

Reduction of Process Chemicals and Energy Use in Single-Wafer Process Applications

Jim Snow, Charles Miller, Rey Tanaka, Jun Shibukawa, Nukui Hiroki,
Yamamoto Tetsuya, Hayashi Masayuki, Shibayama Nobuyuki, and Endo Toru



SCREEN Semiconductor Solutions Co., Ltd.

80th
Anniversary

Agenda

◆ Background

- Environmental Impact of Semiconductor Industry

◆ Approaches

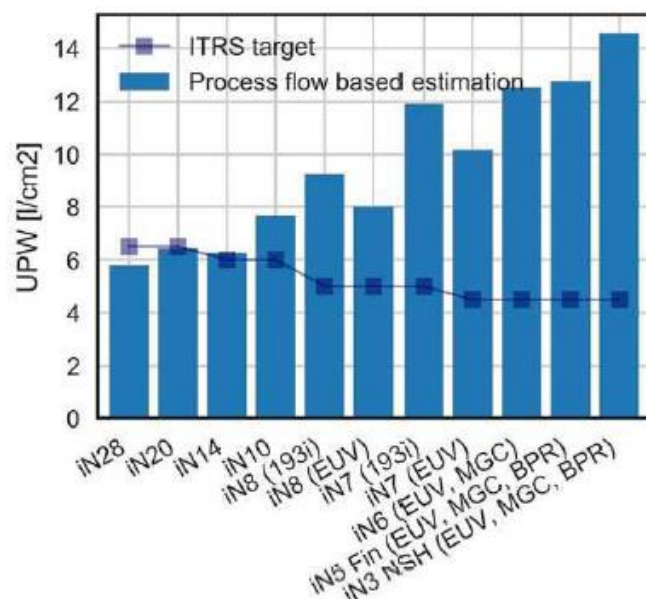
- Hot UPW Recirculation
- Ozonated UPW Reclaim
- SPM Reuse

◆ Conclusions

Relationship between Process Miniaturization and Environmental Impact in the Semiconductor Industry

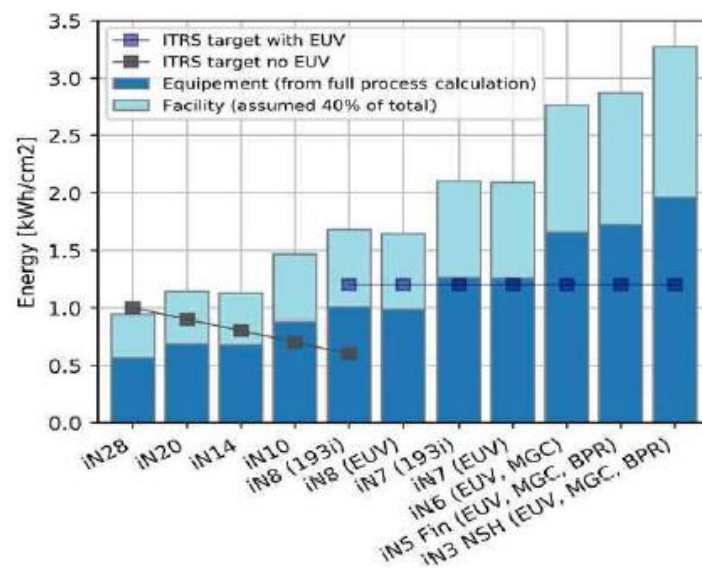
As miniaturization progresses, the number of wafer processing processes increases, which in turn increases the amount of ultrapure water (UPW) and electricity used, and CO₂ emissions also increase.

UPW



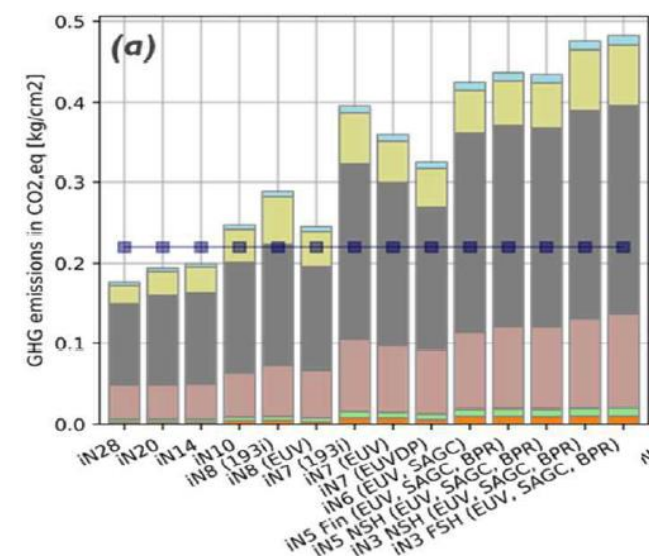
Total Ultra Pura Water(UPW) usage in liters per cm² for full process flows from IN28 to IN3 for 300mm wafer equivalent. ITRS guidelines shown as reference.

Energy



Total manufacturing electricity per cm² for full process flows (300mm wafer = 706cm²). Facility energy is projected assuming 40% of the total energy.

CO₂



GHG emissions in kg CO_{2eq} per cm² of wafer, per node, calculated using the GHG protocol for electronics industry of IPCC.

Chemical Use in Wet Processing Equipment

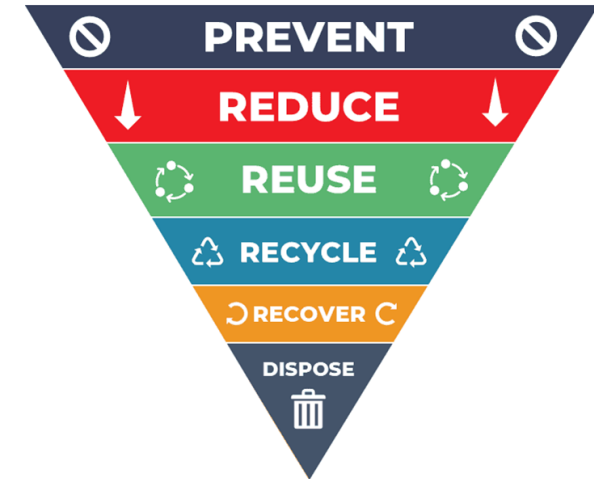
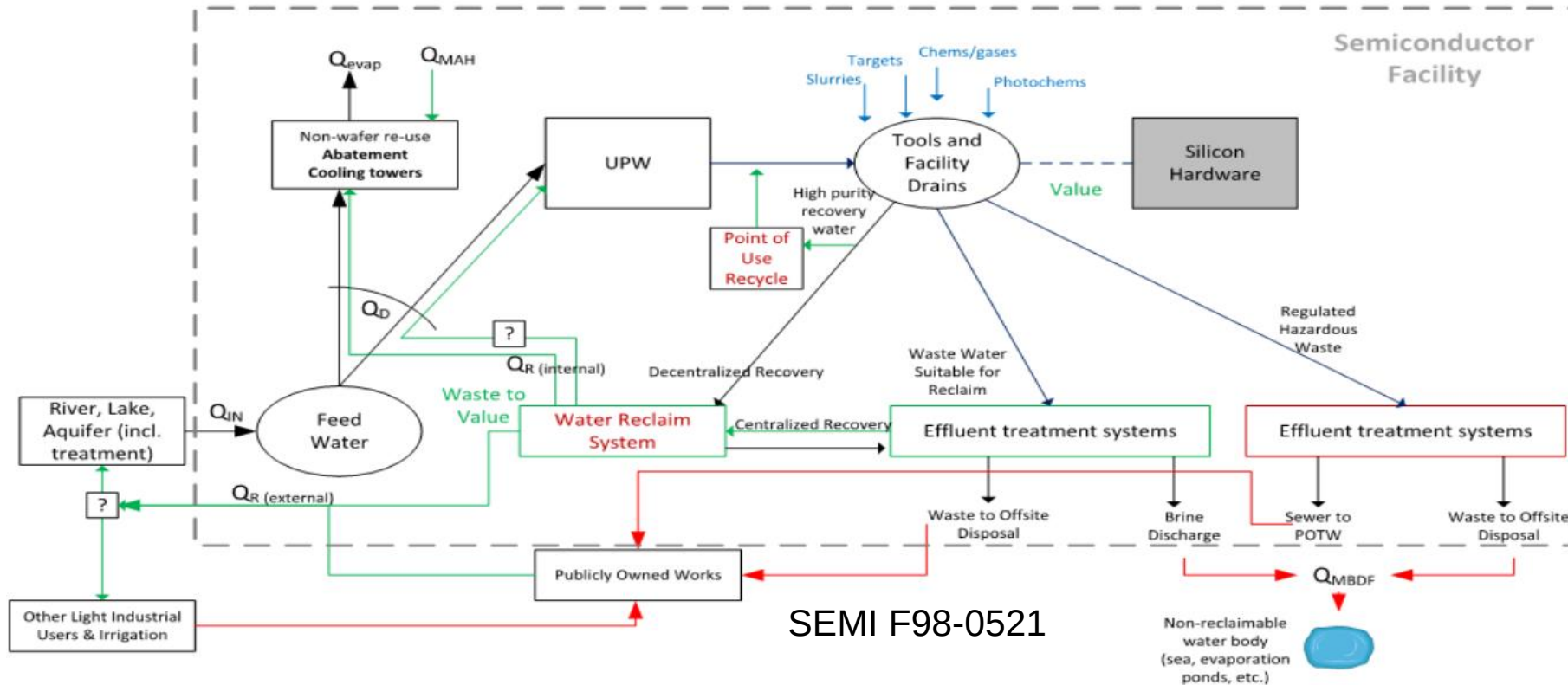
◆ Semiconductor Industry is a significant consumer of UPW

- Modern 300mm wafer fabrication facility can use up to 40 million liters a day, which is equivalent to water consumption of 300,000 households
- Majority use is in wet chemical processing (wafer cleaning, wet etch, CMP)
 - Chemical dilution for process; sometimes heated
 - Heated or room temperature rinse of product wafer
 - Ozonated water for oxide growth or removal of organic contaminants

◆ Sulfuric acid has a large impact on the cost of chemicals and environmental aspects.

- One of the most widely used chemicals in the fab; can be up to 90% of facility acid load
- Needs to be neutralized but limits on sulfate discharge to sewer water
 - Results in expensive brine management systems
- Annual consumption is expected to increase due to increase in the number of processing steps and demand for electronic devices worldwide.

How Can We Conserve Water?



◆ Reduce

- Reduce tool water usage

◆ Reuse

- Reuse rinse water and purges from tools for non process use
 - Up to 88% can reclaimed in cooling and scrubbers
- Treat and reuse wastewater for non process use

◆ Recycle

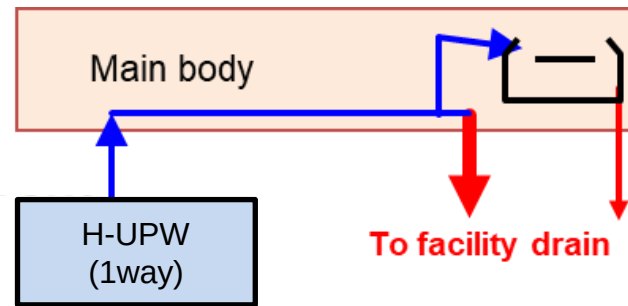
- Recycle water at tool or point of use
- Recycle reclaim water to UPW for process use

Hot UPW Recirculation

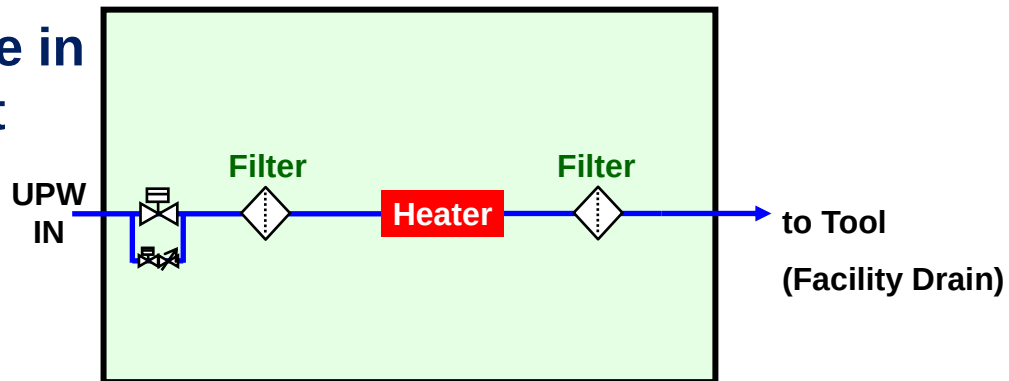
Hot UPW Circulation Unit

- Previously hot UPW used to be sent continuously to drain (one way).
- Now the H-UPW can be collected from the tool in a circulation tank, reheated to the set point, filtered again and returned to the tool.

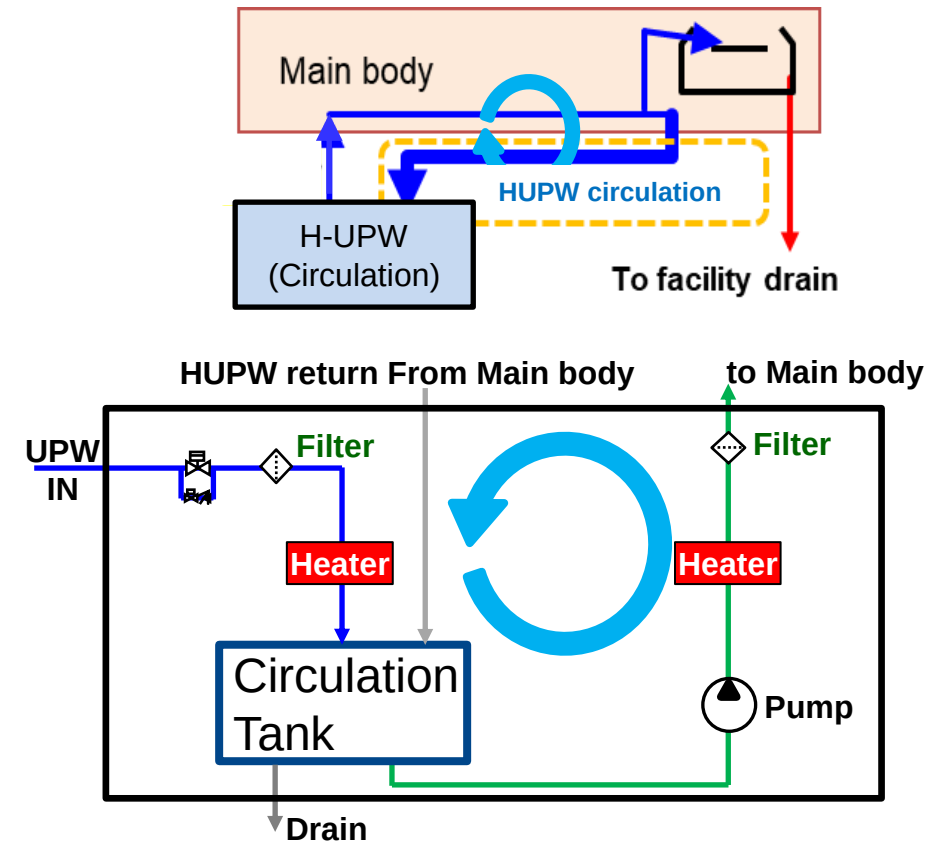
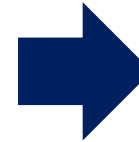
Overall Flow outline



Flow outline in H-UPW unit

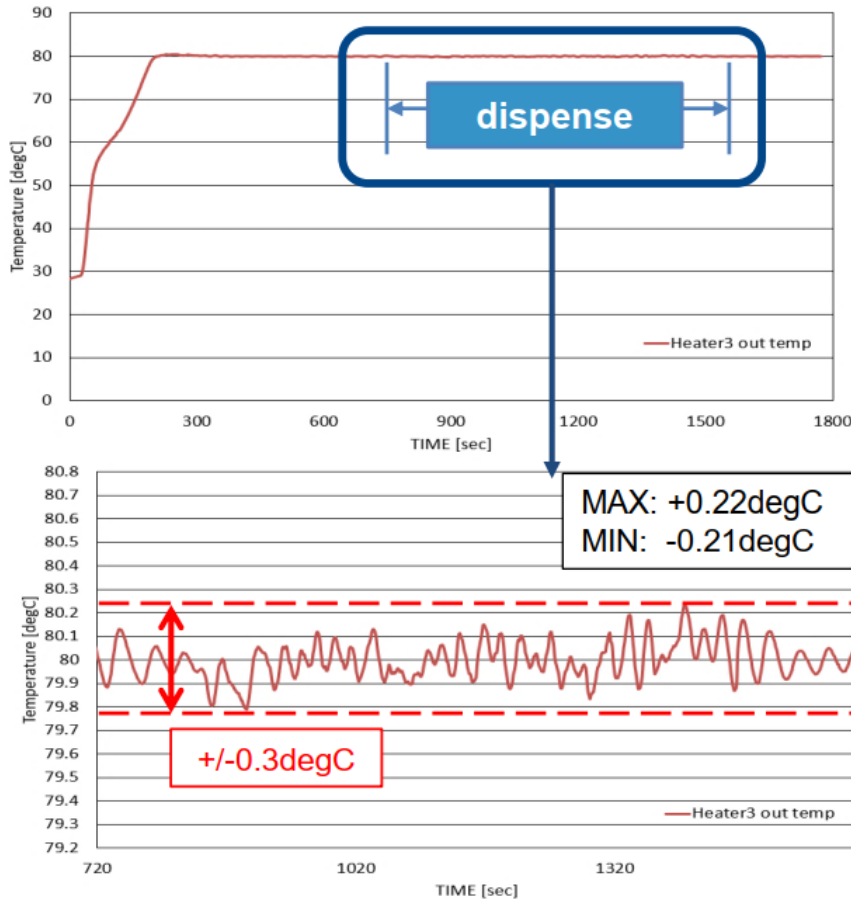


One way unit

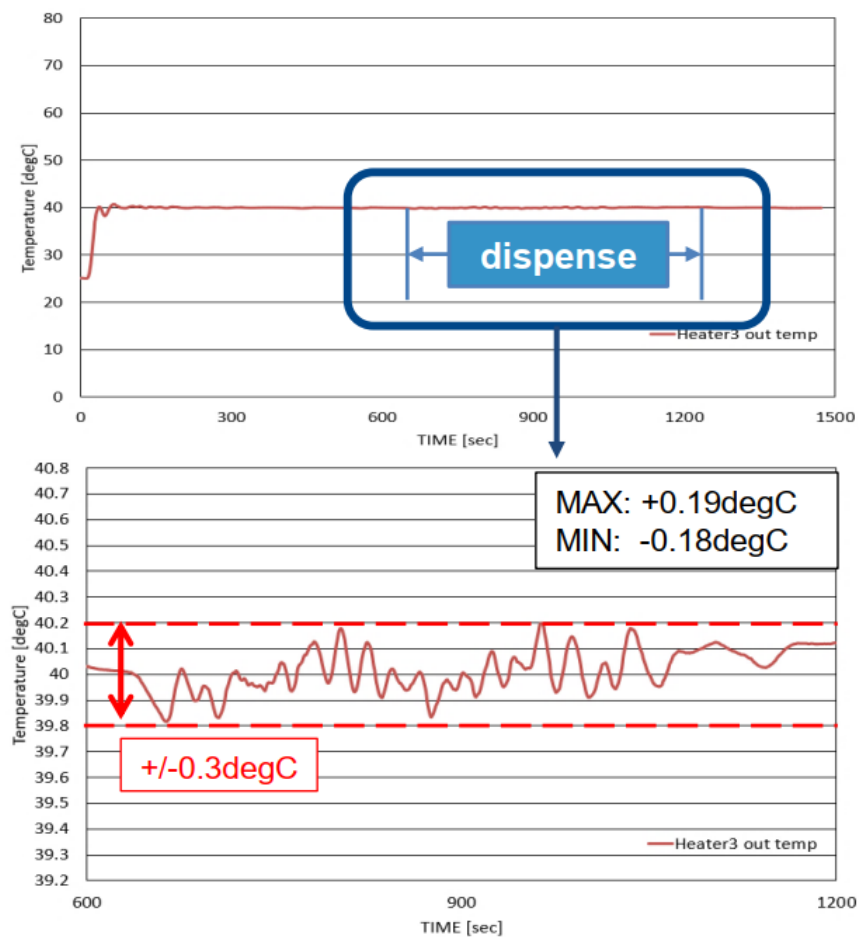


Circulation unit

Recirculated H-UPW Maintains Stable Temperature



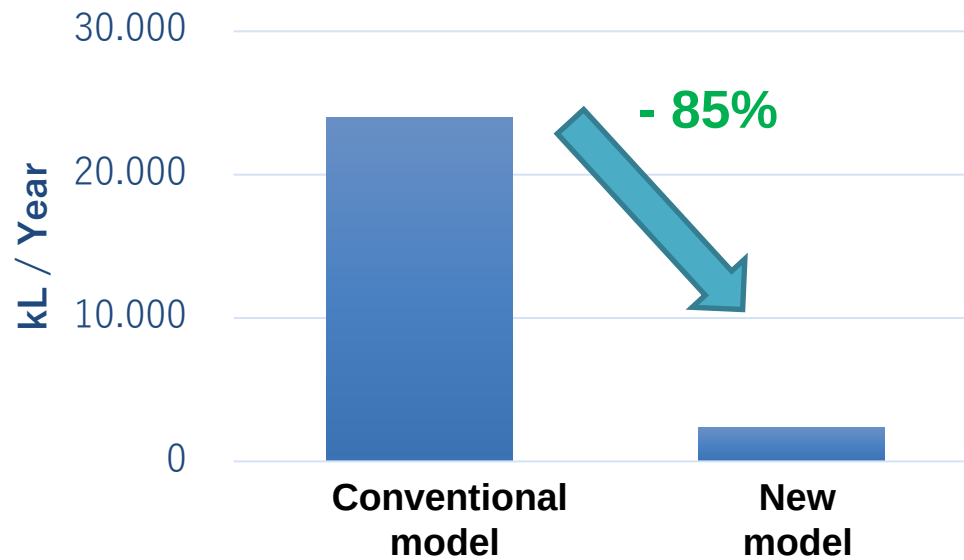
10 L/min @ 80C



35 L/min @ 40C

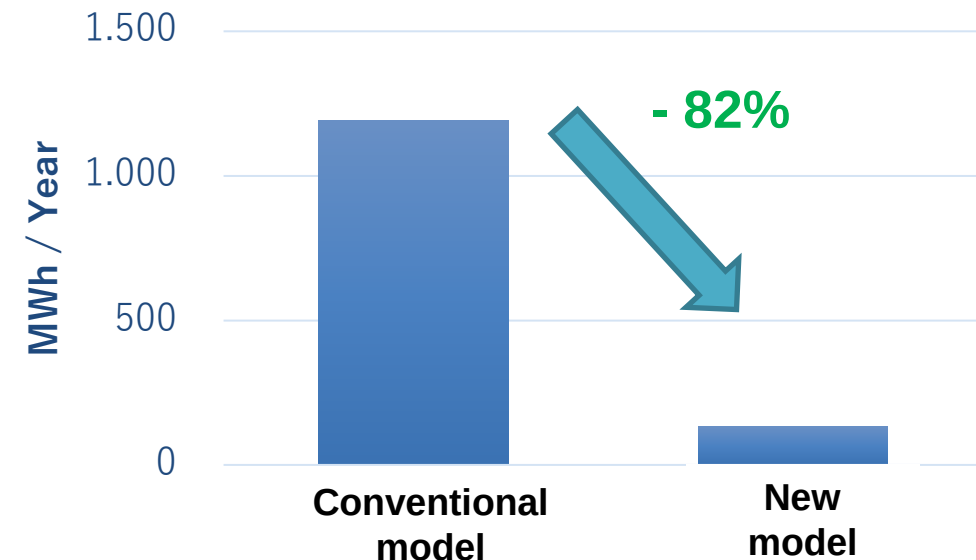
Hot UPW Recirculation Reduces UPW & Energy Consumption

UPW



**UPW usage >
Reduced by 20,000 kL/year**

Energy

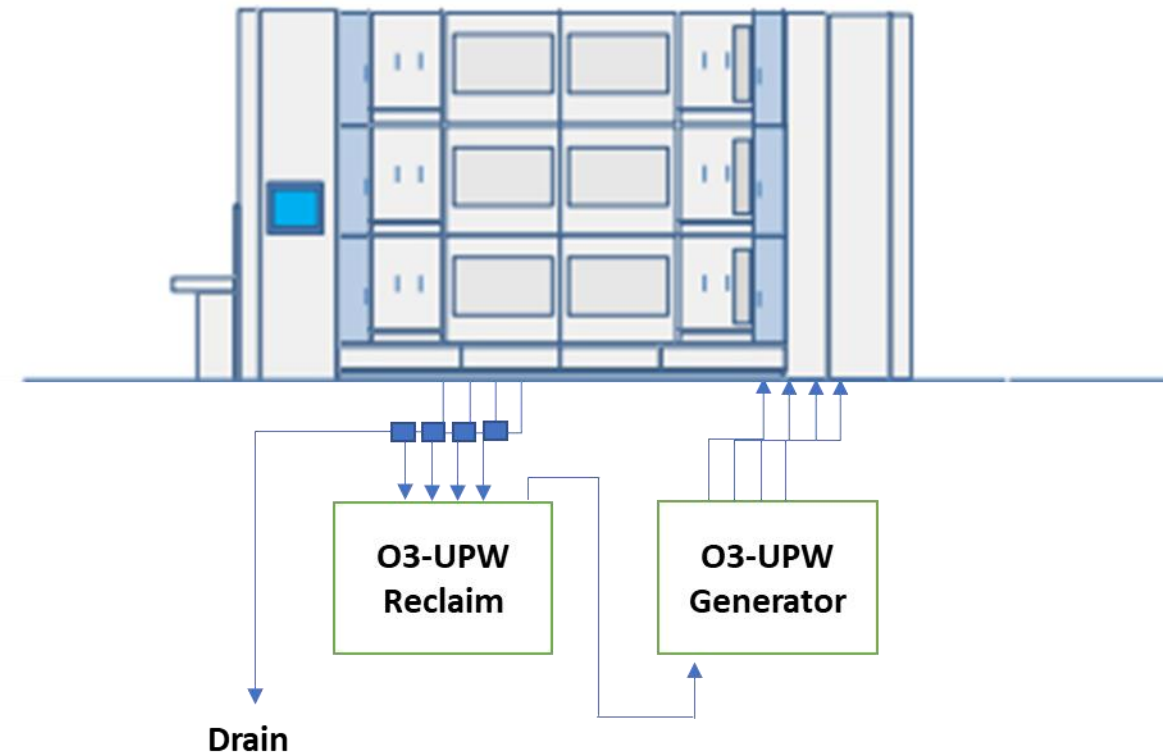


**Power consumption at 60°C H-UPW >
Reduced by 900 MWh/year**

Ozonated UPW Reclaim

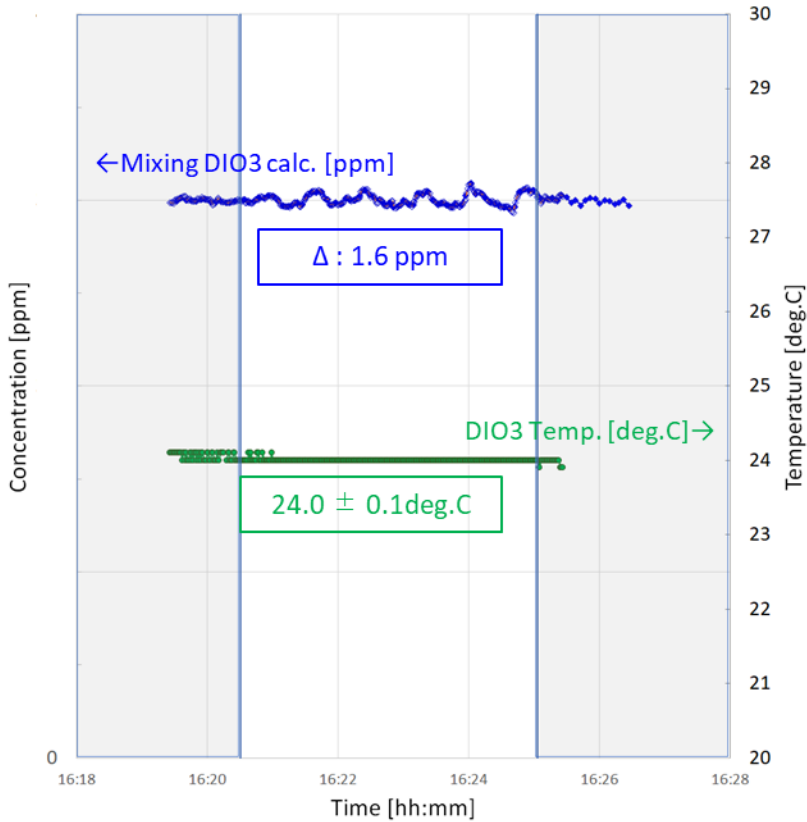
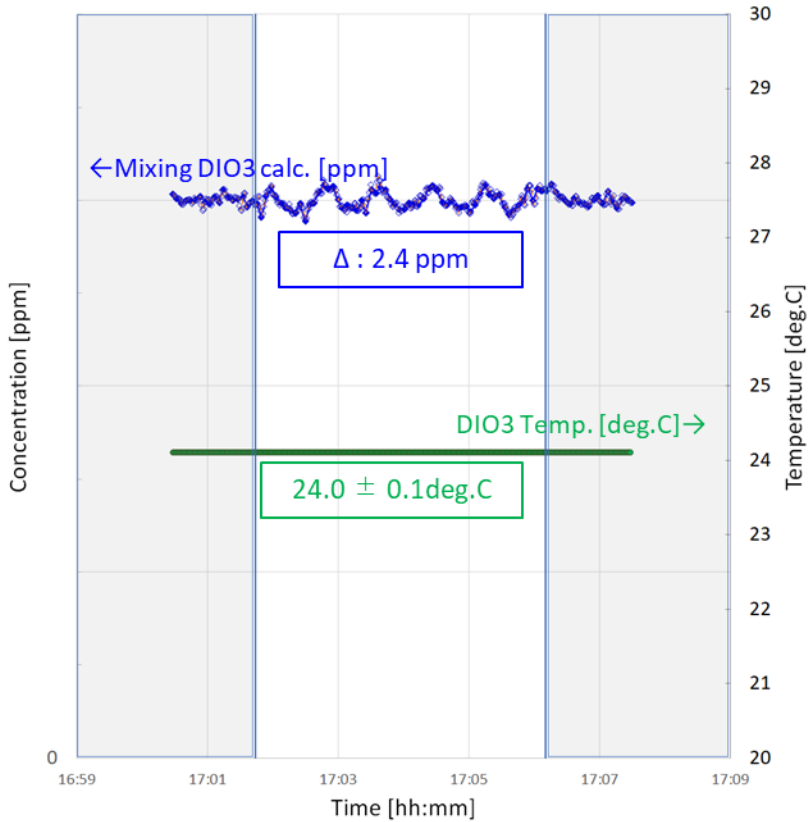
Ozone UPW Reclaim Unit

- ◆ New unit in the subfab can receive unused O_3 -UPW from the tool, which was previously sent straight to drain.
- ◆ The reclaimed O_3 -UPW is fed back through the O_3 generator and concentration is adjusted back to setpoint concentration.
- ◆ CO_2 and O_2 usage decreased.
- ◆ Zero UPW waste.



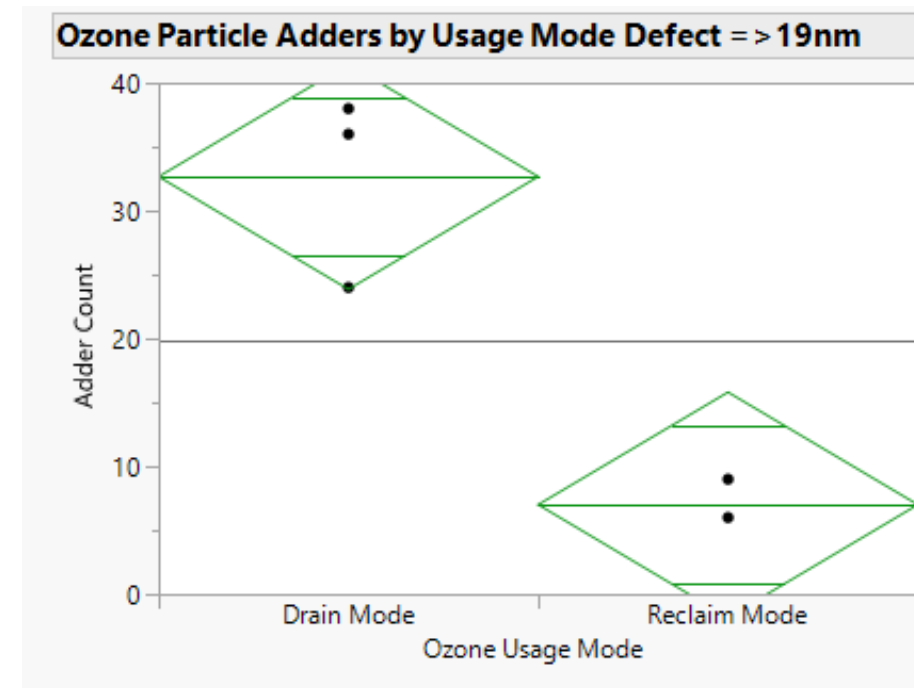
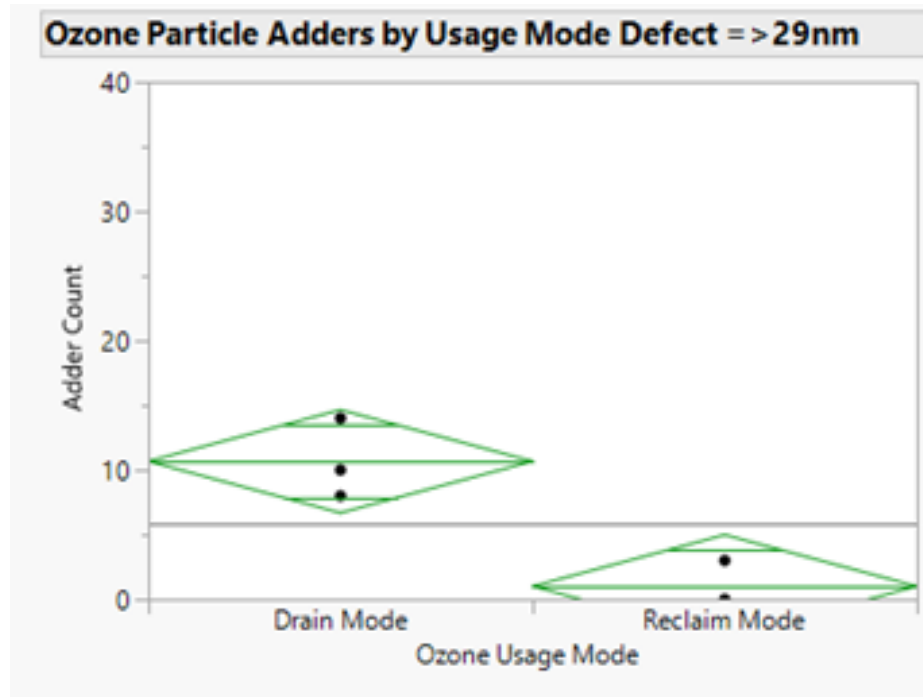
Stable Ozone Conc and Temp in Reclaim Mode Setting

	#1 Drain	#2 Reclaim
Concentration	$\Delta 2.4\text{ppm}$	$\Delta 1.6\text{ppm}$
Temperature	$24.0 \pm 0.1 \text{ deg.C}$	$24.0 \pm 0.1 \text{ deg.C}$



“Reclaim mode” is equivalent to “Drain mode (POR)” for O3-UPW concentration and temperature stability.

Better Particle Performance in Reclaim Mode



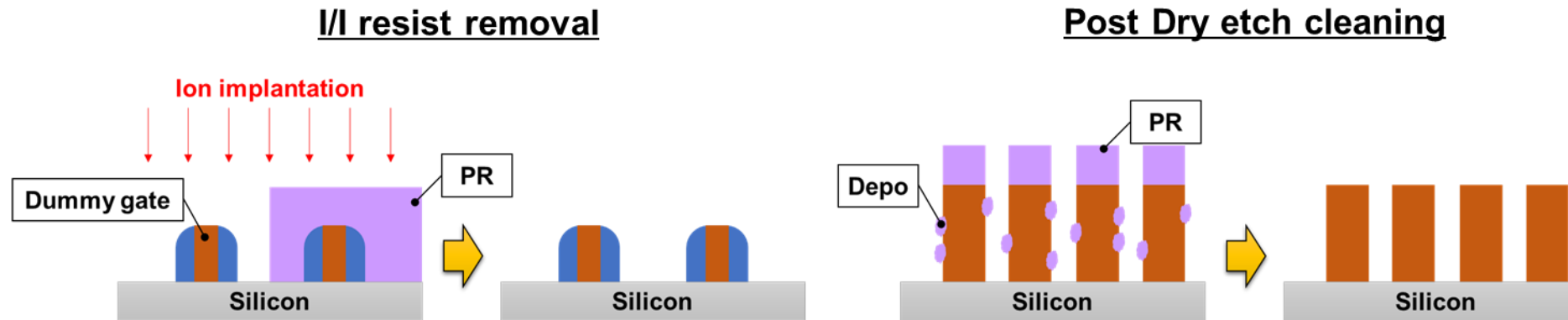
- ◆ Particle performance check conducted with three wafers using 30 sec O₃-UPW → rinse → dry process.
- ◆ Reclaim mode performance was better than Drain mode

Measurement tool: SurfScan SP7 (KLA-Tencor)
O3-UPW filter: 5nm PTFE

Sulfuric Acid Reuse

H_2SO_4 , Sulfuric Acid

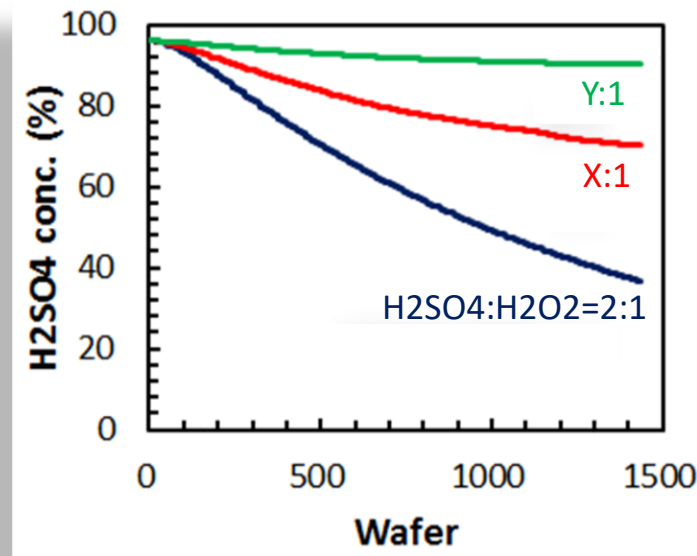
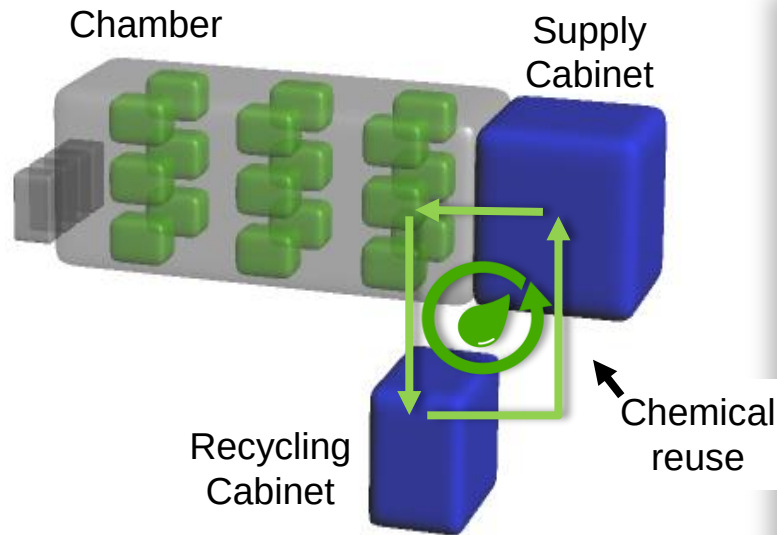
- ◆ SPM, sulfuric peroxide mixture, is used primarily for the removal of organic materials, e.g. photoresist, etch residues, from silicon wafers.



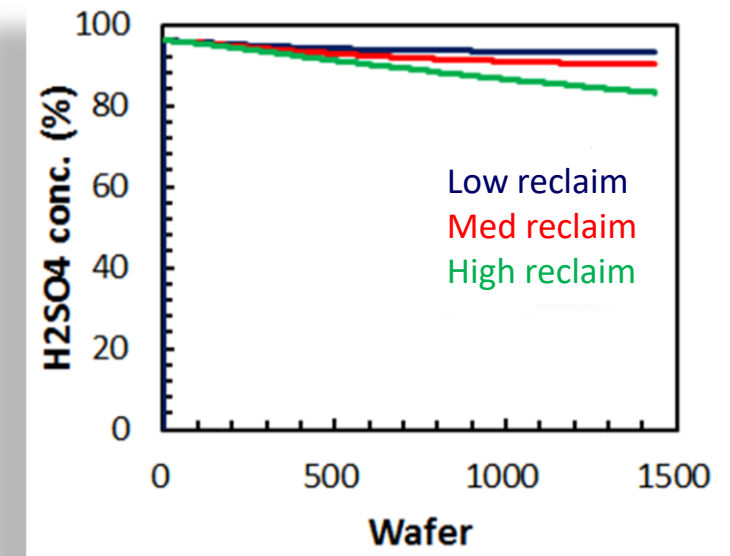
- ◆ One of the most widely used chemicals in the fab.
- ◆ SPM has a large impact on the cost of chemicals and environmental aspects and annual consumption is expected to increase as previously mentioned.

Determination of SPM Reuse Ratio & Reclaim %

- ◆ Using data from the SPM reuse system, the optimum chemical concentration ratio and reclaim percentage can be determined.



Solution Ratio Effect

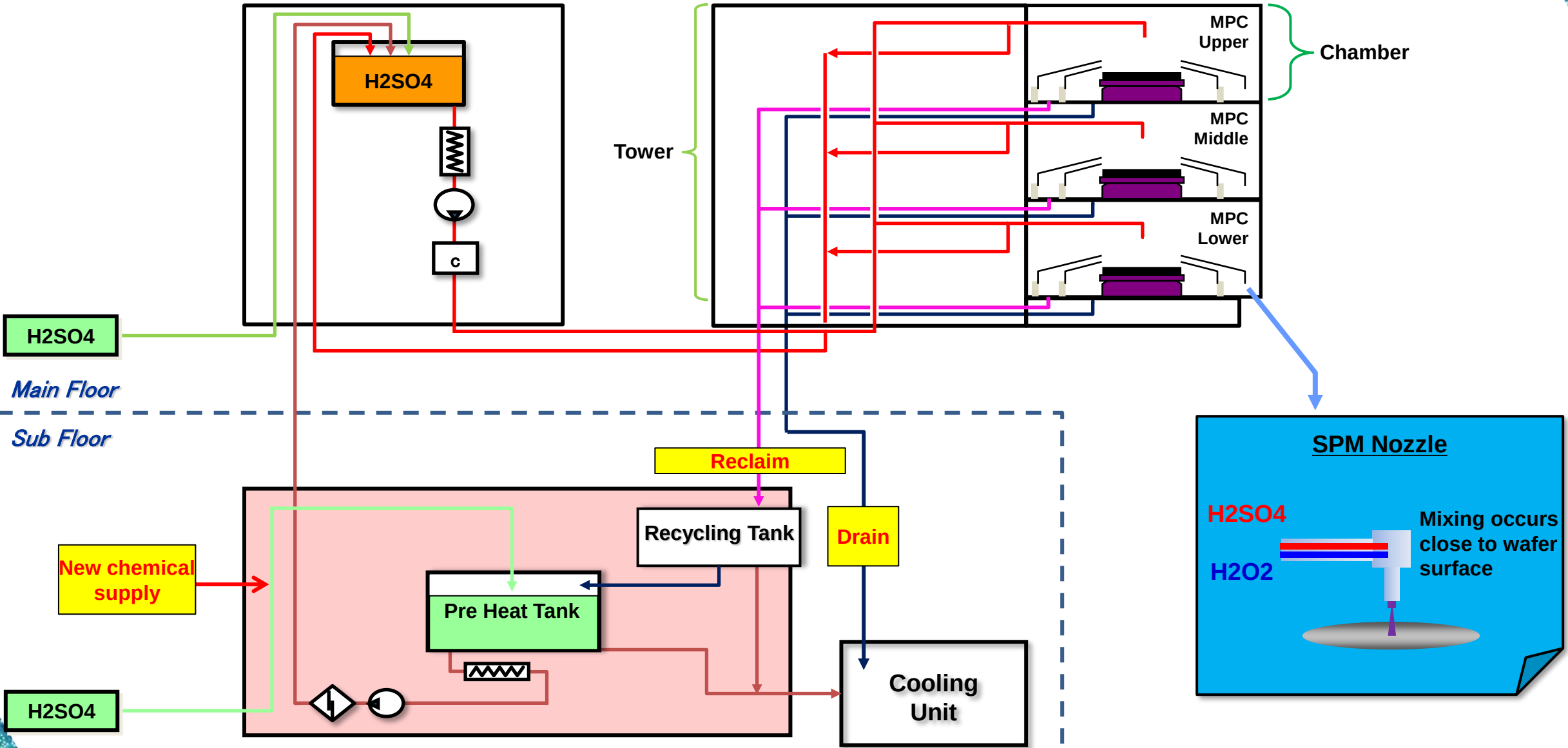


Reclaim % Effect

SPM Reuse Schematic

Supply Cabinet

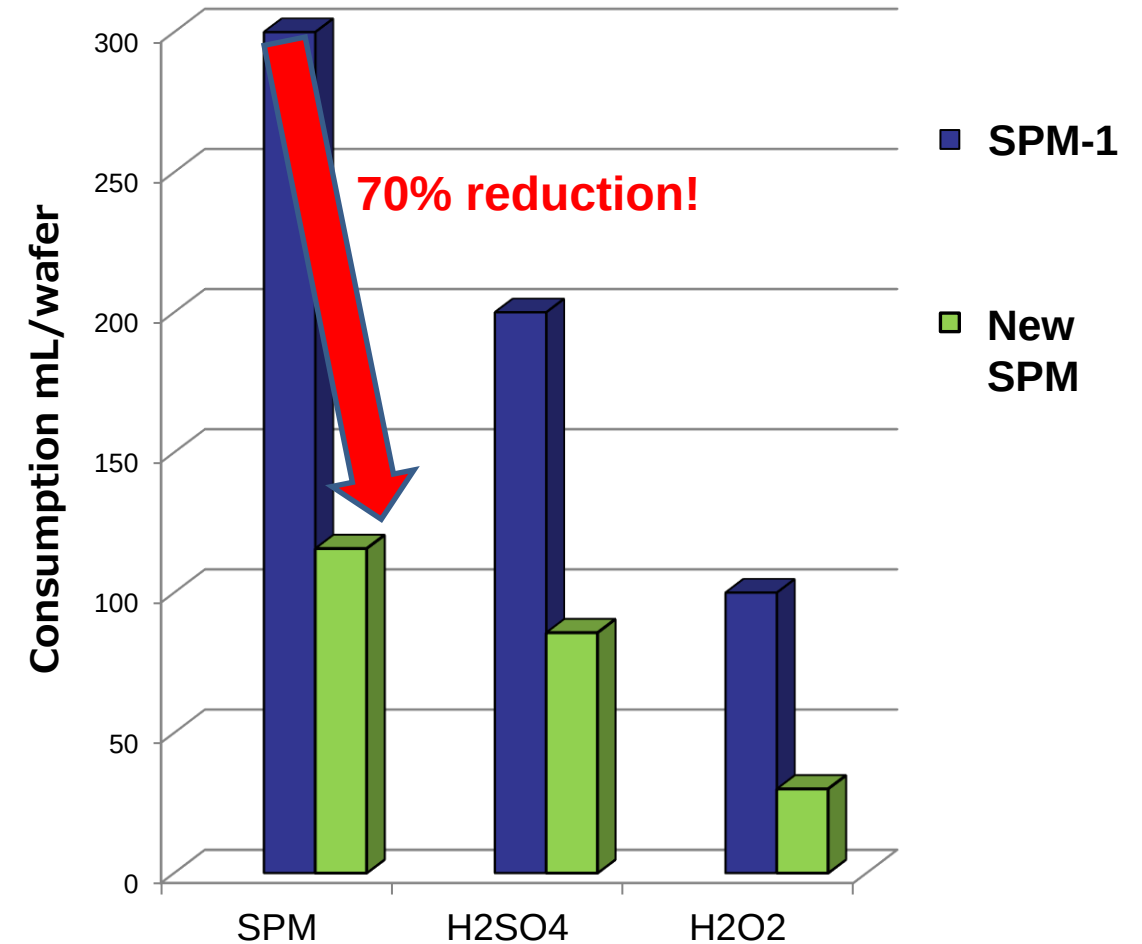
Main Body



SPM Reduction via SPM Reuse

1. SPM-1/No reclaim
SPM mixing ratio : 2:1, 30sec

2. New SPM
SPM mixing ratio : Y:1, 30sec
With Reclaim



Resist Removal Performance Results

- ◆ Resist removal of New SPM using H₂SO₄ conc. of 90% and higher (with reclaim) yielded equivalent results as the removal rate of SPM-1 (POR) using H₂SO₄ conc. of 96%.

	H2SO4 conc.	New PM				SPM-1
		96%	SPM	92%	90%	96%
SPM Time	40s					
	60s					
	100s					
	130s					
	140s					

Summary

- ◆ Consumption of heated ultra-pure water (H-UPW) and associated energy can be reduced by ~80% using recirculation technology.
- ◆ Customer field applications (3+ years in HVM) has confirmed validity of the H-UPW recirculation concept in process capability and resource savings.
- ◆ Unused O3-UPW can be reclaimed and reused with equivalent or better process performance.
- ◆ Projected savings of 3 billion gallons of UPW by 2030 with one customer using ozonated UPW reclaim system.
- ◆ SPM reuse on single-wafer tool can provide equivalent process performance as single-pass dispense with 70% reduction in H_2SO_4 and H_2O_2 .

ADVANCING
GLOBAL TECHNOLOGY
& INNOVATION

SCREEN Semiconductor Solutions Co., Ltd.

Innovation for a Sustainable World

SCREEN