purify

protect

transport

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The materials integrity management company

Production of High Purity Functional Water at Point-of-Use for Advanced Mask Cleaning Processes

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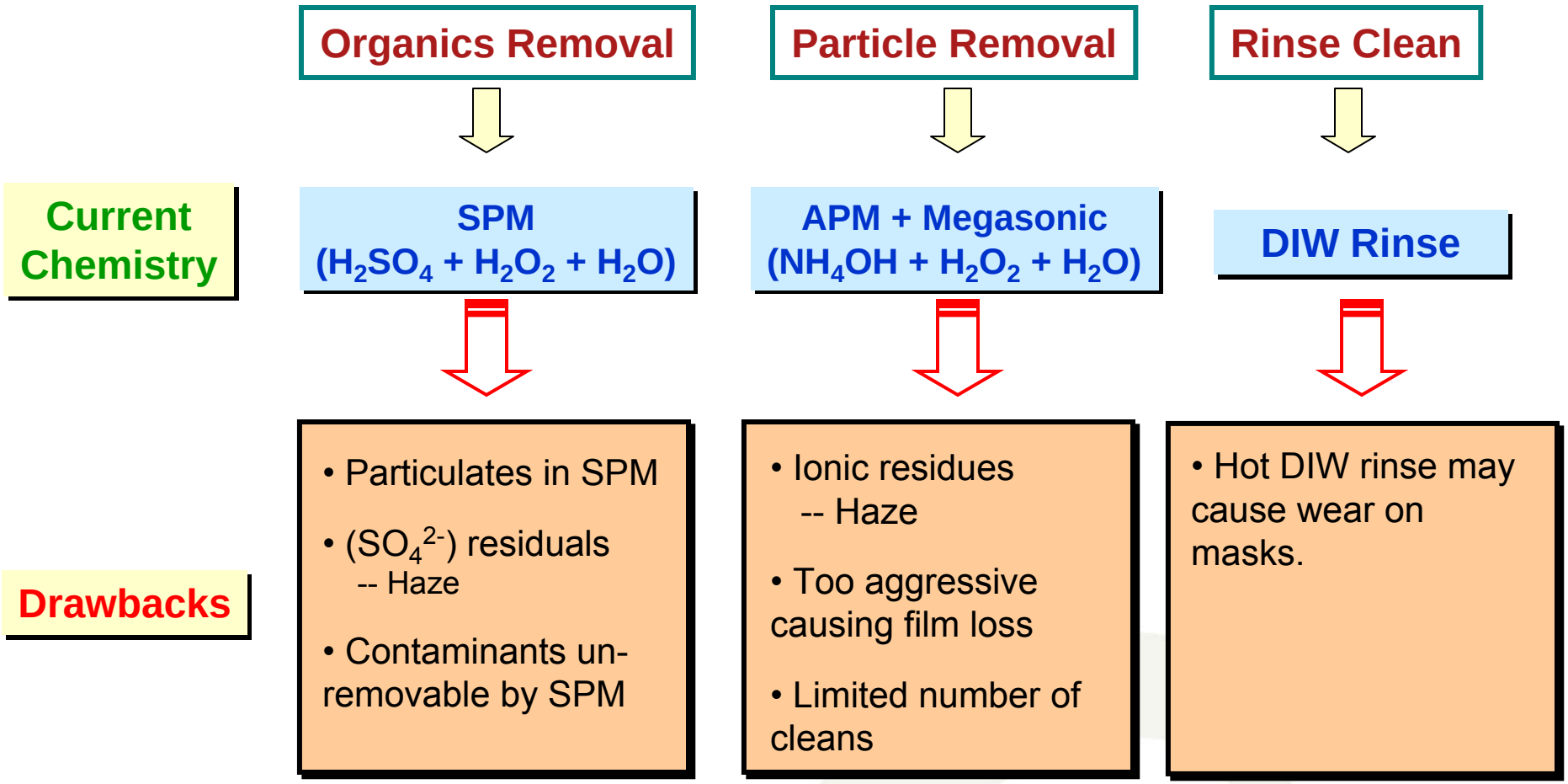
Abstract

- Without the use of traditional pellicles, EUV masks demand high purity and effective but mild cleaning techniques for protection from defects. Recently, trends towards dilute chemistries and progress in megasonic cleaning have brought renewed interest in gasified DI water.

- In this paper, we describe the design and development of a point-of-use functional water treatment system, specifically for advanced mask cleaning applications. The system is comprised of two modules – the purification module and the gasification module. The purification module provides treatment features including TOC reduction, sub-micron particle retention, as well as thermal and pressure control. The gasification module is capable of delivering bubble-free DI water with various gases (O3, N2, H2, CO2, NH3, etc.) over a wide concentration range. The gasification module is also equipped with automatic dissolved gas concentration control feature to allow precise control and minimal process variations.

Limitations of Sulfur-based Wet Cleaning Process



Current cleaning processes do not provide mask surfaces that are free from contamination. → Adders!

Definition of Functional Water

Pure Water

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Physical / Chemical Processing

- Electrolysis
- Gasification
- Chemical Addition
- Light Irradiation
- Ultrasonic Excitation

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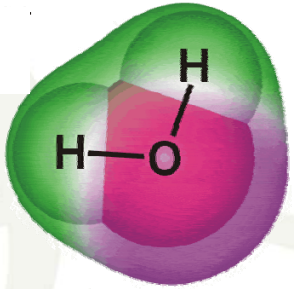
Functional Water:

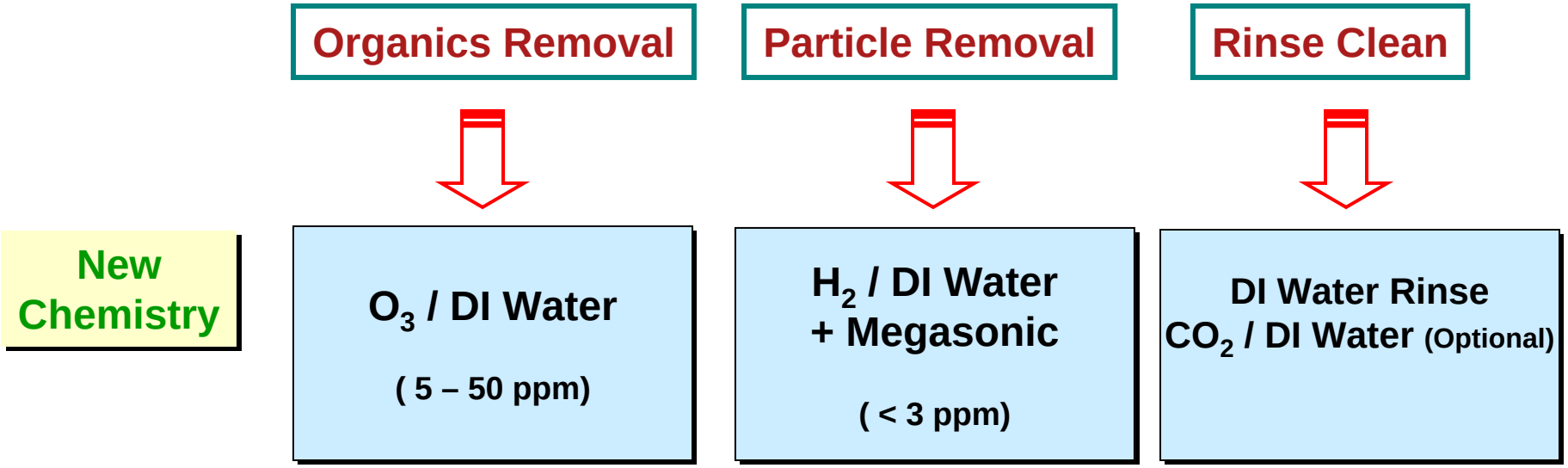
Altered physical / chemical properties:

- Dielectric constant
- Viscous force
- Electrical conductivity
- Surface tension
- Oxidation-reduction potential



Enhanced Cleaning Efficiency!

Sulfur-free Cleaning using Functional Water

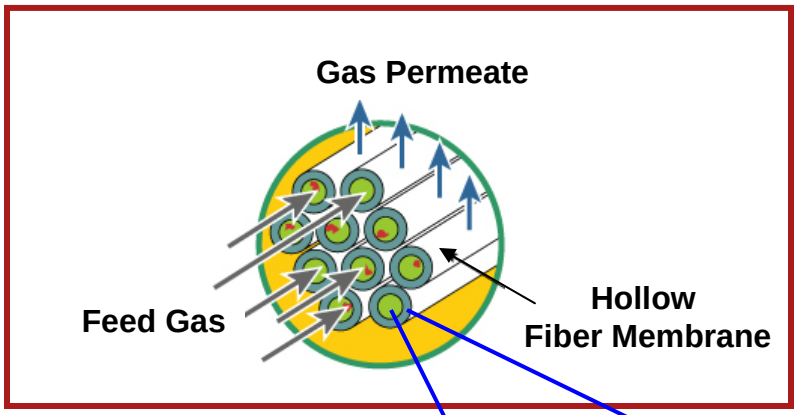


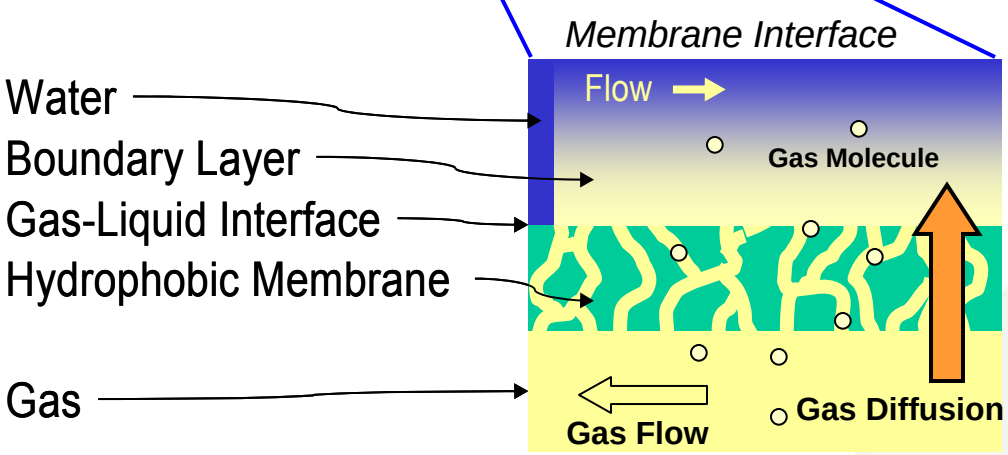
Advantages of Functional Water

* Made at point-of-use
* Cleaner than SPM
* No waste except H_2O and gas
* Relatively low cost
* Good cleaning efficiency
* Compatible with existing tools
* Environmentally friendly
* Can be room temperature

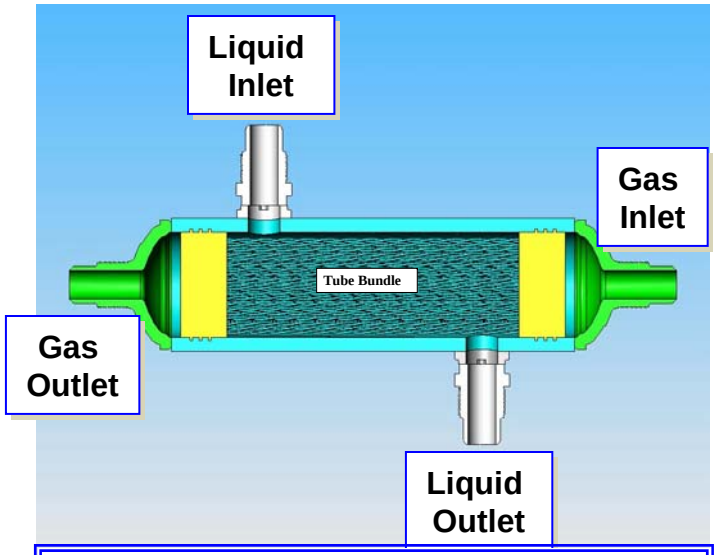
Liquid Gasification using Membrane Contactor

Hollow Fiber Membrane



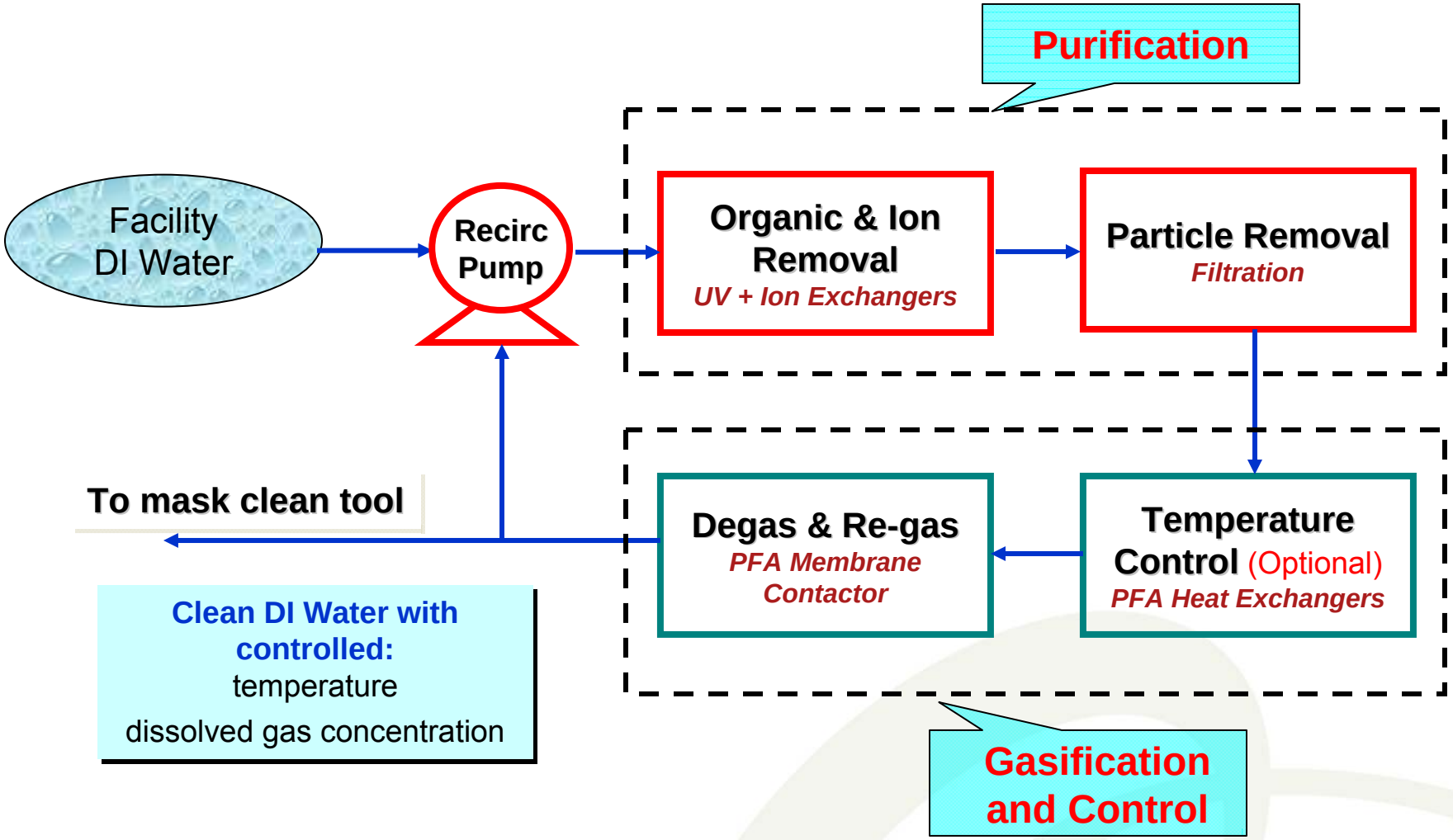


All PFA Membrane Contactor



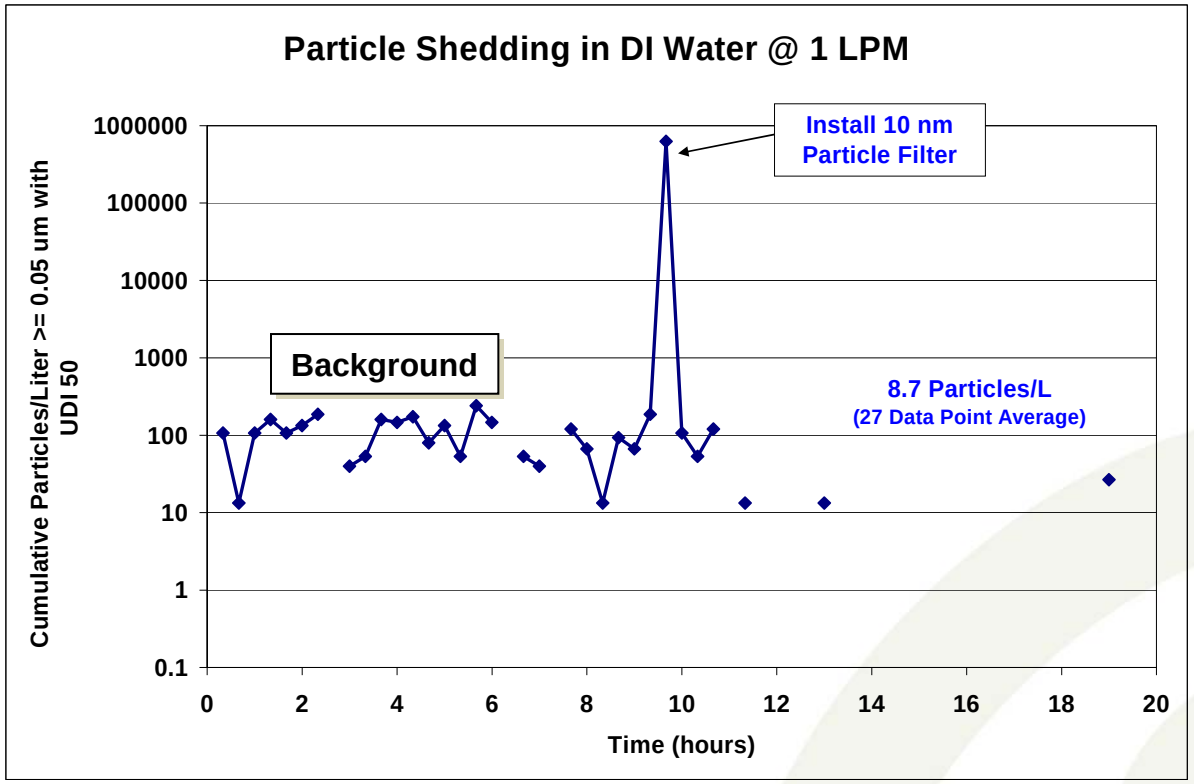
- **All PFA ultra-clean construction**
  - Low extractable and particles
  - Excellent chemical compatibility
- **PFA hollow fiber membrane**
  - Only gas permeable, Hydrophobic
  - 2 m^2 membrane surface
- **Low pressure drop**
  - < 7 kPa @ 8 Liter/min water flow

Concept of Point-of-Use Ultra-pure Functional Water Polishing and Gasification System



Typical Ionic Purification and Particle Removal

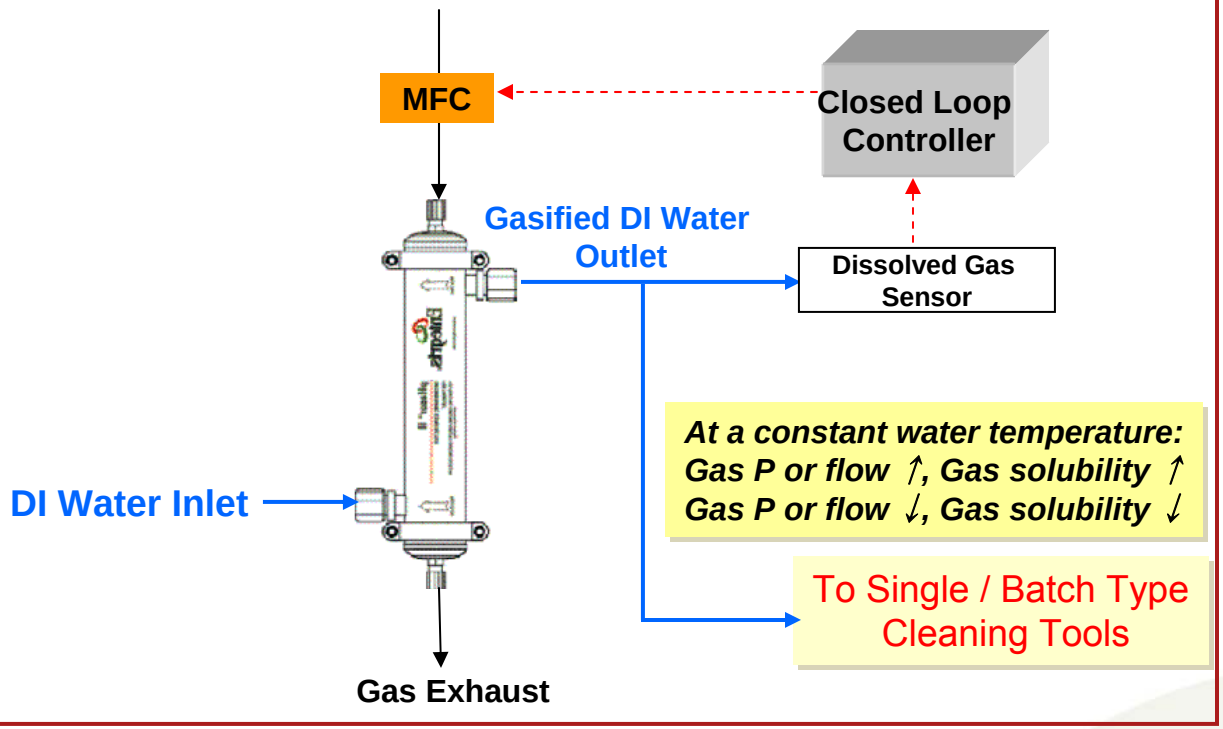
- Typical outlet DI water contains PPQ levels of ionic species:
  - Less than 0.5 ppt / each element
    - (Li, Na, Mg, Al, K, Ca, Ti, Cr, Fe, Mn, Ni, Cu, …)
- Typical outlet DI water contains single digit particles per liter.



Outlet DI water Particles < 10 counts / Liter (> 0.05µm)

Automated DI Water Gasification Process

Degas & Regas in one step



Types of Dissolved Gas Sensors

O3-DIW:	**- Dissolved O_3 sensor** **- ORP sensor**
H2-DIW:	**- Dissolved H_2 sensor** **- ORP sensor**
N2-DIW:	**- Dissolved N_2 sensor**
CO2-DIW:	**- Dissolved CO_2 sensor** **- pH meter** **- Resistivity sensor**

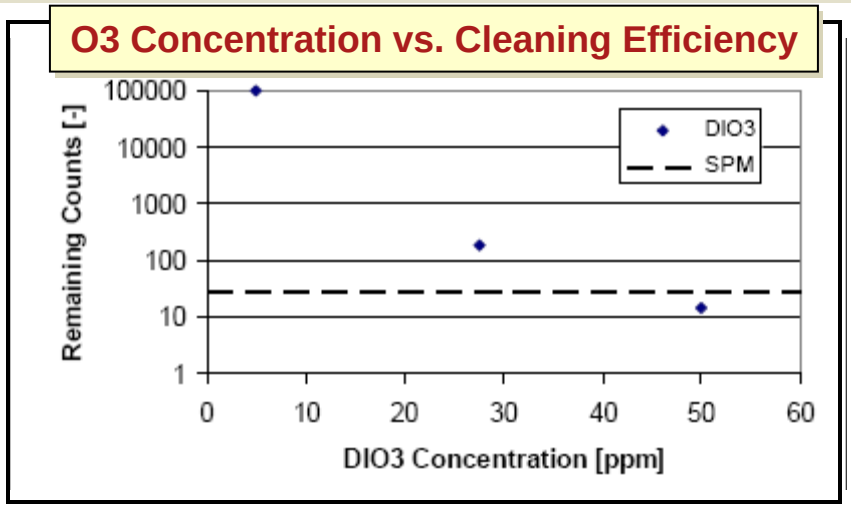
ORP – Oxidation Reduction Potential

How does the control system work:

- Dissolved gas sensor sends feedback to closed loop controller.
- Closed loop controller keeps adjusting gas flow until dissolved gas sensor measurement matches the setpoint.

Direct Gas Injection!
No Gas or Liquid Mixing!

Why do we need to control gas concentration?



O_3 concentration affects cleaning efficiency!

Maintaining stable O_3 concentration

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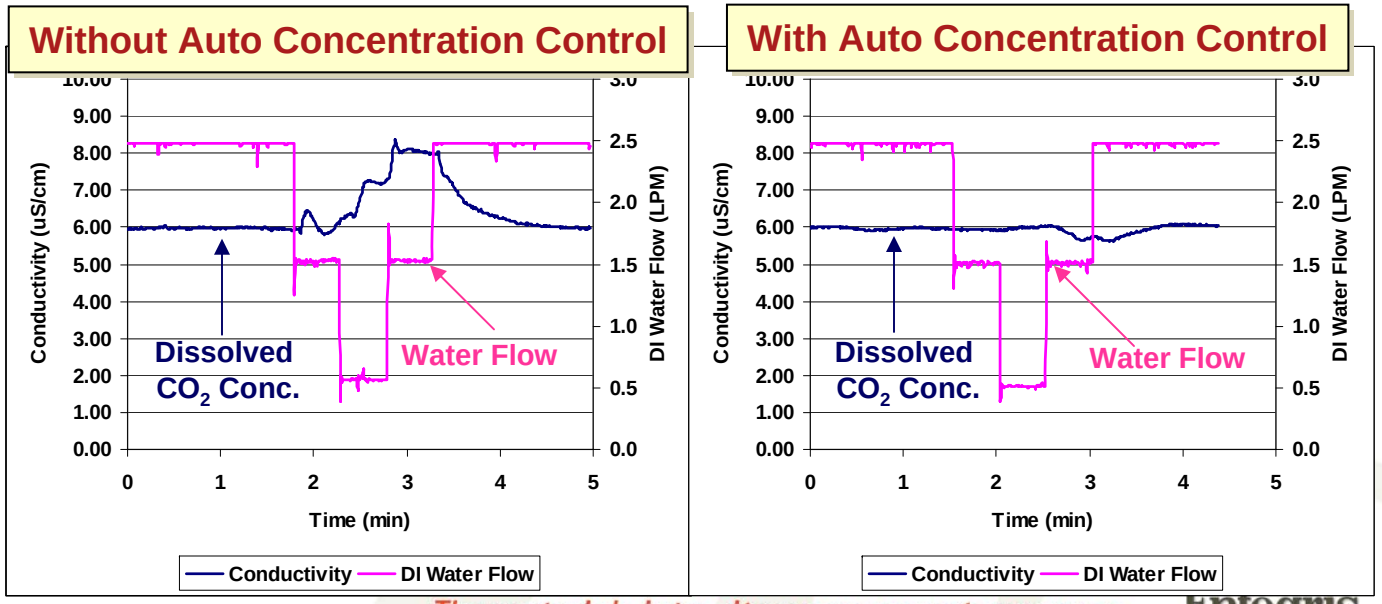
Consistent cleaning efficiency

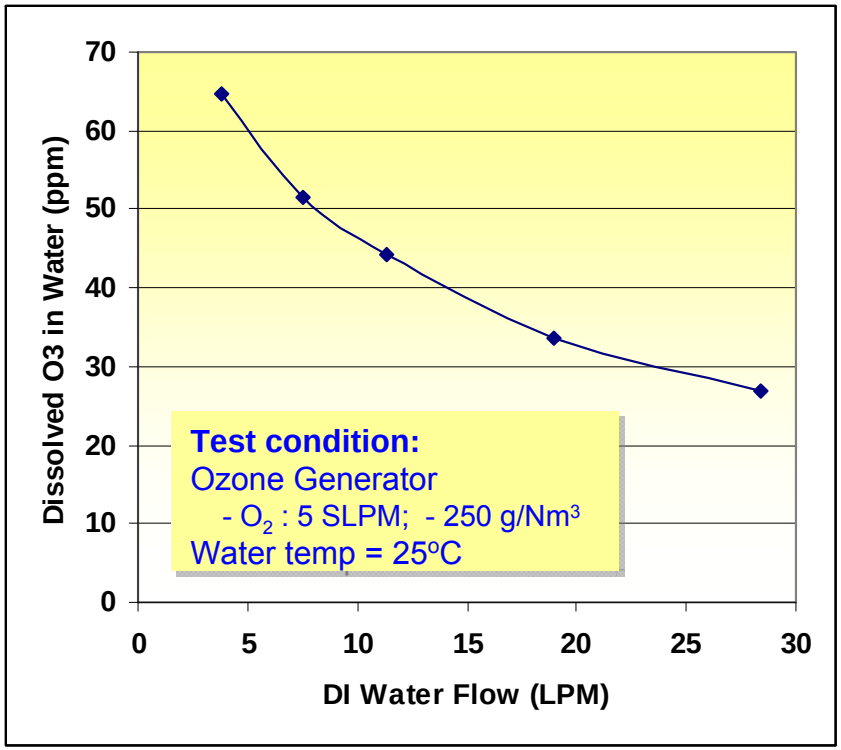
Source: Investigation of Sulfur Free Clean Processes for Next Generation Lithography. C. Chovino, et al, AMTC GmbH

Auto concentration control minimizes process variability!

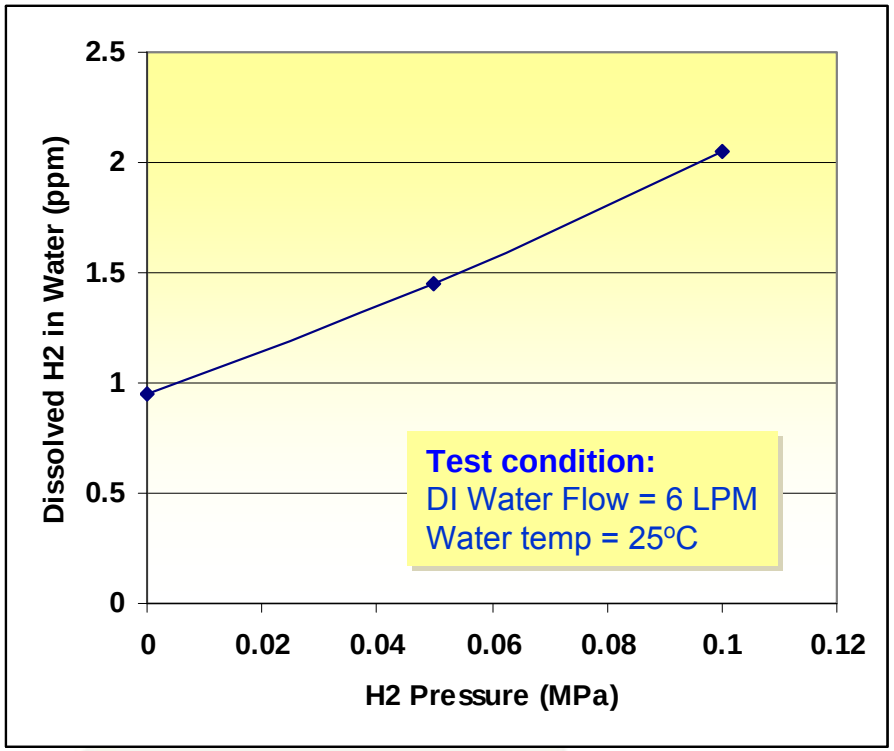


Water Ozonation and Hydrogenation Efficiency

Dissolved O_3 Concentration vs. Water Flow
(Single Membrane Contactor)



Dissolved H_2 Concentration vs. H_2 Pressure
(Single Membrane Contactor)



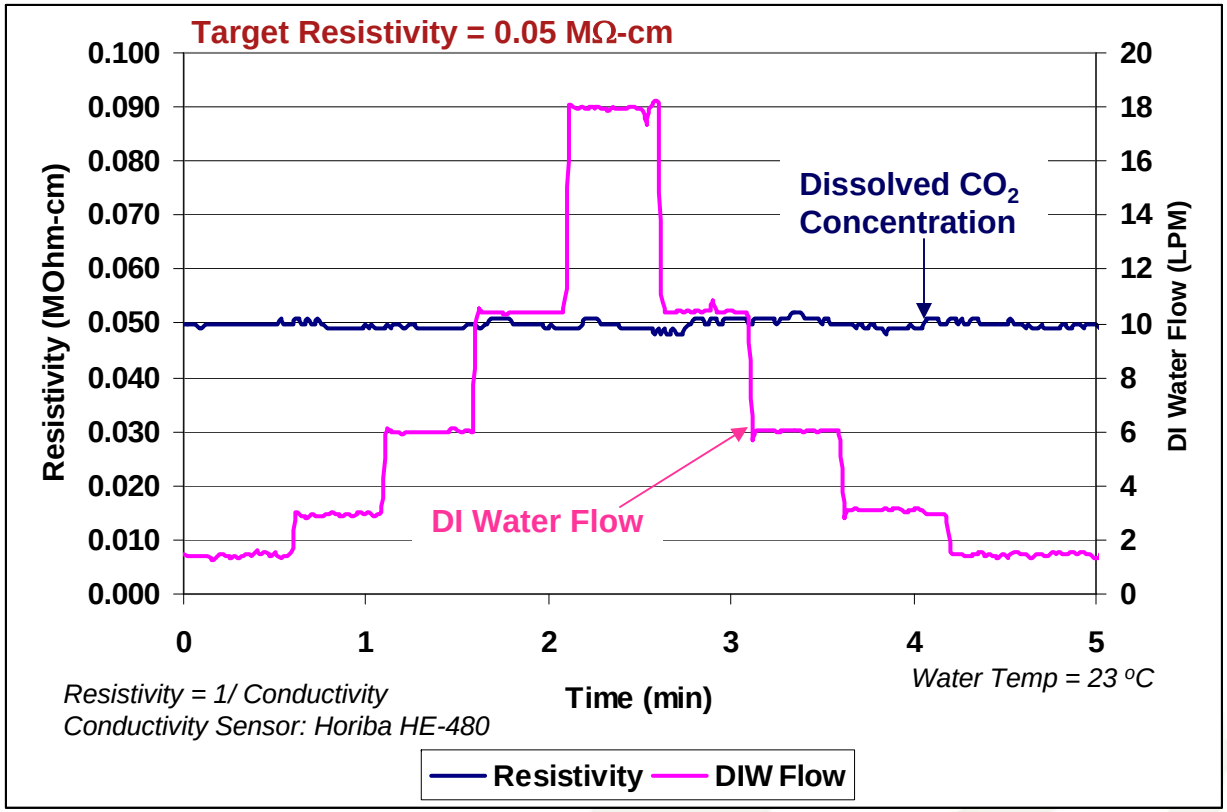
- To adjust dissolved O_3 concentrations:
  - Inlet O_3 concentration ↑, Dissolved O_3 concentration ↑; vice versa
  - Inlet O_2 flow ↑, Dissolved O_3 concentration ↑; vice versa

- To adjust dissolved H_2 concentration at a given flow:
  - H_2 pressure ↑, Dissolved H_2 concentration ↑; vice versa

Gasification System Control Performance

1.5 → 3 → 6 → 10.5 → 18 → 10.5 → 6 → 3 → 1.5 LPM (every 30 seconds)

Dissolved CO_2 concentration (Water Resistivity) stability within ± 5% of Setpoint!



Summary

- A point of use functional water delivery system using membrane contacting technology enables:
  - Purification and filtration at point-of-use
  - Precise control at point-of-use
  - Less chance of contamination at point-of-use
- Automatic control of dissolved gas concentration brings added benefit of ensuring a stable and seamless cleaning process.