



Sustainability with Dissolved Gases in Semiconductor Manufacturing

Dr. Anina Barth
MKS



Sustainability with Dissolved Gases in SEMI Manufacturing



Mission MKS: support sustainability in SEMI manufacturing



LIQUOZON



*green alternative for
sulfuric acid or hydrogen peroxide*

Disolved O_3

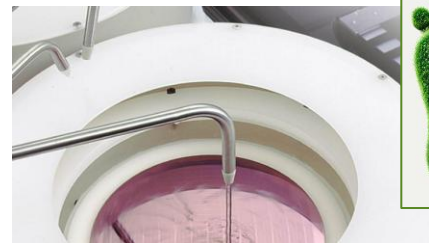
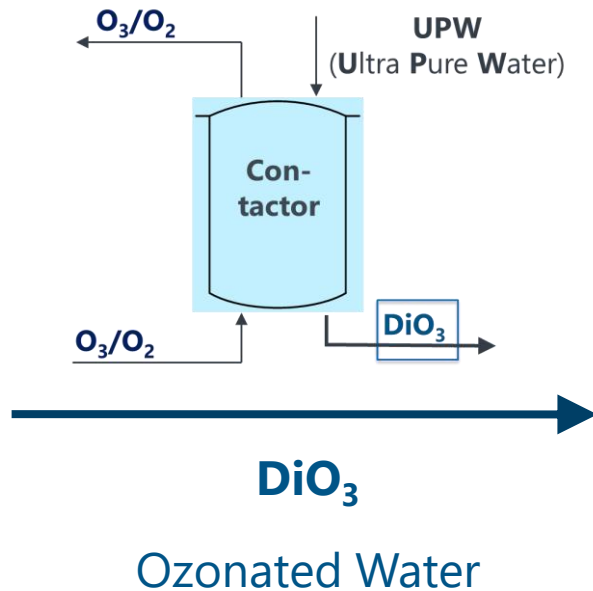
Ozonated Water



Single Wafer Cleaning Tool



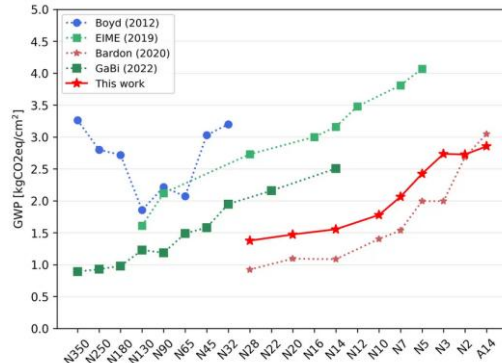
Mission MKS: support sustainability in SEMI manufacturing



Single Wafer Cleaning Tool

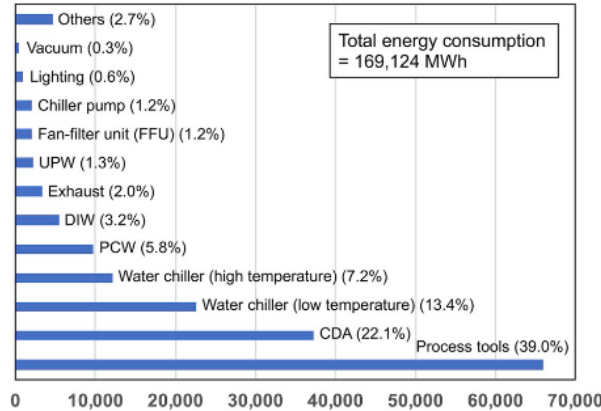
Who has calculated carbon footprint of a process or product?

imec; The road to net-zero emissions in IC manufacturing



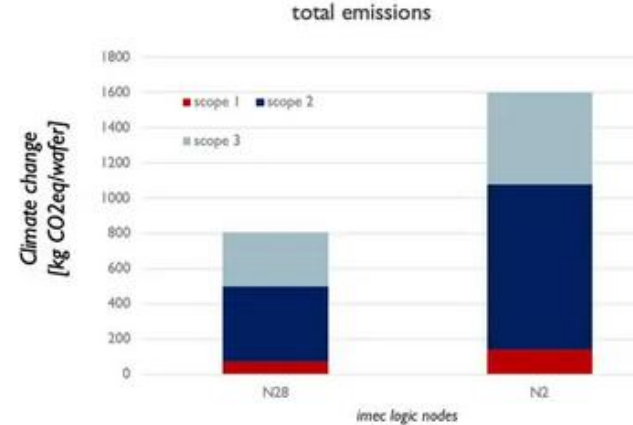
Carbon Footprint per
cm² wafer area

S. Hu; Energy savings approaches for high-tech manufacturing factories. Case Studies in Thermal Engineering. 17.



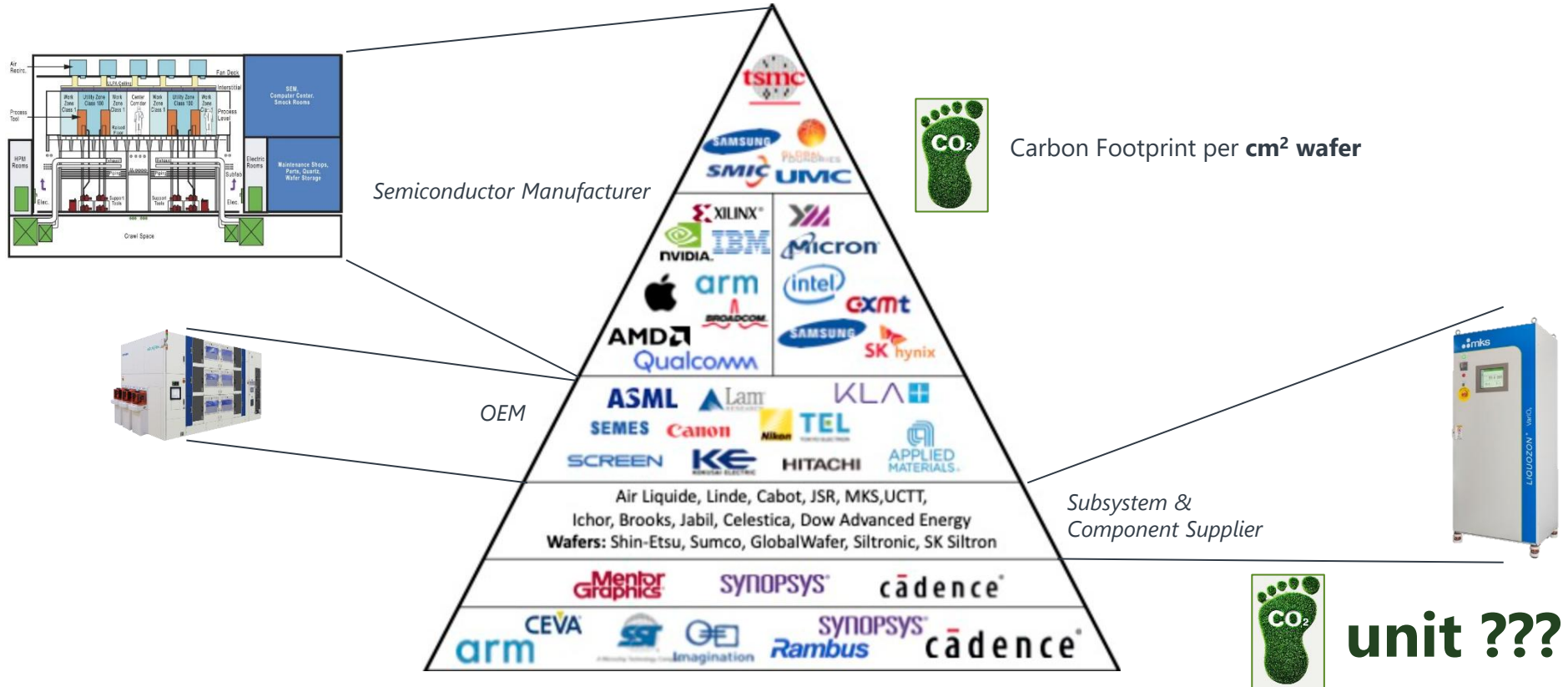
Energy consumption
per **utility**

imec; The environmental footprint of logic CMOS technologies



Carbon Footprint
per **wafer**

Semiconductor Value Chain



Carbon Footprint

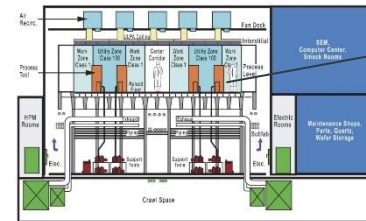
tonnes of emissions (CO₂ equivalent) per **unit of comparison**

- *Power efficiency* $kW / g \text{ DiO}_3 : 20 - 30$
- *Eq energy efficiency* $kWeq / g \text{ O}_3 : 10 - 20$
- *Carbon footprint* $kgCO_2eq / yr \text{ per LIQ} : \sim 50$

→ % energy consumption x **LIQUOZON** per fab

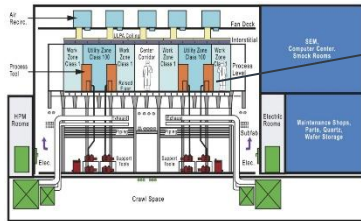
$$\text{CO}_2 \text{ eq./y} \times \text{conversion factor} \times \text{period} \times \text{use rate}$$


ECF / Energy conversion factor
Oxygen = 0.86 kWh/m³

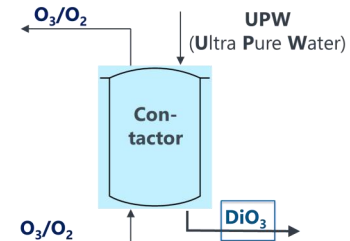


Quantify the sustainability impact for Dissolved Ozone

% energy consumption x LIQUOZON per big semi fab



x 40



SCOPE 1 + 2

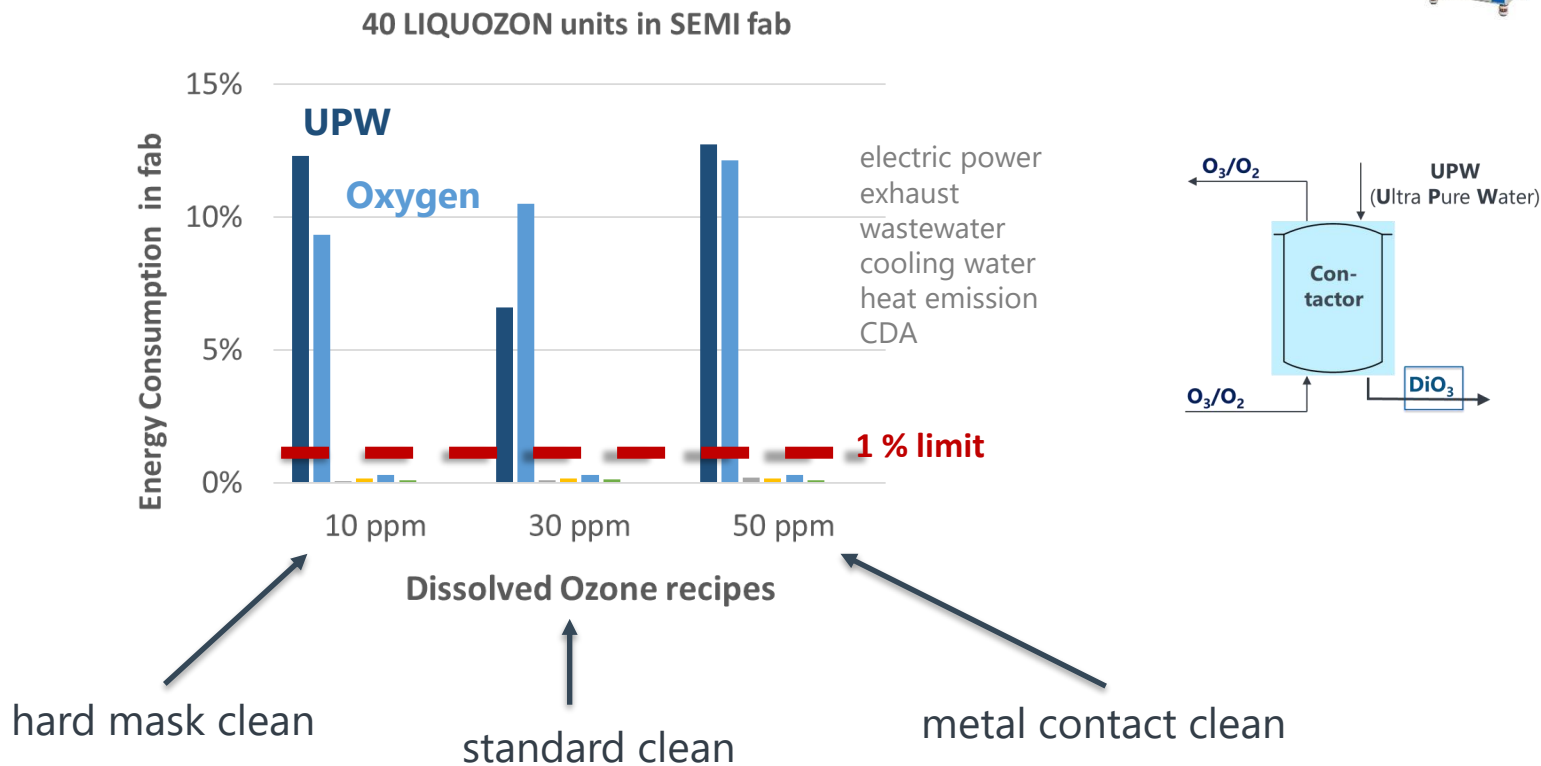
- Electrical Power
- Cooling Water
- Heat
- Oxygen
- Abatement
- Exhaust
- Wastewater
- Ultra Pure Water

SCOPE 3; out of scope

- Carbon Dioxide

PVD w/abatement	59		
CVD All	217		
epitaxial process	104		
etch	248		
		wafer starts per w	29 000
		wafer per h	172
		fab size in m ²	54 000
		steps	700
		kWh / wafer	631

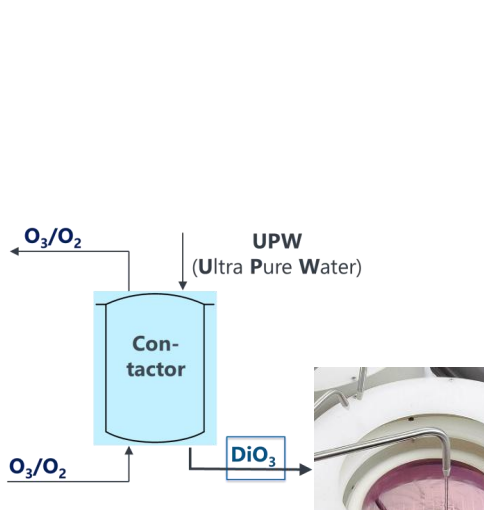
Energy consumption of Dissolved Ozone in FEoL



Energy consumption of Dissolved Ozone systems

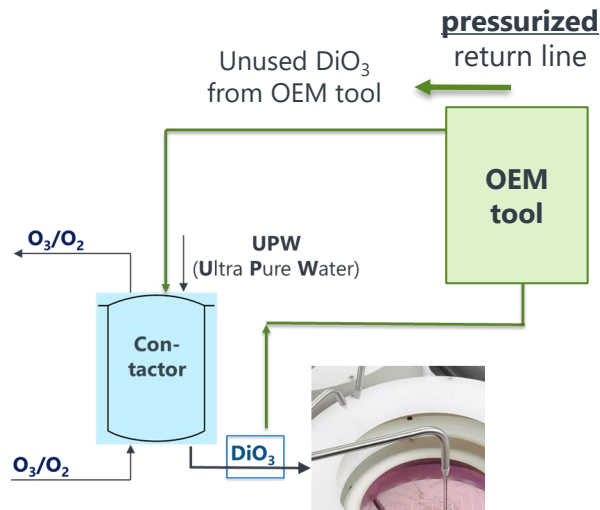


- DiO₃ Saving option #1: **Sleep Modes**
- DiO₃ Saving option #2: Recirculation Mode
- DiO₃ Saving option #3: **Reclaim Mode**

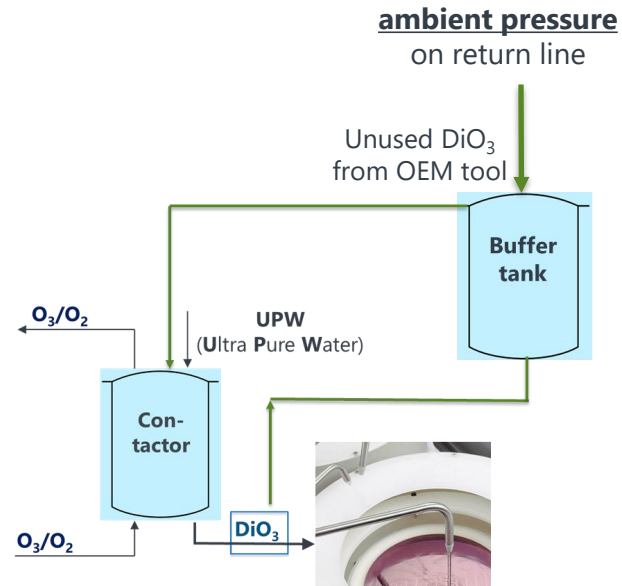


#1

equivalent to Drain Mode



#2

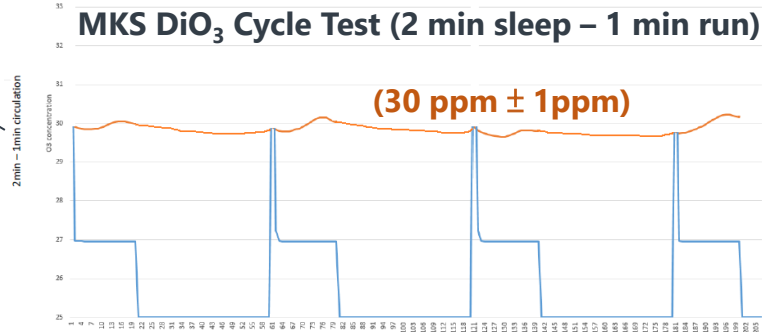
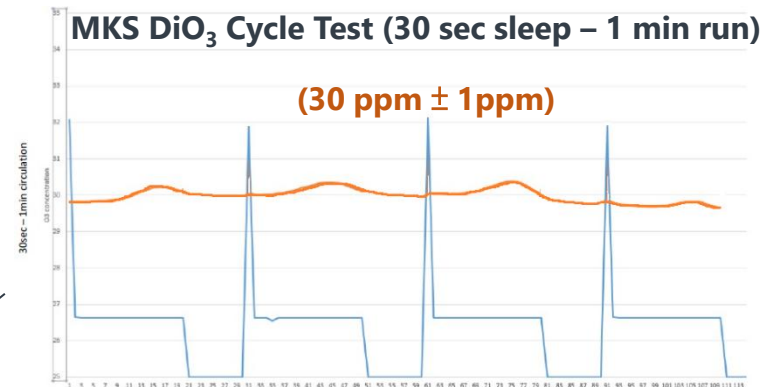
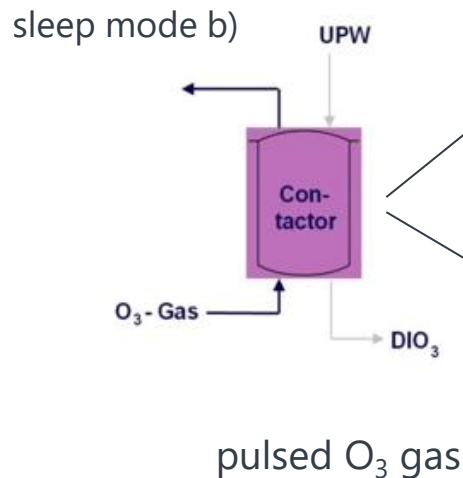
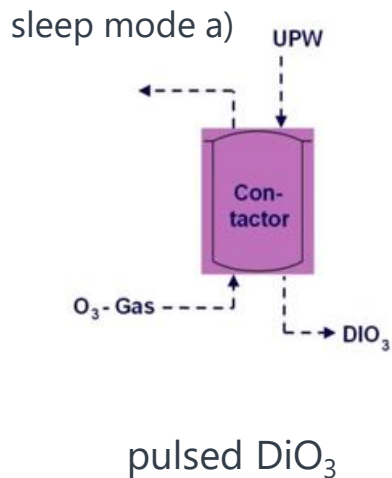


#3

Energy consumption of Dissolved Ozone systems



- DiO₃ Saving option #1: Sleep Modes



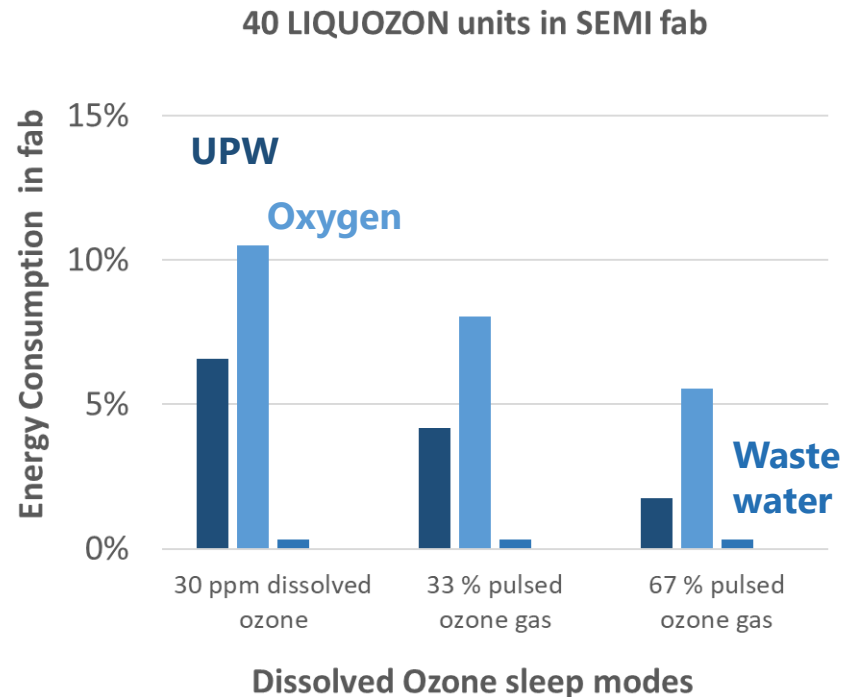
Energy consumption of Dissolved Ozone systems



- DiO₃ Saving option **#1**: Sleep Modes

Total reduction in scope 1+2 emissions
with **sleep modes**:

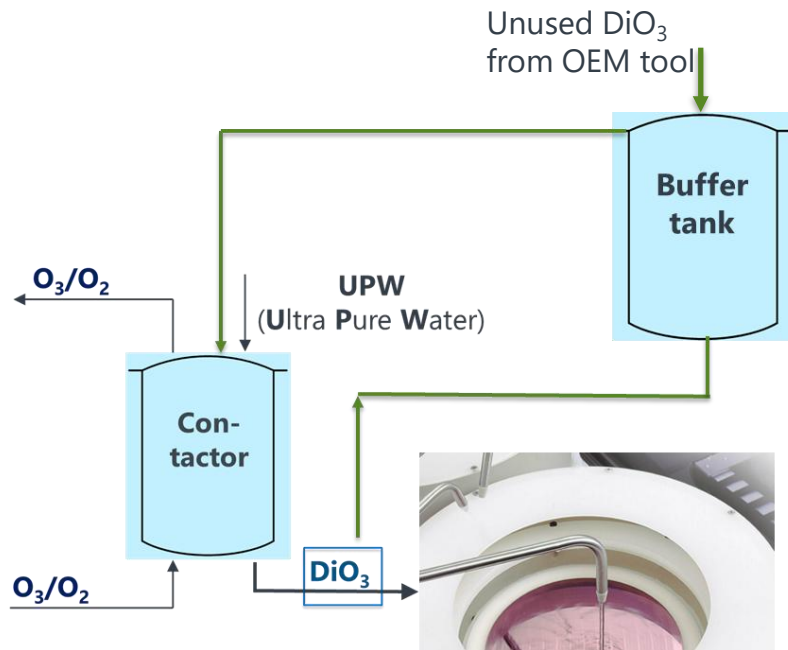
UPW	- 73 %
Oxygen	- 47 %
Wastewater	0 %



Energy consumption of Dissolved Ozone systems



- DiO_3 Saving option #3: Reclaim Mode



a)



Buffer tank is part of
OEM cleaning tool

b)



Buffer is part of
Dissolved Ozone system

Energy consumption of Dissolved Ozone systems



- DiO₃ Saving option **#3**: Reclaim Mode Buffer is part of OEM cleaning tool

➤ Stable ozone concentration

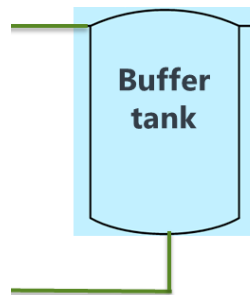
- Drain mode $\Delta 2.4$ ppm
- Reclaim mode $\Delta 1.6$ ppm

➤ Temperature stability

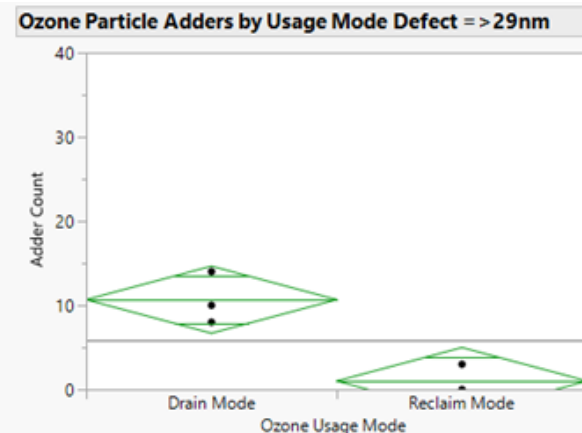
- Drain mode $24\text{ }^{\circ}\text{C} \pm 0.1\text{ }^{\circ}\text{C}$
- Reclaim mode $24\text{ }^{\circ}\text{C} \pm 0.1\text{ }^{\circ}\text{C}$

- Better particle performance
less particle adders in reclaim mode

- Projected **savings of 11 billion liters*** of UPW by 2030 with one customer using Dissolved Ozone Reclaim system



a)



Reduction of Process Chemicals and Energy Use in Single-Wafer Process Applications; J. Snow, SEMICON Europa SCREEN Tech Arena 2023

Energy consumption of Dissolved Ozone systems



- DiO₃ Saving option **#3**: Reclaim Mode;
Buffer is part of Dissolved Ozone system

➤ Stable ozone concentration

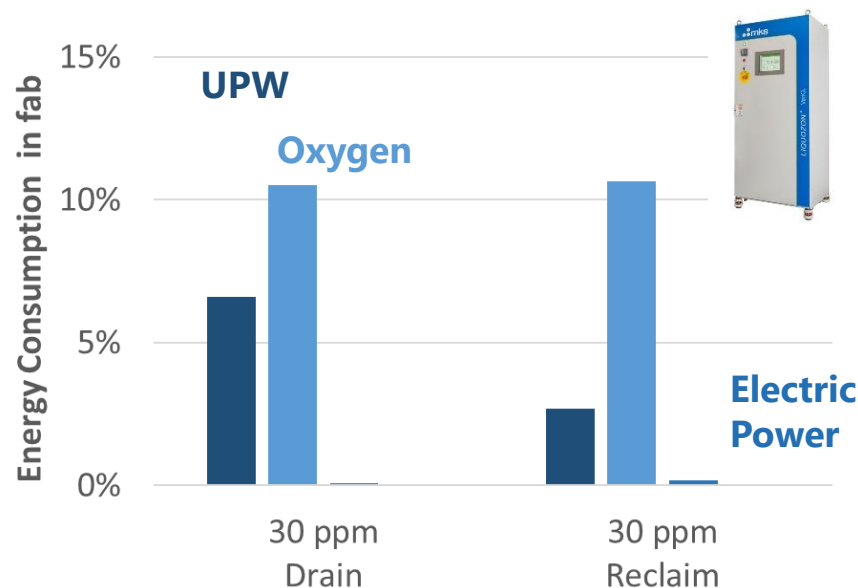
- 90 ppm @ 2 lpm
- 60 ppm @ 32 lpm

➤ Utility savings

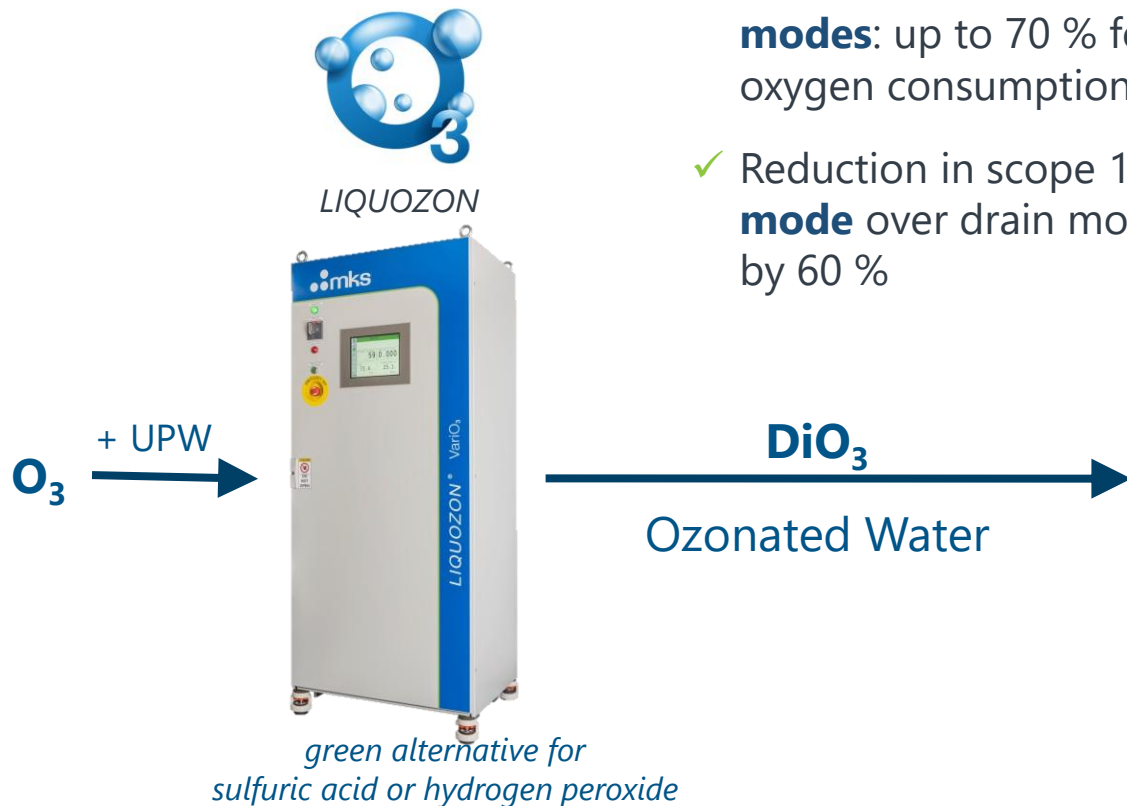
- UPW 15.6 → 6.4 lpm **- 60 %**
- Oxygen 11.2 = 11.3 slpm **-/+ 0 %**
- Electric Power 0.9 → 1.8 kW **+ 200 %**

➤ Also possible for Dissolved Ammonia

40 LIQUOZON units in SEMI fab



Mission MKS: support sustainability in SEMI manufacturing



- ✓ **Total reduction** in scope 1+2 emissions with **sleep modes**: up to 70 % for ultra-pure water and 50 % for oxygen consumption
- ✓ Reduction in scope 1+2 emissions by using **reclaim mode** over drain mode: reduction in ultra-pure water by 60 %



MKS helps the most innovative companies in the world

SOLVE COMPLEX PROBLEMS

MARKET LEADER

MKS is a leading global provider of process control solutions for

- Semiconductor
- Electronics & Packaging
- Specialty Industrial

STRATEGIC GROWTH

- Q3 2022 – acquired Atotech
 - Leader in specialty chemicals, equipment, software and services for PCBs, semi IC packaging and surface finishing
- Q1 2019 – acquired Electro Scientific Industries (ESI)
 - Leader in laser-based manufacturing for the micro-machining industry
- Q2 2016 – acquired Newport Corporation
 - Leader in sophisticated laser, light and motion products

INNOVATIVE SOLUTIONS

- Vacuum Processing
 - Pressure measurement & control, flow, power, reactive gas analysis, automation
- Laser Solutions
 - Precision laser applications
 - Laser-based process equipment
- Motion, Photonics & Optics
 - Vibration & performance motion control, gratings & optics, laser measurement
- Materials Solutions
 - Process and manufacturing technologies for advanced surface modification, electroless and electrolytic plating and surface finishing

KEY FACTS

- Founded: 1961
- HQ: Andover MA
- IPO: 1999 (NASDAQ MKSI)
- Selling in ~100 countries
- In 2024
 - Revenue: \$3.6B
 - Employees: ~10,000
 - Engineers & Scientists: ~1,900
 - R&D Investment: ~\$271M
 - Worldwide Patents: ~3,200