Effects of improved filtration
Contamination Control and Yield

Cleans Contamination Control Model

Collaboration Example

Closing Thoughts
Agenda

Contamination Control and Yield

Cleans Contamination Control Model

Collaboration Example

Closing Thoughts
The need for contamination control to mitigate the formation of defects and the resulting impact on Yield is not a new problem.

The industry continues to evolve to mitigate the ever increasing requirements on contamination control. However the economic landscape has put increasing pressure on materials and consumables suppliers....
Contamination Control Financial Impact

#1 source of wafer Yield loss = $MM / Yr of lost revenue

Cost of tool process qual failures can exceed $20K / Hr

Major detractor to tool availability - can approach 10%

Adds $MM of extra unscheduled annual Opex & Capex

<table>
<thead>
<tr>
<th>Wafer level contamination related Yield detractors</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Particles</td>
<td>What size, how many, What are they</td>
</tr>
<tr>
<td>Metals</td>
<td>Which ones, what level</td>
</tr>
<tr>
<td>Organics / NVR</td>
<td>What quantity</td>
</tr>
</tbody>
</table>

Employing filtration & purification is an option to address these challenges
# Cleans Transformation

<table>
<thead>
<tr>
<th>200mm Wet Etch</th>
<th>300mm Cleans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bay and Chase configuration</td>
<td>Ballroom configuration</td>
</tr>
<tr>
<td>Batch wafer processing</td>
<td>Single wafer processing</td>
</tr>
<tr>
<td>Recirculated Chemical batch</td>
<td>Single pass single wafer chemicals</td>
</tr>
<tr>
<td>Open to cleanroom</td>
<td>Controlled atmosphere</td>
</tr>
<tr>
<td>Limited factory automation</td>
<td>Advanced capabilities</td>
</tr>
<tr>
<td>Chemical based</td>
<td><strong>Chemical and Gas based Cleans</strong></td>
</tr>
<tr>
<td>20-40 Steps (Manage &amp; Control)</td>
<td>200-300+ (Enabling)</td>
</tr>
<tr>
<td>Etch + particle removal</td>
<td><strong>Surface preparation</strong></td>
</tr>
<tr>
<td></td>
<td>Contamination control driven</td>
</tr>
</tbody>
</table>

The evolution of Cleans processing forces greater attention to contamination control a method to mitigate potential effects to wafer yields

**Source:** Antonio L.P. Rotondaro, Anthony J. Muscat, Handbook of Silicon Wafer Cleaning Technology (Third Edition), William Andrew Publishing, 2018
Agenda

Contamination Control and Yield

Cleans Contamination Control Model

Collaboration Example

Closing Thoughts
Cleans Contamination Control Model

EXTERNAL
- Raw Material
- Material Supplier
- Shipping

Primarily Managed by Supplier & Procurement

INTERNAL
- Fab Facilities
- Fab Cleans Equipment
- Process & Wafer
- Metrology

Facilities
Fab Operations
Goal

**NEVER disrupt the Supply Chain** - Collaboration and Alignment between the external and internal parties of the control contamination model

<table>
<thead>
<tr>
<th>Key Drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials</td>
</tr>
<tr>
<td>Chemical Consumables</td>
</tr>
<tr>
<td>Facilities</td>
</tr>
<tr>
<td>Services</td>
</tr>
<tr>
<td>Cleans</td>
</tr>
<tr>
<td>Wafers</td>
</tr>
</tbody>
</table>

“In union, there is strength.” – Aesop
Materials Supplier Element

Primarily Managed by Supplier & Procurement

EXTERNAL

Raw Material

Material Supplier

Shipping

INTERNAL

Fab Facilities

Fab Cleans Equipment

Process & Wafer

Metrology

Facilities

Fab Operations
Simplified Material - Chemical Manufacturing Flow

Incoming Raw Material
Single or multicomponent

Purification

Filtration

Assorted Metrology

Finished Product
Case Study: Material Role in Contamination Control

Goals

Provide quality chemical that does not negatively impact Cleans Operations

How

Implementation of filtration and purification at the material supplier site

Case #1

A chemical supplier is trying to reduce on-wafer 32nm particles as a part of a CIP activity

Results

>30% particle reduction

Particle control is a driver for improved yield, but has the potential to increase cost if increased processing is needed.
Fab Facilities Element

**EXTERNAL**

- Raw Material
- Material Supplier
- Shipping

Primarily Managed by Supplier & Procurement

---

**INTERNAL**

- Fab Facilities
- Fab Cleans Equipment
- Process & Wafer
- Metrology

Fab Operations
UPW POU Heater System

Challenges

- UPW Heater (gas or electric)
  - Material and components breakdown over time
  - Thermal cycling and age

UPW Supply

Process Temperature range is 50C to 70C

Sub Fab Level

Height: 15’ to <35’

Fab Level

Filtration

Purification

UPW Heater

Wet Clean Tool
Case Study: Facilities Role in Contamination Control

Goals

Provide Hot UPW at the necessary quality requirements

UPW is the #1 chemical for wafer processing

How

Implementation of filtration and purification at the UPW pou heater

Case #2

A 200mm fab is running a 180nm process with 100nm particle size sensitivity and experiencing a particle excursion

Results

>40% Particle reduction

0.5% Yield increase

Capture polymer particles shedding from piping and tubing with HAPAS\(^1\) filters

Potential Yield increase <1%, but this equates to a potential $MM increase in revenue

\(^1\)Highly Asymmetric Polyarylsulfone
Typical Distribution system*

*Contamination risk increases with time (age) and repurposing
Case Study: Facilities Role in Contamination Control

Goals

Provide IPA with an improved contamination level profile
Provide chemical with the necessary quality specs without impact to Fab

How

Implement purification on the chemical delivery system

Case #3

A 300mm fab running a 45nm process and encounters an OOC metals event resulting in ~8% Yield loss

Results

Containment provided
Failed item replaced

Captured stainless steel elements released from a failed component seal

Contamination control provides mitigation for process excursions and yield recovery
Equipment Element

Primarily Managed by Supplier & Procurement

EXTERNAL

- Raw Material
- Material Supplier
- Shipping

INTERNAL

- Fab Facilities
- Fab Cleans Equipment
- Process & Wafer
- Metrology

Facilities

Fab Operations
Typical Batch Wafer Process Overview

- Multiple process tanks
- 25-50 wafers / tank
- Wafers travel
- Process tank chemical lifetime is hours to days
- Potential cross-talk: wafer to wafer, in-bath, and batch to batch

Tank volume >15 Liters
Typical Single Wafer Process Overview

- Chamber processes single wafer
- Multiple chemicals in chamber
- One pass chemical usage ranges from 50-200 ml per wafer
- Advanced wafer handling / automation
Case Study: Cleans Role in Contamination Control

Goals

Process wafers with an improved wafer level contamination profile
Provide wafers with the necessary quality to the Fab

How

Implementation of improved filtration on the Cleans process tools

Case #4
A 300mm Fab is running a 28nm process and is trying to reduce on-wafer 40nm particles as a part of a CIP activity

Results

>50% Particle reduction
0.5% Yield increase

Contamination control provides an opportunity maintain and improve wafer yield

Reduced baseline particle level with advanced PTFE and HAPAS\(^1\) filters

\(^1\)Highly Asymmetric Polyarylsulfone
Contamination Control and Yield

Cleans Contamination Control Model

Collaboration Example

Closing Thoughts
Monitoring Methodology

Cleaning Tools Monitored Using PRE and PID

**Process removal efficiency (PRE)**

\[ 100\% \times \frac{\text{cleaned defects}}{\text{cleanable defects}} \]

**Process induced defects (PID)**

\[ \text{added defects} \]

**Old:** post count – pre count

Pre-inspection
- Cleanable
- Non-Cleanable

Post-inspection
- Common
- Removed
- Added
Light Scattering Tool SP3

- Defect localization and sizing
- Two channels at different spatial positions

Haze map
- Surface quality beyond defectivity

Quelle: IMEC
Different types of defects influence the scattering angle and the intensity of the scattered light in various ways. Narrow and wide channels allow a detection of different sizes and defect types.
Filter Replacement Overview

- DIW
  - SP DR 5 nm
- O₃ water
  - XpressKleen XP 5 nm
- HF
  - XpressKleen XP 5 nm
- HCl
  - XpressKleen XP 5 nm

Previous filters (10 nm) replaced by new generation Pall Filters:

- Ultipleat® SP DR 5 nm
- XpressKleen G2 XP 5 nm
Statistically significant change in added defects.

The new filters do help to provide cleaner wafers by adding less defects.

PID was reduced by 25%

> 33 nm on 300 mm wafer
PRE (process removal efficiency) is not significantly affected by the filter exchange.

The filters are not expected to alter the tool cleaning efficiency itself.
Contamination Control and Yield
Cleans Contamination Control Model
Collaboration Example
Closing Thoughts
Closing Thoughts

Cleans contamination control risks are very real........

Collaboration is critical factor to being successful......

Finer filtration - Not only relevant for 7nm nodes, can also help to reduce defects in fabs with broader node devices

State of the art products and technical consultation services can help to increase yield
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### Contamination Control and Yield

**Table 111b  Yield Model and Defect Budget MPU Technology Requirements—Long-term Years**

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>DRAM ½ Pitch (nm) (contacted)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plasma etch</td>
<td>63</td>
<td>50</td>
<td>42</td>
<td>30</td>
<td>25</td>
<td>19</td>
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<tr>
<td>Plasma strip</td>
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<td>23</td>
<td>20</td>
<td>14</td>
<td>11</td>
<td>9</td>
<td>7</td>
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<tr>
<td>RTP CVD</td>
<td>19</td>
<td>15</td>
<td>13</td>
<td>9</td>
<td>7</td>
<td>6</td>
<td>5</td>
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<tr>
<td>RTP oxide/anneal</td>
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<td>10</td>
<td>8</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
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<td>Test</td>
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<td>35</td>
<td>29</td>
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<td>17</td>
<td>14</td>
<td>10</td>
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<td>0</td>
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<tr>
<td>Wet bench</td>
<td>28</td>
<td>23</td>
<td>19</td>
<td>14</td>
<td>11</td>
<td>9</td>
<td>7</td>
</tr>
</tbody>
</table>

**Table 112b  Yield Model and Defect Budget DRAM Technology Requirements—Long-term Years**

<table>
<thead>
<tr>
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<th></th>
<th></th>
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<tr>
<td>DRAM ½ Pitch (nm) (contacted)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Plasma etch</td>
<td>214</td>
<td>109</td>
<td>107</td>
<td>107</td>
<td>57</td>
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<td>54</td>
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<tr>
<td>Plasma strip</td>
<td>164</td>
<td>84</td>
<td>82</td>
<td>82</td>
<td>43</td>
<td>43</td>
<td>42</td>
</tr>
<tr>
<td>RTP CVD</td>
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<td>RTP oxide/anneal</td>
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<td>Vapor phase clean</td>
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<tr>
<td>Wet bench</td>
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<td>43</td>
<td>41</td>
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</table>

Source: ITRS 2005