

Yields and Predictability in fabrication

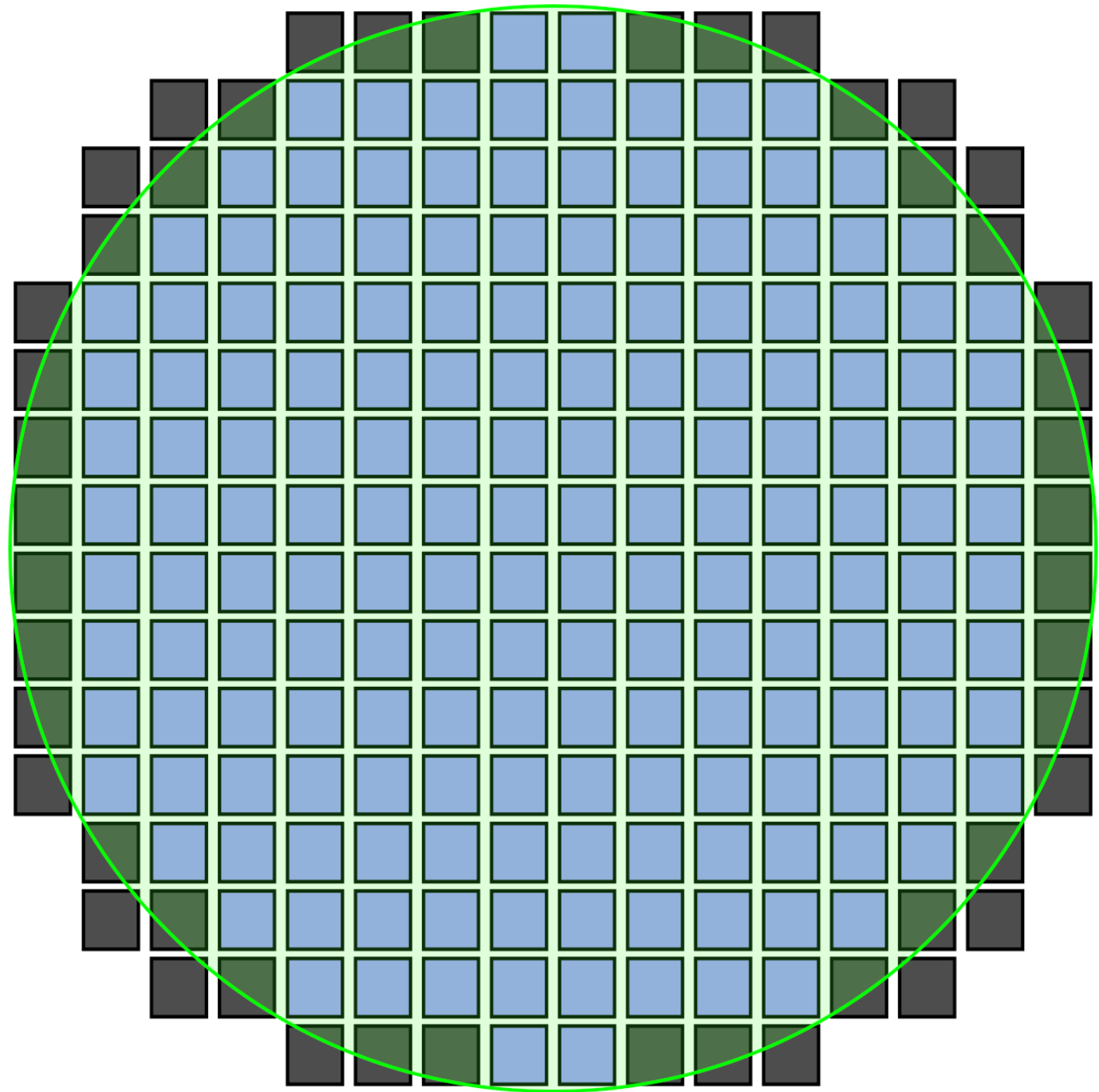
Wafer and Dies

- A Si wafer which is typically > 12" in dia
- A die is a small repeating unit made on the wafer
- Of all the dies only a fraction of dies survive the fabrication process.

$$\gamma_d = \gamma_f * \gamma_p * \gamma_a * \gamma_{bt}$$

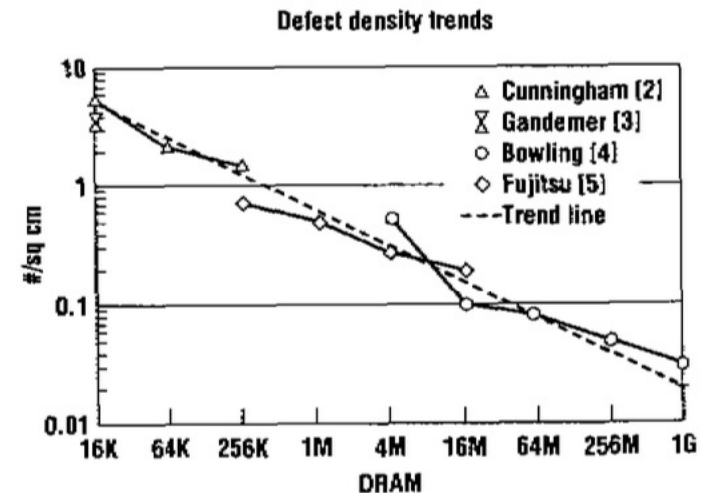
- (i) Wafer yield
- (ii) Process yield
- (iii) Assembly yield
- (iv) Burn test yield

Yield = no.of chips "normal"/no. of chips produced.



The Economics of yields.

- Consider a factory that does 1000 wafers a week
- Each wafer contains 100 die
- When packaged, it sells for 50 \$.
- When the yield is 30%, gross income is 75 M\$.
- When the yield is 50%, the gross income is 125 M\$.
 - With the same inputs.!
- Defects seem to decrease with increase in scale and improvements in technology

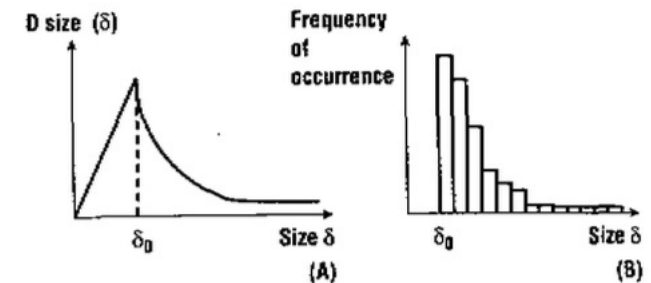
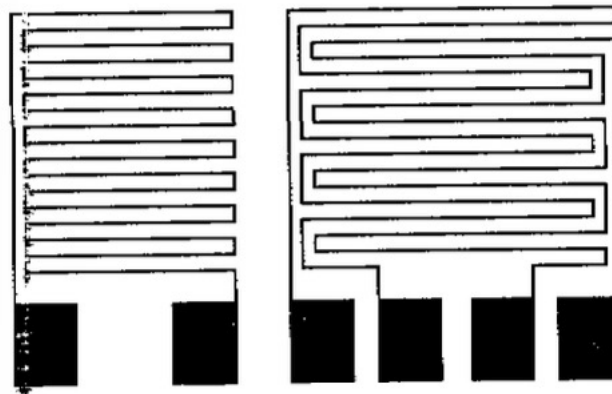
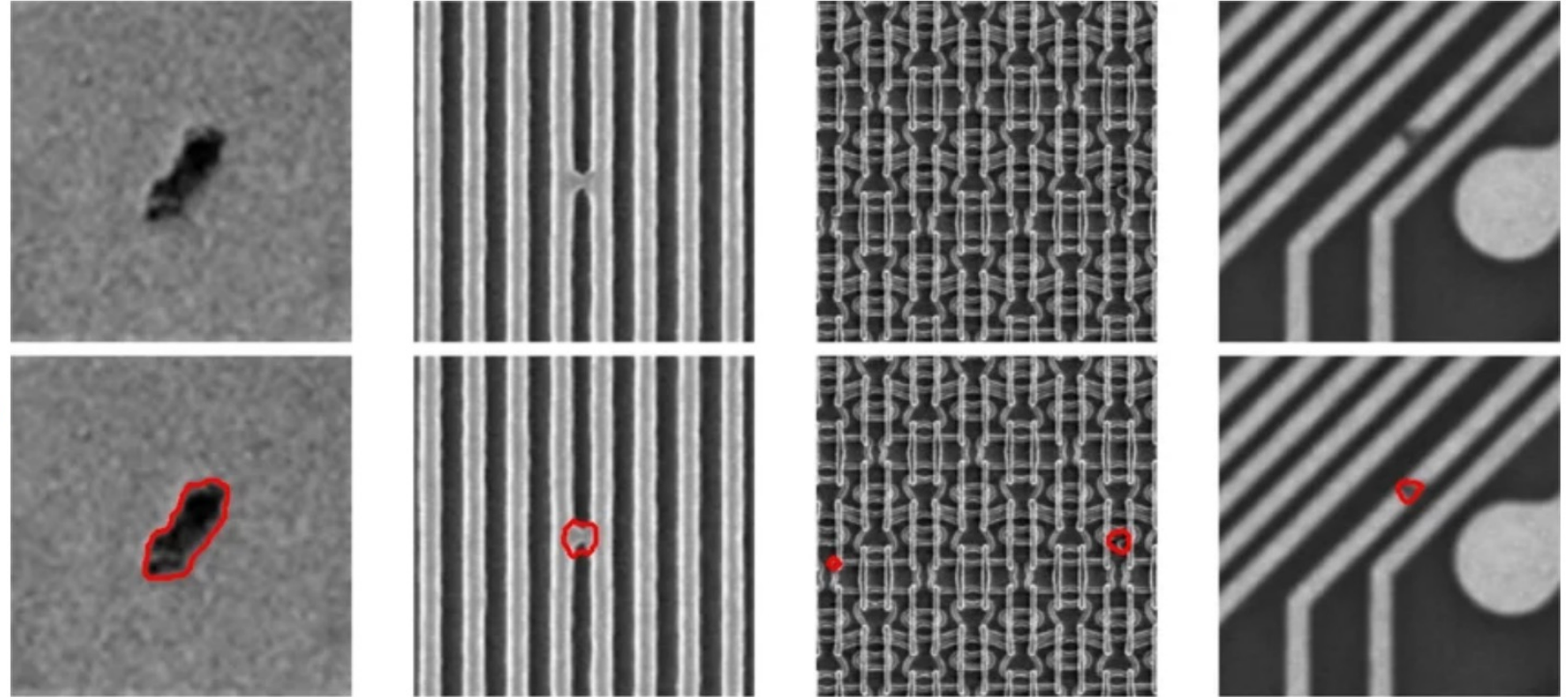


Yields losses - Causes

- Defects
 - Statistical in nature
 - Needs process maturity
 - Eg: Particles, contaminants, macro defects
- Parametric losses
 - Errors in film thickness, feature sizes, resist composition
 - This is a major source of yield loss

Defects

- Benign and killing defects
- Sometimes a smaller defect is more harmful than a larger gap.
- Sometimes, the defect propensity can be measured.

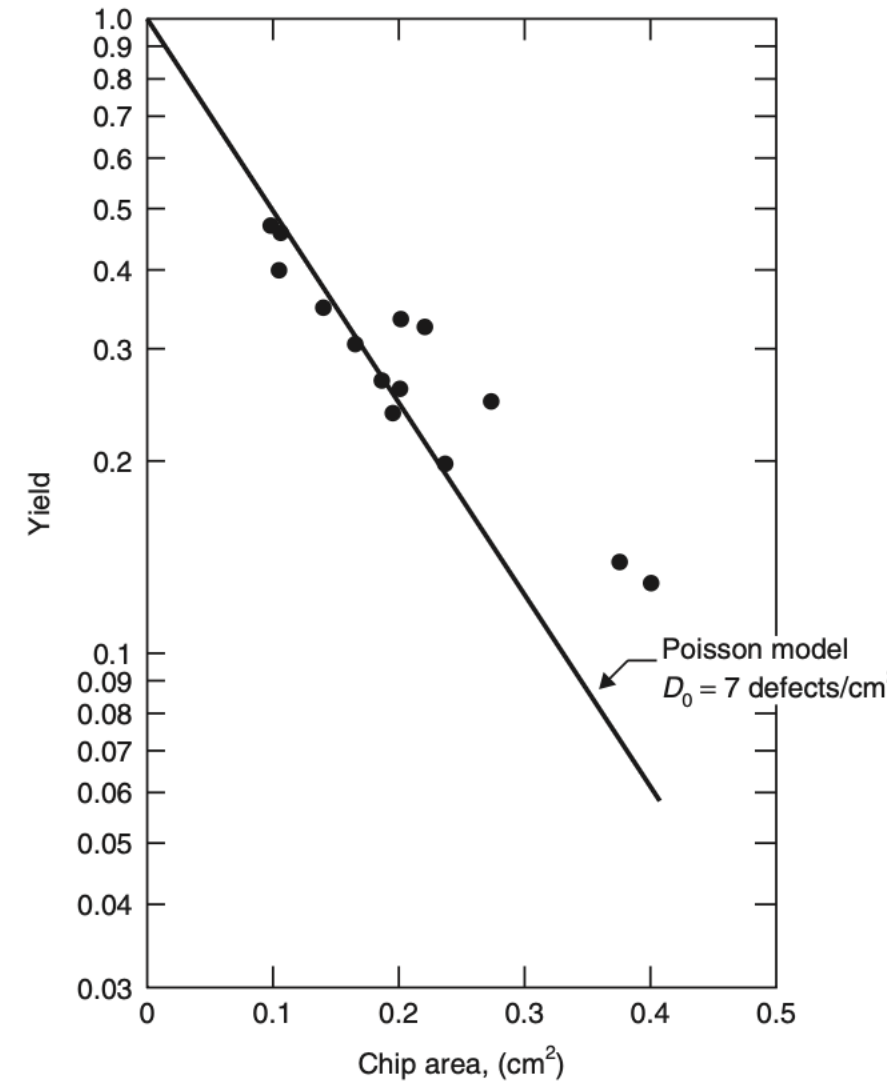


Defect Models

- D_0 Defect density in cm⁻²
- α clustering coefficient
- A – Chip size

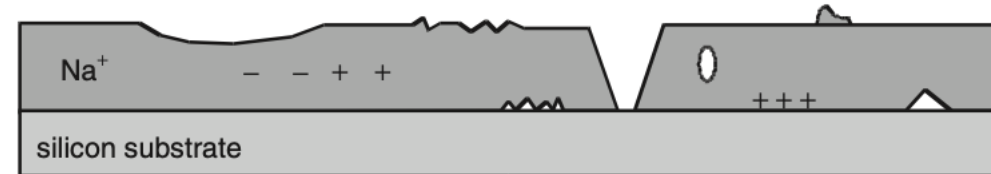
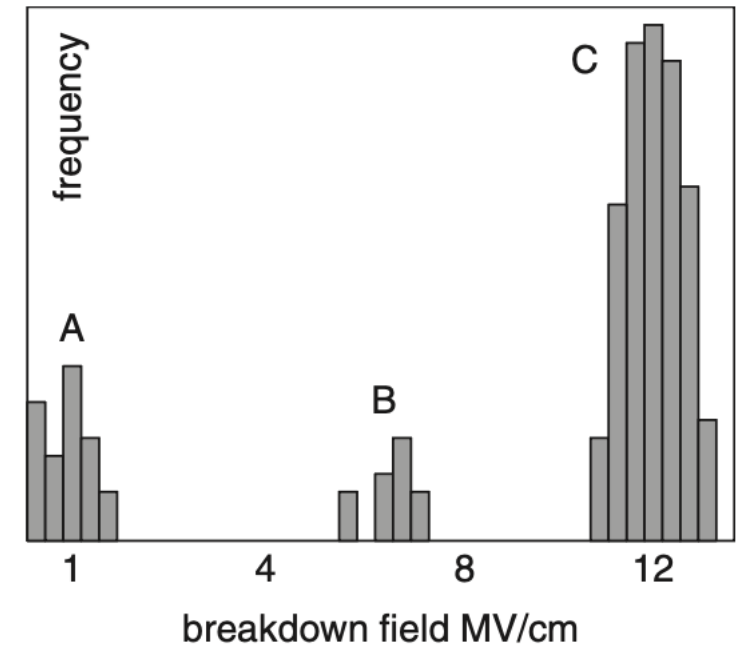
$$\text{Yield } Y = \left(1 + \frac{AD}{\alpha}\right)^{-\alpha}$$

There are other models such as Seed's model and the Murphy's model



Dielectric Defects and failure

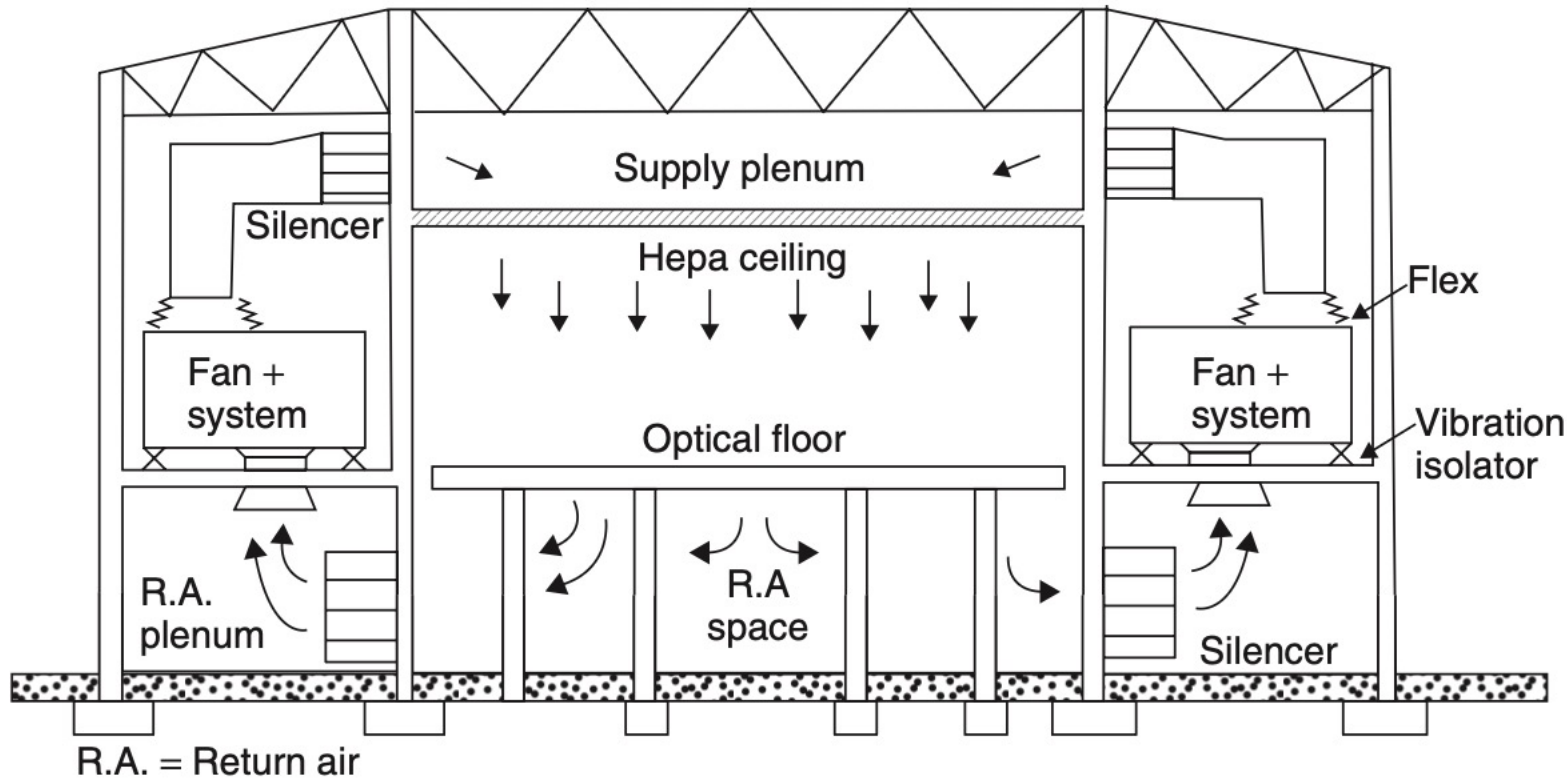
- Oxide breakdown field $> 10\text{MV/cm}$ is good.
- However, defects and other impurities lead to several other effects.
- A mode failure are gross defects (Yield defect)
- B mode are oxide thinning and contamination (Reliability problem)
- C Mode – long-term failure causes.



General Clean Room

Table 35.1 Simplified Fed. Std 209D airborne particle cleanliness classes (particles/ft³)

Class	1	10	100	1000	10 000
No. of particles 0.5 μm	1	10	100	1000	10 000
No. of particles 0.1 μm	35	350	3500	35 000	350 000



Class N with concentration C_n

$$C_n = 10^N \times \left(\frac{0.1 \mu m}{D} \right)^{2.08}$$

D – particle size in μm

Eg: Class 100 means 100 particles ft³



Particles settling on wafer

- Settling velocity = $u_g = \frac{\rho g d_p^2}{18\mu}$
- μ air viscosity
- g acceleration due to gravity
- d_p – particle diameter.
- If n is the particle density, then the sample deposition rate is:

$$J = nu$$

A typical settling velocity is 10^{-3} cm/s.

Other essential clean room utilities

- DI water
- Ultra-pure gas systems
- Air handling systems

Table 35.5 Toxic gases in semiconductor manufacturing

	TLV (ppm)	IDLH (ppm)	Other properties
NH ₃	25	300	DO: 0.04–50 ppm
Cl ₂	0.5	10	DO: 0.03–0.4 ppm
HCl	5	50	
HF	3	30	
BF ₃	1	25	^a
SiH ₄	5	N/A	ER: 1.37–96%
GeH ₄	0.2	N/A	
SiCl ₂ H ₂	^b	N/A	ER: 4.1–99%
AsH ₃	0.05	3	DO: 0.5–4 ppm, garlic
PH ₃	0.3	50	DO: 0.01–5 ppm, fishy
B ₂ H ₆	0.1	15	DO: 1.8–3.5 ppm, sweet

Table 35.4 Production of DI water

- Sand filter
- Active carbon filter
- Particle filtering at 3 μm
- Softening of water
- RO: reverse osmosis
- CEDI: continuous electrical deionization
- UV treatment
- Ion exchangers
- Particle filtering at 0.2 μm
- Storage tank
- Continuous DI water circulation in the cleanroom loop