Cleanroom and safety

Cleaning

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Chapters 35, 12

Previous lectures

- Introduction
- Patterning
- Silicon

Cleanrooms

- Concept and standards
- Design and air circulation
- Subsystems
- Hazards and alarms

When feature widths were far greater than about 10 µm, purity was not the issue!

MICRONOVA Cleanroom

Cleanroom concept

- A cleanroom is an environment, that has a low level of pollutants under very stable ambient conditions

- The air entering a cleanroom from outside is filtered to exclude dust, and the air inside is constantly recirculated through High-Efficiency Particulate Air (HEPA) and Ultra-Low Penetration Air (ULPA) filters to remove internally generated contaminants

- Most cleanrooms also control humidity, temperature and pressure

- All users of cleanroom use special suits to protect the devices from human contamination

Two cleanliness & safety goals:

1) protecting wafers from people and other contamination sources

2) protecting people from hazardous chemicals and gases

Protecting people

Potential danger

- acids and bases
- resists, solvents, pump oils
- gases
- ionizing radiation
- UV-radiation
- fires

Protection

- safety training
- safety goggles
- safety gloves
- safety apron
- working discipline

Protecting wafers

•Unwanted atoms must not move around the lab.

•Because of diffusion, high temperature processes are especially quick to move stuff around.

Solutions:

Processing in dedicated space & equipment.
(Outside cleanroom if necessary).

Cleaning before next step.

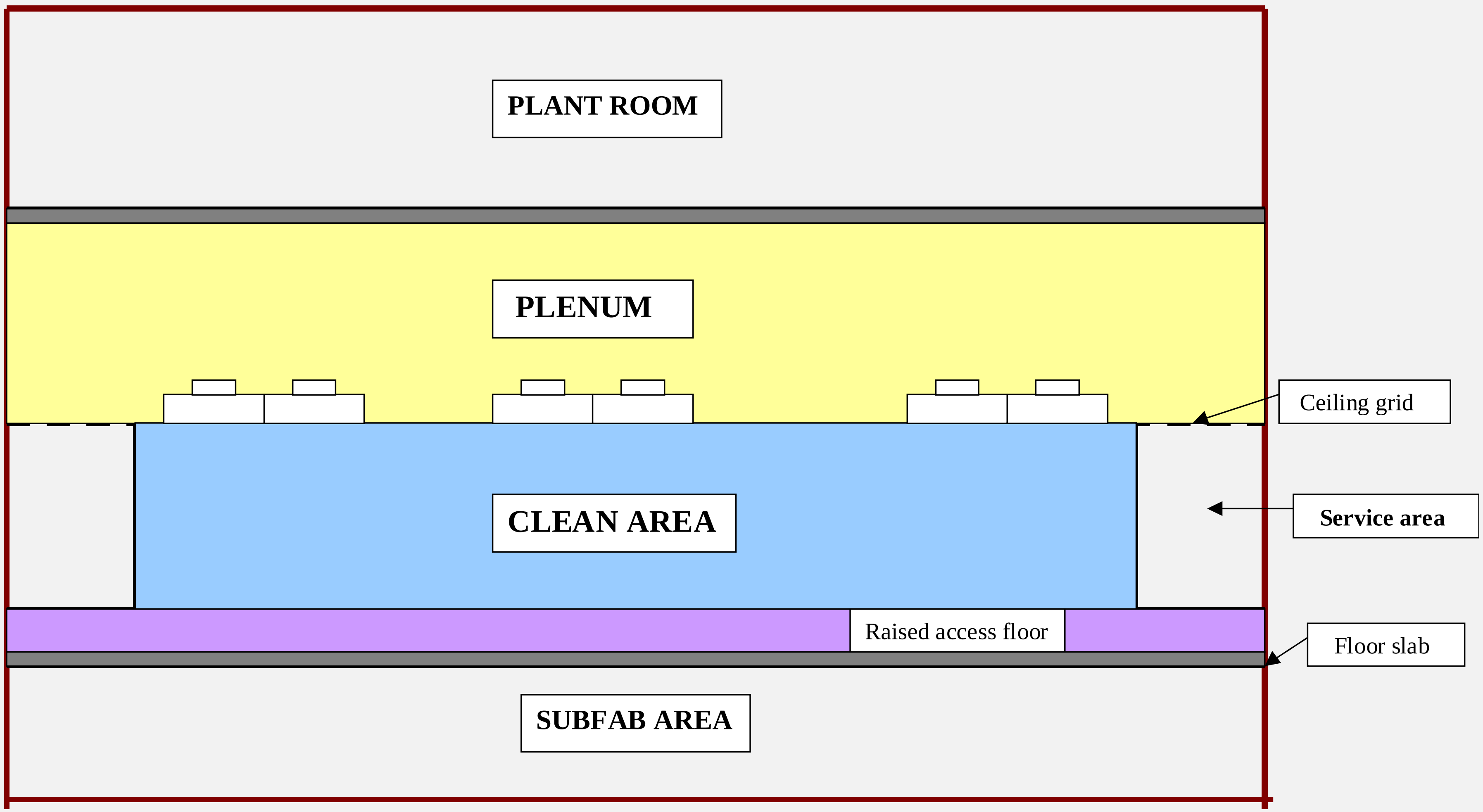
ISO 14644-1 cleanroom standards (particles)

maximum particles/m³

	≥0.1 µm	≥0.2 µm	≥0.3 µm	≥0.5 µm	≥1 µm	≥5 µm
ISO 1	10	2				
ISO 2	100	24	10	4		
ISO 3	1,000	237	102	35	8	
ISO 4	10,000	2,370	1,020	352	83	
ISO 5	100,000	23,700	10,200	3,520	832	29
ISO 6	1,000,000	237,000	102,000	35,200	8,320	293
ISO 7				352,000	83,200	2,930
ISO 8				3,520,000	832,000	29,300
ISO 9		Room air		35,200,000	8,320,000	293,000

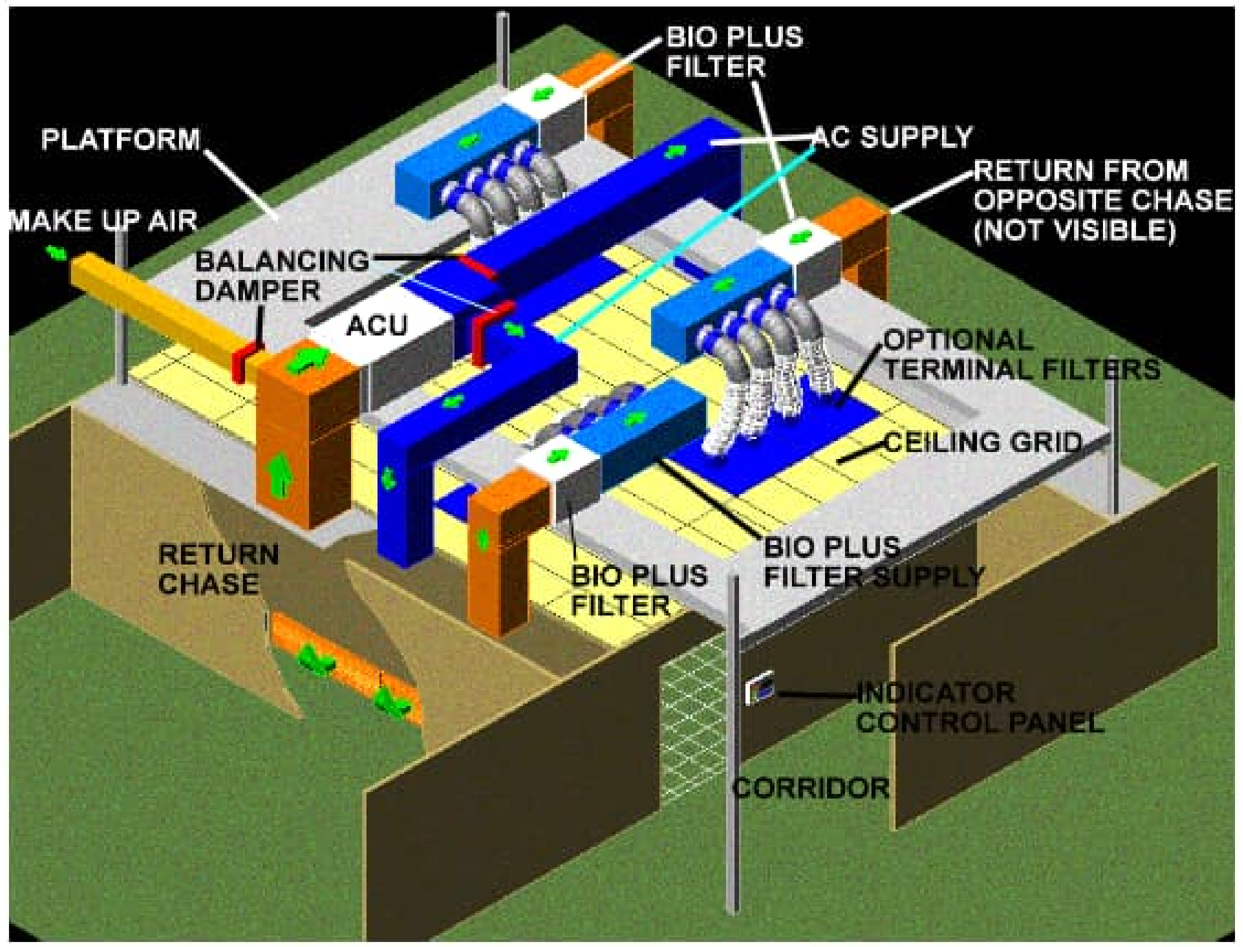
Air extract places

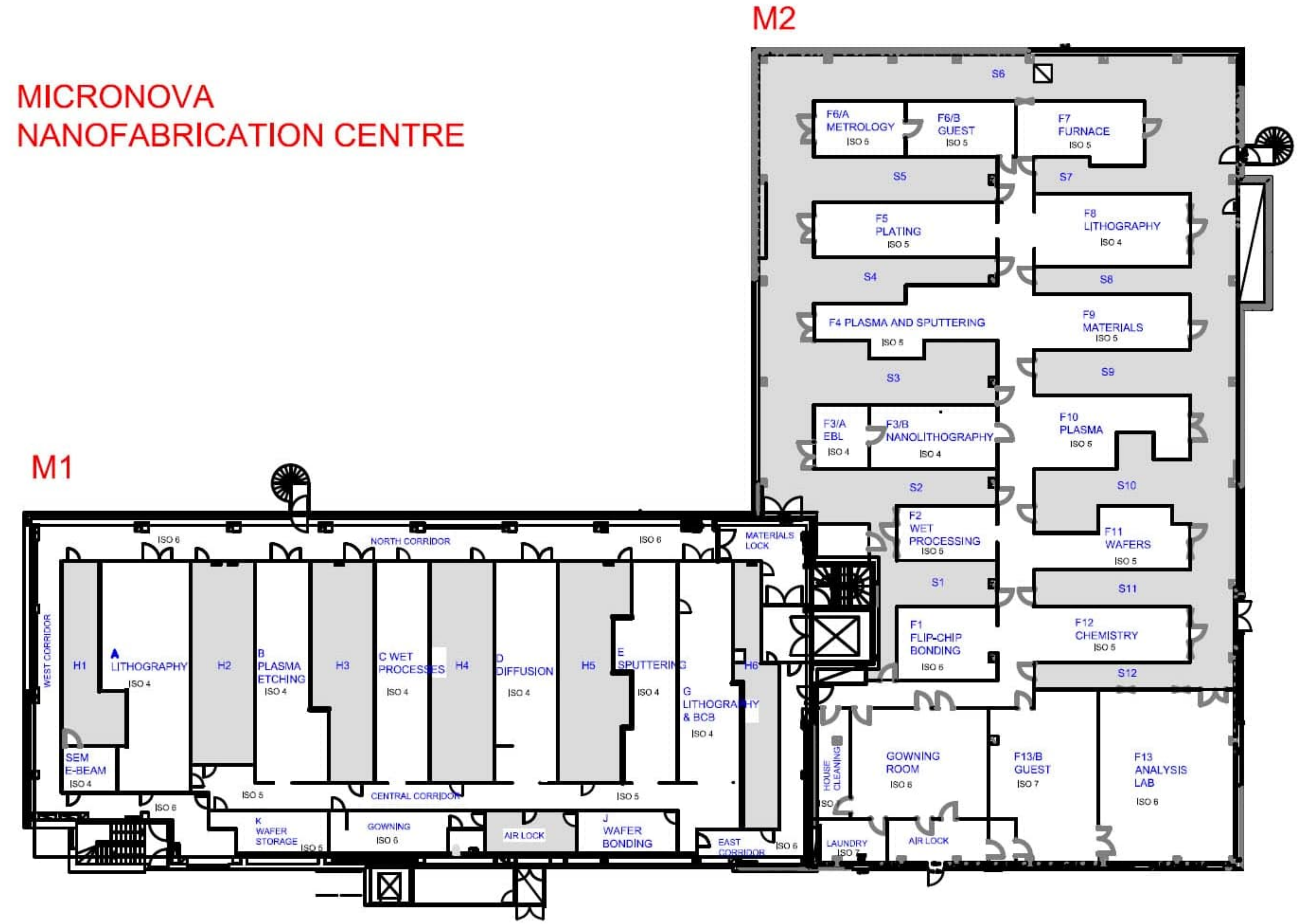
Cleanroom design



Air facilities

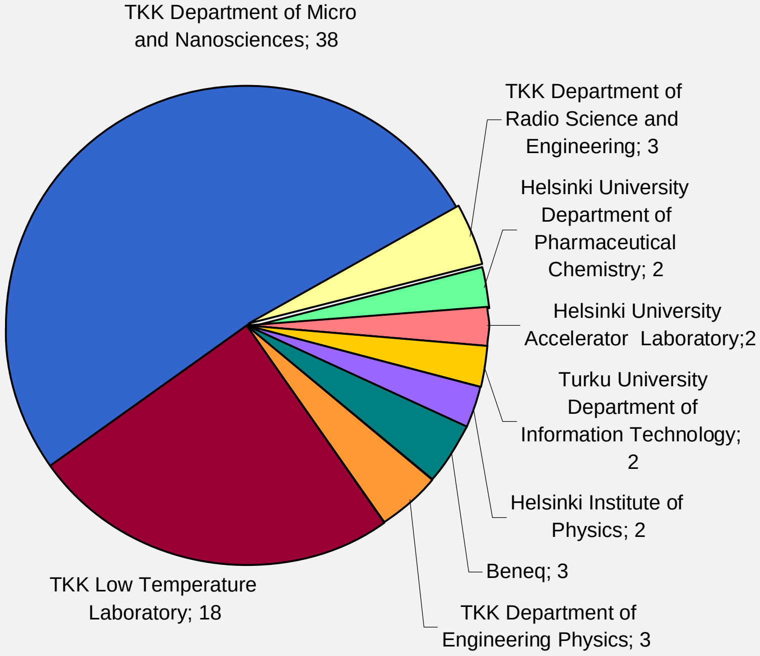
Extraction, conditioning, recirculation (500 air changes per hour), filtration




MICRONOVA
NANOFABRICATION CENTRE
M2
S6
F6/A METROLOGY ISO 5
F6/B GUEST ISO 5
F7 FURNACE ISO 5
S5
S7
F5 PLATING ISO 5
F8 LITHOGRAPHY ISO 4
S4
S8
F4 PLASMA AND SPUTTERING ISO 5
F9 MATERIALS ISO 5
S3
S9
F3/A EBL ISO 4
F3/B NANOLITHOGRAPHY ISO 4
F10 PLASMA ISO 5
S2
S10
F2 WET PROCESSING ISO 5
F11 WAFERS ISO 5
S1
S11
F1 FLIP-CHIP BONDING ISO 5
F12 CHEMISTRY ISO 5
S12
GOWNING ROOM ISO 6
F13/B GUEST ISO 7
F13 ANALYSIS LAB ISO 6
HOUSE CLEANING
ISO
LAUNDRY ISO 7
AIR LOCK
M1
MATERIALS LOCK
ISO 6
NORTH CORRIDOR
ISO 6
WEST CORRIDOR
H1
A LITHOGRAPHY ISO 4
H2
B PLASMA ETCHING ISO 4
H3
C WET PROCESSES ISO 4
H4
D DIFFUSION ISO 4
H5
E SPUTTERING ISO 4
H6
G LITHOGRAPHY & BCB ISO 4
SEM E-BEAM ISO 4
ISO 6
ISO 5
CENTRAL CORRIDOR
ISO 5
K WAFER STORAGE ISO 5
GOWNING ISO 6
AIR LOCK
J WAFER BONDING
EAST CORRIDOR
ISO 6

MICRONOVA cleanroom inside

Cleanroom users



Three colours of overall

Oxidation furnace and ALD reactor

Cleanroom subsystems

- DI-water (UPW) stands for deionized and ultrapure water
- liquid drains
    - acids & bases
    - solvents
    - HF
- vapor exhausts
    - acids & bases
    - solvents
- gas supply:
    - house gases: N_2, O_2, Ar, compressed air
    - specialty gases: SF_6, SiH_4, N_2O, Cl_2
- gas abatement
- gas alarms
- fire alarms

Environment, safety and health (ESH)

- Radiation
  - implanter (X-rays, gamma-rays)
  - plasma tools (microwave energy, UV-radiation)
- High temperature
  - hot plates, furnaces
- Toxic gases
  - implanter, CVD, ALD
- Wet chemical hazards
  - wet etching, wafer cleaning, plating baths
- Fire
  - detection, extinguishing

Gases

- H_2 explosive
- SiH_4 self-igniting
- AsH_3, PH_3, Cl_2, BCL_3, toxic
- BF3 corrosive

Chemicals

- corrosive chemicals (acids, bases)
- strong corrosive chemicals (HF)
- hot chemicals (80^{o}C baths)
- toxic chemicals (old resist solvents)

Fires

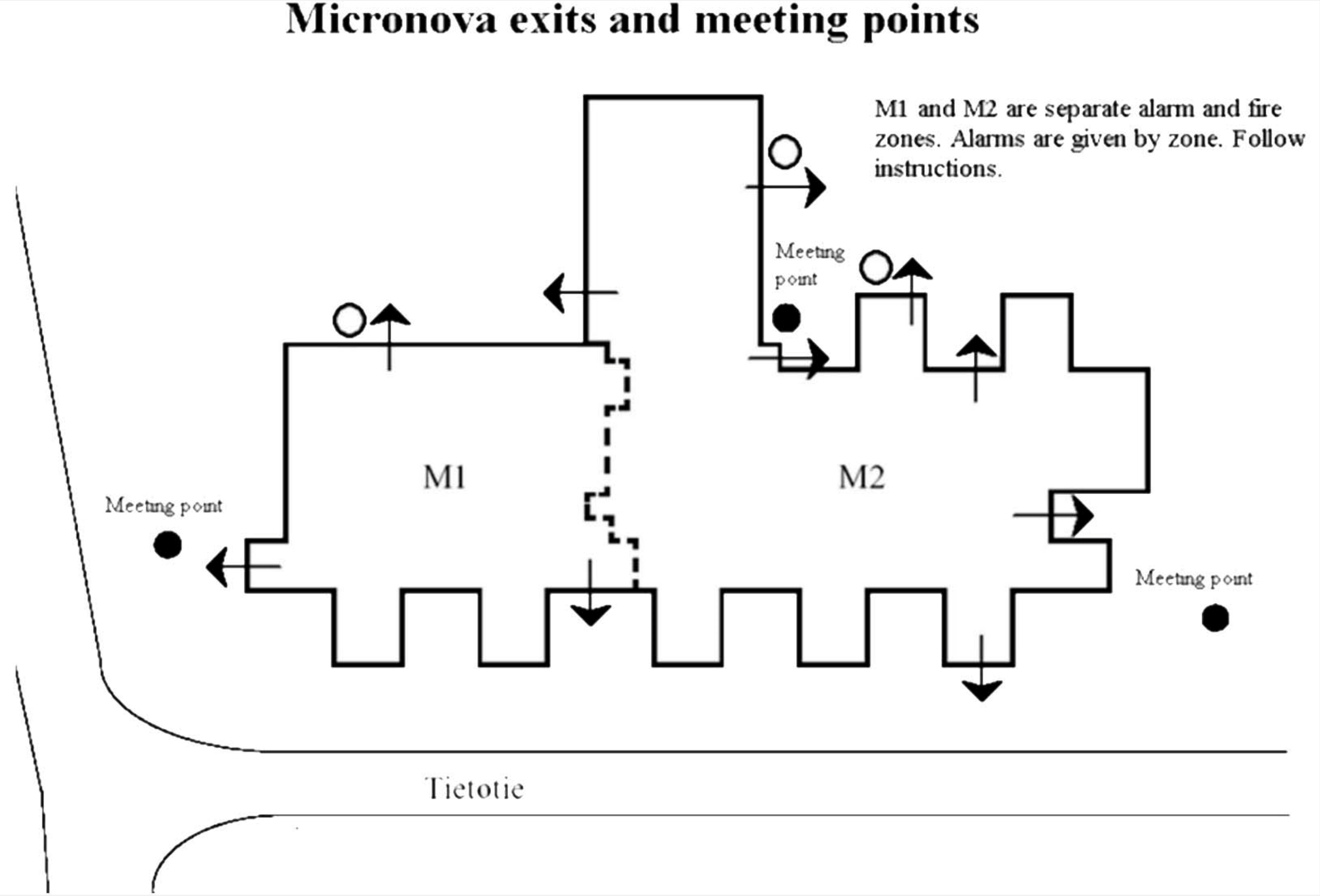
- Lots of hot chemical baths
- Lots of high temperature equipment
- Lots of electrical equipment

- Cannot use powder extinguishers !!
- Even small amount of smoke will cause major damage

Other safety matters

- High voltage (200 kV in ion implanter)
- Solvent vapors
- Wafer cleaving
- Spills and leaks can be anywhere !

In case of alarm…



Do we need cleanroom?

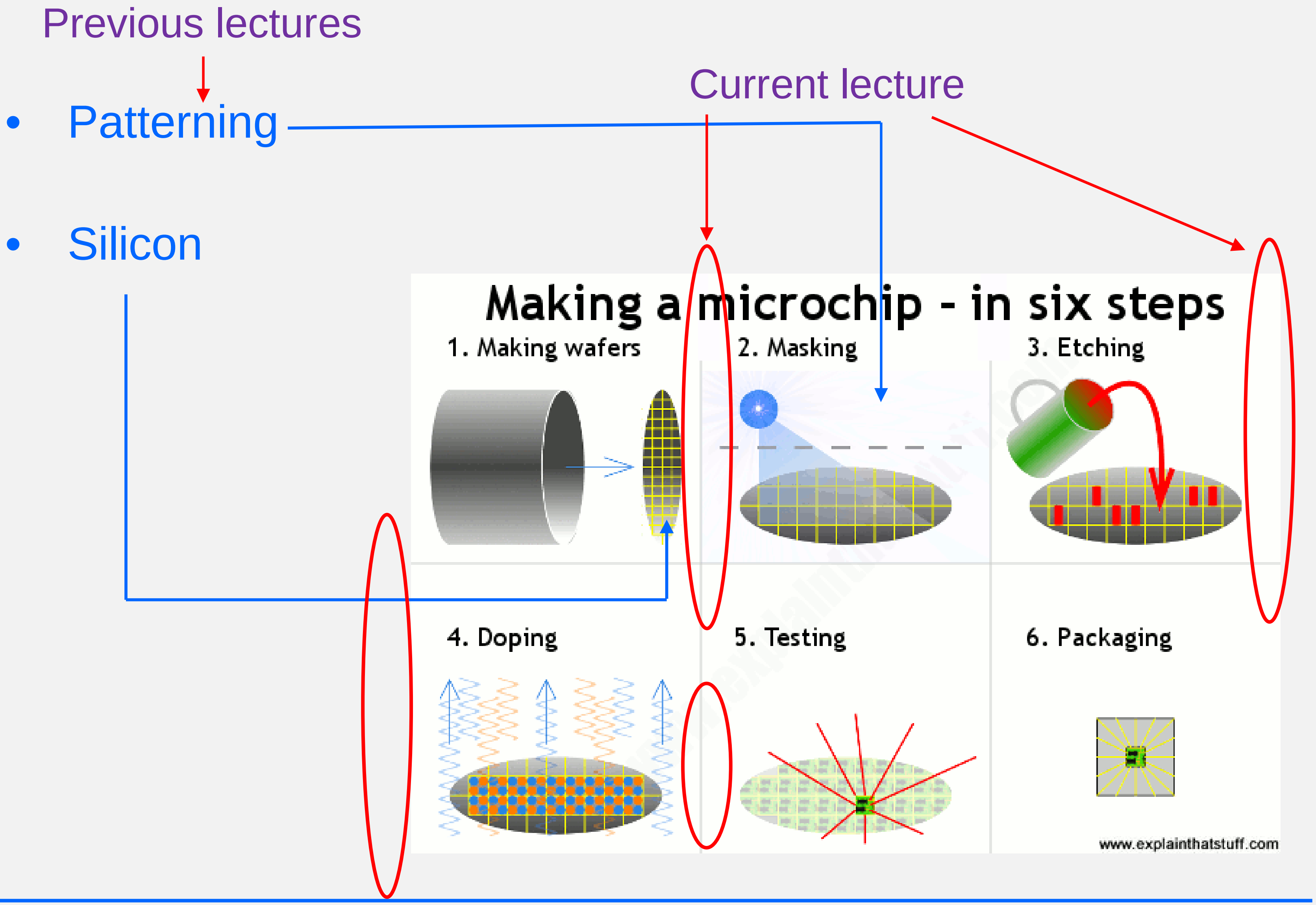
- Expenssive
- Large in size
- Fire and toxicity hazards
- Special overall for operators
- Special staff to support all systems

- Mini-Environments:
  - load wafers and take out ready chips

Summary I

- Microfabrication is impossible without cleanroom environment
- Cleanroom (and its subsystems) provide passive cleanliness
- A cleanroom is expensive in construction and in maintenance

Cleaning



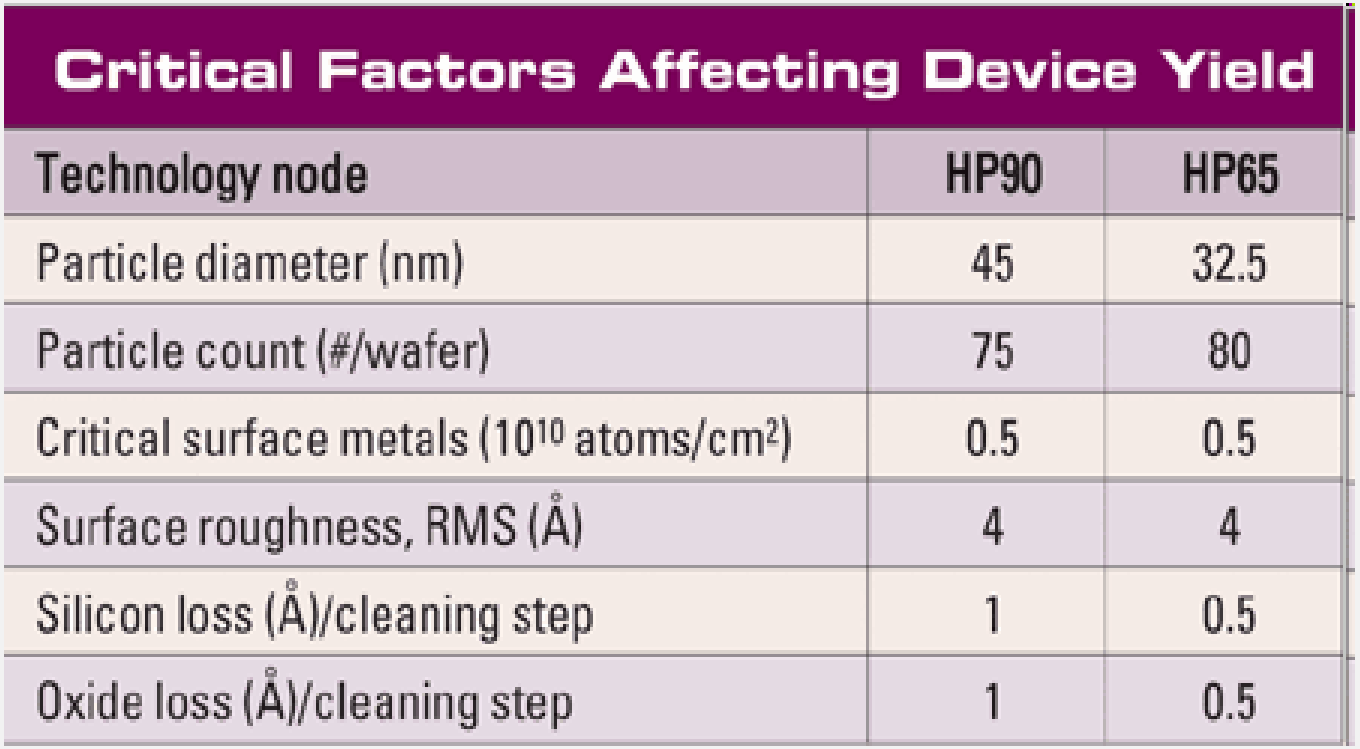
Previous lectures

- Patterning
- Silicon

Current lecture

Making a microchip - in six steps

Critical factors of device yield



Critical Factors Affecting Device Yield

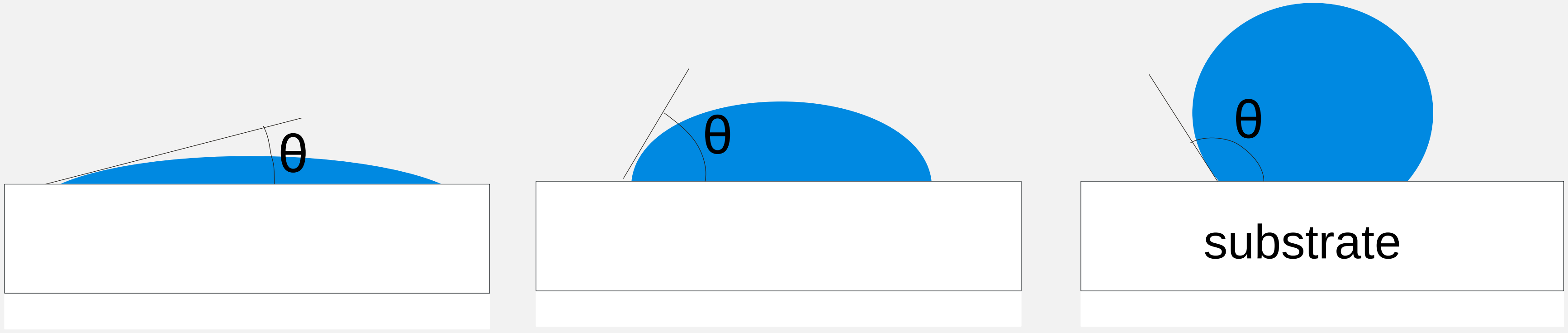
Technology node	HP90	HP65
Particle diameter (nm)	45	32.5
Particle count (#/wafer)	75	80
Critical surface metals (10^{10} atoms/cm^2)	0.5	0.5
Surface roughness, RMS (Å)	4	4
Silicon loss (Å)/cleaning step	1	0.5
Oxide loss (Å)/cleaning step	1	0.5

Wafer cleaning and surface preparation

- Wafer cleaning
    - removal of added contamination
    - chemically clean
    - particle-free
- Surface preparation
    - known surface condition
    - independence of previous step
    - independence of wait time

Contact angle θ and wettability, 0°< θ<180°

Flat surface

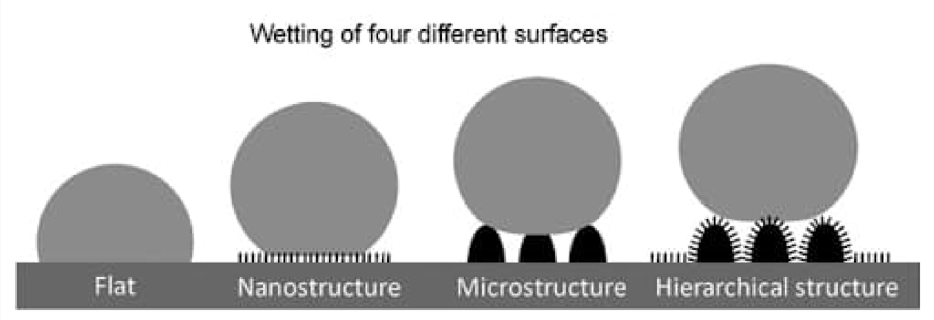


wettable,
hydrophilic
Θ<90°

non-wettable,
hyhdrophobic
Θ>90°

superhydrophobic
Θ>150°

Engineered surface:



Contamination forms and harmfulness

- -particles –> patterning, growth
- -metals (atomic and ionic contamination) –> Si electronic properties, oxide quality
- -organics (molecules and molecular films) –> contact resistance, growth
- -native oxide (nanometer films) –> growth, contact degradation
- -surface roughness –> growth, patterning

Contamination sources

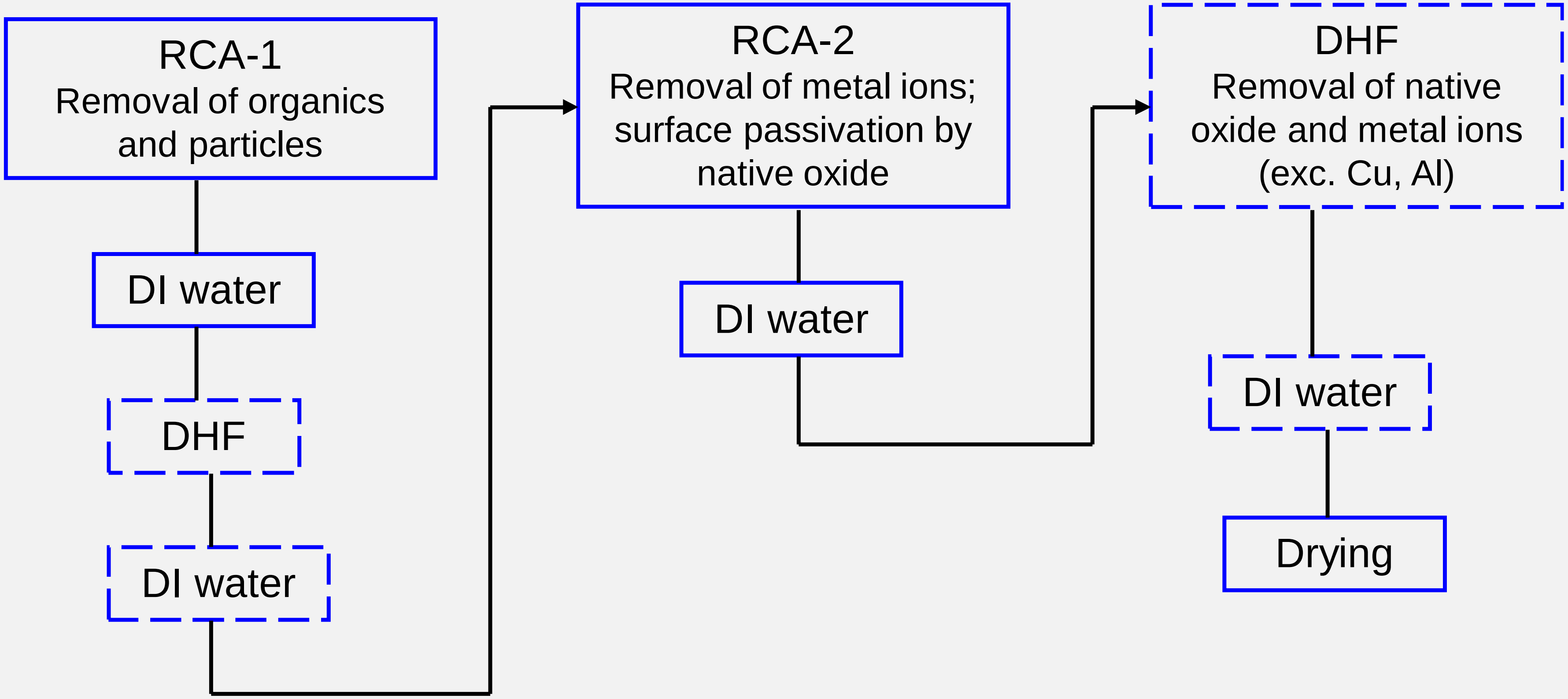
- -reaction (by)products in e.g. etching or CVD
- -flaking of films from chamber walls
- -sputtering of wall materials
- -wafer transport: mechanical handling, chucking/clamping
- -jigs: wafer boats (quartz), polypropylene/teflon cassettes
- -wafer itself: chipping and breakage
- -maintenance: cleaning of chambers and transport mechanisms

Wet cleaning solutions

- **RCA-1** **$NH_4OH:H_2O_2:H_2O$ (1:1:5)**
  - SC-1, standard clean; 50-80ºC, 10-20 min
  - APM; ammonia-peroxide mixture
- **RCA-2** **$HCl:H_2O_2:H_2O$ (1:1:6)**
  - SC-2; standard clean-2; 50-80ºC, 10-20 min
  - a.k.a. HPM, hydrogen chloride-peroxide mixture
- **SPM** **$H_2SO_4:H_2O_2$ (4:1)**
  - sulphuric peroxide mixture; 120ºC, 10-20 min
  - a.k.a. Piranha
- **DHF (dilute HF)** **$HF:H_2O$ (1:100-1000)**

  room temperature, 1 min

Cleaning procedure



RCA-1
Removal of organics and particles

DI water

DHF

DI water

RCA-2
Removal of metal ions; surface passivation by native oxide

DI water

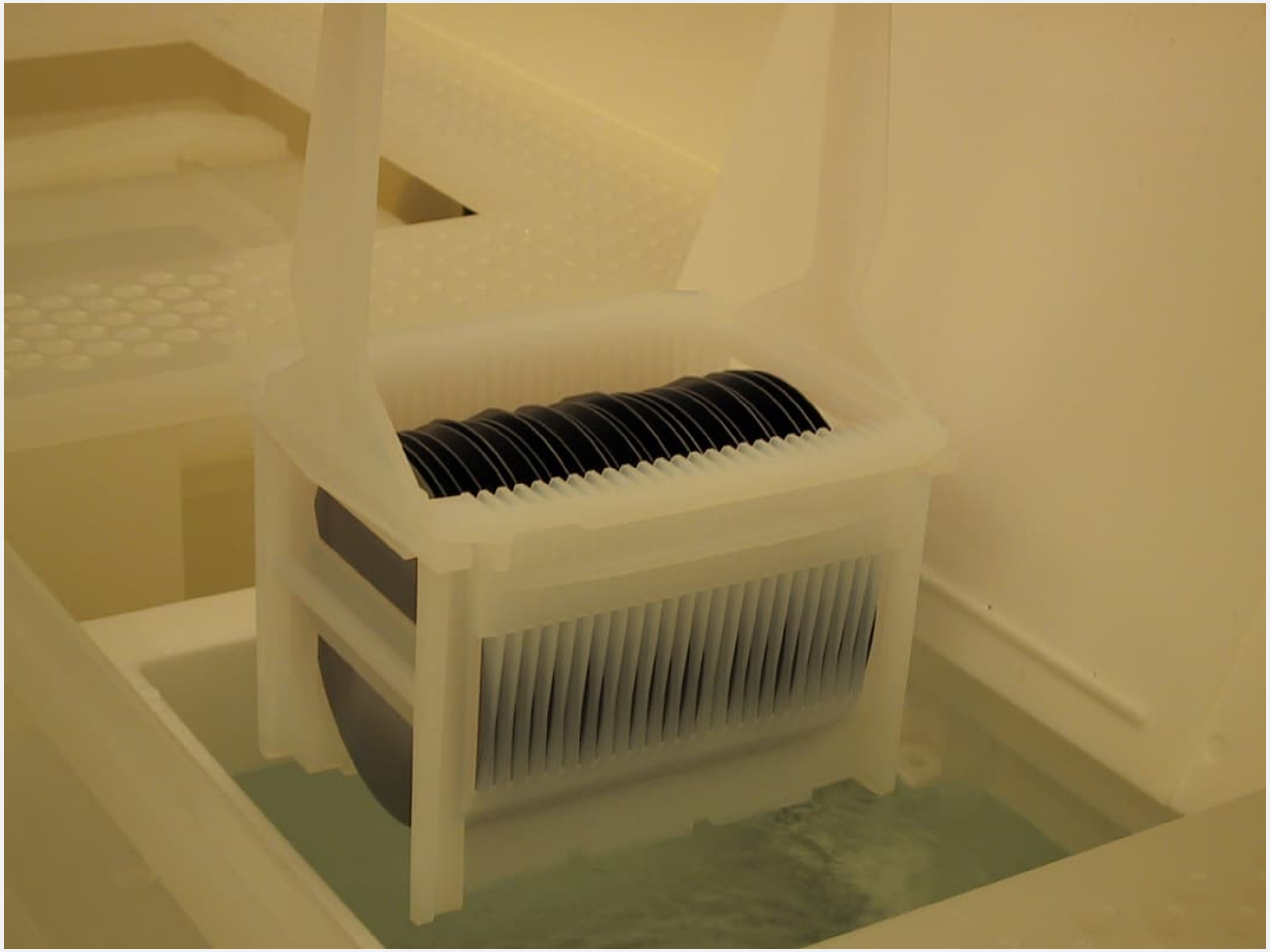
DHF
Removal of native oxide and metal ions (exc. Cu, Al)

DI water

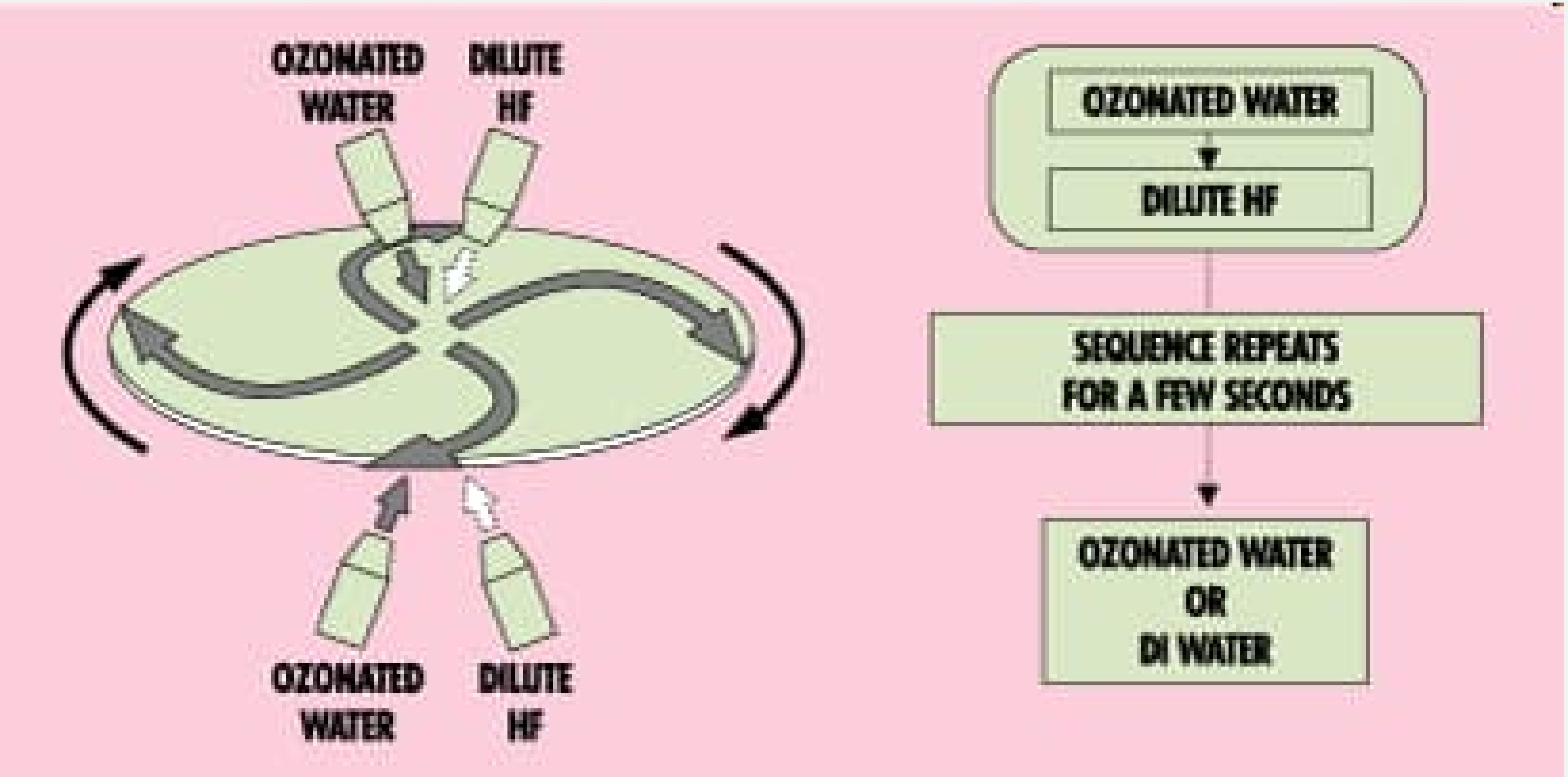
Drying

Wet bench

Wafer cassette, batch cleaning

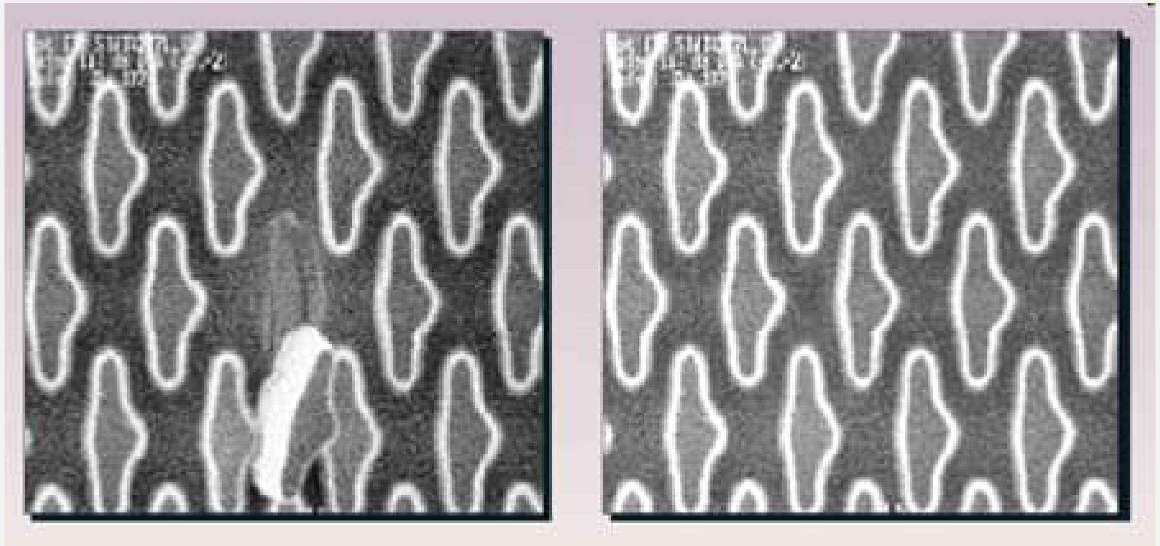


Single wafer cleaning



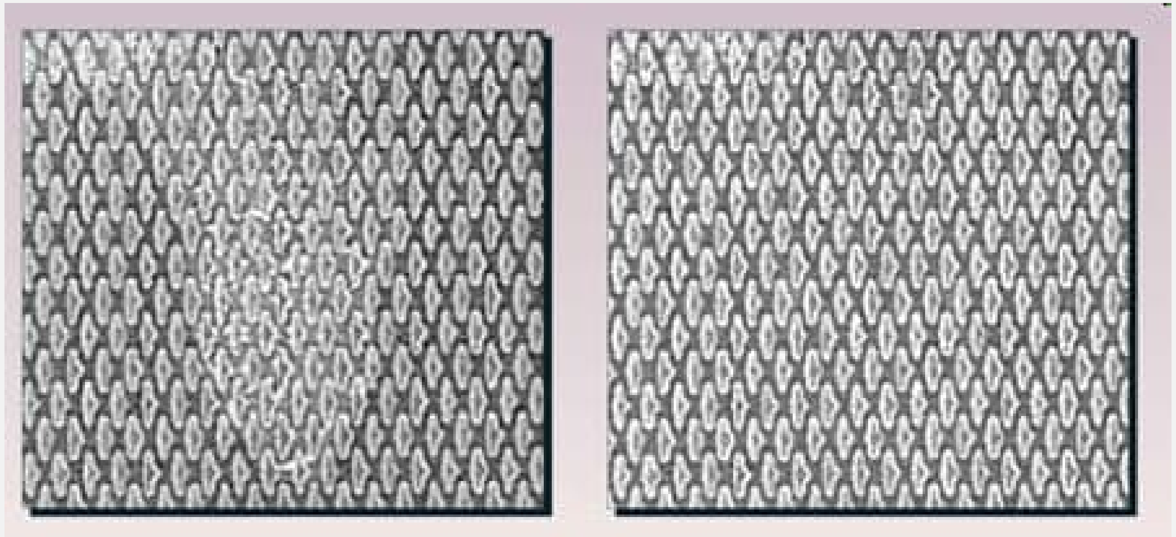
The repetitive use of ozonated water and dilute HF in the SCROD process

Clean defects



Megasonic cleaning in a batch immersion tool shows megasonic-induced damage of a 92 nm STI 300 mm wafer after an SC1/rinse/HF/rinse/dry process

Watermarks for a non-optimized cleaning and drying process on an 82 nm deep trench isolation structure on a 300 mm wafer.



Finishing clean

- In situ NF_3/NH_3 remote plasma preclean
- Ar sputter preclean

- Remember about sputtering of chamber walls!

Typical analysis methods of wafers

Object	Analytical method
Particles	Laser scattering, SEM, EMPA, AES
Metals	TXRF (total reflection X-ray fluorescence), GFAAS (grafite furnace atomic absorption spectroscopy), ICP-MS
Organics	FTIR, TDS, TOF-SIMS
Moisture	TDS (thermal desorption spectroscopy)
Native oxide film (terminated states)	XPS, FTIR, TDS
Microroughness	AFM, STM, laser scattering

Summary II

- Microfabrication is impossible without cleaning and surface preparation

- Wafer cleaning is active cleaning