Ultrapure Water Use in Wafer Cleaning and CMP

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Supported by International Sematech
Rinse Optimization Impacts

**Performance**
- rinse cycle time reduction
- improve cleaning efficiency
- recycling/reclaim/reuse data

**Cost Savings**
- UPW, Energy reductions
- minimize UPW plant size
- increase productivity

**Environment**
Reduced water and energy consumption
## Water and Energy Use Goals (NTRS, 1997)

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td></td>
<td>250nm</td>
<td>180nm</td>
<td>130nm</td>
<td>100nm</td>
<td>70nm</td>
<td>50nm</td>
</tr>
<tr>
<td><strong>Water Use</strong> (gal/in(^2) Silicon)</td>
<td>30</td>
<td>10</td>
<td>6</td>
<td>5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><strong>Energy Use</strong> (KWh/in(^2) Silicon)</td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>
Earth’s Water Supply

- Water Does Not Escape the Earth’s Atmosphere and the Earth’s Water is millions of years old.
- Earth has 326 million Cubic Miles of Water
  - 99.7% UNUSABLE by Humans

<table>
<thead>
<tr>
<th>Water Sources</th>
<th>Water Volume (cubic miles)</th>
<th>Percent of total water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oceans</td>
<td>317,000,000</td>
<td>97.24%</td>
</tr>
<tr>
<td>Icecaps, Glaciers</td>
<td>7,000,000</td>
<td>2.14%</td>
</tr>
<tr>
<td>Ground Water</td>
<td>2,000,000</td>
<td>0.61%</td>
</tr>
<tr>
<td>Fresh-water lakes</td>
<td>30,000</td>
<td>0.009%</td>
</tr>
<tr>
<td>Inland seas</td>
<td>25,000</td>
<td>0.008%</td>
</tr>
<tr>
<td>Soil moisture</td>
<td>16,000</td>
<td>0.005%</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>3,100</td>
<td>0.001%</td>
</tr>
<tr>
<td>Rivers</td>
<td>300</td>
<td>0.0001%</td>
</tr>
</tbody>
</table>
RCA CLEAN

25 MILLION GALLONS OF UPW PER WEEK

Optimization of post-SPM, SC1 and SC2 rinses nearly identical
Classification of Optimizations

- **Non-Intrusive Optimizations**
  Reduce Idle Flow Rates, etc. easily done at Fabs.

- **Rinse Process Optimizations**
  Requires qualification, better done before tool installation

- **Equipment Optimizations**
  Retrofits are expensive, better done before tool installation
Optimization Plan

1.0 Phase 1: Diffusion Wet Tool Water Use Audit.
   1.1 Wet Tool Design Information Documentation (Tank Volumes, Pull-Out Rates, Transfer Times, Possible Modes of Operation, and Flow Rates).
   1.2 Rinsing Response Surface Calculations.
   1.3 Report on Calculated Baseline Performance and Recommendations for Optimized Processes.

2.0 Phase 2: Baseline Characterization
   2.1 Installed Sensor Evaluation.
   2.2 Recommendations for Sensor Upgrades if Necessary.
   2.3 Sensor Installation and Calibrations.*
      2.3.1 Rinse to Resistivity
      2.3.2 Analysis of Particle Counts
      2.3.3 Surface Analysis of Residues
      2.3.4 Chemical Analysis of Down-Stream Baths*
   2.4 Comparisons to Predictions.

3.0 Phase 3: Optimization.
   3.1 Final Recommendations for DOE on Rinse Optimization.
   3.2 Optimization Evaluation 1 - Physical Characterization (e.g. 2.3).*

4.0 Phase 4: Optimization Evaluation 2.*
   4.1 Short Loop MOS Caps - Yield and Reliability.
   4.2 Cost of Ownership (Water, Energy, Throughput, Yield).

*Optional
Critical Steps in Immersion Cleaning/Rinsing Process

- 1. Pull-Out from Chemical Bath
- 2. Transport
- 3. Immersion
- 4. Rinsing
- 5. Pull-Out from Rinse Tank
- 6. Transport
  - Next Chemical Bath
  - Dryer
Important Rinse Process Parameters

- UPW Temperature
- UPW Flow Rate
- Spray Velocity and Duration
- Drain Time Integrated with Spray
- Megasonic Agitation
- Additives, like Ozone, HCl, etc.
- Single Tank versus Separated Tanks
Examples of Rinse Processes

- **Overflow Dump Rinse**
  - Fill
  - Overflow
  - Drain

- **Quick Dump Rinse**
  - Fill
  - Drain

- **Immersion Spray Rinse**
  - Drain
  - Spray

- **Overflow Rinse**
  - Overflow
  - Fill
  - Spray
Post-SPM Rinse
(R. Chiarello, R. Parker, D. Gomez, HP Labs)

<table>
<thead>
<tr>
<th>SPM</th>
<th>Rinse 6 cycle</th>
<th>Dry</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 or 20 Min.</td>
<td>Overflow dump rinse</td>
<td>90 sec</td>
</tr>
<tr>
<td>T = 125 C</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 8 inch diameter wafers
- fully automated wet bench
- 27 liter sink volume
- 54 liter/min max. flow rate
- Standard, Optimized and Extreme rinses
Standard, Optimized and Extreme Optimized Rinses

- wafers enter rinse tank
- Extreme Optimized, post-SPM
  - 10 sec drain
  - 30 sec overflow
  - 3 sec drain
  - 10 sec overflow
  - fill
  - spray

- Optimized Rinse, post-SPM
  - 10 sec drain
  - 30 sec overflow
  - fill
  - spray

- Standard Rinse, post-SPM
  - 3 sec drain
  - overflow

Rinse Time (sec)
-120 -80 -40 0 40 80 120 160 200 240 280 320
Resistivity and Wafer Surface Data
Rinse Optimization Impacts
Applies to SPM, SOM, SC1 and SC2

- Incorporated Optimized Rinse Process
- 67% Reduction in UPW Use
- 62% Reduction in Post-SPM Rinse Time
- 3% increase in overall Fab Throughput
Recipe for Rinse Optimization
(Installed Wet Tools)

- Reduced Volume Rinse Tanks
- Reduce Idle Flow Rates in Rinse Tanks, SRD, etc. to 1 - 3 liters/min.
- Limit Overflow Segments for Post-SPM, SOM, SC1 and SC2.
- Use Highly Programmed Flow Rates
- Use Spray for rinsing non-etching chemistries
Next Generation Wet Tool

- 10 MΩm in 1 min.
- < 50 Liters/50 wafer
- 2.4 m² footprint
- highly dilute chemicals
Reducing Rinse Tank Volume

\[ C(t) = \frac{q}{V} \exp\left(-\frac{tQ}{V}\right) \]

Typical Case

Flow Rate Increased by 2x

Volume Reduced by 2x
## Wet Tool Comparison

<table>
<thead>
<tr>
<th>Tool</th>
<th>Tank Volume</th>
<th>Throughput</th>
<th>Footprint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet Bench</td>
<td>28 liters</td>
<td>220 wafers/hr</td>
<td>9.25 m²</td>
</tr>
<tr>
<td>STT</td>
<td>8.3 liters</td>
<td>90-250 wafers/hr</td>
<td>2.4 m²</td>
</tr>
</tbody>
</table>

- 50% reduction in UPW Consumption
UPW Use Solutions: FEOL

Cross-Functional Teams Needed

Optimized Tools and Processes Reduce UPW Use and Process times by 50% - 80%.

Effective Waster Stream Segregation and Treatment Leave less than 3% “Waste” water.

Engineers have discrete choices for process times and wafer surface quality independent of UPW Use.

Overall Fab Throughput Increases.
SEMICONDUCTOR FAB UPW USE

SURFACE PREP RINSING
45%

POST-ETCH 30%
POST-CLEAN 60%
DRYING 10%

CMP POLISH AND CLEANUP
50%

Supplier A
CLEANUP
POLISH

Supplier B
CLEANUP
POLISH

Supplier C
CLEANUP
POLISH
EHS in CMP
(Level - I Considerations)

- chemical inputs
- energy outputs
- water
- energy inputs
- ergonomics
- chemical outputs
EHS in CMP
(Level - II Considerations)

- publicly owned treatment works
- slurry type
- film type
- IC type
- IC density
- wafer size
- polish tool
- in-fab discharge treatment method
- energy outputs
- chemical inputs
- chemical outputs
- energy inputs
- chemical blending & delivery system
- post-polish tool
- pad type
- post-polish consumable
- UPW system
- process recipe
- wafer starts per week
- fab location
- EHS in CMP
- energy inputs
- chemical inputs
- energy outputs
- chemical outputs
- EHS
- Level - II Considerations
AMD CMP Water Use
(Mike Tritapoe)

- Water Conservation
  - *AMD initiative to reduce water consumption by 25% per site by 2002*
  - *AMD’s Pollution Prevention & Resource Conservation Standard*
  - *Research & Development at Sematech and SRC-University of Arizona*
Tool Layout
Some CMP Results

• Improve UPW fluid dynamics.
• Simplify post-CMP cleaning station.
• Implement a tool UPW low flow modes (cost savings 50K/year/tool)
Conductivity and Volume vs. Time
(end of pad life)

Time (min) vs. Conductivity (microSiemens)

Volume (liters) vs. Conductivity

Run 1 Start
Run 2 Start
A total of 1034 gallons of water was supplied during this time period.