

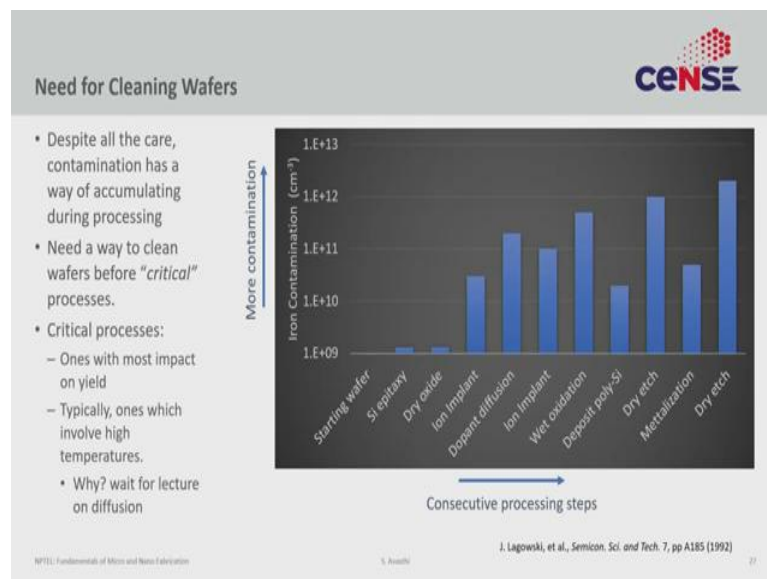
Fundamentals of Micro and Nanofabrication
Prof. Sushobhan Avasthi
Centre of Nano Science and Engineering (CeNSE)
Indian Institute of Science, Bengaluru

Lecture – 05
Contamination and surface cleaning

This is Fundamentals of Micro and Nanofabrication. My name is Sushobhan, I am from IISc, Bangalore and today we are going to talk about cleaning recipes.

In the last lecture, we looked at what is a cleanroom, why do we need a cleanroom, what are the various techniques we use to keep clean rooms clean of particles and chemicals so that contamination does not fall on top of our wafer. However, contamination does always fall because practically no matter how clean a cleanroom is there are always particles. We need to find a way to remove those particles and chemical contamination before critical processes, and that is the subject of this lecture.

(Refer Slide Time: 00:06)




This is an example of a study that was done to track contamination on top of wafers. So, you start with an extremely pure wafer. However, as you do consecutive processing steps on it, as you make a device on it, by the time you get to the end the number of particles on the surface accumulates. This is a known problem that faces any fabrication step. So, before a critical step, you have to find a way to reduce this contamination. Now, what is a critical step? A critical step is any step in a process that has the maximum impact on

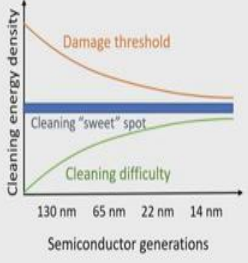
yield. Any process that reduces your yield is a critical process. Typically, these tend to be high-temperature processes. Why that is, is better understood when we discuss diffusion.

(Refer Slide Time: 02:22)

Piranha Clean or Sulfuric-Peroxide-Mix (SPM)



- To clean organics and gross particulate contamination
 - Strips photoresists
 - Standard clean for SiGe & Ge wafers
 - Used as pre-clean before RCA clean
- Recipe
 - H_2SO_4 (98%): H_2O_2 (30%) = 4:1 to 2:1
 - Temperature 120-80 °C
 - Try to use least aggressive recipe
- Mechanism
 - H_2SO_4 reduces organic to carbon
 - H_2O_2 oxidizes carbon to CO_2



More aggressive cleaning recipes cause more damage. Need to strike a balance between

NPTEL Fundamentals of Micro and Nano Fabrication | © Anant | 28

So, how do we do the cleaning? There are several recipes or chemical mixtures that are used to do the cleaning of wafers. Most of this lecture is focused on silicon because it is the workhorse, though we will also touch on what cleaning other substrates can use. A lot of time the other substrates also tend to use the same techniques and chemicals, so it is illustrative to understand how silicon cleaning works.

Let us first look at piranha clean, also called sulfuric peroxide mixture, SPM. It is a mixture of hydrogen peroxide and concentrated sulfuric acid. It is used to clean organics and gross particulate contamination and also strips photoresists. It is a standard and primary process for cleaning Si-Ge wafers because Si-Ge wafers are not compatible with the next clean we going to talk about. It is also used as a pre-clean before the RCA clean.

The recipe: take concentrated sulfuric acid (98 % sulfuric acid in water), H_2O_2 (30 % H_2O_2 in water) and mix in a ratio of 4:1. In the semiconductor world, the molarity and other sorts of concentration measures are not popular. People typically give you recipes in these 1:2, 4:1 type of ratios that mean: for 4:1 mix, you take 98 % sulfuric acid 4 parts and 30 % peroxide one part and the mix the two. This is the common way specifications

are given, partly because we are electrical, electronic engineers and material scientists; we are not chemists.

The temperature of the mixture is often kept at 80-120°C. In general, use the least aggressive recipe. Any cleaning recipe is also an etching recipe as you are trying to etch the contamination on the top, but that etching may also etch the silicon or the structures fabricated on top. In this curve, the cleaning energy density is plotted against the technology node (smallest feature size). The damage threshold is the energy density of the cleaning solution above which you will start causing damage. The cleaning difficulty curve is the minimum energy density needed to clean in the first place. The difference between these two curves is your operating range. Your cleaning methodology needs to be within this range where it does not cause damage but still does the cleaning.

And as the semiconductor generations have progressed the distance between these two curves has become narrower because the structures are flimsier, making this window narrower. As much as possible remain closer to this green curve (not very aggressive cleaning, the most dilute version of the cleaning solution).

What is the mechanism of this clean? H_2SO_4 is an oxidant that dehydrates organic matter to carbon that then gets oxidized by H_2O_2 into carbon monoxide or carbon dioxide which leaves the solution, thereby removing the organic contamination.

(Refer Slide Time: 06:16)

Piranha Clean or Sulfuric-Peroxide-Mix (SPM) 

- Effects:
 - Will etch metal
 - Forms a 1-2 nm thick oxide layer on the surface
- Problems:
 - Very exothermic reaction (BE CAREFUL)
 - Rapidly consumes H_2O_2 , so need to make it fresh.
 - Incompatible with metal-coated wafers
 - Except Cr and some other noble metals.
 - High temperature evaporates H_2O , so poor process
 - Does not clean "hardened" resists.
- Variations:
 - Use O_3 in water instead of H_2O_2



Thick nitrile gloves Splash goggles Face shield

Chemical apron

CAUTION
ALWAYS ADD
ACID TO
WATER

Refluxing acids is dangerous.
Always stay safe and disciplined

NPTEL: Fundamentals of Micro and Nano Fabrication S. Ananth 29

There are certain side effects of the piranha etch or SPM etch. It will etch metal so do not do piranha clean on samples that have metal on them. It also forms 1-2 nm thick oxide layer on the silicon surface because the silicon gets oxidized by H_2O_2 . It is a weak quality oxide, called the chemical oxide which is not useful for any electronic application but does form. It also is a very exothermic reaction. So, you have to be extremely careful. In fact, the solution tends to be self-heating. Even if you do not heat the beaker or the bath extrinsically, just by the virtue of mixing peroxide and sulfuric acid the whole solution will heat up to 80-120°C. The larger the batch, the more heating. This mixture rapidly consumes H_2O_2 as it releases the oxygen. So, you need to make this a fresh solution every single time. You cannot make a batch and then keep it over a week. It has to be made fresh, right, before the experiment (half an hour to one hour).

It is incompatible with metal-coated wafers but there are exceptions like chromium and other noble metals that do not react with sulfuric acid. In those cases, you can use this clean. The high temperature evaporates water, so the concentration of sulfuric acid changes in the system, so the process control is not very good. And it also does not clean very hardened resists; The word hardened will be better defined when we discuss lithography and etching. There are some modern variations of this, where people have started using ozone instead of H_2O_2 , for cost reduction, better control etcetera. We will discuss it later.

This is a very aggressive chemical mixture, more dangerous than sulfuric acid alone. So, you have to be extremely careful in managing this. You always wear PPE or personal protective equipment, which is nitrile gloves, splash goggles, face shields, chemical aprons. Always remember the standard rules such as always add acid to water and not the other way around. This is a refluxing, boiling acid. It is very dangerous, please stay safe and disciplined.

(Refer Slide Time: 08:55)

The slide, titled "RCA Clean" and featuring the CENSE logo, provides a detailed overview of the RCA Clean process. It lists key facts: developed by Werner Kern in 1960 at RCA, it is the gold standard for wafer cleans, and it is a two-step process used before critical steps. The recipe is shown as a three-step flow: SC1 (removes organics and particulates), SC2 (removes metals), and DHF (removes chemical oxide). A safety warning states that RCA clean is dangerous and requires PPE. A note mentions that for dirty wafers, a Piranha or SPM clean is done first. The slide footer includes "NPTEL Fundamentals of Micro and Nano Fabrication", "S. Ananth", and the number "31".

RCA Clean

- Developed by Werner Kern in 1960's at Radio Corporation of America (RCA)
- Gold standard of wafers cleans
 - Two step process removes particulates, organic, and metal contamination
 - Used before most critical steps
- Recipe

SC1
• Removes organics + particulates

SC2
• Removes metals

DHF
• removes chemical oxide

RCA clean is also dangerous. Always stay safe and disciplined

Always wear personal protective equipment (PPE)

- For dirty wafers a Piranha or SPM clean is done prior to RCA clean


NPTEL Fundamentals of Micro and Nano Fabrication | S. Ananth | 31

The next is the workhorse that is used in the industry and also in a lot of research labs and universities is RCA clean, developed by Werner Kern in the 1960s. Kern's original paper is available on the internet and is very insightful to understand the thinking behind the developing of this cleaning recipe. It is a gold standard for wafer cleans, which is a 2 step (or 3 steps) process, to be used before all the critical steps in silicon processing.

SC 1 step removes organics and particulates, SC 2 step removes metals and then there is a step to remove the chemical oxide that always forms on the top. RCA clean is also very dangerous. It is more dilute acid, so arguably less dangerous than piranha, but still very dangerous. Always wear personal protective equipment while doing RCA clean. For very dirty wafers often piranha clean serves as a pre-clean for the RCA clean.

(Refer Slide Time: 10:09)

SC 1 or RCA 1 or Alkaline-Peroxide Mix (APM)



• Recipe:

- NH₄OH (27%):H₂O₂ (30%):H₂O = 1:1:5 to 1:2:7
- Temp = 40-80 °C
- Time = 10-15 min

• Mechanism:

- H₂O₂ oxidizes metals
- NH₄OH forms soluble complexes with some metal oxides, e.g. Ag, Cu, Zn, Cd, Au, Ni, Co, and Cr
- OH ions cause removal of particles

Ag	$Ag + H_2O_2 \rightarrow Ag_2O + H_2O$ $Ag_2O + 4NH_4OH \rightarrow 2[Ag(NH_3)_2]OH + 3H_2O$
Cu	$2Cu + H_2O_2 \rightarrow Cu_2O + H_2O$ $Cu_2O + 4NH_4OH \rightarrow 2[Cu(NH_3)_2]OH + 3H_2O$ $Cu + H_2O_2 \rightarrow CuO + H_2O$ $CuO + 4NH_4OH \rightarrow [Cu(NH_3)_4](OH)_2 + 3H_2O$
Zn	$Zn + H_2O_2 \rightarrow Zn(OH)_2 + H_2O$ $Zn(OH)_2 + 6NH_4OH \rightarrow 2[Zn(NH_3)_6](OH)_2 + 6H_2O$

• Ammonium complexes are very stable, persistent, bioaccumulative, and toxic. Cu and Ag complexes damage to ecology and humans, causing skin disorders, Alzheimer's, Parkinson's, cancer, heart disease, and auto-immune issues

• **Never throw used chemicals down the drain.**

IMEI: Fundamentals of Micro and Nano Fabrication | S. Anelli | <http://blog.associatie.kuleuven.be/danhuayao/> | 31

Let us look at SC 1 (RCA 1) or an alkaline peroxide mix (APM) solution. The recipe is NH₄OH (27 % in water), H₂O₂ (30 % in water) mixed in a ratio of 1:1:5 or 1:2:7 or even more dilute versions in some cases. The temperature of the solution is around 40-80°C and does not self-heat as much because there is a lot more water in this, so you have to externally heat it either using a hot plate or through a bath. Typically, you do this clean for 10 to 15 minutes, the same as piranha before.

The mechanism is similar; H₂O₂ oxidizes the metals, NH₄OH forms soluble complexes with certain transition metals such as silver or copper or zinc. Here is an example: silver gets oxidized into Ag₂O that reacts with NH₄OH to form this ammonium complex and ammonium complexes tend to be very soluble. Silver oxide on its own is not soluble in water, but ammonium the ammonium complex is. Similarly, copper oxide is not soluble in water, but the ammonium complex is. The formation of this complex allows you to make a soluble version of this contamination that you can then wash away. Without NH₄OH, the silver oxide would just precipitate on top of the wafer. Even after oxidation, there would be no way to remove it, solubility is the key. There are safety and environmental concerns; ammonium complexes are very stable are very big environmental hazards. They accumulate and persist for a long time and are toxic, especially if you have a lot of copper or Ag contamination and you are using RCA to remove it. Whatever you form, needs to be treated as a hazardous waste, it should not be thrown away down the drain, the water supply or the sewer as it will cause things like

Alzheimer's, Parkinson's, cancer, heart disease, and autoimmune issues. It is a very bad chemical to throw in the environment. So, please refrain.

(Refer Slide Time: 12:44)

SC 1 or RCA 1 or APM: Particle Removal

• H₂O₂ forms an oxide on Si
• NH₄OH slowly etches the oxide
– In a 1:1:5 SC1, the oxide etch rate is ~0.3 nm/min at 70 °C.

Particles are removed due to modified Zeta potential. Similar to how soap works

Leaves behind a thin oxide layer due to oxidation

H₂O₂ solution → Oxidized surface

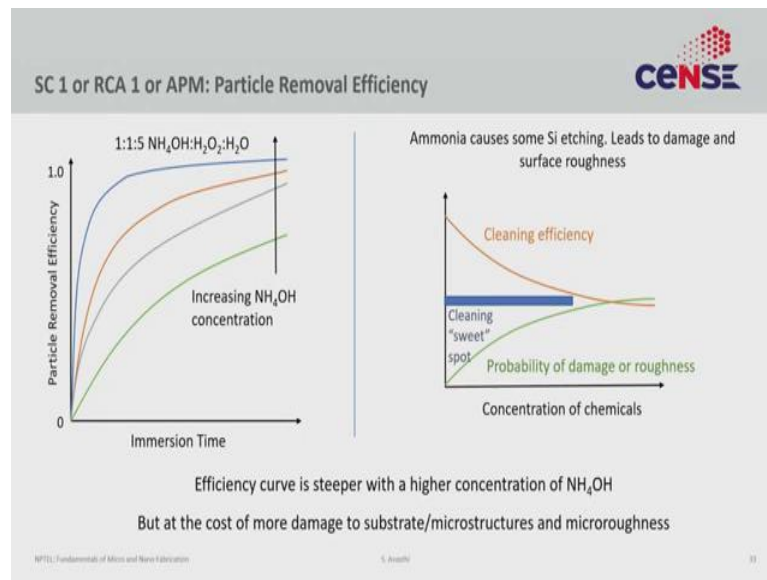
Alkaline solution → In alkaline solution, most surfaces are negatively charged.
Electrostatic repulsion between removed particle and oxide surface prevents re-deposition

NPTEL: Fundamentals of Micro and Nano Fabrication 5. Anandhi 31

OH⁻ ions also help in removing the particles. This is a basic solution; it removes particles very similar to how detergent or soap removes particles from your body. Either the particle gets oxidized with the H₂O₂, in which case you just chemically convert it off or the particle remains in its form, but then the zeta potential of the surface energy of the particle changes because of the OH⁻ ions and there is electrostatic repulsion between the surface and the ion and the particle goes away. This is exactly the same way the soap works or how certain basic solutions are used to clean glass.

A side effect of SC 1 is that you leave behind a thin layer of oxide on silicon because of H₂O₂.

(Refer Slide Time: 13:33)



The particle removal efficiency depends upon what dilution you are using. The more aggressive solutions tend to be better removing the particle; however, you have to be careful because as you increase the concentration of chemicals, the probability of damage or roughness increases and at the same time the cleaning efficiency reduces and again you are looking at this sweet spot in the middle. You have to play with different concentrations; start with the lower one, go higher if it is not getting cleaned.

Ammonia causes some amount of silicon etching, as it is a base and basic solution etch silicon, leading to damage to very small features and might also cause micro roughness. Even though you start with a smooth surface, if you leave it in ammonium hydroxide it will start to roughen up. That can be prevented by going to lower concentrations but at the cost of poor cleaning.

(Refer Slide Time: 14:41)

SC 1 or RCA 1 or APM

CENSE

- Problems:
 - Causes some surface roughness, especially at high NH_4OH concentrations
 - Lower NH_4OH concentration are often used
 - Metal ions insoluble in bases, deposit on the surface, like Al, Fe.
 - Etches Ge and SiGe
- Variations:
 - Reduce NH_4OH , reduce temperature, reduce time
 - Lower micro roughness
- Reagents get consumed with time
 - Can't be stored
 - Need to be made fresh before use

Normalized concentration of reagent

Time (min)

Heat up from 25C to 85C

Processing at 85C

H_2O_2

NH_4OH

NPTL: Fundamentals of Micro and Nano Fabrication

S. Ananth

34

Just like the piranha, APM solutions also degrade with time. If you look at the normalized concentration, within 40 minutes or so, only 10 % of the solution remains. The only way to do this is to make a fresh batch every single time. It takes a certain amount of time to just heat up the solution to around 80°C , then a 10-20 minute window in which you can use the solution after which it is spent. You cannot make it or store it in advance.

(Refer Slide Time: 15:15)

SC 2 or RCA 2 or Hydrochloric-Peroxide Mixture (HPM)

CENSE

- Recipe:
 - HCl (73%) : H_2O_2 (30%) : H_2O = 1:1:6 to 1:2:8
 - Originally developed at 1:1:5
 - Temp = $70-80^\circ\text{C}$
 - Time = 10-15 min
- Mechanism:
 - H_2O_2 oxidizes
 - HCl forms soluble chlorides with metal ions, like Na, Zn, Al, Mg, Fe, etc.
- Effects:
 - Removes most metal contaminants
 - Removes alkali ions, like Na^+ and K^+
 - Leaves behind a thin oxide on the Si surface

Na	$2\text{Na}^+ + 2\text{HCl} \rightarrow 2\text{NaCl} + \text{H}_2$
Zn	$\text{Zn}^{+2} + 2\text{HCl} \rightarrow \text{ZnCl}_2 + \text{H}_2$
Al	$2\text{Al} + 6\text{HCl} \rightarrow 2\text{AlCl}_3 + 3\text{H}_2$ $\text{Al}(\text{OH})_3 + 3\text{HCl} \rightarrow \text{AlCl}_3 + 3\text{H}_2\text{O}$
Fe	$\text{Fe} + 2\text{HCl} \rightarrow \text{FeCl}_2 + \text{H}_2$ $\text{Fe}(\text{OH})_3 + 3\text{HCl} \rightarrow \text{FeCl}_3 + 3\text{H}_2\text{O}$

NPTL: Fundamentals of Micro and Nano Fabrication

S. Ananth

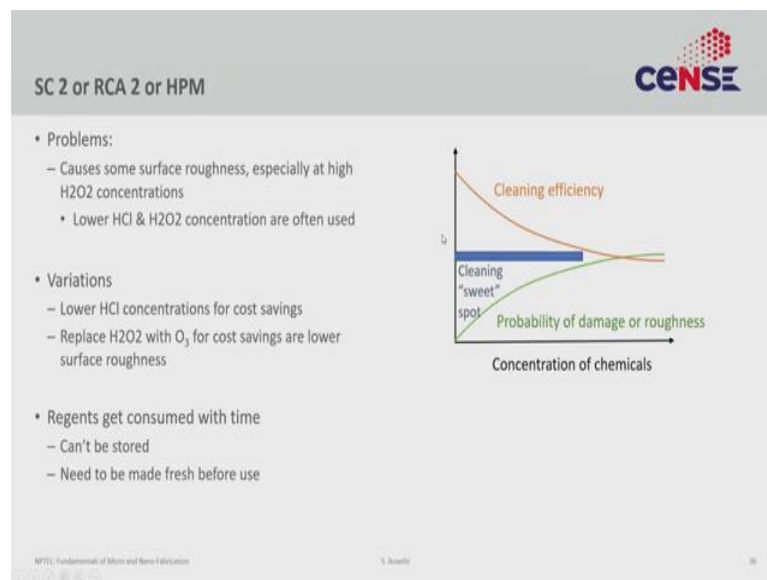
<http://blog.associatie.kuleuven.be/danhuayao/>

35

The other next step in the RCA clean is SC 2 (RCA 2), a hydrochloric - peroxide mixture (HPM). Just like the previous one, it has hydrochloric acid, peroxide, and water in 1:1:6 or 1:2:8 ratios, where instead of ammonium hydroxide, you have HCl (73 %). You heat this to around 70-80°C and leave it in the solution for 10-15 minutes.

The mechanism is similar. It is just an acidic solution instead of alkaline. H₂O₂ oxidizes, then HCl forms soluble chlorides. Sodium or zinc or aluminum or iron impurities react with HCl to form chlorides are very soluble. Just by washing the wafer later, you can remove this contamination from the surface. This also leaves behind a thin layer of oxide on the silicon surface because of H₂O₂ just like the previous two cleans.

(Refer Slide Time: 16:25)



What are the problems? surface roughness, especially at high H₂O₂ concentrations. There again is this tradeoff between cleaning and probability of causing damage and you want to be in a sweet spot. The industry has for cost savings and other reasons tried to migrate toward lower concentrations of HCl and replace H₂O₂ with ozone. The reagents get consumed with time so you cannot store it but have to make it fresh before use.

(Refer Slide Time: 17:03)

SC 2 or RCA 2 or HPM: Principle Behind Metal Cleaning

- During metal cleaning two reactions take place.

$$Si + 2H_2O \rightleftharpoons SiO_2 + 4H^+ + 4e^- \quad (1)$$

$$M \rightleftharpoons M^{+x} + xe^- \quad (2)$$
- This is an electrochemical reaction, where electrons produced in one reaction are consumed in another reaction.
- The stronger reaction will dominate.
 - Generally, (2) is driven to the left and (1) to the right so that SiO₂ is formed and M electroplates out on the wafer. Leading to contamination.
 - Good cleaning solutions drive (2) to the right since M⁺ is soluble and will be desorbed from the wafer surface.

Strength of a reaction gets decided by its oxidation potential.

- Lower the oxidation potential, stronger the oxidant
- In RCA we use H₂O₂ which is a strong oxidant. H₂O₂ ensure (2) goes to right for most M

Oxidant/Reductant	Standard Oxidation Potential (volts)	Oxidation-Reduction Reaction
Mn ²⁺ /Mn	1.05	Mn ↔ Mn ²⁺ + 2e ⁻
SiO ₂ /Si	0.84	Si + 2H ₂ O ↔ SiO ₂ + 4H ⁺ + 4e ⁻
Cu ²⁺ /Cu	0.71	Cu ↔ Cu ²⁺ + 2e ⁻
Ni ²⁺ /Ni	0.25	Ni ↔ Ni ²⁺ + 2e ⁻
Fe ²⁺ /Fe	0.17	Fe ↔ Fe ²⁺ + 2e ⁻
H ₂ SO ₄ /H ₂ SO ₃	-0.20	H ₂ O + H ₂ SO ₃ ↔ H ₂ SO ₄ + 2H ⁺ + 2e ⁻
Cu ²⁺ /Cu	-0.34	Cu ↔ Cu ²⁺ + 2e ⁻
O ₂ /H ₂ O	-1.23	2H ₂ O ↔ O ₂ + 4H ⁺ + 4e ⁻
Au ³⁺ /Au	-1.42	Au ↔ Au ³⁺ + 3e ⁻
H ₂ O ₂ /H ₂ O	-1.77	2H ₂ O ↔ H ₂ O ₂ + 2H ⁺ + 2e ⁻
O ₃ /O ₂	-2.07	O ₂ + H ₂ O ↔ O ₃ + 2H ⁺ + 2e ⁻

NPTEL: Fundamentals of Micro and Nano Fabrication
S. Ananth Ideas from Bo Cui, ECE, University of Waterloo; <http://ece.uwaterloo.ca/~bcui/>

A little bit more about the mechanism behind the HPM clean. On the silicon surface, there are two things that can react; silicon can form silicon dioxide and metal will form the metal ions. So, there is an electrochemical reaction depending on the standard oxidation potential of the impurities. In general, if you do not have any other reagent in the solution, reaction 2 is driven to the left - the metal plates out and reaction 1 is driven to the right - the silicon oxidizes because it has a tremendous tendency to oxidize. Silicon wants to oxidize, and that forces the metal to reduce which is why you actually get contamination.

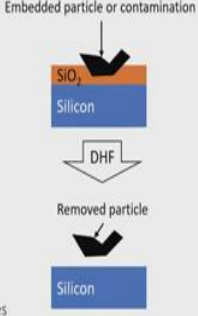
Now, in order to prevent your metal from plating on top of the surface, you need other reagents (for example, hydrogen peroxide). Hydrogen peroxide has a very low standard oxidation potential, making it a very strong oxidizing agent. An oxidizing agent will oxidize everything that is above it in the standard oxidation potential table; gold, copper, iron, nickel, chromium, and silicon will get oxidized. However, things below it will not but that is not a concern for most metals as H₂O₂ will oxidize most of them. This oxidation pushes this reaction to the right and then that iron can react with the chloride to form a soluble complex that can be then washed away. This also tells what sort of oxidation agents would be good. It is good to use H₂O₂, it might be better to use ozone because it is a stronger oxidizing agent and that is why the industry is trying to move towards it. Several ideas and the slide come from Professor Bo Cui's (ECE Waterloo) lectures which are very illuminating.

(Refer Slide Time: 19:26)

DHF-Clean/Oxide-Etch

CENSE

- Recipe:
 - HF (49%) : H₂O = 1:50 to 1:100
 - Temp = Room temperature
 - Time = 1-2 min
- Mechanism:
 - HF etches (dissolves) SiO₂
 - Any soluble particulates embedded in the oxide float away
- Effects:
 - Leaves a hydrophobic clean Si surface
 - Surface Si are hydrogen terminated, i.e. have Si-H bonds
- Problems:
 - Can cause some surface roughness, especially at high HF concentrations and long times



Embedded particle or contamination

SiO₂

Silicon

DHF

Removed particle

Silicon


NPTEL: Fundamentals of Micro and Nano Fabrication


S. Ananth

38

The last step and an optional step: chemical oxide removal. Chemical oxide forms on the surface because of the ammonium hydroxide, sulfuric acid or hydrochloric acid step. This step is typically done with a dilute (1:50 to 1:100) solution of hydrofluoric acid in water at room temperature and it takes only 1-2 minutes depending upon the concentration. Particle contamination embedded in the silicon oxide may go away with the oxide when you put it in the hydrofluoric acid. The problem is it again causes micro roughness. This step should be done in as dilute solution and for as short time as possible. As a side effect, it leaves a hydrophobic surface on which the water does not stick. If you take the wafer out, you will see no droplets on it because the water does not stick to it. That is a sign that the etch has completed. It also passivates the surface of the silicon with silicon hydrogen bonds.

(Refer Slide Time: 20:48)

DHF-Clean/Oxide-Etch: H-Passivation 




Oxide coated Si $\xrightarrow{\text{NH}_4\text{F or HF}}$ H terminated Si

- HF or NH_4F terminate Si with hydrogen
 - Si vacancies get satisfied
 - Surface become chemically inert, i.e. passivated surface
- The passivation can last from minutes to hours!
 - Helps keep surface clean
- Degrades in H_2O , UV, ozone or air
 - Try to do subsequent processing as quickly as possible
 - Preferably within 10 mins.
 - Don't "store" cleaned wafers in ambient for long. They will not remain "clean".


NPTEL: Fundamentals of Micro and Nano Fabrication S. Ananth 31


Once you remove silicon dioxide through ammonium fluoride or hydrogen fluoride, you form the Si-H bonds on the surface that passivate the surface chemically and electronically. The downside is that it just lasts from minutes to hours as ultimately the oxygen from the ambient will react with Si-H bond and form silicon dioxide again. Practically, what it means for the cleaning step is that the cleaning must be done before the critical step, and the time between the cleaning and the critical step must be kept as low as possible because this hydrogen passivation allows the surface to remain clean, and but with time it will degrade and once it degrades you tend to re-accumulate the junk on the surface. A good rule of thumb is that the time between the cleaning and the step after it should not be more than 10 to 30 minutes.


(Refer Slide Time: 21:48)


Labware & Carriers 

- Use quartz/Teflon for SC 1/2
- Use Teflon for DHF
 - Non-coloured only
- Never use pyrex or (soda lime) glass beaker
 - Cause major B, Na and K contamination
- Wafer/samples carriers
 - Teflon or quartz only
 - Use cassettes for processing multiple (full) wafers
 - Use smaller vessels for processing smaller samples
- Labware/tweezers for clean should be kept separate
 - No metals
 - No photoresist
 - Clean tweezer and labware before every use

 Pyrex beaker

 Teflon beaker

 Wafer cassette

 Some tweezer handling tips


RPTEL: Fundamentals of Micro and Nano Fabrication S. Ananth 40

Let us talk about some labware that you must use to do this cleaning. Remember, we are doing this to remove contamination. So, the labware must not introduce unintended contamination. Always use quartz or Teflon labware. Try to avoid colors or pigments, just use virgin clean Teflon. Try to avoid Pyrex or soda lime beakers; they are very cheap, very easily available, but chemically soda-lime glass or Pyrex glass is full of boron sodium and potassium that will cause contamination on top of your wafer. So, please avoid those.

Here is an example of a wafer carrier that allows you to process several wafers at once. For smaller wafers, you can keep them directly into the beaker. We also need some way of manipulating the wafer either a tweezer or wand. Please do not use metal tweezers, photoresists, keep the tweezers clean. Tweezers used to clean the substrate must not be used for anything else, you would always end up creating contamination that will come back to haunt you later. Here is a QR code from a website that actually gives you some tweezers and handling tips. It is very easy to go in buy low-quality tweezers of unknown cleanliness and unknown quality, I would encourage you to use only Teflon or polypropylene tweezers, glass filled Delrin, few other material types. Please do not use metal tweezers, even with Teflon coating as they are not suitable for most applications that require acid or base cleans because over a period of time this Teflon coating comes off and you are back to square one with metal contamination on your wafer. For more advanced cases you might consider using a wand that picks up the wafer using a vacuum.


Never touch the middle of the wafer; only the edges. Do not breathe on the wafer, make sure they are far away from you, do not put them on dirty surfaces, do not touch them with fingers. It is very hard to remove all contamination from a dirty surface.

(Refer Slide Time: 24:45)

Rinsing 

- This is the step that **ACTUALLY** cleans the surface
 - Washes away the impurities
 - Be particular here. Don't get lazy!
- Remember rinsing is "cleaning by dilution"
 - Each rinse dilutes contaminants by 10-100x
 - After 3-5 rinses wafer is clean
- Can be done in a
 - Clean quartz/plastic beaker
 - Simple; Lowest cost; least effective
 - Can lead to carbon contamination
 - Dump rinser
 - Easiest; used for cassettes; costly

<http://www.modutek.com>



Wafer cassette in a dump rinser

MITEL Fundamentals of Micro and Nano Fabrication 9 Anshu 17

Rinsing: before and after every step cleaning step, there is a rinsing step, but often people do not quite understand how important this is. All the chemical reactions make the contamination soluble, which is still there in the solution. The way we remove that contamination is by rinsing. Do not get lazy in the rinsing; if the recipe asks to it rinse 3 times, rinse 3 times. If the recipe asks to it rinse 5 times, rinse 5 times. Rinsing is just cleaning by dilution. Every time you rinse, the contamination level inside the liquid goes down by a factor (of 5-10x). Rinsing 5-6 times reduces the contamination by 5-6 orders of magnitude.

There are certain automatic dump rinsers that you can use if you have several wafers. They are a little more expensive but available. If you have small pieces of single wafers you can do this in the beaker itself.

(Refer Slide Time: 25:53)

Blow Dry 



N₂-gun Spin-rinse dryer Spin-dryer

- Please pay note to the word “blow”
- We are NOT evaporating the solvent
- We are blowing it away
- Otherwise you get coffee stains



doi:10.1038/nrep10335

a 0.3 mm b 0.3 mm

NPTL: Fundamentals of Micro and Nano Fabrication © Asahi https://iurms.gatech.edu/articles/15-en.wikipedia.org/wiki/Spin_coating 41

Once you are done with rinsing there is typically a step of blowing dry the wafer. Please note the word ‘blow’. The idea is not to dry the liquid on top but to push it off the wafer on to some absorbent cloth. You do not want to dry the water because when you dry the water on a surface you tend to form stains. This is what I call coffee rings. Coffee that dries on top of a table will leave a stain as the solvent evaporates away, the solute just precipitates out on top of the surface.

So, if a liquid dries on the wafer, it will form these sorts of contamination rings on top of the wafer, which is undesirable. We need to push the liquid off without drying it using tools like nitrogen gun or spin dryers.

(Refer Slide Time: 27:02)

Wafer Handling: Do's and Don'ts



How to clean a wafer



<https://www.youtube.com/watch?v=su7PKCCeBmEQ>

Wafer handling tips



https://youtu.be/GOnVmfy8_lg

Handling of non-standard wafers & pieces



<https://youtu.be/5FKYUyYUg>

Other things to note:

- Always use PPE
- Hold the wafer only at the edge
- Don't touch by hand
- Always "blow dry", DON'T DRY



www.2isl.com gid.lightmachinery.com www.ibm.com www.medicinenewstoday.com blog.ckbrasil.com

NPTEL: Fundamentals of Micro and Nano Fabrication S. Ananth 44

A few other wafers do's and don'ts that you may look at in these videos. To summarize it all, always use personal protective equipment, hold the wafers from the edges, never hold the wafer with hand and always blow dry. Make sure that the tweezers doesn't touch the device; hold the small substrates from the edges. Any die once touch by hand will always have sodium-potassium contamination which is not good for the device.

In the next lecture, we will look at some more advanced cleaning techniques. See you next time.