Electronic System for Cancer Diagnosis
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Lecture – 37
Etching Process and Figure of Merits

Hi, welcome to this module and actually this module is a short module on a very important process in micro fabrication called Etching, right. So, we will see why it is important and what kind of etching methods are there.

Now, why we are learning this is a part of this course because when you want to develop a electronic system that too for certain diagnosis of a disease in some of the systems we are using a micro engineering technology. And when we talk about micro engineering technology along with few processes like thermal evaporation, E-beam evaporation, you have wet etching, you have dry etching, you have photolithography, you have E-beam lithography you also have the chemical vapor deposition techniques like CVD, LPCVD, P PECVD MOCVD right APCVD. So, a lot of techniques are involved and one of those techniques is wet etching and when you talk about wet etching we will see, why it is important and if I talk about dry etching why it is important.

So, this module is one of etching the etching the materials in the case of micro fabrication.

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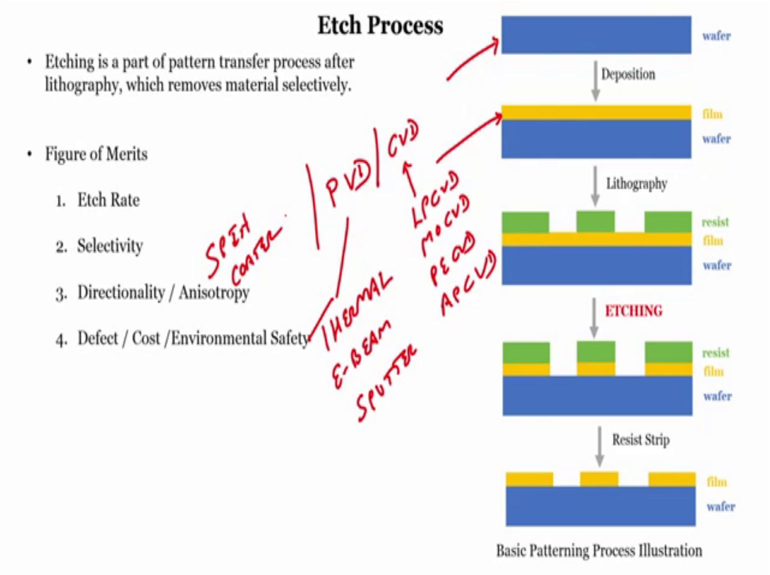

Etch Process

- Etching is a part of pattern transfer process after lithography, which removes material selectively.
- Figure of Merits
  1. Etch Rate
  2. Selectivity
  3. Directionality / Anisotropy
  4. Defect / Cost /Environmental Safety

Basic Patterning Process Illustration

So, if you see the slide we will be talking about etching process the first process is let us see, etching is a part of pattern transfer process after lithography right which removes material selectively. Here I have given you an example of a basic patterning process. So, if you see we start with the wafer, right we start with the wafer then we deposit a film. Now, how it can deposit the film? Now, you should be you should know what are the methods for depositing this particular film. There are two methods one is PVD second one is CVD, right.

And, in PVD we have thermally operation we have E-beam operation, we have sputtering right. In CVD we have LPCVD, we have MOCVD, we have PECVD, we have APCVD hm. Now, once the film is deposited by any of the technique right, you can also use spin coating you can also use spin coater for spin coating the film on the wafer. So, using any one technique if we deposit a film on the wafer and if I want to pattern the film; pattern the film what kind of patterning I want? I want to pattern the film so that finally, I only have this particular structure that is at certain point film is there in certain area the film is not there, right.

So, how can I etch the film in this area alright? So, for that we have to first deposit a film on a wafer, we will perform a photolithography how can you go from photography by first using photo resist right and then doing lithography after doing that you can see that if we do the lithography, what you see here is photo resist is not saving the area which we want to etch and the remaining area, there is a photo resist is not covering the area where we want to etch.

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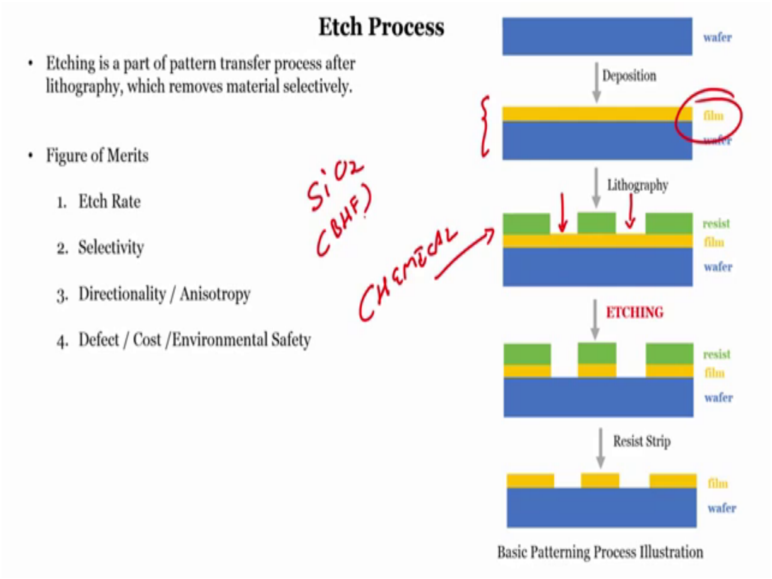

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Basic Patterning Process Illustration

So, now, if I dip this wafer if I dip this wafer in a chemical; what kind of chemical I can use based on the film that we need to etch, right. Suppose, if the film is silicon dioxide then what chemical I can use? I can use buffer hydrofluoric acid, right. So, different chemicals are therefore, different films. So, when we dip in when we performed lithography and dip the wafer to etch it you will see that the film will get etch from the area which is not protected by photo resist and the area which was protected by photo resist the film is still intact.

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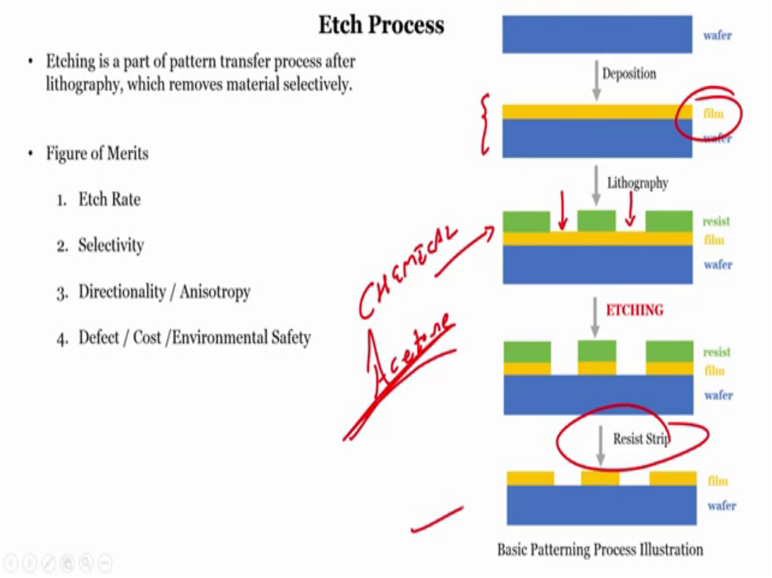

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Basic Patterning Process Illustration

After that we had to strip of the photo resist and stripping of the photo resist is done using acetone. We already remember right similar photo resist during acetone, right. Finally, when you strip off the photo resist right like here you can obtain your film, this is the wet etching technique or you can say a dry etching technique. So, I will tell you in detail what are wet etching and dry etching, but before that let us take an example.

So, you understand in detail the figure of merits for this one are etch rate, selectivity, directional, anisotropy, directionality anisotropy, defect, cost and environmental safety these are some of the figure of merits.

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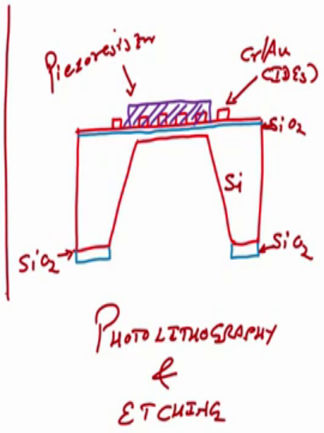

So, if I take an example let us take an example where we want to fabricate we want to fabricate pressure sensor we have a get pressure sensor right which will look like one that I am trying right now. So, alright and, then on this you want to have piezoresister. So, now, what exactly these things are? So, I would just may piezoresisters like this, right.

So, what are the areas? First area is silicon dioxide which is right over here these also silicon dioxide right, here is silicon dioxide, this is silicon, this is chrome gold or interdigitated electrodes made using chrome gold, this one is our piezoresister ok. This is what I want, this is what I want using photolithography, photo lithography and etching and etching. So, to obtain this particular device right what are the steps and how etching is important that is our today’s module ok.

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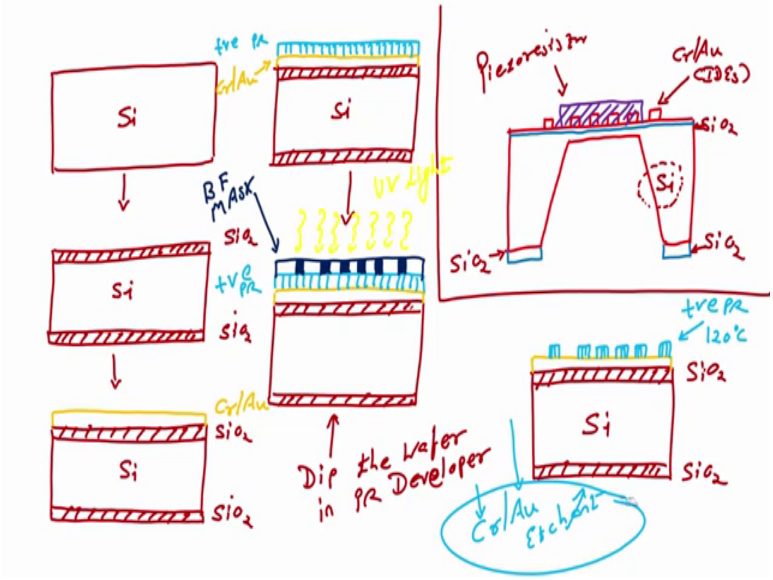

So, now what do you see, you see a silicon wafer right you see a silicon hm. So, we will start with a wafer and we say that we are starting with a wafer alright. This is my silicon wafer. The next step is I have to grow silicon dioxide or deposit silicon dioxide, right. So, if I deposit silicon dioxide using thermal oxidation SiO 2, SiO 2 right and this is my silicon.

Next step is I will deposit metal on this silicon dioxide, right. I will deposit a metal on the silicon dioxide so that I can obtain my chrome gold interdigitated electrode, right. So, I will deposit chrome gold this is my chrome gold right and then remaining things are silicon dioxide silicon dioxide, right.

Next step in the next step I have to spin coat photo resist I have to spin coat, photo resist. So, let us use blue color to show our photoresist, alright and let us use this pattern. So, what is this one this is my positive photo resist then what else I have silicon dioxide, here also I have silicon dioxide, right. This is silicon and then what do I have here? I have chrome gold, alright this one is chrome gold, right.

What is the next step? Next step is we had to use a mask we have to use a mask. So, I will draw quickly wafer oxide, right oxide, then we have chrome gold right chrome gold, then we have photo resist which is positive photo resist and we have spin coated this positive photo resist and cure it at 90 degree, this is spin coated photo resist and we have done soft bake at 90 degree for 1 minute.

On this we have a use a mask, right. So, let us use a mask and mask is such that I had to only protect the interdigitated I want to pattern interdigitated electrode. So, our masks would be my mask would look like this, it is a bright field mask; field is bright, pattern is dark, it is a bright field mask, right. So, this is my bright field mask, right. What is the next step? Next step is we will expose it. We will expose it with UV light UV light, right.

After exposing what we will do? What is the next step? Next step is to dip this wafer the wafer in photoresist stripper or photo resist stripping solution. So, or in another terms it is also called photo resist developer not stripper let us use this corrector it is not called stripper. Stripper is when photo resist will be stripped off we are using photo resist developer right. So, when you dip this wafer in a photo resist developer what you will have? You will have you will have oxidized silicon wafer, on that there is a chrome gold on that you have photo resist, but this time photo resist is developed 1 1 2 3 4 and 5 right this is my positive photo resist, alright.

Now, I will perform hard bake; hard bake is done at 120 degree centigrade for 1 minute on hot plate. When I go for hard bake what is the next step? Next step is I will dip this wafer I will dip this wafer in chrome gold etchant. First what your top layer? Top layer is cold bottom layer is chrome.

So, first I will dip oh well first I will etch the gold from the wafer and then I will rinse the wafer with DI water then I will place the wafer in a chrome etchant right and to etch chrome it will etch chrome and gold only in the area which is exposed to the chemicals. The area which is protected by the photo resist we will not be etched. This etching of chrome gold using a chemicals is called wet etching is called wet etching because we are dipping the wafer in a etchant in a chemical.

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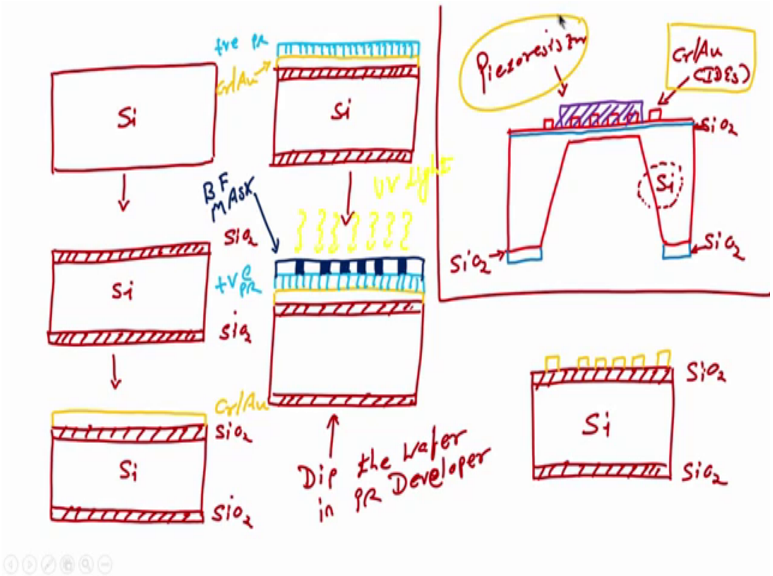

Now, if I do that what will I have if I etch the chrome and gold using wet etchant what will I have? I will have chrome gold. I will have chrome gold in this area, right. So, you see here the chrome gold we can fabricate or we can pattern using photolithography and wet etching, alright. What is the next step? Next step is we have to pattern piezoresister.

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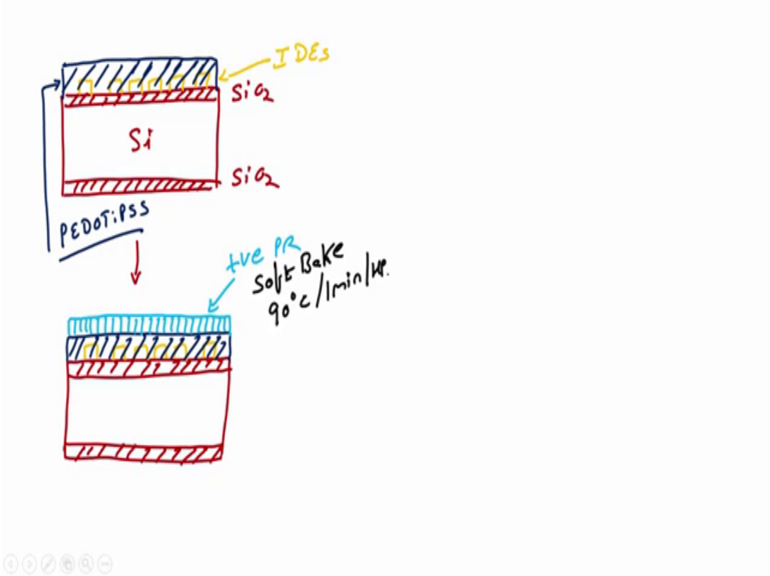

So, to pattern piezoresister let us see we will take again we will start from the chrome gold and then we will continue. So, we have oxidized silicon wafer, right and on oxidized silicon wafer we have chrome gold in the pattern way which is called interdigitated electrodes which is called interdigitated electrodes hm. So, let us see we have chrome gold like this, right. This is my interdigitated electrodes, alright. Let us you know this is silicon and then the 2 bottom and top part of the silicon is silicon dioxide.

Now, on this on this what I want? I want a piezoresistor. So, what I will do, I will spin coat I will spin coat PEDOT PSS. What is this material? This material that I am spin coating is PEDOT let me write it down because this top part of the screen we have little bit problem. So, I will just write it down again right this is my piezoresistor film for piezoresistive film and this is nothing, but PEDOT:PSS this is my conducting polymer which acts as a piezoresistive material.

The next step: next step here is I have oxidized silicon wafer because I have oxide in the bottom part oxide on the top part with interdigitated electrodes on top of it, right and then on that we have PEDOT PSS which will act as the piezoresistive material and we need to pattern this material, right. We have to pattern at this material. So, this is my piezoresister or piezoresistive material right, there is a chrome gold inside on this what we will do, we will deposit or we will spin coat rather we will spin coat positive photo resist. This is my positive photoresist right. Remaining you know interdigitated electrode PEDOT PSS silicon dioxide silicon dioxide and silicon.

After spin coating positive photo resist the next step is to use mask, right we have do we have to go for soft bake of course; soft bake positive photo resist you know 90 degree, 1 minute hot plate and then on this I will load a mask. So, I will just delete this one for now.

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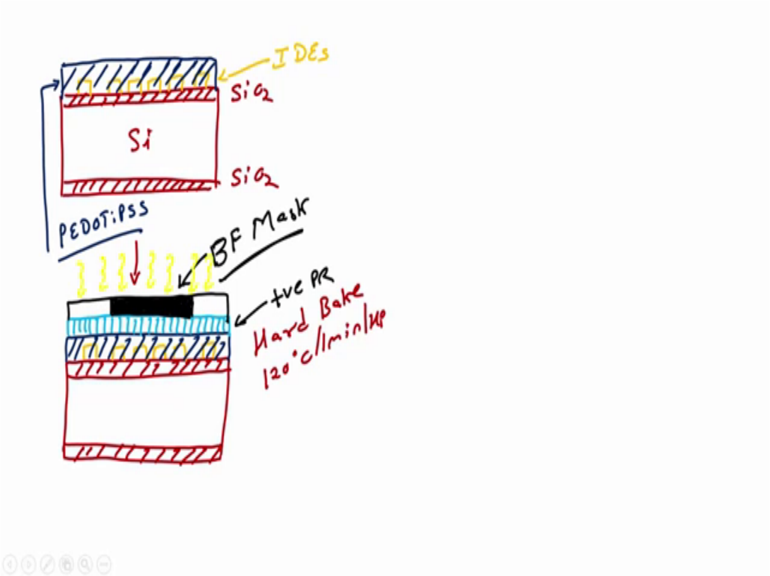

And, let us show a mask, right. So, how should the mask look like? If you go back you want piezoresister only in this area, right. So, we had to protect piezoresistive material only in this area. For that we have to have a mask which will protect my piezoresistive material in the area of my on the desired area that will help me to get the piezoresistive or piezoresistor right. It not a help me get piezoresistive you had been get or pattern piezoresister. This is my bright field bright field mask, ok.

Now, you understand this thing why I have used that film mask because I have here positive photo resist. Now, what is a characteristics of positive photo resist? That the area which is not exposed by UV light will get stronger. The area which is not exposed by UV light will get stronger. So, now you can see that the area that is in black shade will not get exposed in the area which is in white shade will get exposed, right.

So, after this the next step would be that I have to go for after this, I have to remove the mask and then do a hard bake. Hard bake it is direct hard bake, hard bake is hard bake hard bake hard bake is done it 120 degree centigrade 1 minute on hot plate easy, right.

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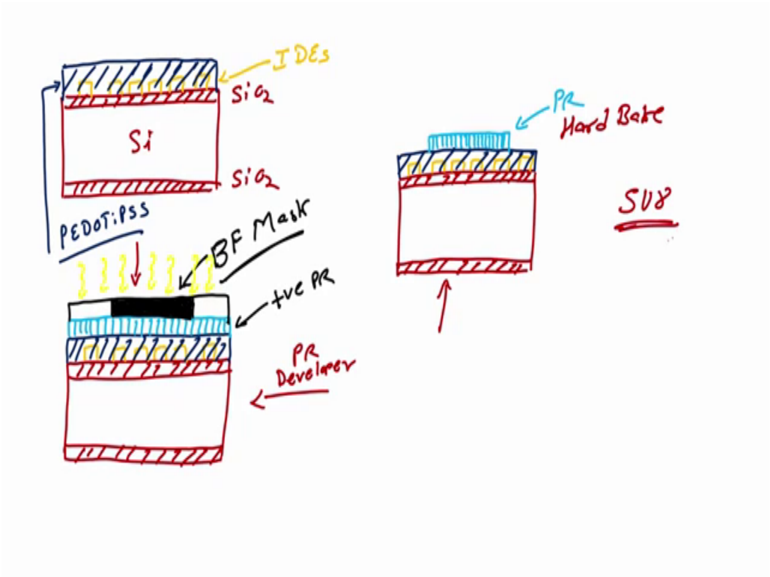

So, now, next step is after hard bake or next step is we have to dip this wafer we will dip this wafer in photo resist developer photo resist developer. When I do that what will I have I will I will get let me draw it little bit here, like this. My silicon dioxide layer is intact on that my chrome gold layer is also intact or chrome gold pattern, introduce the electrodes, right on that my piezoresistive material is still intact piezoresistive material is still intact , but my photo resist layer will be patterned now. So, I will have a photo resist only in this area right. So, this is my photo resist.

What is the next step? Next step is next step is that I will I will dip this wafer I will dip this wafer in we missed the stair actually the we have used hard bake before photo resist developing, that is not a correct statement. So, let us understand what I mean. After positive photo resist you have to do soft bake then you have to expose the wafer with UV light; of course, I am loading the mask. Once that is done you have to develop the wafer and after developing the wafer you have to go for hard bake, ok. You do not have to do hard baking before you develop the wafer, so, that you can do only when you are using SU8 material SU8 material.

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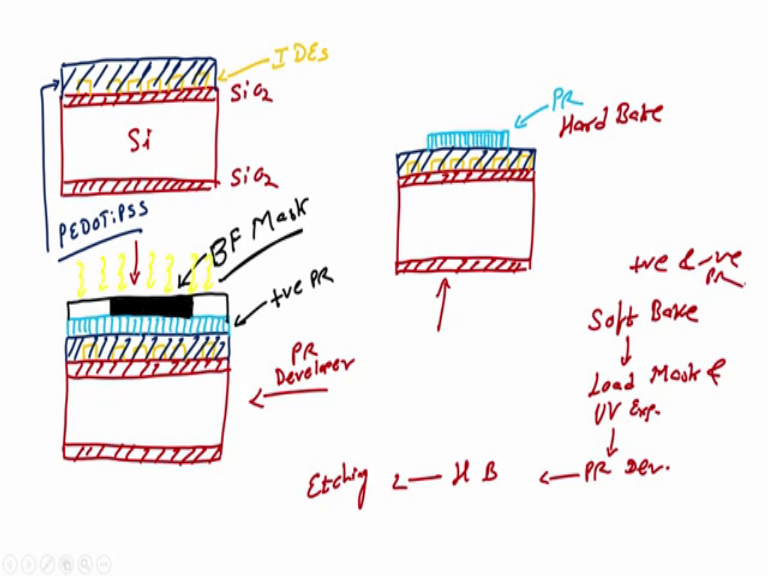

In case of positive and negative photo resist you had to go for soft bake soft bake after you spin coat it, after soft bake the next step is load loading of mask and UV exposure. Next step is photo resist developer, next step is hard bake, next step is etching alright; this is in case of positive and negative photo resist right. So, what we have to do after the UV exposure step we have to load the mask we after photo resist exposure step we have to develop the wafer or develop the photo resist and then after photo resist develop it will look like this particular pattern followed by which we had to do hard bake at 120 degree centigrade for 1 minute on hot plate.

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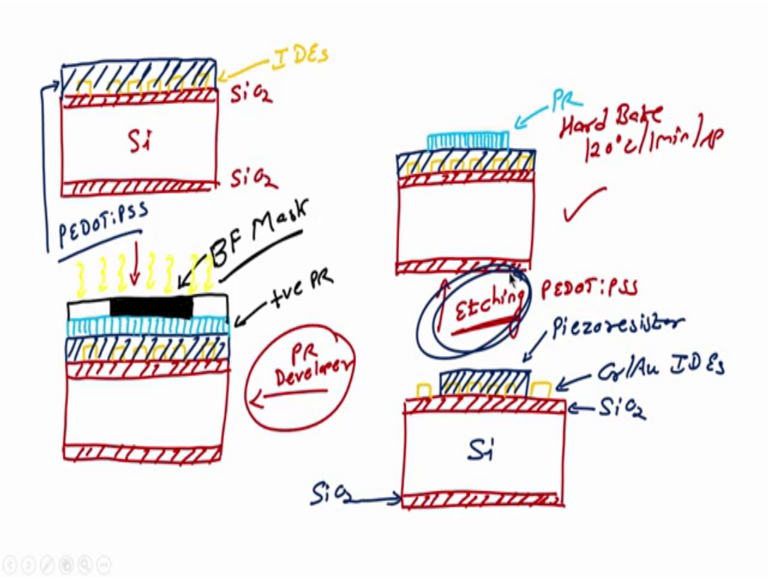

Followed by followed by etching PDOT PSS followed by etching PDOT:PSS again you see etching is very important. When you etch PDOT PSS what will happen what will happen? You will have a wafer oxide because the etching chemical or material will not affect oxide or it will not affect the chrome gold interdigitated electrodes.

So, that is why we do not worry in this case and we do not have to go for the liftoff technique I have explained you liftoff this is my piezoresister patterned this is chrome gold, interdigitated electrodes, silicon dioxide, silicon dioxide, right. So, again we have used etching hm. So, where are we now? We have done IDE and we have patterned the photo the piezoresistive material.

Next step is we have to do this bulk etching of silicon bulk etching. Let me go for the one more slide where I can show you the next step where we are to create a diaphragm, right.

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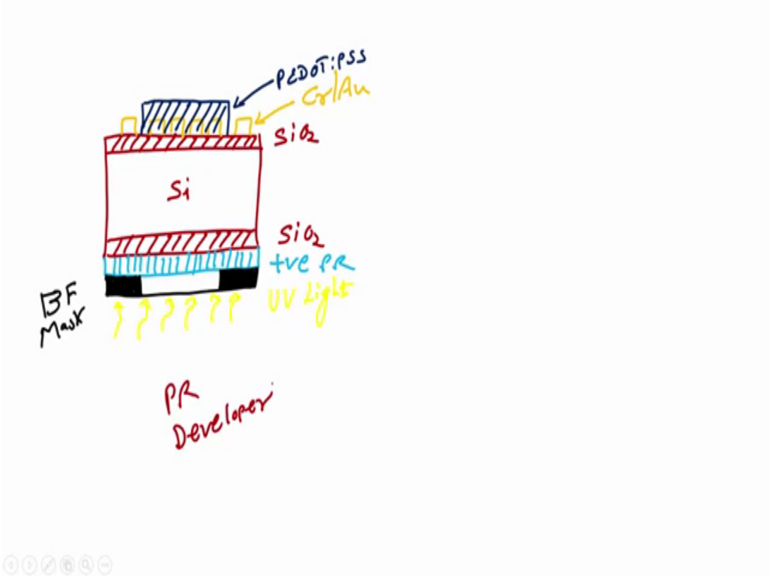

So, what we have? We have oxidized silicon wafer alright all oxidized silicon wafer, we have chrome gold; on chrome gold we have PEDOT:PSS right this much we have now we have to etch the silicon wafer from backside from the backside. So, what we will do, for that we will spin coat photo resist we will spin coat positive photo resist right, then we will do a perform soft bake process a step after soft bake, we load a mask load a mask such that my photo resist will protect the area of my interest and the remaining area will be etched after I expose this wafer with UV light and develop it in the photo resist developer right. This is my be this is my bright field mask, right.

After this what is the next step? Next step is we have to expose the wafer expose the wafer in UV light, right. After exposing the wafer next step is where to unload the mask and perform and we where we are to dip this wafer in photo resist developer dip this wafer in photo resist developer.

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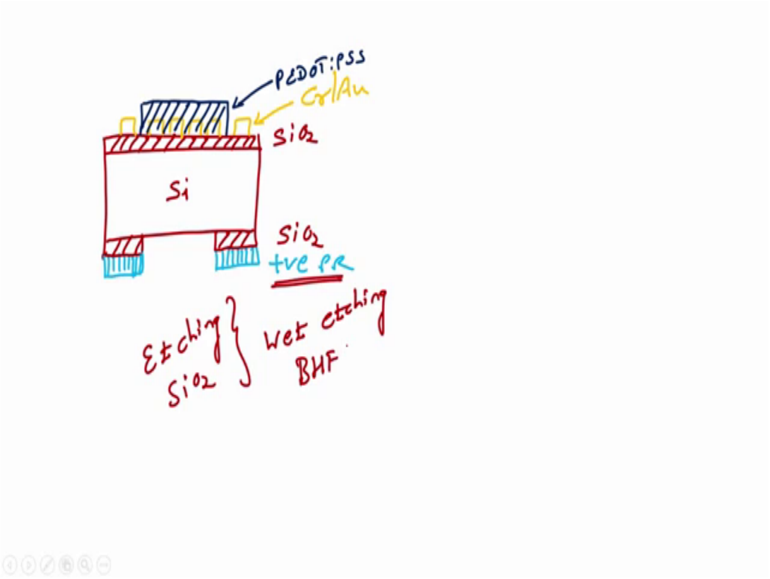

If I dip the wafer in a photo resist developer what will happen what will happen? I will have photo resist in this two area and this area is exposed now for further process. So, now, what can I do? I had to go for hard bake right photo resist developer then hard bake. After that I will deposit this wafer in I will not deposit I will etch silicon dioxide by dipping the wafer in buffer hydrofluoric acid, alright.

So, when I dip the wafer in buffer hydrofluoric acid what will happen? What will happen? I will have I will have silicon dioxide only here I have silicon dioxide only in this particular region, right. Why? Because other area was protected by positive photo resist. So, now, when I am etching silicon again we have to use process called etching of silicon dioxide that we have used which kind of etching we have used wet etching and the chemicals that we used is buffer hydrofluoric acid, ok. After this we had to strip off the positive photo resist. So, if I strip off the photo positive photo resist I will have this pattern.

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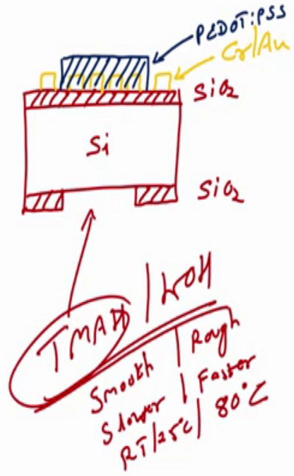

Now, I will depose I will dip this wafer in either TMAH or KOH. These are both chemicals and that is why it is a wet etching. KOH and TMAH has some kind of pros and cons if you want to know these are the pros and cons. TMAH gives us is a smooth wall smooth wall when we etch KOH gives us a rough wall when we etched TMAH is lower, KOH is faster, faster etching slower etching. Then TMAH can be done at room temperature or 25 degree centigrade KOH is done at or carried out at 80 degree centigrade, alright.

So, these are advantage disadvantage TMAH is also neurotoxic. TMAH is neurotoxic or this is as for the research literature survey, but both things are used TMAH and KOH for wet etching.

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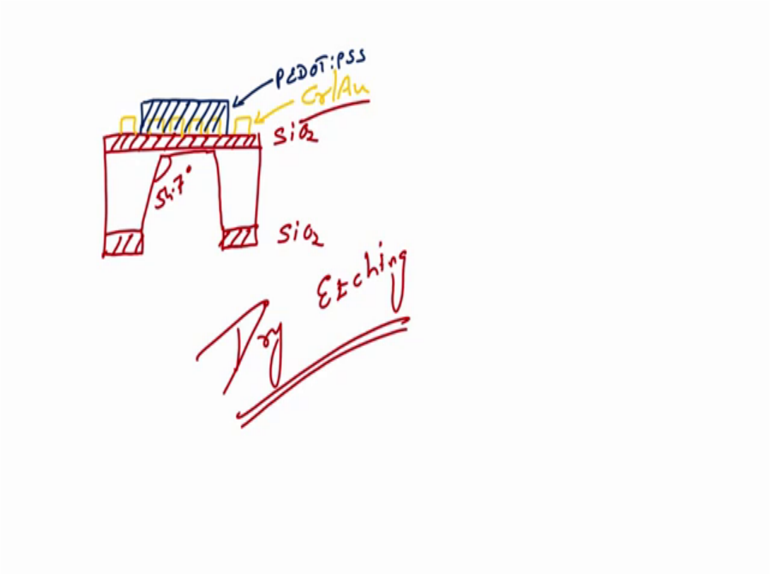

When we dip this wafer in TMAH and KOH what we will get? We will get a diaphragm like this and this angle is 54.7 degree, right. So, what we got? We got this pattern understood. So, this is the beauty of wet etching we are using wet etching to etch the silicon wafer on which there is the piezoresister and inter digital electrodes and etching from the backside by removing silicon dioxide and dipping the wafer invert etchant, which are KOH and TMAH. Alternatively, we can also go for dry etching. We can also use dry etching. We will talk about that in a few slides. Let us continue this particular module and here.

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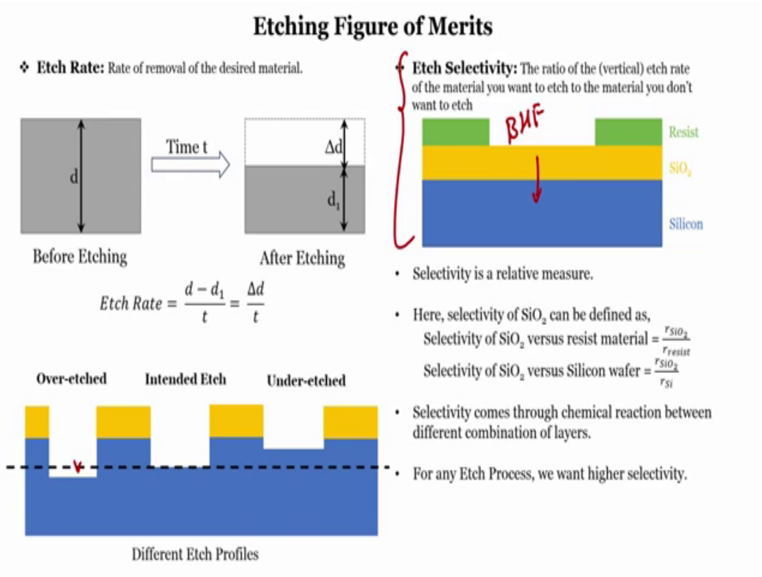

Etching Figure of Merits

❖ **Etch Rate:** Rate of removal of the desired material.

$$Etch\ Rate = \frac{d - d_1}{t} = \frac{\Delta d}{t}$$

❖ **Etch Selectivity:** The ratio of the (vertical) etch rate of the material you want to etch to the material you don't want to etch

- Selectivity is a relative measure.
- Here, selectivity of SiO_2 can be defined as,
  Selectivity of SiO_2 versus resist material = $\frac{r_{SiO_2}}{r_{resist}}$
  Selectivity of SiO_2 versus Silicon wafer = $\frac{r_{SiO_2}}{r_{Si}}$
- Selectivity comes through chemical reaction between different combination of layers.
- For any Etch Process, we want higher selectivity.

If you see the how there are several things that we had to understand the first is etch rate. Rate of removal of the desired material; how fast we can etch, ok. So, if I will etching silicon dioxide what is a etch rate, chrome gold what is the etch rate that is what I mean by etching rate or rate of removal of the desired material. For example, you have d as a thickness and then you can see that after time t delta d will be etched from the wafer so, before etching, after the etching. Etch rate can be given by d minus delta d 1 d minus this is total thickness minus the leftover thickness right divided by the time taken which can we can write as delta d. So, delta d d minus d 1 can be delta d and delta d by t is your etch rate, ok.

Now, second is very important thing which is the etch rate profiles or etching profiles. First is if we keep the wafer in the etchant for more time than it is required, then you have over etching. If you keep the wafer less for less time than the etch rate then the time required to etch some material you will have under etching and if the time is perfect then we will have intended etch, right; over etch, under etch, intended etch, alright.

So, let me move to the next merit. Next merit it is etch selectivity very important hm. Suppose, I have a resist and there is silicon dioxide and silicon, right. The etchant for silicon dioxide should not affect my silicon. If my etchant of silicon dioxide that is my buffer hydrofluoric acid will etch the silicon, then I will not be able to use this particular etchant and that is why selectivity is very important.

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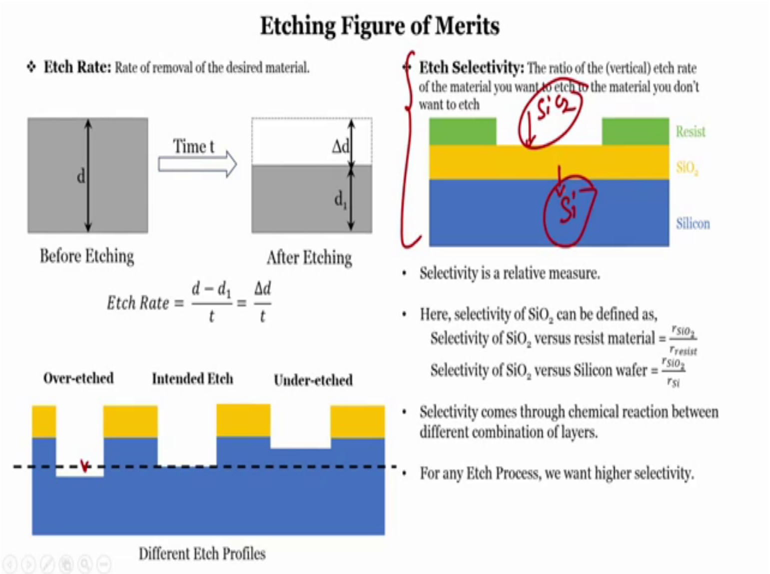

Etching Figure of Merits

- **Etch Rate:** Rate of removal of the desired material.

Before Etching

After Etching

$$Etch\ Rate = \frac{d - d_1}{t} = \frac{\Delta d}{t}$$

Different Etch Profiles

- **Etch Selectivity:** The ratio of the (vertical) etch rate of the material you want to etch to the material you don't want to etch

- Selectivity is a relative measure.
- Here, selectivity of SiO_2 can be defined as,
  Selectivity of SiO_2 versus resist material = $\frac{r_{SiO_2}}{r_{resist}}$
  Selectivity of SiO_2 versus Silicon wafer = $\frac{r_{SiO_2}}{r_{Si}}$
- Selectivity comes through chemical reaction between different combination of layers.
- For any Etch Process, we want higher selectivity.

So, etch selectivity is defined as the ratio of the vertical etch rate which is here right of the material you want to etch to the material you do not want to etch. So, this is the material we do not want to etch, right; silicon, you want to etch the silicon dioxide right. So, ratio of the vertical etch rate; this is a vertical etch rate of the material you want where there is silicon dioxide to etch to the material you do not want to etch which is silicon you do not want to etch. So, it should be extremely high, right.

So, selectivity is a relative measure and selectivity can be defined as selectivity of. So, in this case if you talk about silicon dioxide what is a resist material you can also understand that another way of doing it that what is the etching rate of the resist material because you see there not only the silicon that we need to protect, but also the photo resist should not get etched, right. If the photo resist get etched then the silicon dioxide from the area below the photo resist also starts etching.

So, selectivity here we are going to use two selectivity first one is selectivity of SiO 2 versus resist material and second will be selectivity of SiO 2 versus silicon wafer. So, first one is given the ratio of r SiO 2 by r resist and second one is r SiO 2 by r silicon. Selective selectivity comes through chemical reaction between different combination of layers for etch process we want to have higher selectivity right, as high as possible, ok.

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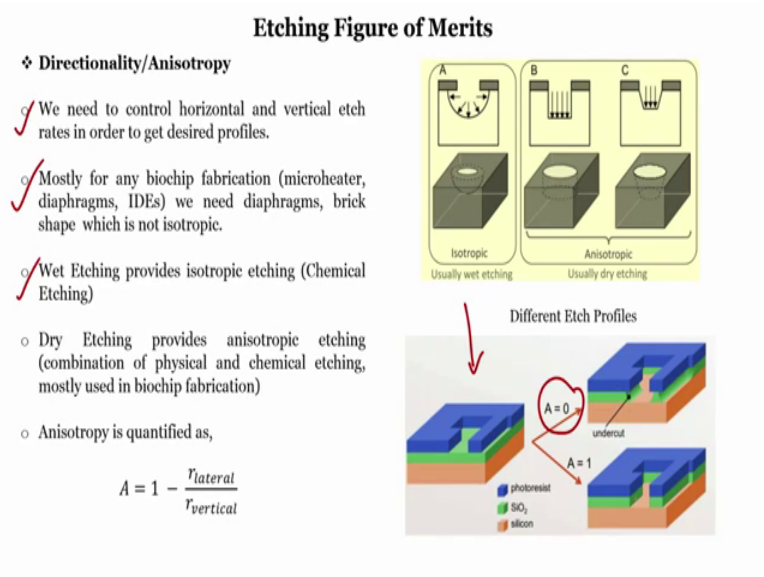

Etching Figure of Merits

- **Directionality/Anisotropy**
  - We need to control horizontal and vertical etch rates in order to get desired profiles.
  - Mostly for any biochip fabrication (microheater, diaphragms, IDEs) we need diaphragms, brick shape which is not isotropic.
  - Wet Etching provides isotropic etching (Chemical Etching)
  - Dry Etching provides anisotropic etching (combination of physical and chemical etching, mostly used in biochip fabrication)
  - Anisotropy is quantified as,

$$A = 1 - \frac{r_{lateral}}{r_{vertical}}$$

Let us go to next one etching figure of merits. First one directionality versus anisotropy we need to control horizontal and vertical etch rates in order to get desired profile right, first thing very important. So, second one is mostly for any biochip fabrication like micro heater diaphragms in the digital electrodes we need diaphragm brick shape which is not isotropic, right.

Wet etching provides isotropic etching. So, we can get this kind of etching which is isotropic etching, alright where sorry, it will have this kind of a etching where the undercut is there and then it will start etching from the material which is below the mask material, mask layer below the mask layer. This material is also getting etched; this is what we do not want in lot of applications in the micro engineering domain.

Dry etching provides anisotropic etching combination of physical and chemical etching mostly used in biochip fabrication. For example, this one is a dry etching technique and it is better because it provides us anisotropic etching. Anisotropic is defined as 1 minus r lateral to r vertical. How much the later etching work ratio of retro etching to vertical etching?

Now, if you take this particular example then you can very easily see that the photo resist is on blue color green color is silicon dioxide and the orange color is of silicon here if the anisotropic is 0, then we will have the undercut which you can see here in a 3D representation, but if the anisotropy is 1 then we have a perfect etching of the you know desired area. So, this is the importance of the etching figures of merits.

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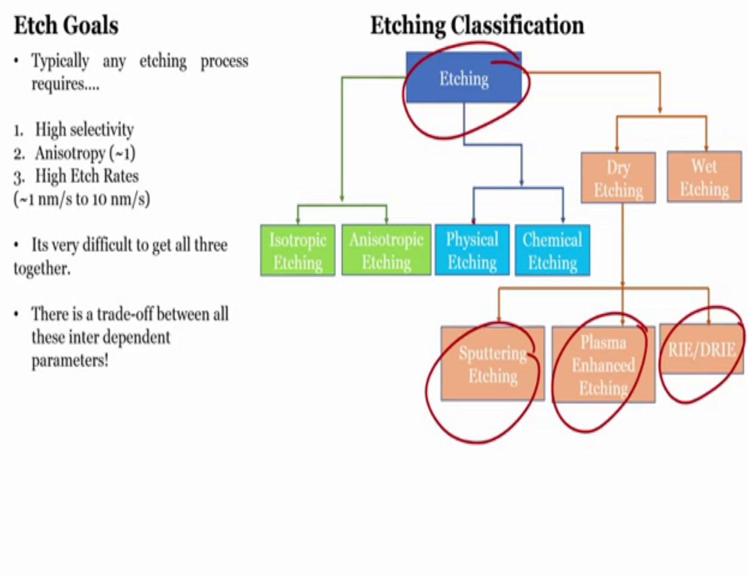

Etch Goals

- Typically any etching process requires....

1. High selectivity
2. Anisotropy (~1)
3. High Etch Rates (~1 nm/s to 10 nm/s)

- Its very difficult to get all three together.
- There is a trade-off between all these inter dependent parameters!

Etching Classification

Further, if I want to have etch goals then typically any etching process requires this few points the first is it should be highly selective; second point is anisotropy that is approximately one of; third one is high etch rates and it is difficult to get all three together because it can be like a ideal situation and there is a tradeoff between all these interdependent parameters. So, when you use the etching classification in particular then the etching classification is like this, you have a etching then in that etching you have isotropic etching and anisotropy etching.

Further, you have physical etching you have chemical etching right and then you also can divide it in this particular format where you have dry etching and wet etching, ok. Wet etching is the chemicals that will see; dry etching is where you can use sputter etching, you can use plasma enhanced etching and you can use reactive ion etching or deep reactive ion etching, alright.

So, we have a etching classification. So, like from the isotropic point of view we have isotropic, anisotropic; from the physical and chemical point of view we have physical etching versus chemical etching; from the dry etching versus wet etching point of view, we have wet etching where we have used certain chemicals to etch the material while the dry etching we have further at the implication as sputter etch or it is a plasma enhanced etch or it is a RIE or DRIE, like I said RIE sensed for reactive etching, DRIE sends for deep reactive ion etching, alright.

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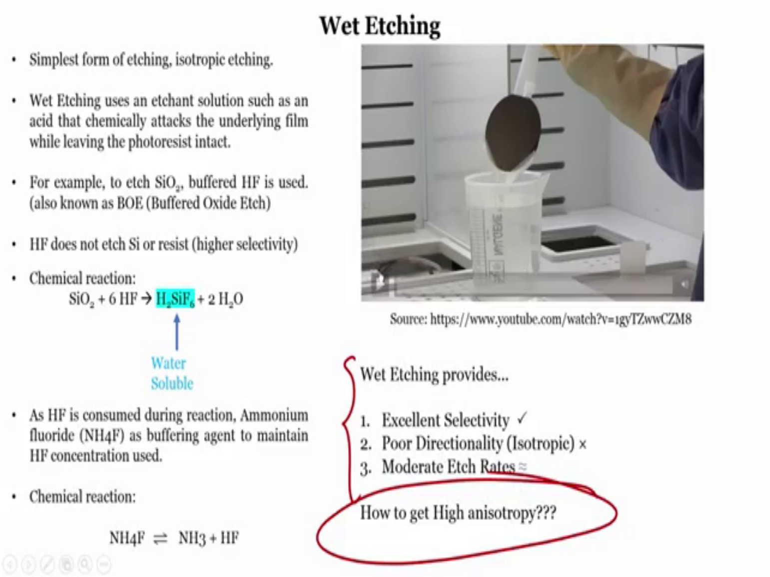

Wet Etching

- Simplest form of etching, isotropic etching.
- Wet Etching uses an etchant solution such as an acid that chemically attacks the underlying film while leaving the photoresist intact.
- For example, to etch SiO_2, buffered HF is used. (also known as BOE (Buffered Oxide Etch)
- HF does not etch Si or resist (higher selectivity)
- Chemical reaction:

$$SiO_2 + 6\,HF \rightarrow \underset{\uparrow\ \text{Water Soluble}}{H_2SiF_6} + 2\,H_2O$$

- As HF is consumed during reaction, Ammonium fluoride (NH4F) as buffering agent to maintain HF concentration used.
- Chemical reaction:

$$NH4F \rightleftharpoons NH3 + HF$$

Source: https://www.youtube.com/watch?v=1gyTZwwCZM8

Wet Etching provides...

1. Excellent Selectivity ✓
2. Poor Directionality (Isotropic) ×
3. Moderate Etch Rates ≈

How to get High anisotropy???

So, if you see the wet etching in this particular slide what you see is it is a simplest form of etching and we get isotropic etching. Wet etching uses an etchant solution such as acid that chemically attacks the underlying film while leaving the photo resist intact. We have seen in the earlier slide right where I was teaching you or showing you how we can fabricate a piezoresistive material or piezoresistive sensor. There we have used the wet etching to etch the piezoresistive material to etch silicon dioxide and to as the chrome cold.

Now, here for example, to a silicon dioxide about for HF is used also known as BOE Buffered or Oxide Etch. HF does not etch silicon or resist that is why it is higher selectivity. So, that is the importance of HF or b HF in case of a etching the silicon dioxide because it is highly selective, it will not etch the silicon.

Further when you see the chemical reaction this is how the chemical reaction occurs when you dip the wafer oxidized silicon wafer in HF then SiO 2 plus 6 HF gives us H 2 SiF 6 plus 2 H 2 O and this guy is water soluble and that is how you get the silicon dioxide out from the etchant now using the etchant. Now, etch as the HF is consumed during reaction ammonium fluoride as buffer etchant to maintain HF concentration is used and the chemical reaction is NH 4 F uses NH 3 plus HF. You can see this particular video.

Let us first see this thing first is wet etching provides excellent selectivity, poor directionality that is isotropic and moderate etch rates. So, the question now lies in front of us is how we can get a higher anisotropy? Because the there is a limitation of wet etching and that is as it is isotropic. So, if I want to go for higher and as isotropic etching, what can be the next step? Let us first see the isotropic etching in this video and then I will go to the next slide, ok.

(Refer Slide Time: 41:33)

Wet Etching

Source: https://www.youtube.com/watch?v=1gyTZwwCZM8

(Refer Slide Time: 41:43)

Wet Etching

Source: https://www.youtube.com/watch?v=1gyTZwwCZM8

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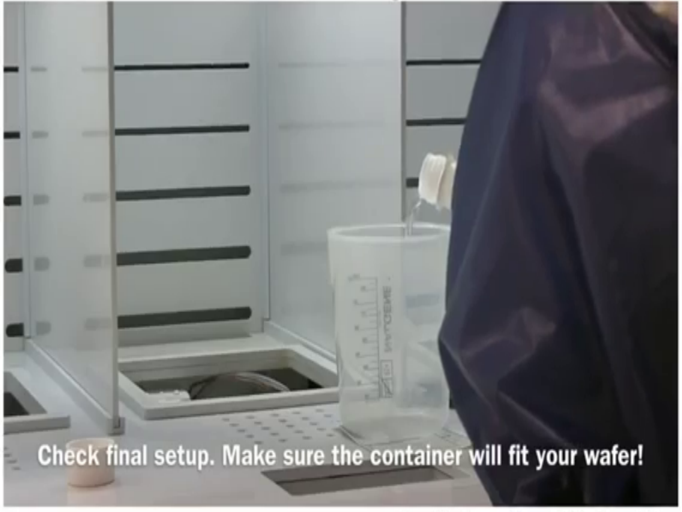
Wet Etching



Check final setup. Make sure the container will fit your wafer!

Source: https://www.youtube.com/watch?v=1gyTZwwCZM8

(Refer Slide Time: 41:55)

Wet Etching

Make sure to use a chemically compatible container!

Source: https://www.youtube.com/watch?v=1gyTZwwCZM8

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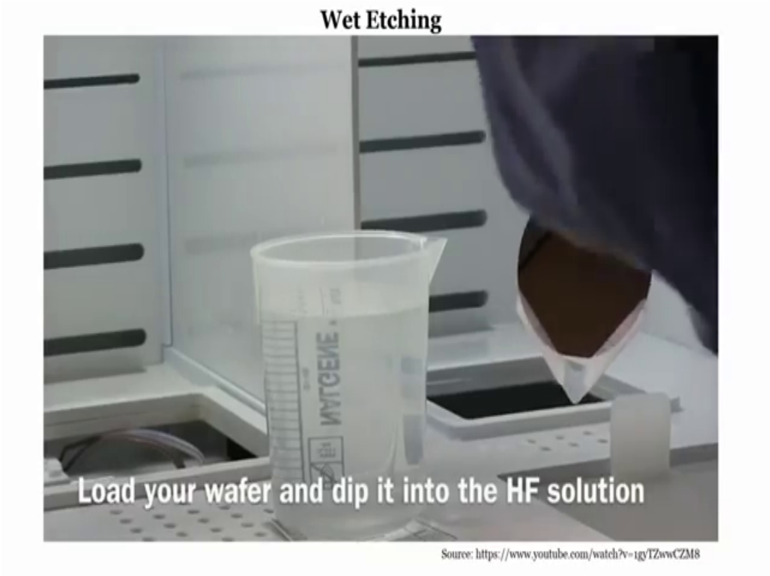

Wet Etching

Load your wafer and dip it into the HF solution

Source: https://www.youtube.com/watch?v=1gyTZwwCZM8

(Refer Slide Time: 42:07)

Wet Etching

The liquid adheres to the surface of the wafer (due to the oxide layer)

Source: https://www.youtube.com/watch?v=1gyTZwwCZM8

(Refer Slide Time: 42:13)

Wet Etching

Let your sample etch for the amount of time needed

Source: https://www.youtube.com/watch?v=1gyTZwwCZM8

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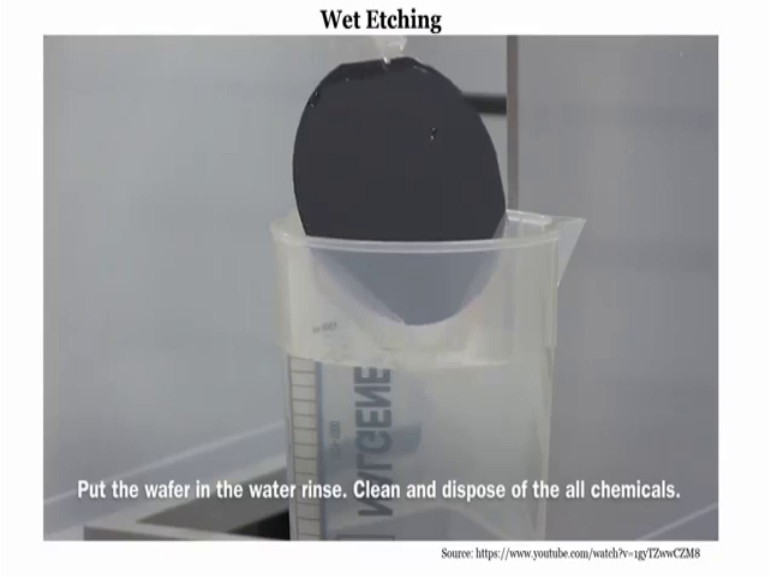

Wet Etching

Put the wafer in the water rinse. Clean and dispose of the all chemicals.

Source: https://www.youtube.com/watch?v=1gyTZwwCZM8

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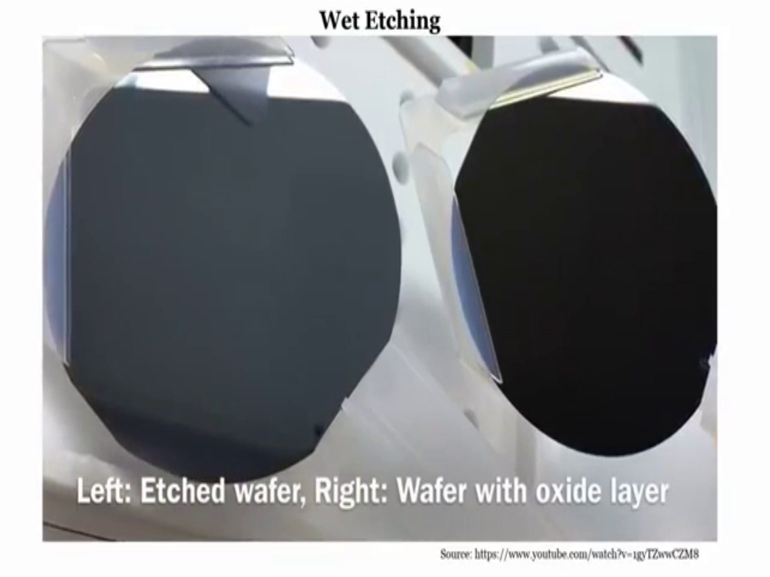

Wet Etching

Left: Etched wafer, Right: Wafer with oxide layer

Source: https://www.youtube.com/watch?v=1gyTZwwCZM8

Now, since you have seen the wet etching right, let us see the dry etching variance and I like to go into deep in this particular lectures because this is how we are using it to fabricate a device. This is not a detail about how exactly the etching occurs. This you should know that ok, there are two different types of etching and you should have the idea that what is used for or how it is used. So, without getting into deep chemistry let us see how the dry etching works.

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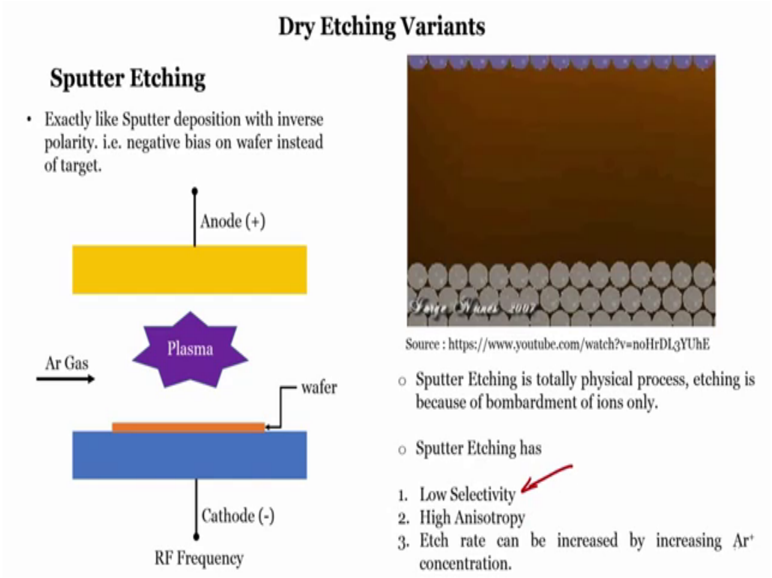

Dry Etching Variants

Sputter Etching

- Exactly like Sputter deposition with inverse polarity. i.e. negative bias on wafer instead of target.

Source : https://www.youtube.com/watch?v=noHrDL3YUhE

- Sputter Etching is totally physical process, etching is because of bombardment of ions only.
- Sputter Etching has

1. Low Selectivity
2. High Anisotropy
3. Etch rate can be increased by increasing Ar^+ concentration.

So, if you see these slide what you find is then when we talk about sputter etch exactly like sputter deposition with inverse polarity we can get the sputter etch. So, negative bias in the wafer instead of target. When you want to deposit the material you have to have negative polarity in a bias on the target and positive on the wafer, but we want to etch it you can reverse the polarity or inverse the polarity.

Sputter etching is totally physical process. Etching is because of bombardment of ions sputter etching has low selectivity that is a disadvantage because the mechanical way of etching it will etch the material below it highly anisotropic etching rate can be increased by increasing the argon ion concentration, right and now let us see this video of sputter etch, ok.

(Refer Slide Time: 44:13)

Dry Etching Variants

Source : https://www.youtube.com/watch?v=noHrDL3YUhE

So, let us further see the dry etching variance and the second variant is the plasma etch. So, if you see the slide the plasma etching where the enhanced version of the discuss sputter etching for better selectivity and higher etching rate modifications are like add reactive ions into the plasma. So, if you add reactive ions like argon plus CF 4, then you can etch the desired material higher etch rate can be achieved by increasing pressure.

But, increasing pressure will result in less mean free path you know what is mean free path is a collision between two atoms in the in the case of vacuum. Higher the vacuum larger the mean free path and less the collision better the film, ok. So, me less me less mean free path which is affect the directionality. So, your mean free path should be extremely high.

Hence, there is a tradeoff between higher etch rate and anisotropy, ok. So, that is the trade off that you need to understand that either you want higher etch rate or you want isotropic or anisotropic etching. Plasma etching is combination of physical and chemical etching by adjusting the pressure and DC bias we can completely remove the physical physical etching component. However, that is etching can be considered as chemical etching or wet etching.

Plasma etching like chemical wet etch has excellent selectivity, poor directionality and moderate etch rates. This is the second type of etching the first type of etching we have seen is the sputter etching, then we are talking about plasma, etching let us see one more kind of etching and that is called the so RIE or DRIE.

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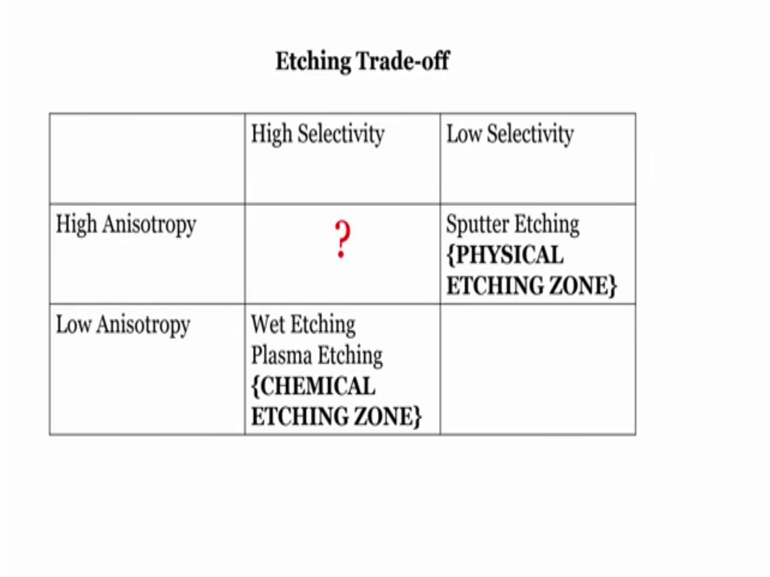

Etching Trade-off

	High Selectivity	Low Selectivity
High Anisotropy	?	Sputter Etching **{PHYSICAL ETCHING ZONE}**
Low Anisotropy	Wet Etching Plasma Etching **{CHEMICAL ETCHING ZONE}**	

But, before we go that yeah you see here that it is etching trade off is if there are material is highly selective then you have to which one you to see a go for and if the material is a low selectivity which one you have to go for. So, high anisotropy then you can have low selectivity, but if you have low anisotropy you can have a higher selectivity and that is why we said it is a trade off.

So, wet etching, plasma etching, chemical etching zone you can have low anisotropy and high selectivity, but if you want to have a high anisotropy then sputter etching and physical etching zone is a better way to go for now in a dry etching variance.

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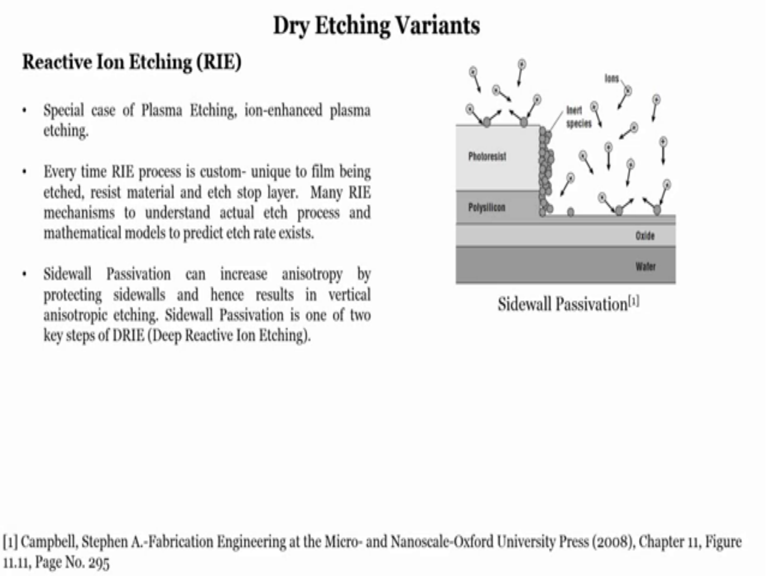

Dry Etching Variants

Reactive Ion Etching (RIE)

- Special case of Plasma Etching, ion-enhanced plasma etching.
- Every time RIE process is custom- unique to film being etched, resist material and etch stop layer. Many RIE mechanisms to understand actual etch process and mathematical models to predict etch rate exists.
- Sidewall Passivation can increase anisotropy by protecting sidewalls and hence results in vertical anisotropic etching. Sidewall Passivation is one of two key steps of DRIE (Deep Reactive Ion Etching).

Sidewall Passivation[1]

[1] Campbell, Stephen A.-Fabrication Engineering at the Micro- and Nanoscale-Oxford University Press (2008), Chapter 11, Figure 11.11, Page No. 295

Let us see the third one which is our reactive ion etching. In reactive ion etching special case of plasma etching ion enhanced plasma etching. It is a so, so if it is a special casing in of plasma etching and ion enhanced plasma etching where every time RIE process is custom my is the is unique to film being etched resist material and etch stop layer. So, either you want to etch the resist material or the film or the silicon this RIE has a customized process. Many RIE we can able to understand actual etch process and mathematical models to predict etches exist. Sidewall pacification passivation increases anisotropy by protecting sidewall.

So, what happens is once you send the etch etching gas then it will etch it. And, then you use another chemical to smooth the sidewalls, ok. So, first you etch and then this smoother smooth the sidewalls this process keeps on repeating. So, sidewall pacification can increase anisotropy by protecting sidewalls and hence results in vertical isotropic anisotropic etching. So, in this case you will have a perfectly fine vertical anisotropy etching and side wall pacification is one of the two key steps of deep react to etching. Like I said first it will etch, then it will protect, then it will etch again, it will smoothen. So, this keeps on you know going on.

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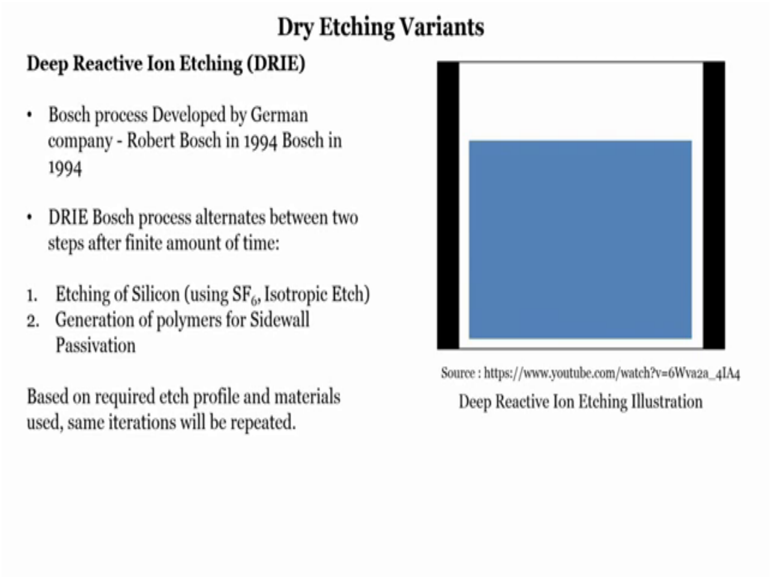

Dry Etching Variants

Deep Reactive Ion Etching (DRIE)

- Bosch process Developed by German company - Robert Bosch in 1994 Bosch in 1994
- DRIE Bosch process alternates between two steps after finite amount of time:

1. Etching of Silicon (using SF_6, Isotropic Etch)
2. Generation of polymers for Sidewall Passivation

Based on required etch profile and materials used, same iterations will be repeated.

Source : https://www.youtube.com/watch?v=6Wva2a_4IA4

Deep Reactive Ion Etching Illustration

And, the deep reactive in etching the Bosch process developed by German company Robert Bosch in 1994, Bosch is. So, this is also called the Bosch kind of etching and deep reactive and etching illustration is shown in this particular video. The main idea of DRIE process is that the etching of silicon can be used can be done using silica S SF 6 and isotropic etch and generation of polymers for side one passivation can also be done using the DRIE.

Based on the required etch profile and material used some iterations can be provided. So, if you see the DRIE in this particular video also in the next video you will understand how it is done.

Let me play the video for you, ok.

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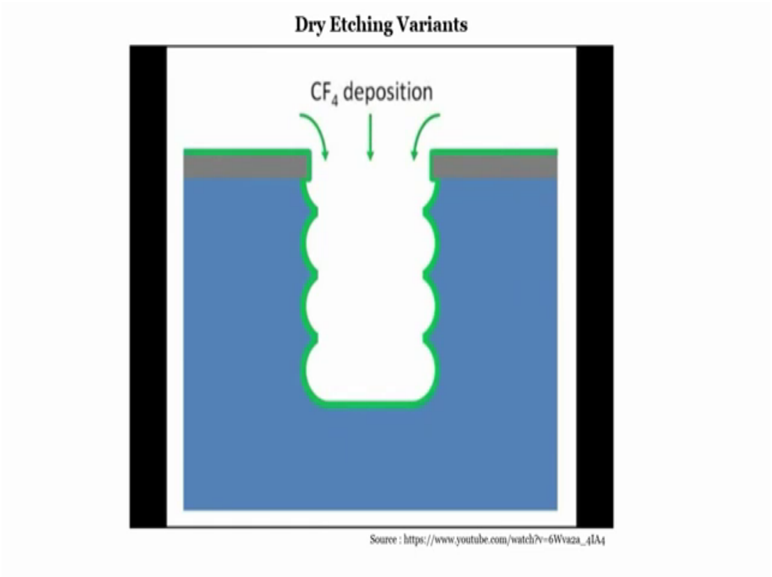

Dry Etching Variants

Source : https://www.youtube.com/watch?v=6Wva2a_4lA4

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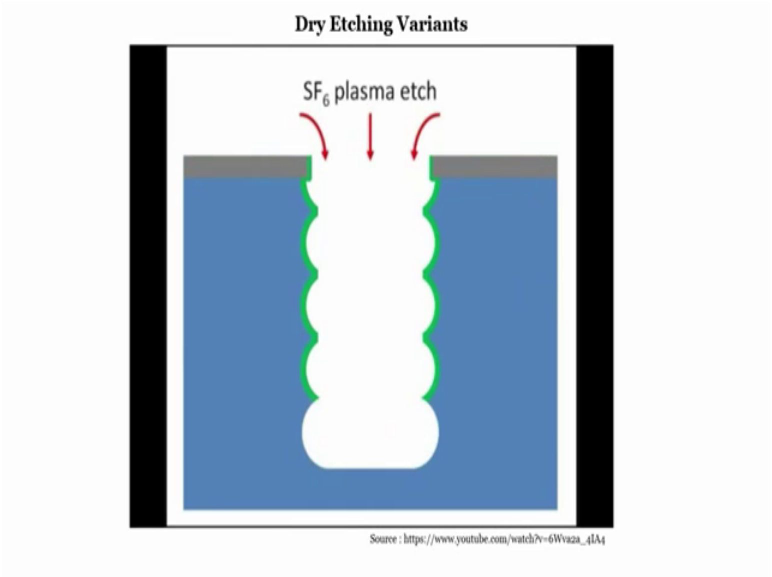

Dry Etching Variants

Source : https://www.youtube.com/watch?v=6Wva2a_4lA4

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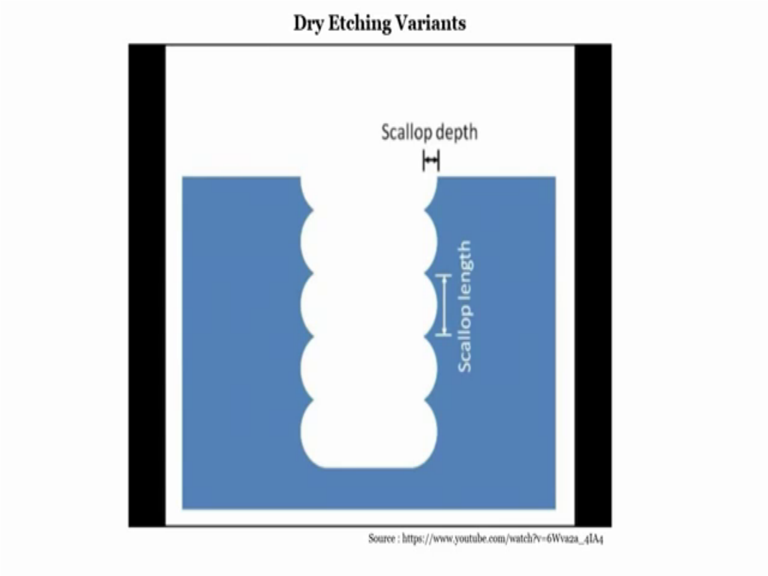
Dry Etching Variants

Source : https://www.youtube.com/watch?v=6Wva2a_4IA4

.

Let me play one more video where you will see that details about how the etching is done and that will be the end of the DRIE process. So, in principle what I wanted to show it to you is what kind of etching mechanisms are there in basically there is wet etching and dry etching. Dry etching your since sputter plasma and now you are looking at the DRIE. So, let me play the video and then will end the module.

(Refer Slide Time: 49:23)


DRIE Process in Clean Room

Please refer to the SOP documentation for further information on the procedures covered in this video.

To view the SOP documentation, click on the link located in the video's description area.

Source : https://www.youtube.com/watch?v=kj_UYQ3HAoo

Welcome to the STS room. We are going to explain you quicker over overview of how to provide the STS machine.

(Refer Slide Time: 49:47)

DRIE Process in Clean Room

Source : https://www.youtube.com/watch?v=kj_UYQ3HAoo

So, the first thing to do is once you are arrived into the room is to check the tag through (Refer Time: 49:41) or otherwise if the machine has any problem and cannot be operated. In case of the package down or like even you can operate the machine normally. The first thing to is like come next through the, to the screen of the room to the small laptop and I am logging. Once you are logged in we will have to proceed to the gas chase next to the STS room.

(Refer Slide Time: 50:11)

DRIE Process in Clean Room

Source : https://www.youtube.com/watch?v=kj_UYQ3HAoo

The first thing to check in the gas room the gas chase is like the ceiling of box. The ceiling of box is responsible of neutralizing the exhaust gases from the STS. So, by burning them it makes them harmless. The thing that we have to check is that all the lights are green and the temperature it is within parameters as well as the levels of the water, nitrogen and oxygen. So, once we check that everything is under working conditions, we will have we will check if the operating gases are flowing.

(Refer Slide Time: 50:51)

DRIE Process in Clean Room

Source : https://www.youtube.com/watch?v=kj_UYQ3HAoo

As you can see the gases in this side of the room we going to be using the first with the first the four gases that are the C 4 F 8. So, we have to check if it is in use, then the SF 6, the oxygen and the helium.

(Refer Slide Time: 51:07)


DRIE Process in Clean Room

Source : https://www.youtube.com/watch?v=kj_UYQ3HAoo

If once you are right here you noted that any of the taxes that they are nothing use please contact the supervisor or staff to turn them on and once you are inside the room take advantage to check for any weird noises or like funny smells. If everything is in place, you can proceed with operation operating the machine.

(Refer Slide Time: 51:37)


DRIE Process in Clean Room

Source : https://www.youtube.com/watch?v=kj_UYQ3HAoo

And back in the STS room, the first thing that we will though it is check the STS tower and then we will record the conductivity of the water and the temperatures on the on the STS the SCU 5 and like 3 and 1. So, we will record the values and once you have recorded the values from tower, we will go to the computer to record the other different values that we have to record. The ones that you need are going to be the high vacuum, pressure, the cab mum pressure, the 4 line pressure.

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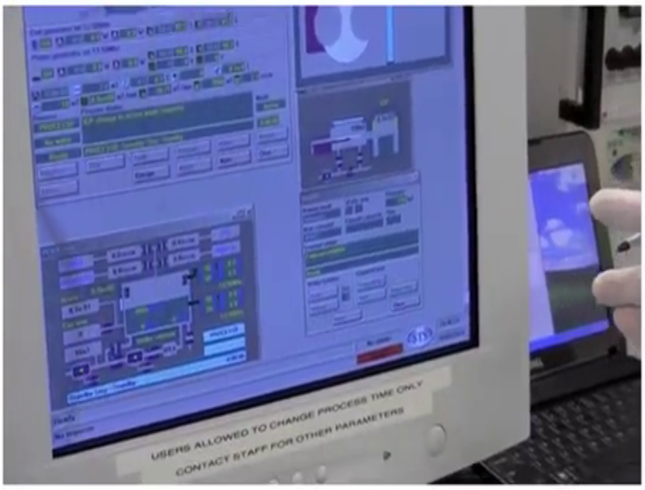
DRIE Process in Clean Room



Source : https://www.youtube.com/watch?v=kj_UYQ3HAoo

And the load knock pressure. So, if you have any problem finding any of the values in the springs you only have to go on top of them to see what are the values. Once you record that the parameters the first thing that, we have to those change the operator mode in the in the software of the STS you know that without we go to array operative mode and we change from monitor to development.

The first change and then we will lock in the password with a better price and we changed now to develop the mode where we can operate the machine. And, now the first thing to do it is to note the design wafer to the load knock chamber with that going to the threshold window and pressing vent.

(Refer Slide Time: 53:27)

DRIE Process in Clean Room

Source : https://www.youtube.com/watch?v=kj_UYQ3HAoo

And, once we press vent we have to wait for the load knock chamber to which unrestrained pressure once the transfer chamber is a under atmospheric pressure we can through we open it we will charge the desired wafer into the into the chamber. As you will see like usually the wafers have a flat and loading to ourselves we have small line. Please align the flat with the line on the on the desired path. Once we have wafer loads we cross the low much chamber and we go to the transfer window I going to press pump and map.

And, now there load knock chamber it is get a be patent and under running conditions and it is going also scan to see where are the wafers placed. When the software has mapped sludge in the in the corrosion we will look the desirable line in our case we have our wafer in the slab number one we just have the press load and now the machine it is proceeding to load the wafer into the chamber.

Once the wafer is load into the chamber we have a flashlight here in the machine to check that the wafer has been load properly so, we have to turn on the light and check during the window that the wafers is placed properly and the clamps inside the machine are holding it on the place.

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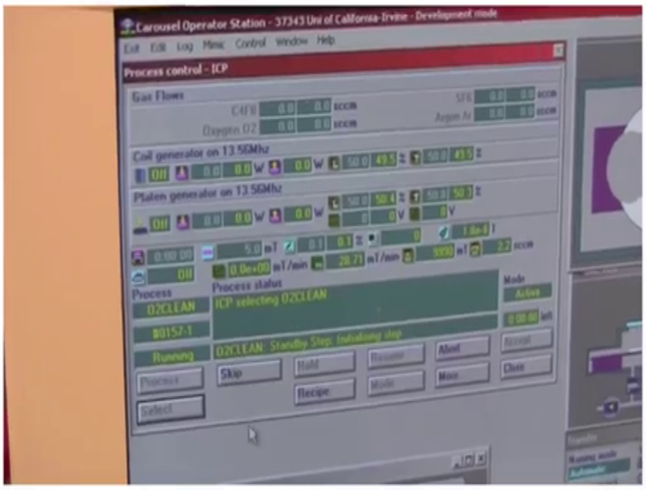
DRIE Process in Clean Room



Process: O2CLEAN

80157-1

Running

Process status: ICP selecting O2CLEAN

O2CLEAN: Standby Step: Initialising step

Mode: Active

Source : https://www.youtube.com/watch?v=kj_UYQ3HAoo

Once the wafer it is note that in to the chamber we have to proceed by selecting the process that we will we will use. We have three standard processes process B, process A and O2 clean. In this case we going to just the O2 clean you pre press select, do not press process otherwise you will go straight the help into processing the wafer. Please press select and while the machine is selecting the process, it compares the recipe button to modify the values of the recipe.

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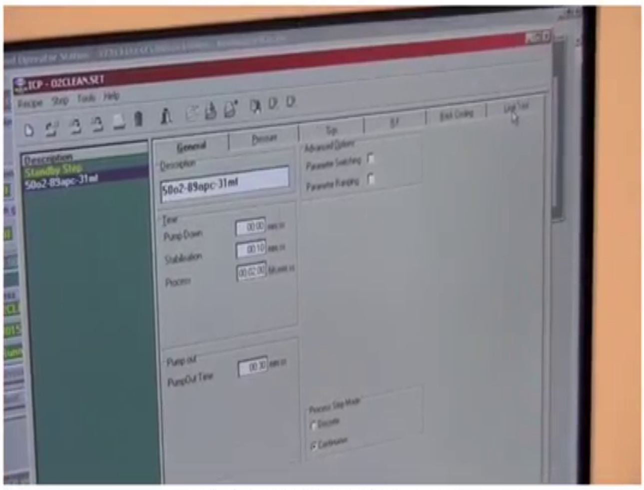
DRIE Process in Clean Room



Standby Step

50o2-89apc-31ml

Description: 50o2-89apc-31ml

Time

Pump Down 00:00

Stabilisation 00:10

Process 00:02:00

Pump out

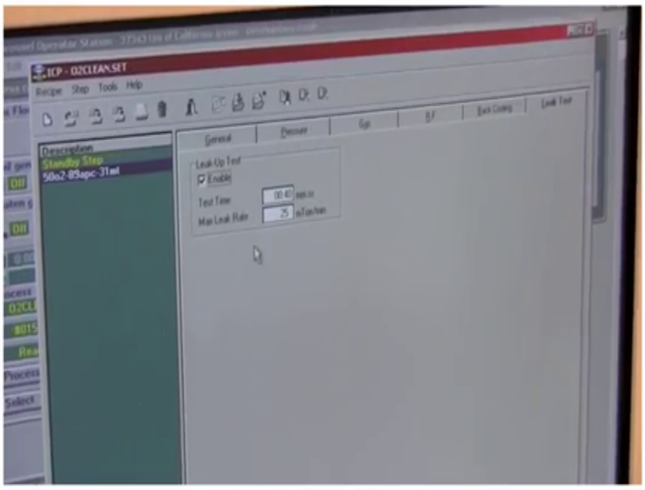
PumpOut Time 00:30

Source : https://www.youtube.com/watch?v=kj_UYQ3HAoo

And, in our cress in that second menu because it is in an example we going to use only like 3 minutes of O2 clean and also I am going to show you how to perform in the makeup test. We should do that like probably at the first ram of your day to check that there is no major lake of scaling coming from the prevailing side of the wafer.

(Refer Slide Time: 56:13)

DRIE Process in Clean Room



Leak-Up Test

☑ Enable

Test Time 00:40

Max Leak Rate 25

Source : https://www.youtube.com/watch?v=kj_UYQ3HAoo

In order to the wrap you press enable do not touch anything else and just save one a second. Once we said the recipe and the recipe has been selected we all we need to press process. As we can see now the gasses are stabilizing as we can see here we have the wafer inside the chamber and also we have like (Refer Time: 56:36) that if just change to agenda or we see that change of color main the profit process just started. Once the processes starts we were have to record the remaining values in the lock.

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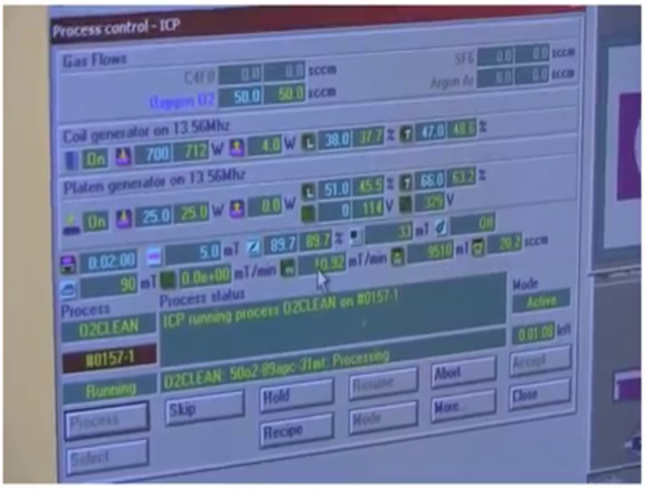
DRIE Process in Clean Room



C4F8 0.0 0.0 sccm
Oxygen O2 50.0 50.0 sccm
SF6 0.0 0.0 sccm
Argon Ar 0.0 0.0 sccm
Coil generator on 13.56Mhz
On 700 712 W 4.0 W 38.0 37.7 % 47.0 48.6 %
Platen generator on 13.56Mhz
On 25.0 25.0 W 0.0 W 51.0 45.5 % 66.0 63.2 %
0 114 V 329 V
0:02:00 5.0 mT 89.7 89.7 % 33 mT Off
90 mT 0.0e+00 mT/min 10.92 mT/min 9510 mT 20.2 sccm
Process: O2CLEAN
#0157-1
Running
Process status: ICP running process O2CLEAN on #0157-1
O2CLEAN: 50o2-89apc-31mt: Processing
Mode: Active
0:01:08 left

Source : https://www.youtube.com/watch?v=kj_UYQ3HAoo

They are the four gas fluxes the C 4, F 8, the SF 6 and the oxygen. In our case the O2 clean click only used O2 flux on we have the flux of oxygen. We also we have to record the coil generative power that is placed here and the platen etch. We have to record the coil generation for passivation and etching. In our case or maybe we only have etching. We also have to record the APC and the process pressure and if we were helium recap test the helium leakage and if you have a any problem finding any of the parameters, we can only leave the cursor in top of the window and allowing the wafer path telling you what this playing.

(Refer Slide Time: 57:47)

DRIE Process in Clean Room

Source : https://www.youtube.com/watch?v=kj_UYQ3HAoo

Once the process is completely finish you will say that the wafer color reaches from blank to green. Once that is done, the next thing to go it is just under the wafer it is very is easy you go to the transfer window and press unload.

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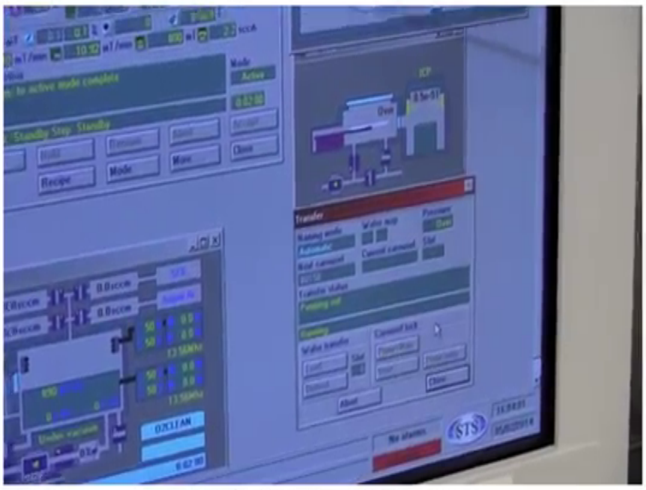
DRIE Process in Clean Room



Source : https://www.youtube.com/watch?v=kj_UYQ3HAoo

And, we will see how the other wafer it is going to be return into the load knock chamber once the wafers in the load knock chamber the next thing is to press vent and wait until the chamber is into 1 atmospheric pressure.

Now, the load knock chamber it is back into an atmospheric pressure. So, we open it we grab the wafer that we just processed , we put in a (Refer Time: 58:37) box wafer box to keep it in the safe place and next thing to do is a the (Refer Time: 58:47) chamber into standby pressure whether that like clicking pump only in the threshold in the and because we do not we do not need processing anything else and nobody is after us, you will go to the edit the menu go operator mode and press monitor to product into standby.

Once we done that the next thing to do is to log off from the laptop. So, that is it for like the operation of the STS. If you have any doubts please contact staff, but you can also check the SOP for the STS and also the comaparative videos that the explain more in detail you just the of the operative perceive here, ok.

So, what you understand you are you understood I hope you understood that why etching is so important in the case of micro fabrication in particular this device fabrication technology. And, the next in lecture I want to show it to you what kind of electronic systems are there that we call electronic modules you can design so as to interface with the sensor and that is how your electronic system can be can come into realization phase.

So, you are looking at the fabrication where you are developing some sensors and chip, but what to do with those chip, you had to integrate those chip with some kind of electronic module for further processing we also say it has a signal conditioning circuits, ok. So, till then you see this video once again and if you have any question feel free to ask me through forum, right my TA’s or me, I will be we will be able to answer your queries to best of our abilities till then you take care and I will see in the next class. Bye.