Water Usage in the Semiconductor Industry

Jeff Hanson, P.E.
Facilities Engineering Manager
Texas Instruments, Inc.
May 13th, 2009
Texas Instruments

- Businesses
  - Semiconductors
    - Analog
    - Digital Signal Processors
    - Wireless
    - DLP Technology
  - Education Technology
Texas Instruments

Semiconductors

Educational & Productivity Solutions

Sensors & Controls
Texas Instruments
A sustainable system delivers services without exhausting resources. It uses all resources efficiently both in an environmental and economic sense.
Water Optimization Strategy

- Leverage industry associations for best practices and consumption data
- Utilize semiconductor manufacturing equipment data to drive improvements
- Leverage internal consumption data to understand gaps and close
- Water Systems Team
  - Facilities organization which works with fab(s) to optimize consumption and reduce cost
Industry Facts

• Semiconductor Industry Association (SIA)
  – Industry trade association representing over 70 US companies
  – **Profile of the U.S. Semiconductor Industry**
    • U.S. 2008 Sales = $120 Billion
    • Worldwide 2008 Sales = $249 Billion
    • 2008 World Market Share = 48 percent of $249 Billion Market
    • U.S. Jobs = 216,400
    • Percent of Sales Outside U.S. Market = 77 Percent
    • Capital Equipment = $13 Billion, 11 Percent of Sales
    • R&D Investment = $20 Billion, 17 Percent of Sales

• SEMATECH
  – Industry consortium that reduces the time from device research to a manufactured product
    • International subsidiary ISMI (International SEMATECH Manufacturing Initiative)
Wafer Processing Technology

- **Interconnect**
  - 6 Dielectric Deposition Steps
  - 12 Dielectric Etch Steps
  - 6 Ta/Cu PVD Steps
  - 6 Cu Plating Steps
  - 6 Cu CMP Steps
  - 1 W CMP Step
  - 12 Wet Clean Steps

- **Copper**
  - PVD + WCVD

- **Transistor**
  - 16 Thermal Steps
  - 11 Implant Steps
  - 5 Etch Steps
  - 2 CMP Steps
  - 38 Wet Clean Steps

- **Silicon Wafer**
Semiconductor Factory Water Consumption

Source: 2006 ISMI Water Balance Survey
Semiconductor Factory Water Production

Source: 2006 ISMI Water Balance Survey
Normalized Water Used

Gallons per cm² Wafer Outs

Industry Average = 3.91 gal/cm² wafer outs

Source: Semiconductor Industry Association
Normalized UPW Used

Gallons per cm² Wafer Outs

Source: Semiconductor Industry Association
Equipment Vendor UPW Consumption Data

- Common wet clean hood recipe data shown
- Comparison of UPW rinse time across many companies
- Large variations present for same process
Facilities Water Systems Team

- World wide team with members from all major manufacturing sites
- Focus is on cost reduction and learning new water technologies
- Forum for best practice sharing
- Develops strategy for recycle and reuse of “waste” streams
  - 1\textsuperscript{st} cut → Spent rinse water
  - 2\textsuperscript{nd} cut → “clean” acid waste water
  - Others
    - RO reject
    - Water system instrumentation consumption
Typical Wet Process Tool Setup
Spent Ultrapure Rinsewater

Two Main Water Sources:
- City Water
- Spent Rinse Water

Two Main Water Users:
- Cooling Towers
- UPW Plant

Which source to send to which user?

Minimum Quality Requirement

Highest Quality Requirement
Spent Rinsewater Recycle Benefits:
- Improved final UPW quality
- Less demand on the municipal water supply and waste water treatment systems
- Reduced chemical usage for ion exchange regenerations and waste treatment
- Less risk of municipal water supply variations
Risk Analysis

**Reward**
- City Water Offset
- Chemical Savings
- Increased savings by recycling to low end users
- Improve water quality

**Risk**
- Bio-fouling
- Dumping Chemical other than organics
- Project not succeeding
- FAB impact
- Equipment Malfunction
- Project not succeeding

---

[Image of a graph with points labeled #1 to #8]
Review of Water Demand – 1st Pass

City Water Demand

- A = 850
- B = 1705
- C = 315
- D = 150
- A = 50
- A = 300
- D = 125

% Water Re-used = 29%

Total City Demand = 3495

Internal Re-use

- B Brine Recovery = 270
- A DI R = 250
- A Brine = 200
- A DI R = 150
- D DI R = 125
- E IWW Re-use = 150
- F IWW Re-use = 280

Total Water Demand = 4920

Total Internal Re-use = 1425

*All values in gpm
Review of Water Demand – 2nd Pass

City Water Demand

A = 850
B = 1705
C = 25
D = 35
A = 50

Internal Re-use

DI Recycle = 250
Brine Recovery = 270
DIW Plant

DI R = 115
DIR = 175
KFAB DIR = 185
DI Reclaim = 150
IWW Re-use: D = 250, E = 150, F = 280, A = 300

% Water Re-used = 46%

Total City Demand = 2665
Total H2O Demand = 4920
Total Internal Re-use = 2255

*All values in gpm
RO Brine Recovery

“Winner 2001 AWWA Bob Derrington Award”

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Recovered</td>
<td>216 GPM</td>
</tr>
<tr>
<td>Yearly Water Savings</td>
<td>$295,000</td>
</tr>
<tr>
<td>Installation Cost</td>
<td>$142,000</td>
</tr>
<tr>
<td>Yearly Operating Cost</td>
<td>$33,500</td>
</tr>
</tbody>
</table>
Conclusion

• The semiconductor industry is actively searching for more ways to optimize water consumption
• Benchmarking with industry and internal data will continue to drive industry water consumption down
• The “low hanging fruit” has been picked; new ideas are needed for existing water reuse barriers (reduce risk)