Metrics and Methods for Reducing Rinse Water Consumption in an Immersion System

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Outline

- Introduction
- Overflow rinse uniformity
- Overflow rinse chemical carryover
- Dump rinse uniformity
- Dump rinse chemical carryover
- Conclusions

Water Usage in IC Manufacturing

- 7570 liters UPW per 200mm wafer (SEMI, 2001)
- 80% for wet etching and cleaning (SEMI, 2001)
- 60% is for rinse steps (Micro, May 1995)
- 5-7 liters/cm^2 Fab UPW use in 2003 (ITRS 2001)
  (= 3500-5000 liters per 300mm wafer)
- 0.075 l/cm^2 Tool UPW use in 2003 (ITRS 2001)
  (= 53 liters per 300mm wafer per run, or 2650 liters/50 wafer run)
- ITRS requires significant reductions in future

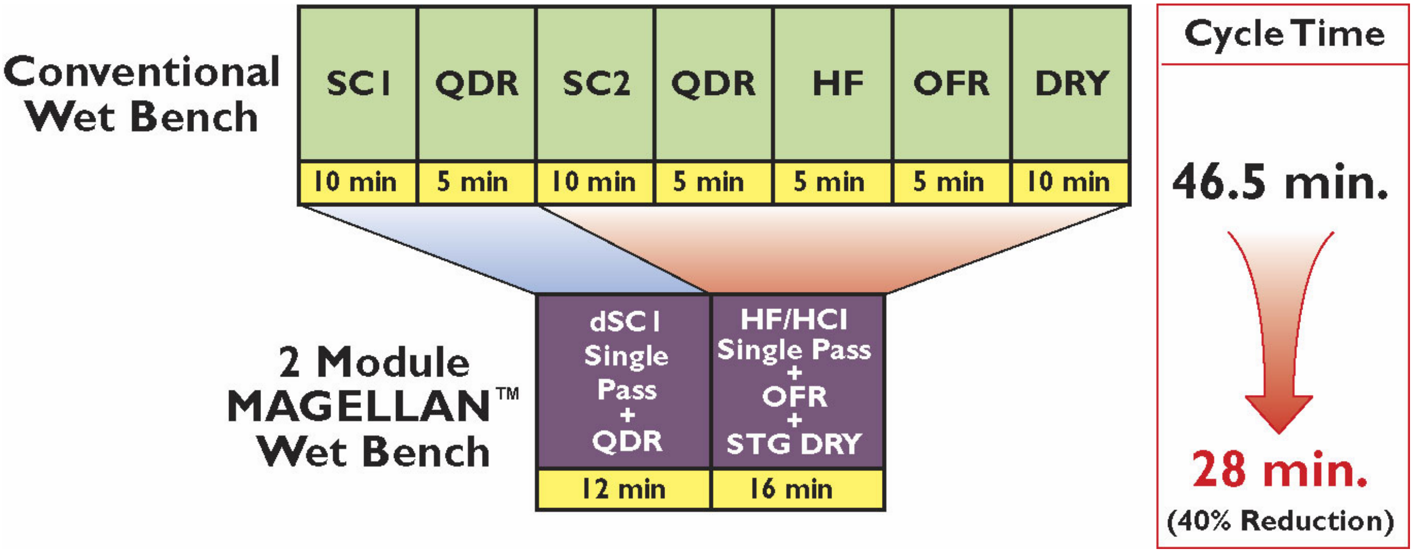
Cleaning Optimization

Multiple Goal Optimization

- Process Performance
  - uniformity, defects, surface termination
- Productivity
  - COO, footprint, cycle time, throughput
- Chemical and DI Water Usage
  - continuous improvement

Small Footprint, Short Cycle Time

- In Batch Immersion Reduced cycle time achieved with:
  - Muli-use tanks
  - Dilute, single-pass chemistry
  - Chemical injection in final rinse tank
- Challenge: Minimize Chemical and Water Usage



Conventional Wet Bench

SC1	QDR	SC2	QDR	HF	OFR	DRY
10 min	5 min	10 min	5 min	5 min	5 min	10 min

2 Module MAGELLAN™ Wet Bench

dSC1 Single Pass + QDR	HF/HCl Single Pass + OFR + STG DRY
12 min	16 min

Cycle Time

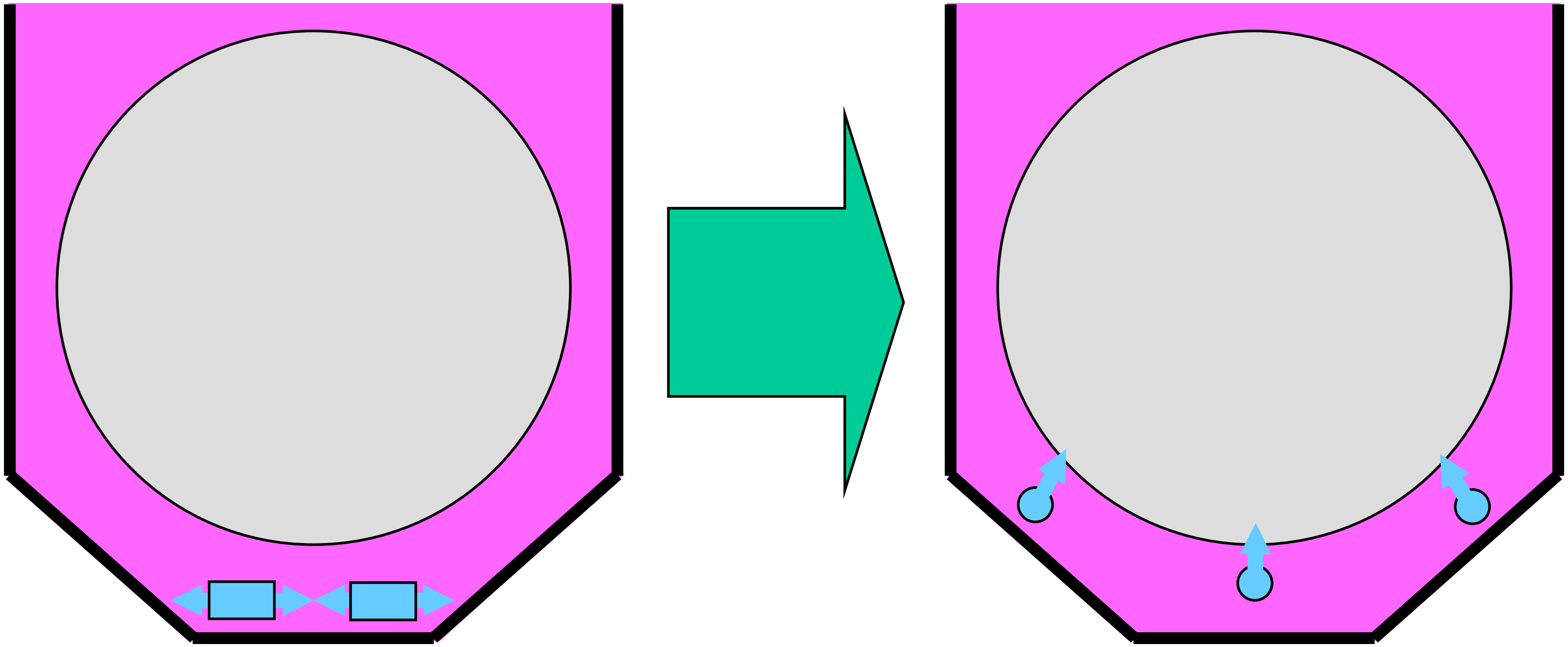
46.5 min.

28 min.

(40% Reduction)

Overflow Rinsing

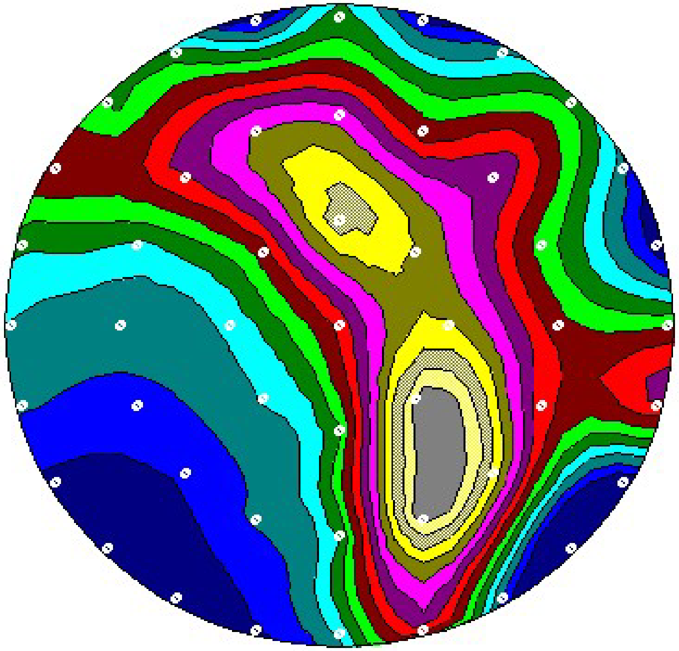
Plug Flow Rinsing versus High Velocity Water Jet Stir Rinsing



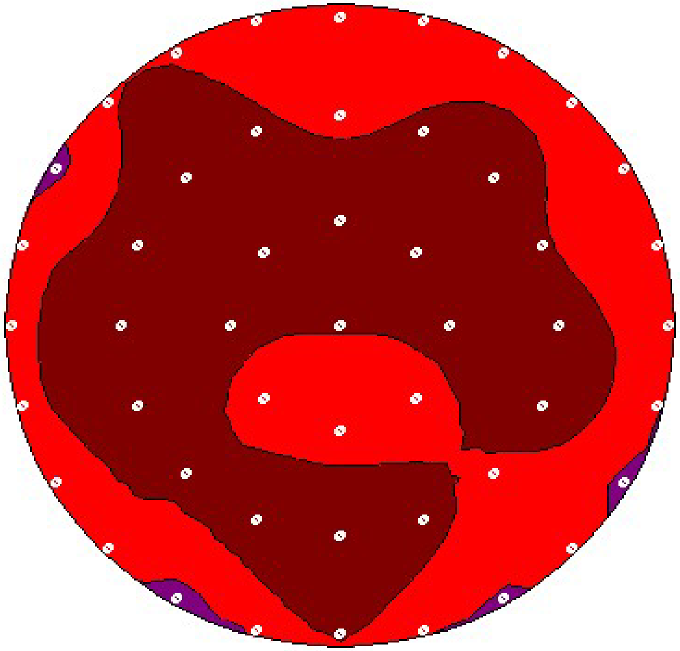
$$C = C_o e^{\left(-qt/V\right)}$$

Overflow Rinse Uniformity

200:1 HF thermal oxide etch,
followed by in-situ rinse, 300-mm wafers



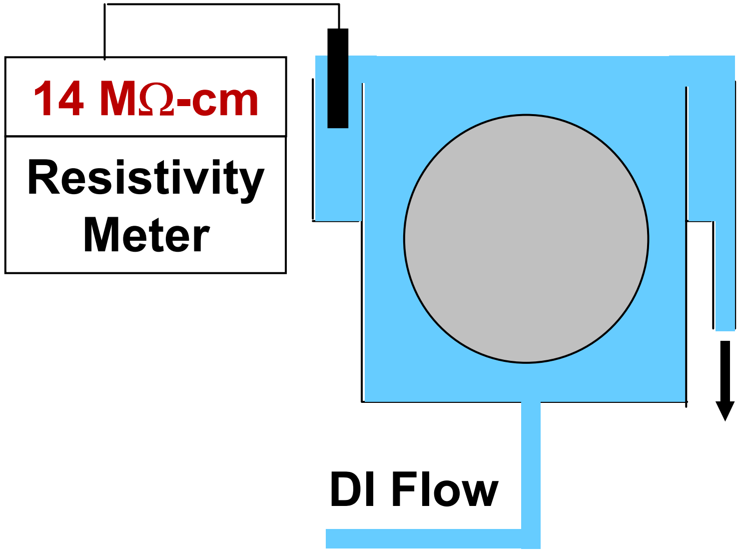
Original Rinse Design
stdev = 7.8 Å
range = 33.6 Å



New Rinse Design
stdev = 1.2 Å
range = 4.4 Å

Overflow Rinse Carryover

Traditional "Rinse-to-Resistivity"



14 MΩ-cm

Resistivity Meter

DI Flow

- In-situ resistivity probe installed in overflow catch weir
- Standard practice = rinse to 14 Mohm
- Not representative of water near wafer boundary layer.
  - residual chemical in weir
  - CO_2 dissolution.

Mendicino et al., SEMI Technical Symposium, SEMICON West 2001

Measuring at the Wafer

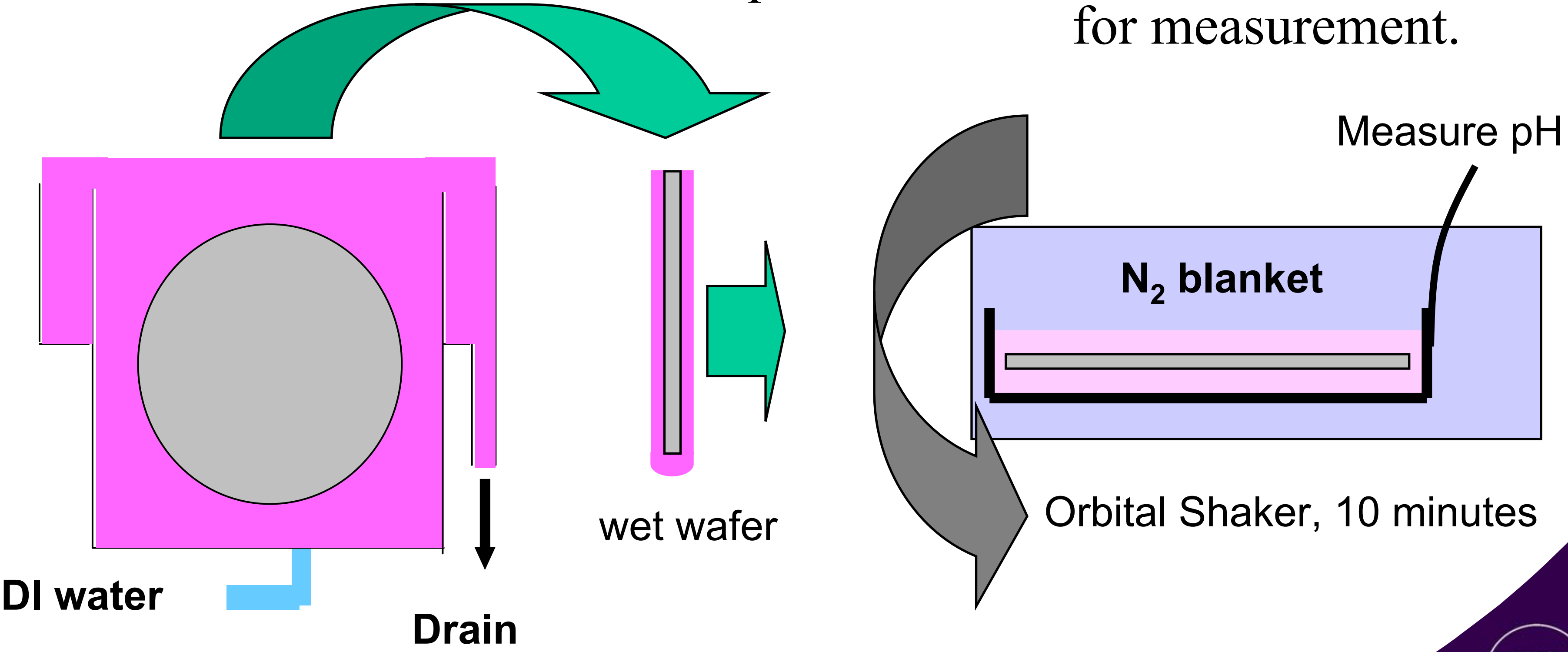
- Wafer Gap Conductivity Cell
  Lindquist et al, p.55, MRS Proc. Vol 386, 1995
- Oxide Trench w/ Buried Poly
  Shadman et al, p.189, Solid State Phenomena Vols. 76-77 (2001) [proceedings of UCPSS 2000]
- Measure pH of Carry Over Layer
  This work

Carry Over Layer Method

Fill tank with dilute HCl solution and soak wafer.

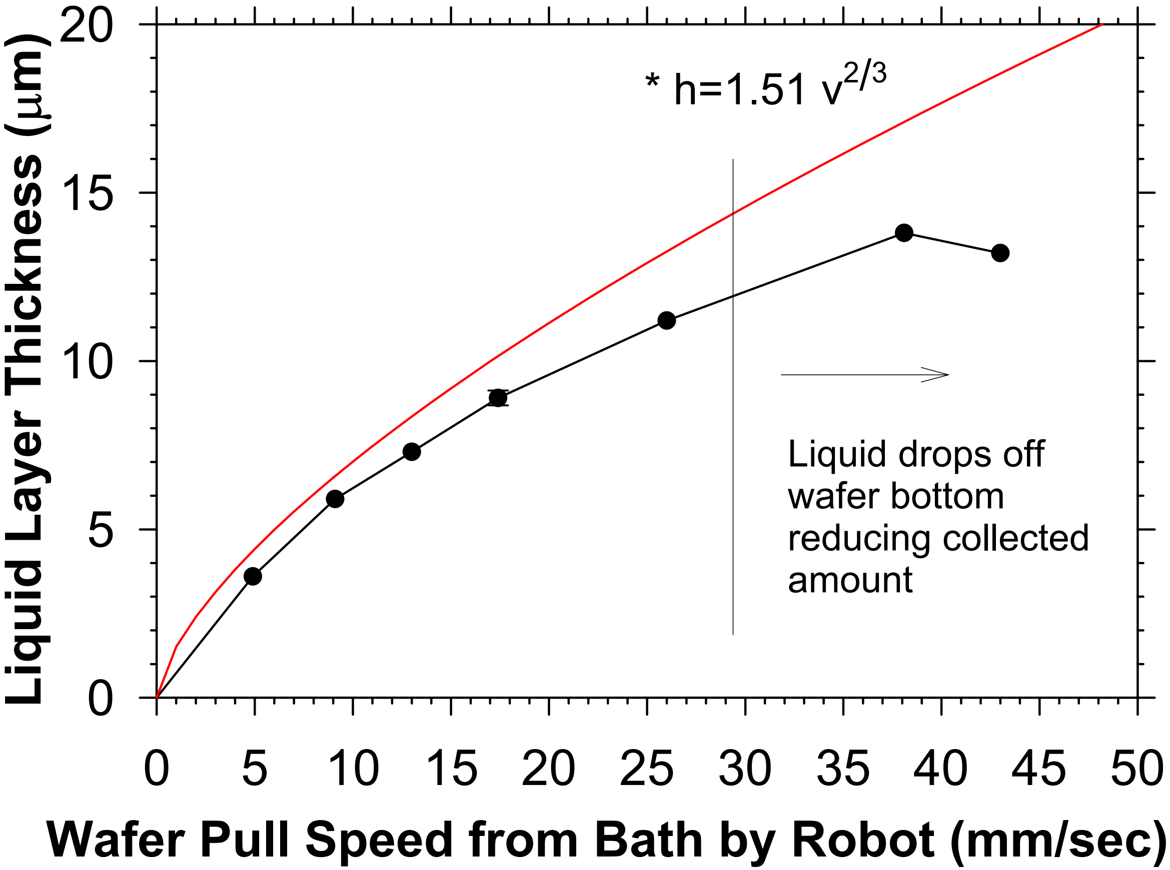
Pull Philic wafer From tank with some liquid

Place wet wafer in tray with DI water to collect chemical for measurement.



Carryover Layer Calibration

300-mm wafer pulled from 0.05 M HCl

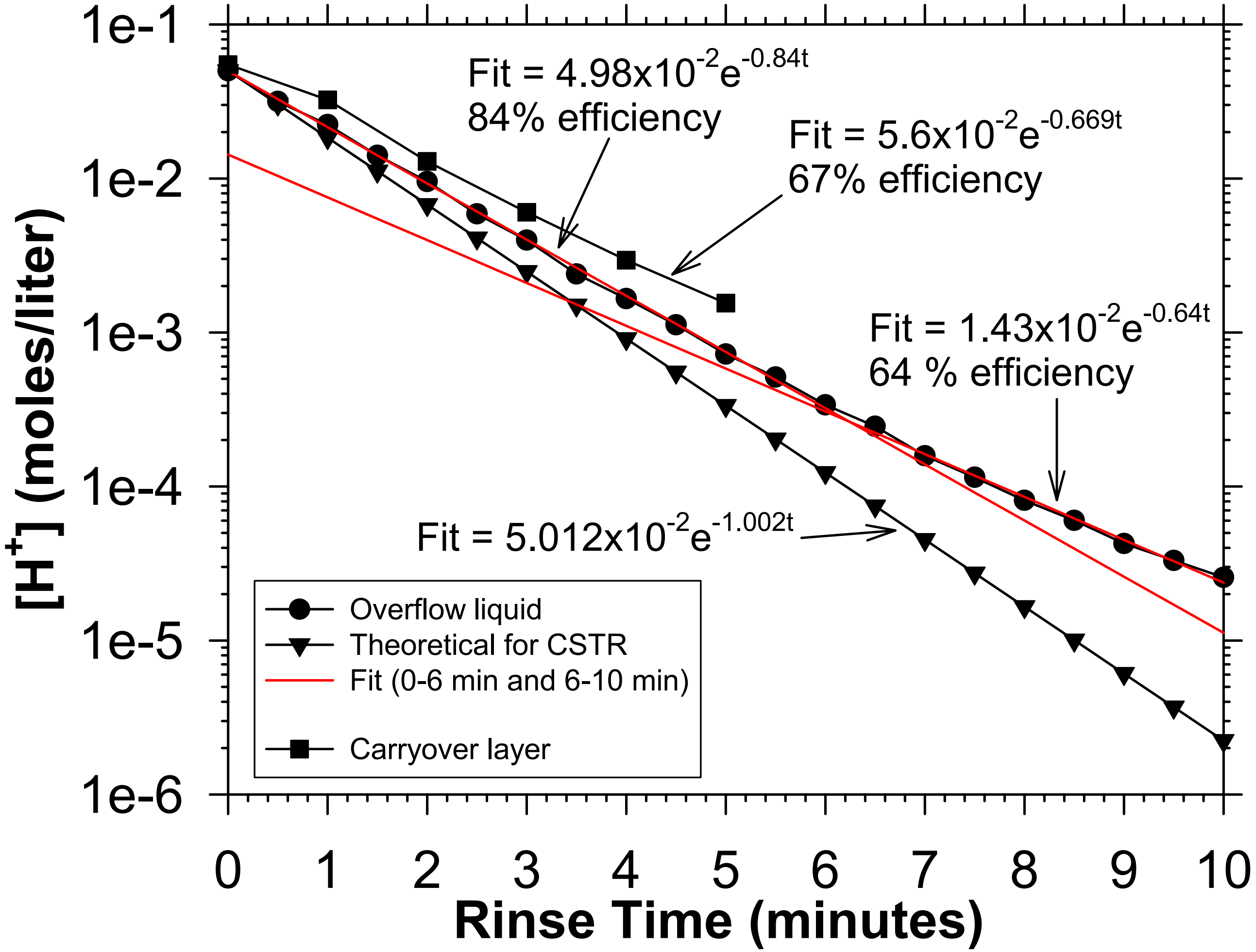


$$h = 1414.7\left[\frac{10^{-pH_{collected}}}{10^{-pH_{\tan k}}}\right]$$

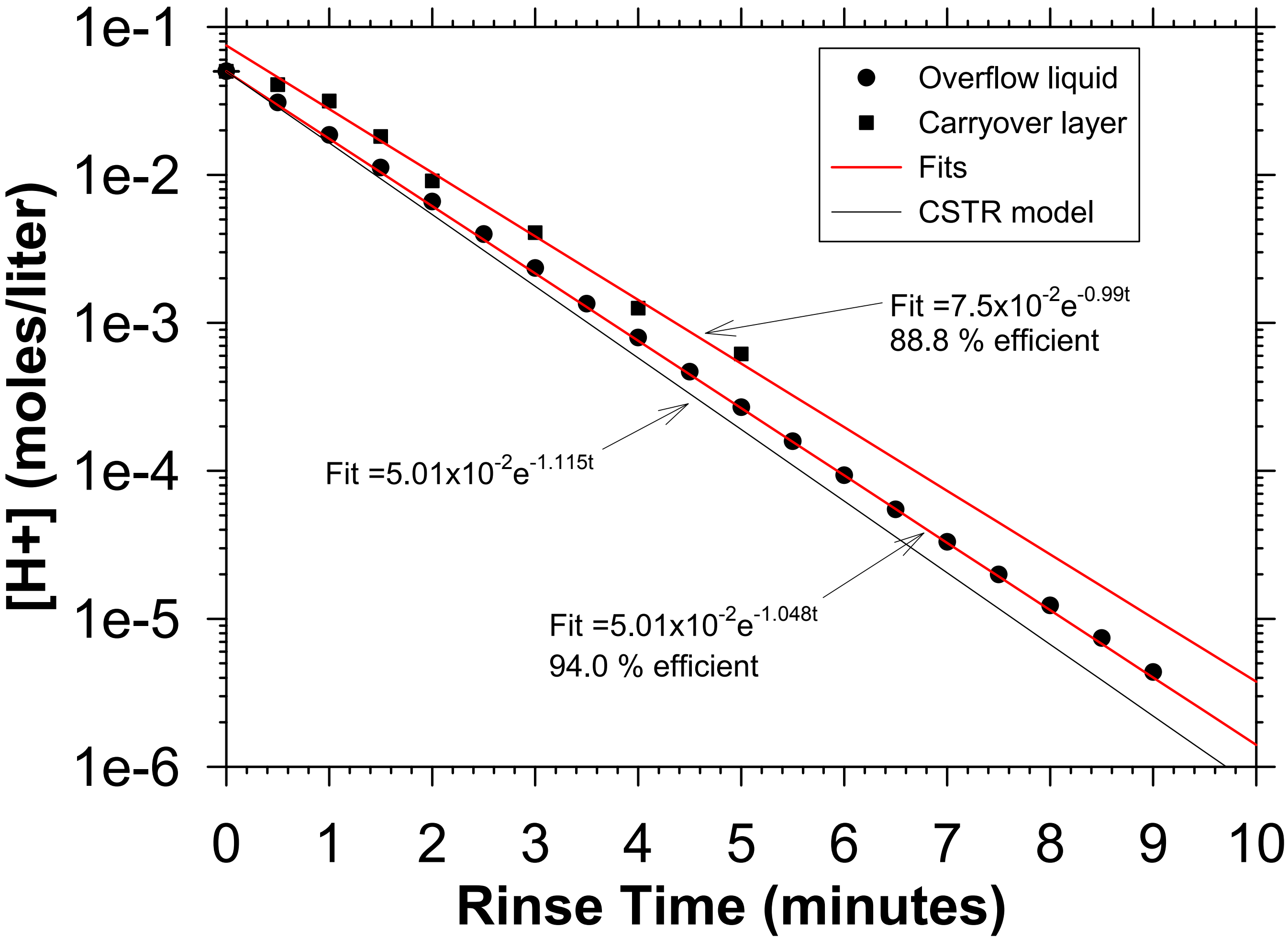
Surface area of wafer and dilution with water In collection tray.

* R. Spearow, J. Rosato and C. R. Helms, "Studies of Rinse Efficiencies in Wet Cleaning Tools," Proc. 3rd Intl. Symp. on Cleaning Technology in Semiconductor Device Manufacturing, J. Ruzyllo and R. Novak, Eds., The Electrochemical Society, Pennington, NJ, PV 94-7, 1994, pp. 140-152.

Original Rinse Design Results

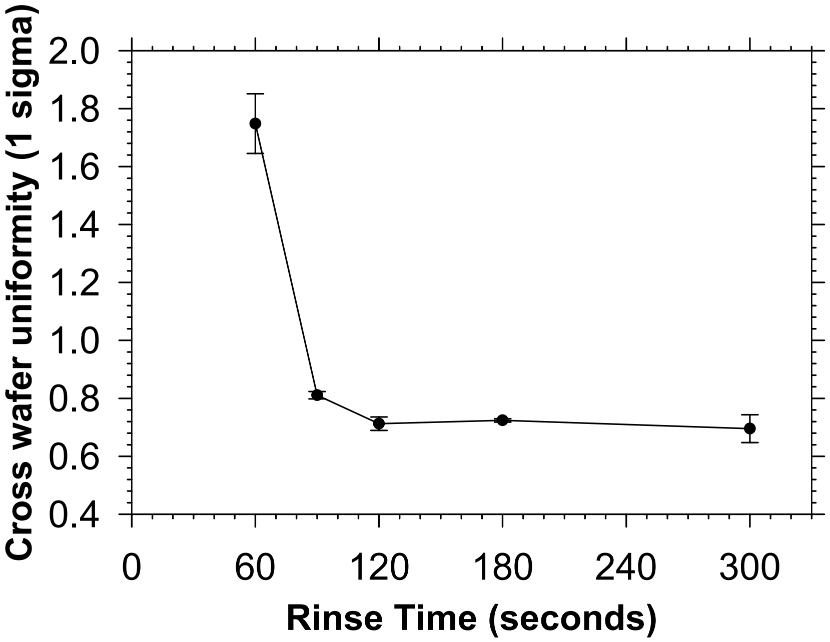


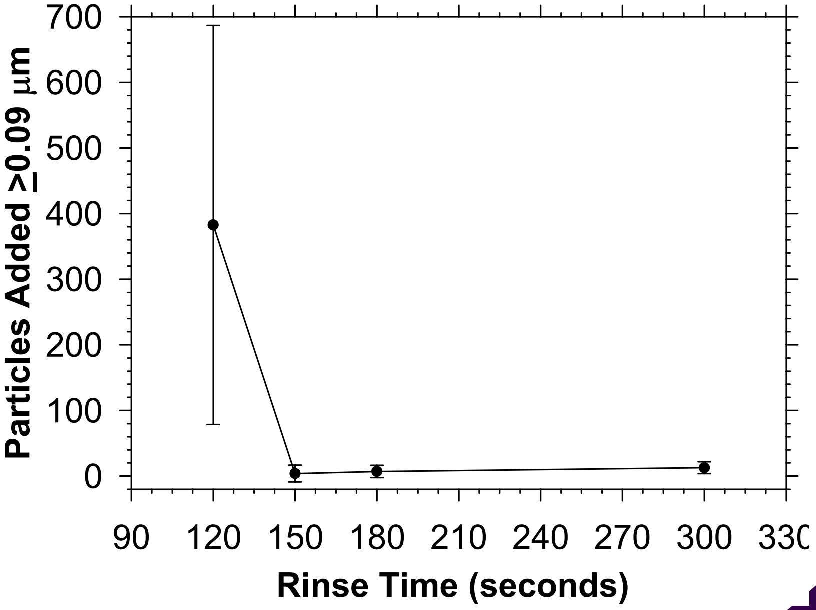
New Rinse Design Results



Etch Uniformity and Particle Results after Rinse Optimization

200:1 HF with in-situ overflow rinse using new rinse hardware and settings. 180-second rinse time. Followed by IPA dry.





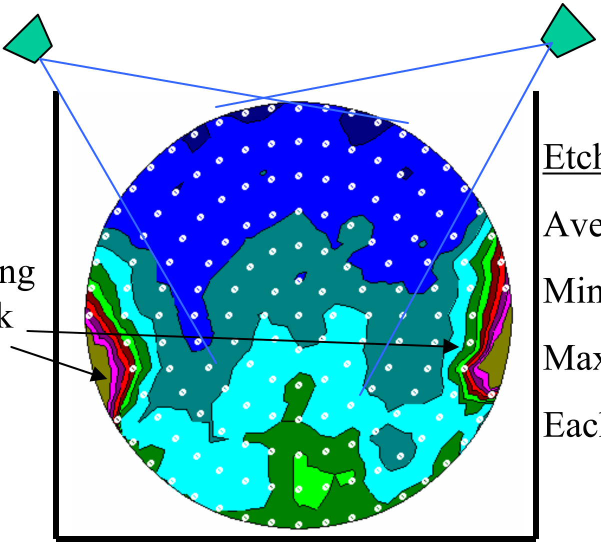
Benefits for 300-mm Production

	Old Rinse Method	New Rinse Method
Rinse Time	600-seconds	180-seconds
Water Used	400-Liters	120-Liters

Dump Rinsing

Dump Rinse Uniformity

200:1 HF thermal oxide etch
followed by chemical dump and spray



Shadowing
from tank

Etch Data

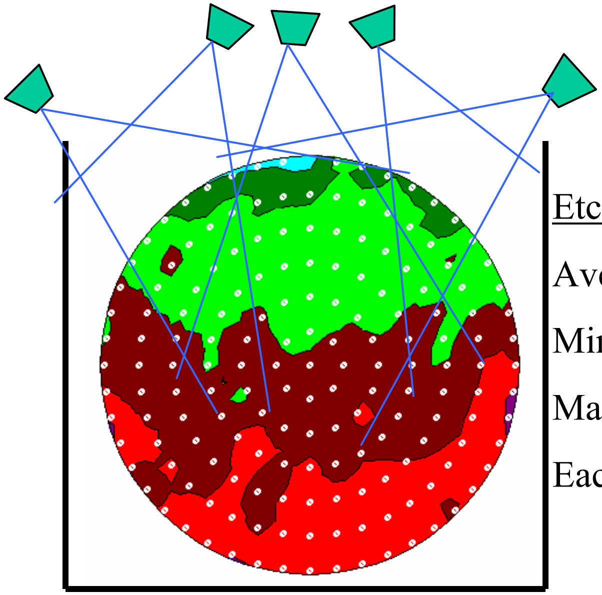
Ave. = 20.7 Å

Min. = 17.7 Å

Max. = 36.2 Å

Each color = 1Å

Side spray bars



Etch Data

Ave. = 23.8 Å

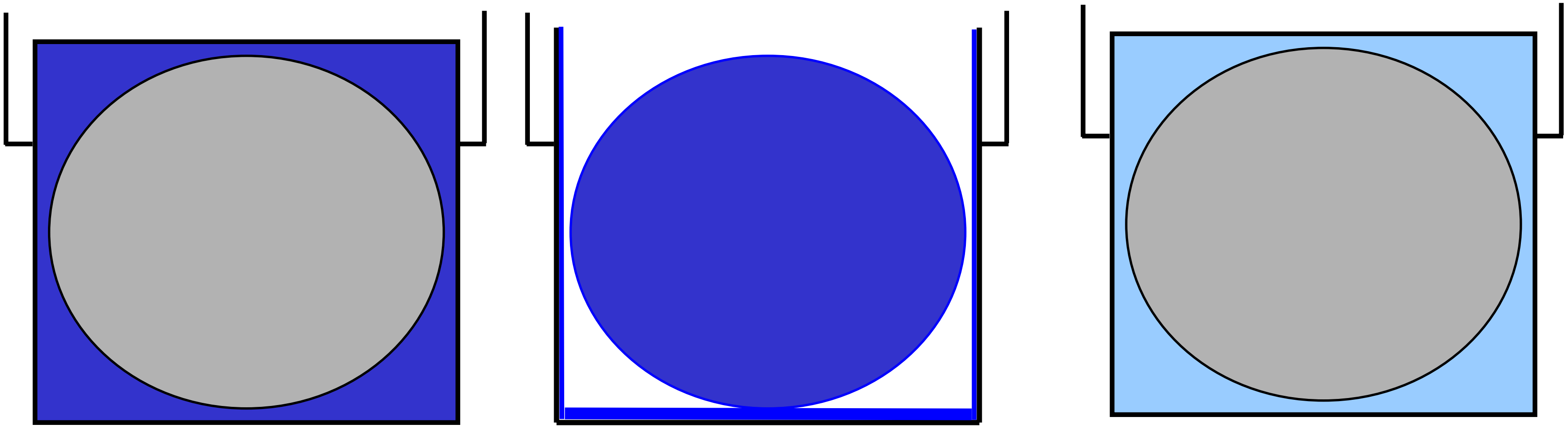
Min. = 20.6 Å

Max. = 26.0 Å

Each color = 1Å

Overhead spray bars

Tank Bottom and Wafer Surface Carryover



Tank and wafers with dilute HCl.

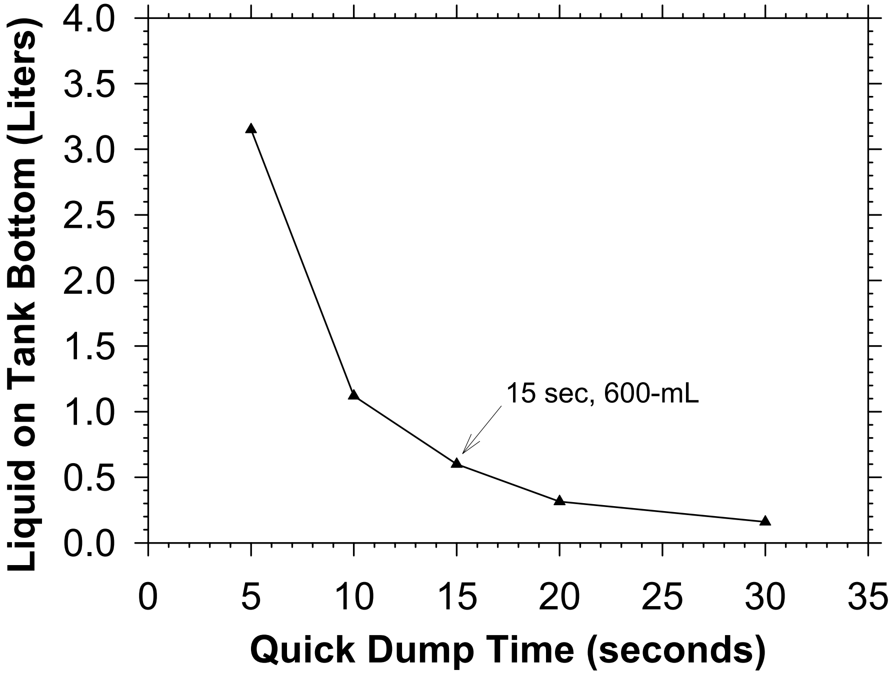
Dump tank, wafers and tank coated with chemical.

Refill tank with water. Use megasonics to mix chemical with water to collect and measure.

830-mL chemical remained in the tank after 15 second dump.

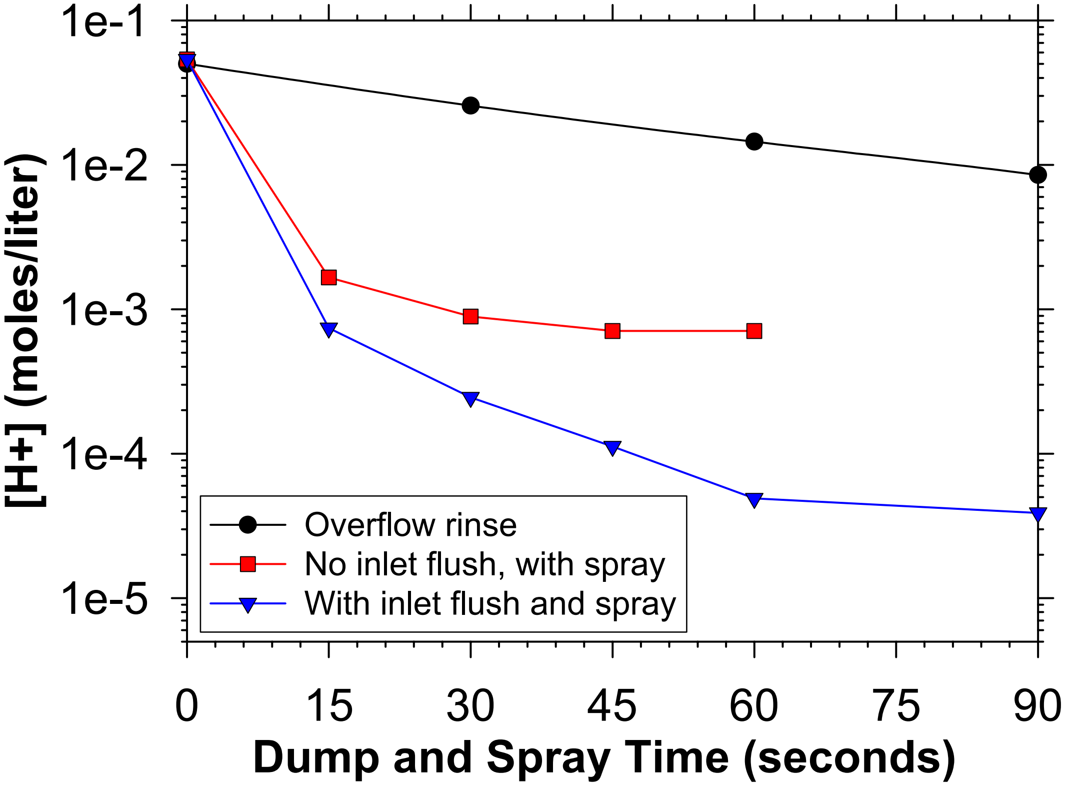
Accounting on Liquid when Tanks Dumps

Liquid remaining in bottom of tank, collected with sponge and measured



- Liquid remaining on wafer $= \pi r^2 h \times 2 \times \#$ wafers, $h = 1.51 v^{2/3} = 170$-mL
- Liquid remaining on tank walls = 10-mL
- 600+170+10 = 780-mL

Spray Rinse During Dump Step



- Tank inlet flush needed to rinse chemical out of tubing or it ends up in tank in next fill.
- With good coverage spray, chemical is removed faster with dump time up to 60 seconds.

Dump Rinse Recipe Changes

	Old Dump Rinse Recipe and Hardware	New Dump Rinse Recipe and Hardware
Number dump cycles	5	2
Total Rinse Time	425-sec	270-sec
Total Water Used	305-Liters	145-Liters
Dilution	40,000	3,000,000

Conclusions

- Oxide etch uniformity and pH measurements can be effective rinse characterization tools.
- Rinsing chemical from the wafer surface behaves different than rinsing the bulk of the liquid.

- Good spray coverage recommended for dump rinsing.
- Tank inlet flush recommended for dump rinsing.
- Longer dump times with fewer dumps save time and water and rinse better.