From Waste Treatment to Waste Recycling

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Background
Waste Generation in Future
Projected Global Waste Amount

A recent World Bank report projected that the amount of solid waste generated globally will nearly double by the year 2025, going from 3.5 million tons to 6 million tons per day.

Waste Amount in Taiwan

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Waste Output</th>
<th>Industrial waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>22,006K tons</td>
<td>64%</td>
</tr>
<tr>
<td>2010</td>
<td>25,688K tons</td>
<td>69%</td>
</tr>
<tr>
<td>2015</td>
<td>26,447K tons</td>
<td>73%</td>
</tr>
</tbody>
</table>

Data source: EPA, Industrial Waste Report and Management system
EPA, Environment statistics Database
Waste amount will increase significantly due to the complexity of advanced technology in semiconductor Industry.

Waste Amount vs. Tech. Node of Semiconductor

- Waste amount will increase significantly due to the complexity of advanced technology in semiconductor Industry.

Waste Amount by Technology Node

- >N28: 1x
- N28: 1.9x
- N20/16: 5.3x
- N10/7: 8.3x
Total waste amount will increase according to capacity ramp-up and contribution from the process complexity.

Need to set goals to find environmental friendly solution to control and reduce total waste even capacity increasing of advanced technology.

Projected Waste Trend in Semiconductor Industry

- Waste Amount If Follow Current Practice
- Capacity*Process Complexity
- Waste Amount to Have More Technical Breakthrough

Time
Waste Treatment in Semiconductor Industry
Waste Treatment in Semiconductor Industry

- Following is typical waste content in a semiconductor plant.
- More than 70% of waste is liquid waste from daily operation.

- H$_2$SO$_4$ 53.6%
- Solvent for Reclaim 9.9%
- CuSO$_4$ 5.8%
- H$_3$PO$_4$ 2.2%
- Sludge 13.9%
- Empty Drum 2.4%
- Others (Activated Carbon, wood...) 2.7%
- Solid Waste to Incinerate 2.3%
- Solvent to Incinerate 5.7%
- Empty Drum 2.4%

More than 70% of waste is liquid waste from daily operation.
Liquid Waste in Semiconductor Plant

The complexity is because the process relies on a combination of solvents, acids and water to spray, scrub, etch and dissolve contaminants from the wafer surface. For instance,

- **SPM,** $\text{H}_2\text{SO}_4/\text{H}_2\text{O}_2/\text{H}_2\text{O}$ is usually used to remove organic contaminants.

- **HF** it removes oxides, etches silicone oxides and dioxides, and reduces metals contamination of the surface.

- **NH}_4\text{OH}/\text{HF}/\text{H}_2\text{O}$ is used in place of buffered oxide etch.

- **APM, NH}_4\text{OH}/ \text{H}_2\text{O}_2/ \text{H}_2\text{O}$ remove particles, organic and metal contaminants from the surface.

- **HPM, HCL/\text{H}_2\text{O}_2/\text{H}_2\text{O}$ removes metallic contaminants from silicone substrate.

- **Thinner/developer and solvent** are used in photolithography process to transfer a geometric pattern from a photo-mask or clean process.
Waste Treatment in Semiconductor Plant

- More drain segregation from 5 to 36 due to process complexity.
Waste Treatment in Semiconductor Plant

- Management of Waste water
  - Comprehensive pipe networks to classify and collect the specific waste water to have cost effective solution for maximum reclaim rate.
Waste Treatment in Semiconductor Plant

- Establish the rule of drain segregation for every IC process tools.
- Clear and right segregation will be easier to identify the cost-effective solution of waste post-treatment.

Drain Piping Classification of Process Tools
## Waste Treatment in Semiconductor Plant

### Example of Drain Segregation

<table>
<thead>
<tr>
<th>AWD, CWD</th>
<th>HF</th>
<th>CMP, Cu CMP</th>
<th>Liquid Waste</th>
</tr>
</thead>
</table>
| **DIR:** DI Water Reclaim  
**DIR-\(O_3^*\):** DI Water Ozone Reclaim  
**AWD:** Acid Wastewater Drain  
**AWR:** Acid Wastewater Reclaim Drain  
**AWD-\(O_3\):** AWD Containing Ozone  
**AWD-\(H_2SO_4\):** AWD Containing \(H_2SO_4\)  
**CWD:** Caustic Wastewater Drain  
**CWD-\(O_3\):** Caustic Wastewater Ozone Drain | **HFD:** Diluted HF Drain  
**HFD-\(O_3\):** Diluted HF Ozone Drain  
**HFC:** Concentrated HF Drain  
**LSD:** Local Scrubber Wastewater Drain  
**NH\(_4\)F:** Ammonium Fluoride Wastewater Drain | **CMP:** CMP Wastewater Drain  
**Cu CMP:** Copper CMP Wastewater Drain  
**ECP:** Electrochemical Plating Wastewater Drain  
**BG:** Backside Grinding Wastewater Drain | **W-\(H_2SO_4\)**  
**W-\(H_3PO_4\)**  
**W-CuSO\(_4\)**  
**W-Chem-A**  
**W-Chem-B**  
**W-IPA 80%**  
**W-IPA 10%**  
**W-Thinner**  
**W-Chem-C**  
**W-Chem-D**  
**W-Chem-E**  
**W-Chem-F**  
**W-Chem-G**  
**W-Chem-H**  
**W-M2**  
**W-M1**  
**W-TMAH** |

**AOR**  
**AOR/ AOR-I:** Advanced Organic Wastewater Reclaim
Waste Treatment in Semiconductor Plant

- Process water reclaim rate from 64% to 88% in past 20 years.
Waste Treatment in Semiconductor Plant

- Treatment Units in a Semiconductor Wastewater Plant

Basic Wastewater Treatment
- Neutralization
- Chemical Sedimentation

Enhanced Water Reclaim
- Activated Carbon
- Resin Ion Exchange
- RO Technology
- UV Photo

Go for Material Reclaim
- Membrane Technology
- Catalyst Reaction
- Electrolysis

Evolution in Waste Material Reclaim
Evolution in Waste Material Reclaim

- Innovative and systemic solution to reclaim $\text{H}_2\text{SO}_4$ and $\text{NH}_4\text{OH}$ simultaneously. Not only reduce waste $\text{H}_2\text{SO}_4$ disposal but also present environmentally friendly to strip $\text{NH}_4\text{OH}$ from final discharge.

As-Was

- Process Tool
  - $\text{W-H}_2\text{SO}_4$ ➔ External recycling
  - $\text{W-NH}_3\text{-N}$ ➔ Final discharge

Integrated Solution

- Process Tool
  - $\text{W-H}_2\text{SO}_4$ ➔ $\text{De-H}_2\text{O}_2$ reclaim ➔ External recycling
  - $\text{W-NH}_3\text{-N}$ ➔ $\text{Membrane stripping}$ ➔ $\text{NH}_4\text{OH Reclaim}$ ➔ $\text{On-site}$ ➔ $\text{NH}_4\text{(NH}_4\text{)}_2\text{SO}_4$ ➔ $\text{External}$ ➔ $\text{Reduce H}_2\text{SO}_4$ Disposal ➔ $\text{NH}_4\text{OH Reclaim}$
Evolution in Waste Material Reclaim

- **Remove H₂O₂ from waste H₂SO₄**
  - Build treatment unit to decompose H₂O₂ from the waste H₂SO₄ drain.
  - The treated H₂SO₄ can be reused instead of extra buy from industrial H₂SO₄ for non-process requirement.

- **Process Flow**
  
  
  H₂O₂ + 2HCl → Cl₂ + 2H₂O
  H₂O₂ + Cl₂ → O₂ + 2HCl
  
  2H₂O₂ → O₂ + 2H₂O

  HCl plays the catalyst role in reaction.
- **NH₄OH and (NH₄)₂SO₄ reclaim from NH₃-N Removal in Wastewater**
  - A pioneer and environmentally friendly solution is successful to utilize reclaim H₂SO₄ to absorb NH₄OH from NH₃-N rich wastewater.
  - The (NH₄)₂SO₄ can be stripped to reclaim the NH₄OH or direct dry for industrial requirement.
  - Aim for achieving electronic grade NH₄OH for IC manufacturing process.

\[(\text{NH}_4)_2\text{SO}_4 + \text{Ca(OH)}_2 \rightarrow 2\text{NH}_3 \uparrow + \text{CaSO}_4 \downarrow + 2\text{H}_2\text{O}\]
Evolution in Waste Material Reclaim

Special thanks go to Mega Union and those who have involved and assisted to make this NH₄OH recycling process happen.

New Process
New Breakthrough
Evolution in Waste Material Reclaim

- **Copper Reclaim from Waste CuSO4 Drain**
  - Build the in-house electrolysis unit to reclaim the copper from waste CuSO4 drain instead of external reclaim to minimize waste from transportation.
  - It’s estimated to reclaim 1,000kg high purity copper per month from each single IC manufacturing plant.
Evolution in Waste Material Reclaim

- Turning the thinking and it’s about going “circular”.

Process Purpose (Mixing)

H₂SO₄ | H₂O₂ | NH₄OH | CuSO₄

Environment Friendly (C2C)

H₂SO₄ | NH₄OH | Copper

SEMICON TAIWAN
TSMC collaborates with over 40 waste handling contractors to achieve 95% reuse & recycle rate.

In these three years, we strive to go for further efforts to increase value of waste.

Evolution in Waste Material Reclaim

- Reuse by Other Industries
  - $H_2SO_4$
  - Sludge
  - Developer
  - Solvent
  - Metal Liquids

- Incineration
- Landfill with <0.4% Hazards
- H$_2$SO$_4$ Reclalm
- Reuse & Recycle in TSMC
  - Ammonia Waste Water
  - H$_2$SO$_4$ Reclalm

80%
Conclusion
Conclusion

- Facing the trend and challenge of waste increasing from the population, economic growth and change of human lifestyle.
- In past 20 years, having technology efforts to increase water and waste recycling rate to 90% and 95% respectively in tsmc.
- Continue moving efforts from waste treatment, water reclaim to add the value of waste, pursue more eco-friendly solution to environment.