Overview

- Scrubbing technologies
- Etch processes; reactants and effluent
- Effluent scrubber priorities
- Pumping and abatement - a Systems Approach

There is no one-size-fits-all abatement technology
Exhaust Chemistry and Scrubber Technology
Families of Etch Gases

- **Acid gases** - HF, HCl, HBr, BCl₃, AlCl₃, SiF₄, COCl₂, COF₂
  - Very toxic, can corrode ductwork
  - Water reactive, water soluble
    - Water scrubbers, dry bed scrubbers

- **Corrosive gases (oxidizers)** - Cl₂, F₂
  - Very toxic, can corrode ductwork
  - Water soluble, somewhat water reactive
    - Water scrubbers, dry bed scrubbers, fuel-heated combustors

- **PFC Gases** - CF₄, CHF₃, C₄F₈, SF₆
  - Not generally toxic, not corrosive
  - Global warming gases; not water soluble
    - Dry bed scrubbers (reactive or catalytic), combustors, plasma
Water Scrubbers

- Countercurrent air flow desired
  - Air and water are mixed in a tower filled with packing material (air enters bottom and water enters the top)

- Good N₂ inject design can prevent:
  - Water backstreaming
    - Subsequent blockages
    - Corrosion
  - Heated inlet required for aluminum etch

- Handles acid gases, corrosives, and particulates well
  - PFCs not abated

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Exhaust Management of Etch Processes

BOC EDWARDS
Dry Bed Reactors

- **Granular solid medium in container; gases reacted**
  - Room temperature or elevated
  - Can be consumed (chemisorption) or catalytic for PFCs

- **Different solids required based on process**
  - Optimized for metal etch vs. poly etch vs. oxide etch

- **Endpoint detection required**
  - Tells when medium is consumed
  - Susceptible to maximum gas flows (residence time)

- **Acid gases, corrosives, PFCs (depends on packing)**

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Exhaust Management of Etch Processes
Combustors

- Combustors burn fuel to destroy exhaust gases
  - Natural gas (methane, CH₄) or H₂
    - Fuel is source of H so halogens, halides can form HF, HCl
  - PFC gases require more effort to burn completely
    - Additional fuel, O₂ may be needed

- Most combustors have incorporated wet scrubbers
  - Removal of particulate
  - Removal of acid gases (HF, HCl)
  - Removal of heat

- Combustors use air
  - CDA or room air

- Be wary of side reactions
  - HBr may form Br₂ at high temperatures - combustors not recommended for poly etch
Plasma Device

- This plasma device operates in foreline
  - Uses “forming” gas to complete the reaction
    - H₂O, H₂/O₂, CH₄
  - Atmospheric plasma also available
- High levels of destruction for PFCs
  - 95 - 99% DREs for all PFCs
  - Conversion to HF, CO, COF₂, CO₂
  - Breakdown products cannot be eliminated
    - POU required

See Sematech report 99123865A-ENG
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Exhaust Management of Etch Processes
Dielectric Etch

**Input Gases:**
- CF₄
- HBr
- NF₃
- Cl₂
- C₄F₈
- SF₆
- CHF₃
- O₂

**Output Gases:**
- Input gases

**Byproducts:**
- SiF₄
- SiBr₄
- SiCl₄
- HF
- HCl
- HBr

- **Safety:** Cl₂ is toxic (TLV=1 ppm) and an irritant; byproducts are acidic with TLVs levels below 5 ppm. SiX₄ will block ducts, generate HX (X = F, Cl, Br)
- **Environmental:** byproducts are acid gases, CF₄ is global warmer
- **Downtime:** routine pm; relatively clean process (maintenance low)
Dielectric Etch

- **Water Scrubber**
  - Will remove acid gases and most Cl₂
  - Will not remove SF₆, CF₄, CHF₃ …

- **Combust / scrub**
  - All the gases and byproducts will be combusted into non toxic chemicals and scrubbed from exhaust

- **Cold Absorbers / Hot bed Reactor**
  - Ensure not only the input gases but the byproducts are also abated.

- **Plasma PFC abatement**
  - Ensure the abatement device does not generate other hazardous compounds
Dielectric Etch

- **Input:** CF$_4$, HBr, CHF$_3$, SF$_6$, Cl$_2$, HCl, NF$_3$, C$_4$F$_8$
- **Output:** Process gases, HX*, SiX*$_4$

<table>
<thead>
<tr>
<th></th>
<th>CF$_4$</th>
<th>HX*</th>
<th>CHF$_3$</th>
<th>Cl$_2$</th>
<th>SF$_6$</th>
<th>NF$_3$</th>
<th>C$_4$F$_8$</th>
<th>SiX*$_4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Burn</td>
<td>?</td>
<td>N**</td>
<td>Y</td>
<td>?</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Cold Bed</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Hot Bed</td>
<td>?</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Plasma</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Burn/</td>
<td>?</td>
<td>Y**</td>
<td>Y</td>
<td>?</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Scrub</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*The “X” in SiX$_4$ and HX refers to F (fluorine), Cl (chlorine), or Br (bromine).
**HBr dissociates to Br$_2$ in combustors - not removed by scrubbers.
Metal Etch

Input Gases: Cl₂, BCl₃, CHF₃, CF₄

Tool

Byproducts: HF, HCl, AlCl₃, B₂O₃, chlorinated photoresist

- Safety: Cl₂ is toxic (TLV=1 ppm) and an irritant; chlorinated photoresist is teratogen, carcinogen

- Environmental: byproducts are acid gases, CF₄ is global warmer

- Downtime: AlCl₃ & BCl₃ will form solids in contact with moisture - may cause blockages. AlCl₃ sublimes below 100° C and is notorious for duct blockages after the pump. Heat trace required.

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Exhaust Management of Etch Processes
Metal Etch

Pumping: Run pump hot to keep acid gases in gaseous form. The exhaust line must be heated to keep AlCl₃ from condensing.

- Water Scrubber
  - Removes acid gases and condensible byproducts
  - Will not remove SF₆, CF₄, & CHF₃
  - Chlorinated photoresist is not water-soluble.

- Combustion
  - Electrically heated tube not recommended for Cl₂; may form ClO₂
  - Combustion must be done with excess H (fuel) to form HCl.
  - Chlorinated photoresist may form chlorinated dioxins if not combusted thoroughly.

- Hot bed dry reactor works well.
  - CoO may be high
  - Trapping of AlCl₃ NOT recommended !!!
**Metal Etch**

- **Input:** Cl₂, BCl₃, CHF₃, CF₄
- **Output:** Process gases, AlCl₃*, chlorinated photoresist CP), HF, HCl

<table>
<thead>
<tr>
<th></th>
<th>Cl₂</th>
<th>BCl₃</th>
<th>CHF₃</th>
<th>AlCl₃</th>
<th>CF₄</th>
<th>CP</th>
<th>HF</th>
<th>HCl</th>
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</thead>
<tbody>
<tr>
<td>Hot Bed</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>?</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Water</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Burn</td>
<td>?</td>
<td>?</td>
<td>Y</td>
<td>N</td>
<td>?</td>
<td>?</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Cold Bed</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Burn/Scrub</td>
<td>?</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>?</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

*AlCl₃ condenses out as a solid after the pump and requires heat trace to prevent blockages. DO NOT COLLECT.
Prioritizing Effluents

It is the responsibility of the customer to select appropriate abatement:

- Some considerations:
  - Dilute or remove flammable gases to avoid fires
  - Remove solids to prevent blockages
  - Remove acid gases to prevent corrosion
  - Consideration to municipal regulations
  - Remove gases to below IDLH
    - IDLH (Immediately Dangerous to Life and Health level)
  - Remove gases to below TLV
    - TLV (Threshold Limit Value)
  - Remove all gases including non hazardous but environmentally damaging gases e.g. PFCs

- Technology to use will be decided by performance level needed
Prioritizing Effluents

Priority usually based on production demands:

1. Prevent duct blockages (mostly metal etch)
   - Heated pipework moves AlCl₃ to POU abatement
     - Water scrubber, dry scrubber

2. Prevent duct corrosion (acids, corrosives)
   - HCl, HF, BCl₃, COF₂, Cl₂
     - Water scrubber, dry scrubber

3. Abate PFCs, global warmers
   - CF₄, SF₆, CHF₃, C₄F₈
     - Plasma, combustion, dry bed (catalytic)
A Look into the Future
International Technology Roadmap for Semiconductors (ITRS)

- ITRS guides semiconductor industry into future
  - Many details - from photolithography, geometry, and low k, to facilities usage and installation of new equipment

- Utility Reduction - power
  - 50% reduction in 300mm production fab equipment energy consumption compared to 1999 200mm value by 2003
    - Per square inch of silicon

<table>
<thead>
<tr>
<th>Year of Production</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
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<tbody>
<tr>
<td></td>
<td>130nm</td>
<td>115nm</td>
<td>100nm</td>
<td>90nm</td>
<td>80nm</td>
<td>70nm</td>
<td>65nm</td>
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</table>

Chemicals, Materials and Equipment Management Technology Requirements

<table>
<thead>
<tr>
<th>Energy Consumption</th>
<th>Overall fab equipment (KWh/cm²)</th>
<th>Fab facility (KWh/cm²)</th>
<th>Tool energy usage per wafer pass (300mm vs 200mm); baseline 1999</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.5-0.7</td>
<td>0.4-0.5</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>0.5-0.7</td>
<td>0.4-0.5</td>
<td>1.0</td>
</tr>
</tbody>
</table>

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Exhaust Management of Etch Processes

BOC EDWARDS
### ITRS Driving Forces

- **Utility reduction – water**

  - **Aim for 5% water usage reduction per year**

<table>
<thead>
<tr>
<th>Year of First Product Shipment Technology Generation</th>
<th>1997 250 nm</th>
<th>1999 180 nm</th>
<th>2003 130 nm</th>
<th>2006 100 nm</th>
<th>2009 70 nm</th>
<th>2012 50 nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decrease net feed water use, gal / in² silicon</td>
<td>30</td>
<td>10</td>
<td>6</td>
<td>5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Decrease UPW* use (gal / in² silicon)</td>
<td>22</td>
<td>10</td>
<td>7</td>
<td>6</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Lower water purification cost</td>
<td>X</td>
<td>90% X</td>
<td>80% X</td>
<td>70% X</td>
<td>60% X</td>
<td>50% X</td>
</tr>
</tbody>
</table>
ITRS Driving Forces

- PFC reduction to <90% 1995 value by 2010

Graph showing:
- Recovery / Recycle
- Abatement
- Alternative Gases
- Optimization

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Exhaust Management of Etch Processes
ITRS: Integration of Pumps and Abatement

- Combine vacuum pumps and with scrubbers in single system
  - Engineered to work together “out of the box”
- Operational Benefits
  - Wafer Security
  - Reduced COO
  - Fewer Components, less servicing
- Safety
  - Risk Minimisation/ Transfer
  - SEMI Certification
- Installation Cost Savings
  - Space Saving
  - Time/ Cost/ Ease of install
  - Single Vendor

Integration concept known as ZENITH
Integration Detail

- Individual Components
- Space Management
- Utilities Management
- Proximity Pumps
- ZENITH

Increasing Integration

Install Cost / Install Time

0

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Exhaust Management of Etch Processes
Minimized Footprint

- Equipment footprint reduced by 44% vs. Individual components
- Required service footprint reduced by 68%

<table>
<thead>
<tr>
<th></th>
<th>Individual components</th>
<th>Zenith &amp; Proximity Pumps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Footprint Reduction</td>
<td>4.45m²</td>
<td>2.47m³</td>
</tr>
<tr>
<td></td>
<td></td>
<td>44%</td>
</tr>
<tr>
<td>Service Footprint</td>
<td>7.26m²</td>
<td>2.34m³</td>
</tr>
<tr>
<td>Reduction</td>
<td></td>
<td>68%</td>
</tr>
</tbody>
</table>

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Exhaust Management of Etch Processes

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Reduced Utility Hook-ups

- Save 60% on utilities connections

<table>
<thead>
<tr>
<th>Individual components</th>
<th>Zenith &amp; Proximity Pumps</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCW Supply</td>
<td>7</td>
</tr>
<tr>
<td>PCW Return</td>
<td>7</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>5</td>
</tr>
<tr>
<td>Power</td>
<td>7</td>
</tr>
<tr>
<td>Fuel</td>
<td>1</td>
</tr>
<tr>
<td>Make up water</td>
<td>1</td>
</tr>
<tr>
<td>Acid Drain</td>
<td>1</td>
</tr>
<tr>
<td>Oxygen</td>
<td>1</td>
</tr>
<tr>
<td>Vac-EMS Hookup</td>
<td>4</td>
</tr>
<tr>
<td>Bypass Hookup</td>
<td>4</td>
</tr>
<tr>
<td>Sub Wafer Forelines</td>
<td>6</td>
</tr>
<tr>
<td>F15 Extraction</td>
<td>0</td>
</tr>
<tr>
<td>Acid Extract</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total Reduction</strong></td>
<td><strong>45</strong></td>
</tr>
</tbody>
</table>

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Exhaust Management of Etch Processes

BOC EDWARDS
Safety and Reduced Risk

- Zenith is tested and built to the following standards:
  - SEMI Standards
    - SEMI S2-0302 (EHS)
    - SEMI S8-0701 (Ergonomics)
    - SEMI S14-0200 (Fire risk mitigation)
    - SEMI F15-93 (Leak testing)
  - CE Legislation and Standards
    - Machine directive 98/37/EC
    - Low voltage directive 73/23/EEC
    - EMC directive 89/336/EEC
    - Potential explosive atmosphere directive 94/9/EC - ATEX
    - Electrical safety laboratory measurement EN61010-1
    - EMC Emissions/immunity EN61326

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Exhaust Management of Etch Processes
Mini – TPU For Etch Processes

- Smaller, more economical unit for etch processes
  - Proven Inward fired combustion
  - New compact wet scrubber

- Reduced fuel consumption

- Quench zone for cooling

- Scrubber to remove HAPs
Atmospheric Plasma - Ionis

- 2.45 GHz Microwave
  - Compressed high density electric field
- Inducement of a stable plasma
- Suitable chemical environment for the destruction of PFC gases
EPX – Dry Pumps

- **EPX500P**
  - Peak Speed – 500 m3h⁻¹
  - Atmospheric – 10⁻⁶ mbar

- **Purge gas flow**

- **Only 1.4 kW power at Ultimate**

- **600W idle mode**
Zenith Etch Development Roadmap

- Incorporation of miniature TPU (CF₄ DRE > 90%) or ionis atmospheric plasma (CF₄ DRE > 90%) into cabinet with EPX pumps
- Footprint ~ 1m X 2m for scrubber and 4 pumps
- Single electrical, N₂, water, PCW, and exhaust drops
Summary

- Etch exhaust byproducts contain corrosives and PFCs
- Some abatement technologies don’t remove all the exhaust gases
  - This is for the customer to decide
- ITRS is driving towards integration of pumps and abatement
  - Smaller footprint, better CoO, lower utilities demand
- Etch-specific technologies are available to address ITRS guidelines