*Welcome to*

# *EE669: VLSI Technology*


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**Office hour: Friday 10:00 – 11.00 AM, EE Annex, Room: 104**

# Wafer cleaning: Why is it so important?

**Wafer contamination causes a loss of $550 million, so TSMC downgraded Q1 quarterly revenue guidelines.**

Source: Editor: Jacquelyn Update Time :2019-02-23

As the global largest wafer generation foundry, TSMC has a huge impact on the market in the process of 28 to 7 nm. Safe production of TSMC will affect a number of semiconductor design companies. Last year, TSMC was affected by a Win7 computer poisoning incident in the wafer factory. Unfortunately, a wafer contamination incident broke out at the end of last month. The


**The global largest wafer generation foundry, TSMC has a huge impact on the market in the process of 28 to 7 nm.**

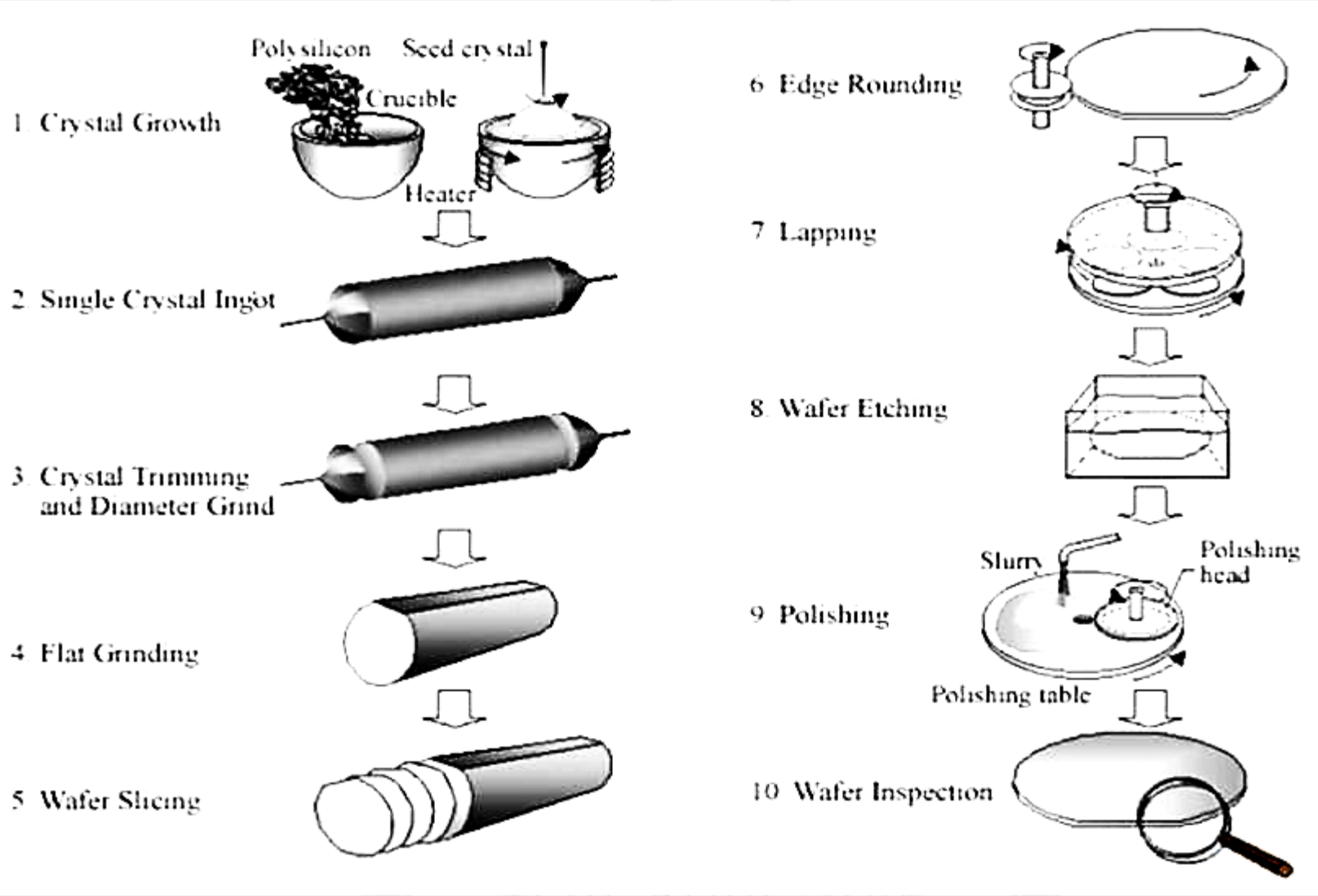
# Wafer handling and cleaning

Terminology

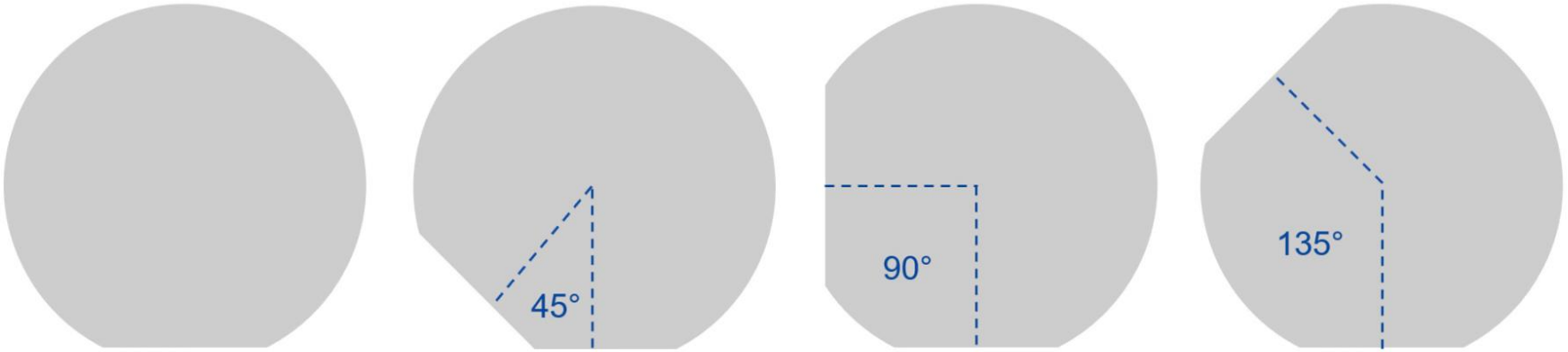
- **Wafer/Substrate**

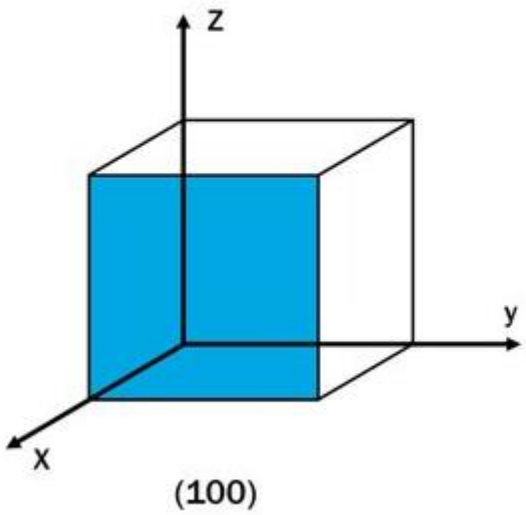
– a complete round disk of the semiconductor, usually cut from a grown crystal boule.

# Si Crystal growth


*A typical wafer is made out of extremely pure silicon that is grown into mono-crystalline cylindrical ingots (boules) up to 300 mm (slightly less than 12 inches) in diameter using the* ***Czochralski process*** *( as shown below ). These ingots are then sliced into wafers about 0.75 mm thick and polished to obtain a very regular and flat surface.*

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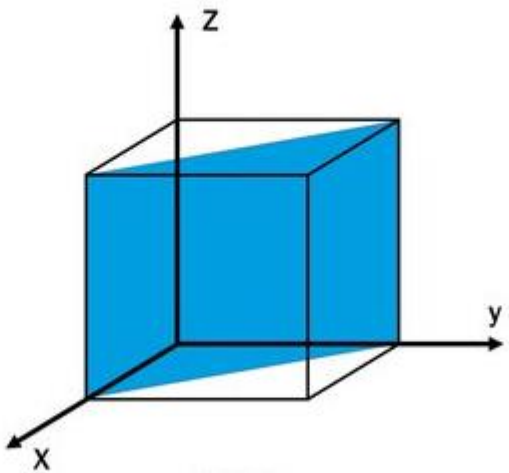


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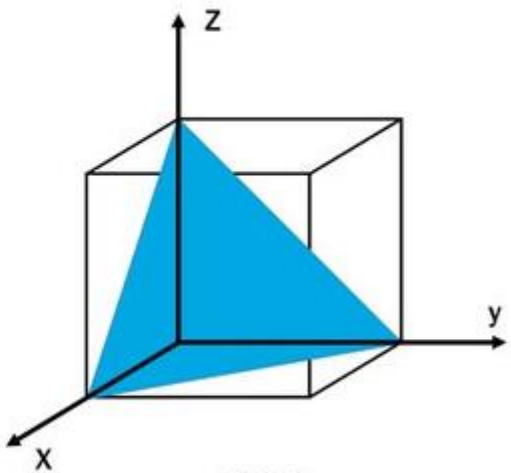


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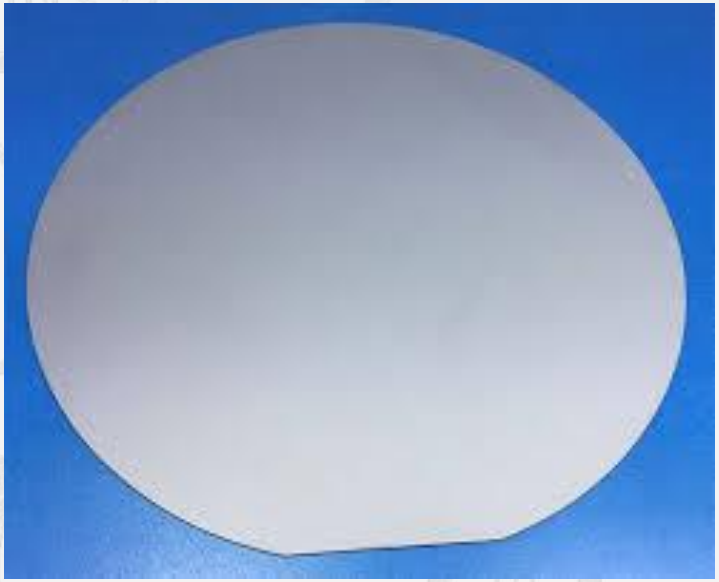
# Wafers of different semiconductors



# Standard Wafer Features

- **Surfaces**

– Top: ground, lapped, and polished.

– Bottom: usually just ground; looks like a dull or matte finish.

- **Orientation flats**

– Used to mark crystallographic orientation.

- Primary flat indicates the (011) plane for both (100) and (111) wafers.

– Used also to distinguish n-type from p-type.

- **Position of the secondary (smaller) flat relative to the primary flat**.
- **Edge radius**

– Ground after wafers are cut from the parent boule.

– Edge radius is usually half the wafer thickness.

- **Serial number (on backside)**

– Optional; usually done by a laser marking system.

# Standard Silicon Wafer Grades

- **Epi grade**

– Has a thin epitaxial film deposited over top to create a smoother, more defect free working surface

- **Recycled/reclaimed grade**
- **Test grade**

– Most common for research purposes

– A good compromise of quality to cost

– No flatness or backside specs and a wide resistivity range

– Usually a prime grade wafer that has failed a spec

- **Prime grade**

– The best available and suitable for any state-of-the-art process at any major IC manufacturer

– Essentially defect-free and usually expensive (up to ~10X the cost of test grade)

- **Mechanical grade**

– Only the dimensions are controlled

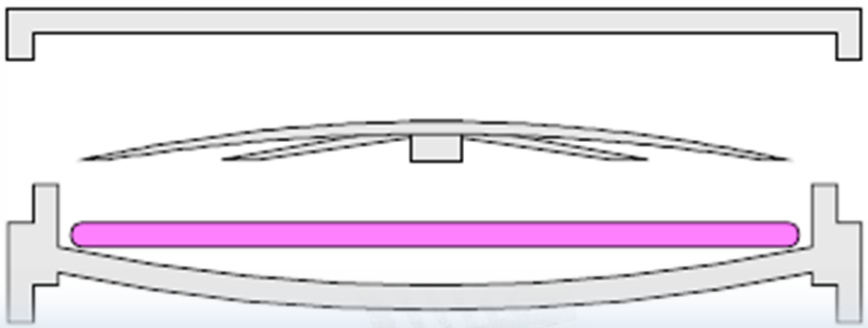
- **Furnace grade**

– Tightly controlled oxygen and carbon content, resistivity, and dopant uniformity

# Wafer Tray Assembly

Wafer Tray Assembly

- Standard design – polypropylene material.
- Available for 1, 2, 3 – inch; 100, 125, 150 mm wafers.
- Tray and spring should only contact the wafer on the edges.
- Can and should be cleaned with solvents prior to loading



lid - left handed cam lock

spring - inserted convex up

wafer - top side facing down

tray - can be stacked in lieu of lids

# The Evolution of Silicon Wafer Cleaning Technology

- **Wafer cleaning chemistry has remained essentially unchanged in the past 45 years**
- **It is based on hot alkaline and acidic hydrogen peroxide solutions, a process known as "RCA Standard Clean"**

## Contamination:

## Type, Origin, and Effects of Contaminants

(i) contaminant films,

*(ii)* discrete particles

(*iii)* adsorbed gases,

# Common Wafer Contaminants

- **Surface oxides**

– native oxides

– metal oxides from prior processing steps

- **Non-reactive dust**

– not chemically bound, but often electrostatically or van der Waals bonded to the wafer surface

- **Water marks**

– precipitated salts and organic debris after water has evaporated

- **Chemical residue**

– residual photoresist, wafer primers, plasticizers, pigments, ballasting resins

- **Organic films**

– oils, waxes, greases, carbonized residue

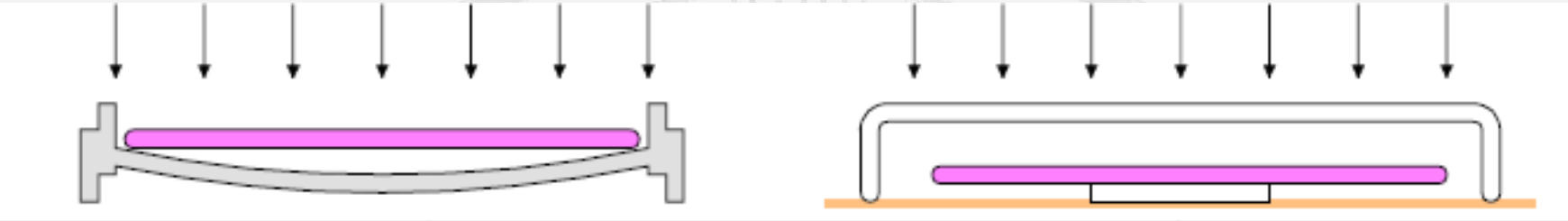
# Keeping Wafers Clean while In Process

- **Most air flow in a clean room is down.**
- **Gravity also sends suspended particles in the air down.**
- **Wafers that are face-up will accumulate more particulate contamination than wafers which are face-down.**

**2 solutions:**

– Place wafers in process (WIP) face down in wafer trays while in between processing steps.

– Place wafers in process (WIP) face up on top of a clean filter paper and microscope slide and underneath a petri dish cover.



# Wafer Cleaning Methods

- **Acid / alkali – oxide etch**

– used to remove native and non-native oxides

- **Plasma oxygen ashing**

– used to remove organic films and residues

- **Ultraviolet-ozone clean**

– used to remove organic films and residues

- **Solvent clean**

– used to remove oils, greases, waxes, and carbonized residues

- **De-ionized water clean**

– used to remove all loose material

# RCA Wafer Clean

Developed by **Kern** and **Puotinen** at **Radio Chemical America** in 1960.

- **Standard Cleaning solution** 1 (SC-1):

– $NH_4OH : H_2O_2 : H_2O$ @ 1:1:5 to 1:2:7 ratio of standard concentrations.

– Etch at 70-80°C.

– High pH (basic) solution removes organics, carbonized residues, and chemically-bound surface particles by oxidation.

- **Standard Cleaning solution 2** (SC-2):

– $HCl : H_2O_2 : H_2O$ @ 1:1:6 to 1:2:8 ratio of standard concentrations.

– Etch at 70-80°C.

– Low pH (acidic) solution desorbs and leaches out metals.

- **Both of these solutions will produce some oxidation of a silicon wafer.**

– This can be removed by another BOE etch as part of the overall process.

**Buffered oxide etch** (**BOE**), also known as buffered HF or BHF

# Standard Wafer Clean with Oxide Strip

**BOE: mixture of a buffering agent, such as ammonium fluoride ($NH_4F$), and hydrofluoric acid (HF)**

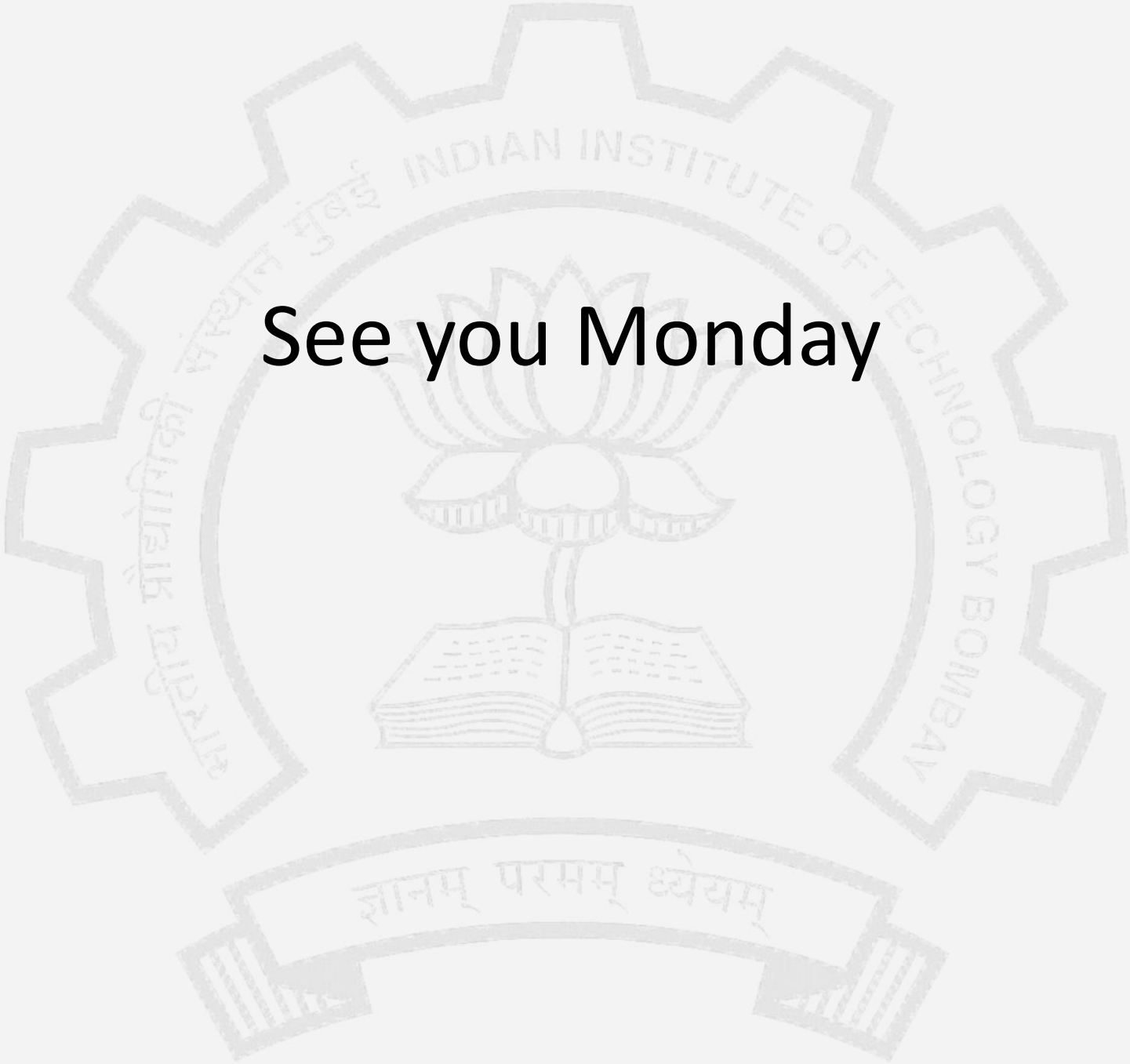
*Note: Concentrated HF (typically 49% HF in water) etches silicon dioxide **too quickly** for good process control and also **peels photoresist** used in lithographic patterning. **Buffered oxide** etch is commonly used for more controllable etching*

1. SC-1 (RCA 1): 1:3:15 NH4OH : H2O2 : H2O @ 75°C for 15 min.
2. DI $H_2O$ rinse @ RT for 5 min.
3. 10:1 BOE @ RT for 1 min. (this is what strips the oxide)
4. DI H2O rinse @ RT for 5 min.
5. SC-2 (RCA2): 1:3:15 HCl : H2O2 : H2O @ 75□C for 15 min.
6. DI H2O rinse @ RT for 5 min.
7. Spin, rinse, & dry –

– use an automated SRD for best results and sparkling clean wafers.

# Piranha Etch

- An extremely aggressive etch for organic residue.
- $H_2SO_4$ : $H_2O_2$ @ 4:1 standard concentrations.
- Etch at 90□C for 10 minutes.
- Mixing of acid and peroxide is extremely exothermic – mixture often reaches the boiling point all on its own.
- The pot life is fairly short – only 20-30 minutes before the peroxide is decomposed by the heat of the solution.
- This etch solution must be treated with great respect and care.




# See you Monday