantilever fabricated using surface micromachining process, and you can see multiple cantilevers the authorize try to fabricate right some are really beautiful, you can see here, it is a perfect example of how cantilever can be released.

Some have the curvature right, some are not released. So, you can see here the cantilevers which are released are this cantilevers, but they are buckled up right, this cantilever in particular is not released, because otherwise it will come up. So, this cantilever is not released this one is released again buckled up right same way this cantilever is not released right. So, it is difficult to release the cantilever like I said because surface tension forces are greater than gravitational forces.

However, if you see that there are few cantilevers that were destroyed during the fabrication process, few cantilevers they are got buckled up because of the stress in the metal film right. However, you can get if you optimize the parameter, you can get excellently released cantilevers right. I will show you an example of how to release a cantilever, but using a bulb micromachining process in the following slides. So, point is using surface micromachining we can easily fabricate a structure, but then we need to optimize the parameter, otherwise because of the surface tension being higher or greater than gravitational force, the it is very difficult to release the structure in a proper fashion right.

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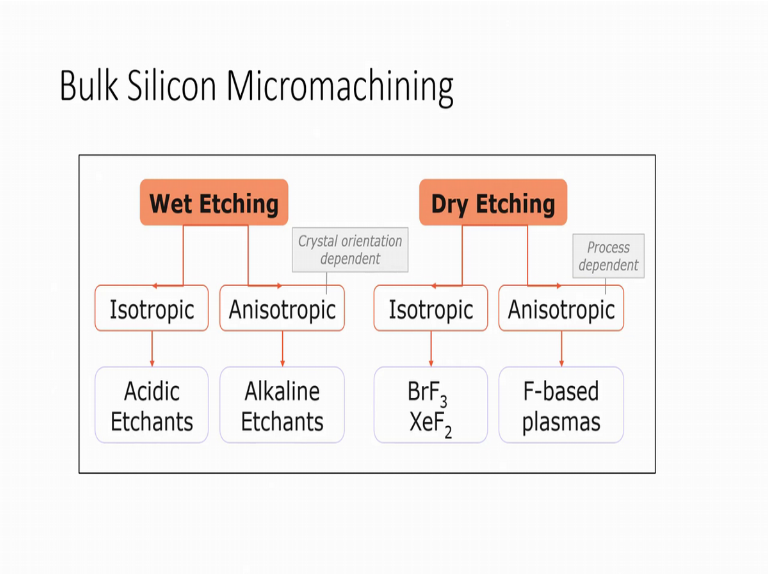

So, when you see now, if you go back to the slide, what you will see there is a bulk silicon micromachining right, bulk silicon micromachining. So, in bulk silicon micromachining, we will see two I two kind of etching, one is wet etching and another one is dry etching all right. One is wet etching; another one is dry etching. Now, in wet etching, there is isotropic etching and anisotropic etching. Similarly, in dry etching, there is isotropic etching and there is anisotropic etching. Now, dry etching anisotropic property depends on the process; while in case of wet etching the anisotropic is dependent on crystal orientation.

Now, if it is acidic etchants, then will generally get isotropic; while if it is alkaline will get anisotropic. In the case of F-based plasma, we will get an isotropic; while it is a case of dry etching, while we have Br F 3or Xe F 2 will can get isotropic etching. So, DRI is a deep reactive ion etching is a example of dry etching. And dry etching is also commonly known as plasma etching, because we are generating a plasma and the electron energy in the plasma creates a very high temperature, but the overall over overall process it has is at low temperature. So, the gasses will etch the silicon. And for silicon, we use generally

C 4 F 8, and S F 6. While we also use helium and oxygen in case of the deep reactive ion itching. We will see video of how deep reactive ionature can be used from STS.

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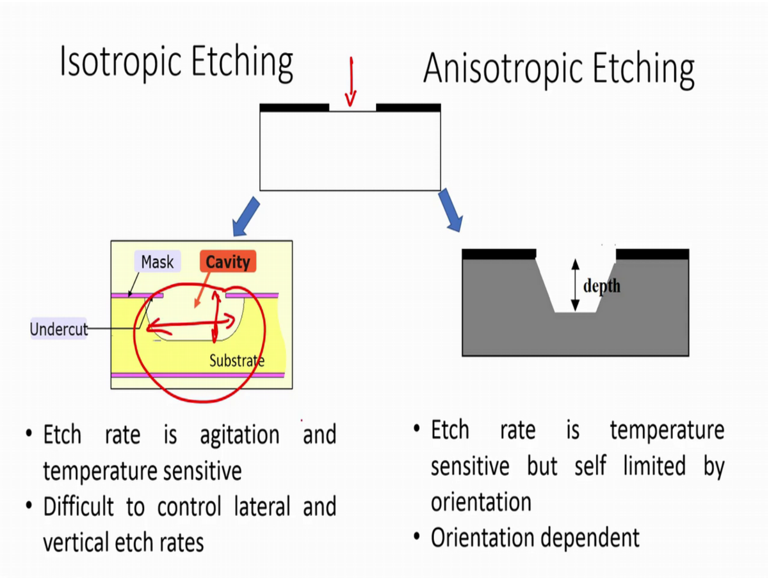

So, the one of the big problem in the isotropic in the etching world is the undercut problem right. So, you can see here isotropic etching, an anisotropic etching. So, if we if this is the window, we want to etch this window, then etch rate is agitation and temperature sensitive. So, here it will be temperature sensitive and depending on the chemical difficult to control lateral and vertical etch rates right. This and this very difficult to control, lateral and vertical etch rates very difficult to control. While in the case of an anisotropic etching, etch rate is temperature sensitive, but self limited by its orientation. And of course, it is orientation dependent; it is orientation dependent. Then this is about the isotropic and anisotropic etching ok.

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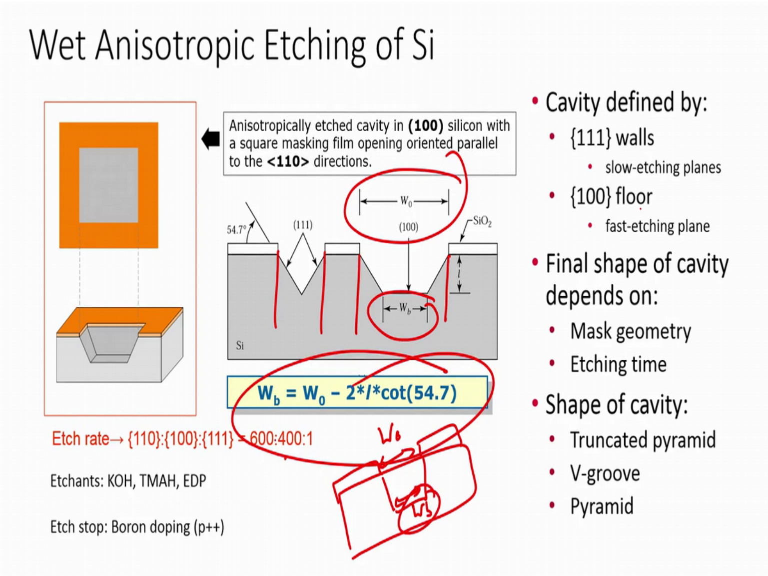

Now, when we are talking about isotropic and anisotropic etching, let us talk about wet anisotropic etching, wet anisotropic etching ok. So, you can see here that anisotropically etched cavity in 100 silicon with a square mask film opening oriented parallel to the 1 0 0 direction right. So, when we want to etch, we have to take this the etch rate is defined in this particular fashion where the 110 is to 100 is to 111. As you can see 111 will not get etched compared to 100 and 110 right.

So, the cavity defined walls 111 walls slow etching planes while 100 which is floor right, this one is slow etching plane by the floor which is 100 is a fast etching plane. The floor is faster the cavity walls would be slow because of the 111 crystal orientation. If you want to see this is a what is the final depth the that you are you are etching right that we want to see then you need to calculate what is the final depth that you want and depending on that you have to open the window which is W o.

So, if I say the opening of the window is W o, the final depth this one this width right, this one this will be my W b initial window that I would open is W o. How is related. So, W b equals to W o minus 2 into I into cot theta where cot theta is nothing but 54.7 degree. So, when you want to etch it right, the etching is done wet etching is done wet etching of silicon, it creates a angle of 54.7 degree.

Now, you can I said I, but you can say L or I you will say length is the length. Of course, the silicon dioxide will act as a mask. So, when you dip this wafer in KOH or TMAH the silicon below silicon dioxide will not get etched as you can see here or here right. And if it is a 111 a wall creating plane, and you can see that you know it is slow; but if it is 100 creating plane, it is faster.

So, the opening of the window, if I want a particular depth with a particular lateral etching, I need to know what is the initial opening of the window that I have to create. For example, if I have oxidized silicon wafer, if I create a window which is the my W o right, what will be my final etching W b, because this W b can be calculated using this formula right. What is at depth that I want to etch right, what is the initial window that I would have. And if I know the angle, then I can create which is angle is 54.7 degree, I can create my W W o accordingly, so that I can receive I can achieve my W b of a particular damage right.

Now, the final shape of the cavity also depends on geometry of the mask and etching time ok. So, etching time and geometry of the mask are the another two factors that decides the final shape of the cavity. Also the shape of the cavity can be V-grooved like a V-groove. It can be a pyramid right or it can be a truncated pyramid. So, these three are the patterns that you can obtained when you are etching a silicon wafer - V-groove, pyramid or a truncated pyramid.

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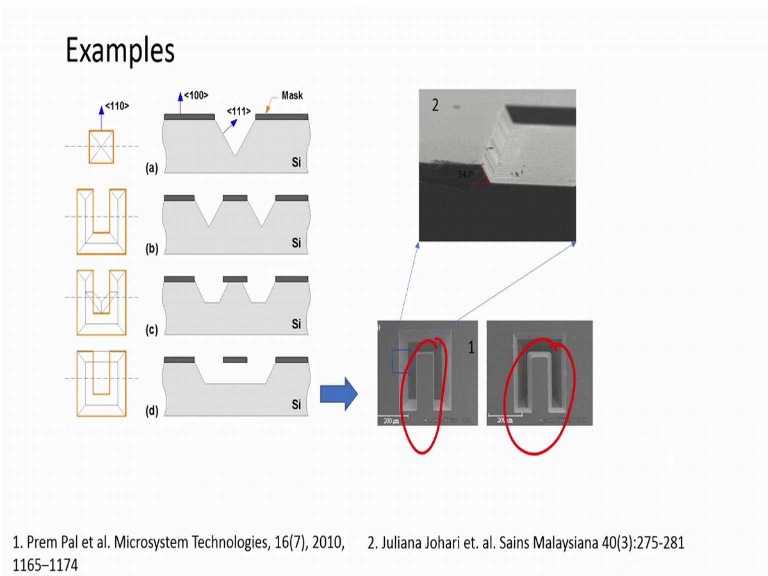

So, if you see the example here, you can see right V-groove, pyramid or truncated pyramid. And these are cantilevers which are released you can see here a completely released cantilever right. And of course, this is taken from Microsystem Technologies written by Prem Pal et. al. It is just a schematic diagram. Also there is another paper that we have used from Johari et. al to get the idea of how the cantilever looks like when it is released with the help of the etching technology right. So, like I said we can have V-groove, we can have truncated pyramid and we can have pyramid, three types of structure when we are using micromachining.

So, until now what we have seen, we have seen that the micromachining can be two types one is bulk micromachining, one is surface micromachining. And then we have seen how the bulk micromachining and surface micromachining can be used with a example of releasing a cantilever using surface micromachining. Now, we will see an examples that is will be I will I will show you the examples in the next module of how to create a volatile organic compounds based sensors using bulk micromachining and using bulk plus surface micromachining right. Till then you just go through this module. I will see you in the next module to discuss more about how to use micromachining technologies to create a device.

Yeah, till then take care, I will see you in next class bye.