Advanced Process Control Implementation in Plasma Etch at Infineon Technologies Richmond
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Presentation Agenda

- Presentation Objective
- About the Environment
- The Opportunity in Plasma Etch
- Our Vision of APC
- An Implementation in 3 Phases
- Applications and Operational Benefits
- Conclusions
- Acknowledgements
Presentation Objective

- Share the IFR Plasma Etch APC experience
- Help the community learn from our successes and failures

Tell the Decision Makers:
- Return on Investment (ROI) can be achieved with APC

Encourage the Doers:
- Focus on ROI to make APC happen in your Fab
About the Environment

Infineon Technologies Richmond

- 200mm CMOS Fab (1st Si in March 1998)
- Deep trench based DRAM
- 140nm technology in volume production

Plasma etch department

- Process, equipment and manufacturing
- > 20 manufactured etch stages
- >10000 wafers per week passing through each etch stage
- >180 process/chamber combinations under control
- >170 product/parameter combinations under control

Assuming

300 die per wafer
$2 per die

1 scrap lot (25 wafers)

$15 000 revenue
About the Environment

Where we came from

- Statistical process control (SPC) on in-line product data
- Equipment health monitoring through blanket wafer qualifications
- Activity based preventive maintenance
- Unscheduled maintenance driven by excursions (SPC, parametric or yield) and hard tool faults
The Opportunity in Plasma Etch

- Irreversible yield critical process
- Sensitive to all incoming variations
- 3-dimensional process output limits the ability of metrology to represent process health and predict yield

After etch there is no way back!
The Opportunity in Plasma Etch

- Single wafer processing is the rule
- Multiple tool subsystems act independently and/or interact with each other to impact yield

At throughput of 100 wafers per hour per mainframe

Ch 1 produces 33 scrap wafers in one hour and >500 scrap wafers in one day!!!!!!!!!

Ch 1 goes bad on wafer 13. This could be caused by:

- Pressure
- Temperature
- Gas Flow
- RF power
- Magnetic Field
- … or a combination of …
The Opportunity in Plasma Etch

More data needed from More sources
Our Vision of APC

- Divergences from optimal conditions will be detected and compensated on first wafer (FDC)
- Every wafer leaves the Fab achieving its maximum yield potential – dynamic artisan processing (R2R)
- Capital equipment time will be utilized solely for production or predictive maintenance (OEE)
- Metrology will be a value added process (R2R)
Our Vision of APC

Future Considerations

- APC systems should be scaleable
- Wafer level ➔ Fab Cluster level
- High volume commodity products ➔ Complex multi-generational portfolios
An Implementation in 3 Phases

- **Phase 1**: Dedicated APC h/c added and spun off
- **Phase 2**: Engineering Man hours
- **Phase 3**: Projected m/h

**Engineerings**
- Non-APC m/h
- Dedicated APC m/h
- Non-dedicated APC m/h

**Timeline**
- Jan-00 to Jul-04
- 190nm, 170nm, 140nm, 110nm
An Implementation in 3 Phases

Phase 1 – Demonstrate Return On Investment (ROI)

- Reduce scrap with FDC
  - Deep trench and metal etch
  - ~$3M revenue savings over 12 months

- Increase yield with R2R
  - Shallow trench isolation depth control
  - 3% yield increase over 2 technology nodes

- Identify infrastructure and database requirements

- Justify additional resource allocation
An Implementation in 3 Phases

Plasma Etch Wafer Scrap

FDC impact at two critical process steps ~$3M revenue savings

65% reduction

Normalized Wafers Scrapped

6 Month Period
An Implementation in 3 Phases

Phase 1 – Demonstrate Return On Investment (ROI)

■ Obstacles
  • Inertia – reliance on traditional paradigm
  • Skepticism – uncertainty of new paradigm
  • Skills gap – no experience in APC

■ How We Overcame Them
  • Charismatic project manager
  • Small team of consensual junior engineers
  • Utilized internal competence centers
  • Workshops and conferences
  • Hired for missing skills
An Implementation in 3 Phases

Phase 2 – Develop Infrastructure and Applications
- Develop infrastructure based on Phase 1 learning
  - Equipment to CIM communication
  - Server hardware upgrades for functionality
  - “Tool server” creation for each vendor mainframe
- Hardware and software training for engineers
  - Data access
  - Data handling and manipulation
- Identify applications for automation and roll-out
- Justify additional resource allocation
An Implementation in 3 Phases

Phase 2 – Develop Infrastructure and Applications

- Obstacles
  - Unrealistic expectations
  - Multiple databases with incompatible data structure
  - Lack of resources both capital and human

- How We Overcame Them
  - Prioritized projects
  - Pareto and FMEA
  - Included product yield and quality groups
  - Focused on ROI as top priority
An Implementation in 3 Phases

Phase 3 – Automate Applications and Rollout Area-wide

- Automate four applications
  - Statistical machine control (FDC)
  - SPC by chamber (FDC)
  - Run to run (R2R)
  - Qual elimination (OEE)

- Monitor progress and stay on timeline

- Justify additional resource allocation
An Implementation in 3 Phases

Phase 3 – Automate Applications and Rollout Area-wide

■ Obstacles
  • Lack of capital
  • Lack of human resources
  • Managing a large quantity of milestones

■ How We Overcame Them
  • Focused on ROI
  • Created a graphical metric
  • Tracked unique milestone completion
An Implementation in 3 Phases

Phase 3 – APC Implementation Metric

<table>
<thead>
<tr>
<th>Item #</th>
<th>Process</th>
<th>Target Completion Week</th>
<th>Actual Completion Week</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SMC Capability</td>
<td>EP logbooks</td>
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<tr>
<td>1</td>
<td>Proc1</td>
<td>03ww06</td>
<td>03ww07</td>
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<tr>
<td>2</td>
<td>Proc2</td>
<td>03ww06</td>
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<tr>
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<tr>
<td>5</td>
<td>Proc5</td>
<td>03ww18</td>
<td>03ww07</td>
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</table>

> 20 processes total
An Implementation in 3 Phases

Phase 3 - Etch APC Implementation Metric

- Target Milestones Completed
- Actual Milestones Completed

<table>
<thead>
<tr>
<th>Fiscal Week</th>
<th>03ww01</th>
<th>03ww04</th>
<th>03ww07</th>
<th>03ww10</th>
<th>03ww13</th>
<th>03ww16</th>
<th>03ww19</th>
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</table>
Applications and Operational Benefits

- Wafer-chamber data enabled chamber level yield tracking and improved troubleshooting
Applications and Operational Benefits

- **Product etchrate data enabled qual elimination**

<table>
<thead>
<tr>
<th>Wfr#</th>
<th>Chamb</th>
<th>Diffusion Mean</th>
<th>Rng</th>
<th>1% sig</th>
<th>ARC EP Time</th>
<th>Etch Rate</th>
<th>POLY HM EP Mean</th>
<th>POLY HM EP Range</th>
<th>Etch Tool:</th>
<th>Recipe:</th>
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<tbody>
<tr>
<td>25</td>
<td>D</td>
<td>42.60</td>
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<td>97.00</td>
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<td>1303.25</td>
<td>92.60</td>
<td>96.60</td>
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</tr>
</tbody>
</table>

- Availability to production increased by 2% on average, test wafer usage reduced by 80% and associate productive time was increased
SMC data enabled improved fault management for OEE and predictive maintenance without loss of resolution.

Allowing production in the expanded operating region increased availability by 1% and yield by 0.1%.
Applications and Operational Benefits

*SMC data provided context to OEE statistics*

<table>
<thead>
<tr>
<th>Productive Wafers</th>
<th>Idle Time</th>
<th>Eng</th>
<th>Unsched Down</th>
<th>Non Productive Wafers</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>69.5%</td>
<td>6.9%</td>
<td>3.8%</td>
<td>18.4%</td>
<td>1.2%</td>
<td>0.2%</td>
</tr>
</tbody>
</table>

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Unscheduled wet cleans

Chamber idle: Eng eval for yield issue

Gradient = \( f(UT) \)

Process restriction

- Process 1
+ - Process 2
• - Process 3
Applications and Operational Benefits

- SMC data provided context to chamber yield performance

- Process dedication increased yield by 0.7%
Applications and Operational Benefits

- Systems and data for monitoring dynamic metrology performance

Tool2 does not match other gauges
Applications and Operational Benefits

- Happier engineers
  - Workload reduced by approx. 15%
  - Able to answer more questions
  - Able to prove the answer with data
  - Fewer excursions to clean up
  - More time to focus on interesting engineering projects **... like sensors!**
Conclusions

- APC implementation was a long road (3+ years for reasonable functionality and process coverage)
- The payoff is worth the effort
- Operational benefits in addition to FDC and R2R will be obtained
- Focus on ROI to overcome obstacles
- We still have not reached the final destination

- Next step – sensor integration??$$??
Acknowledgements

- **Contributions to the success of APC in etch were made by:**

  - **The IFR CIM and EI team** - Glenn Thompson, Mike Bussey, Norman England, Joyce Hartley and Bennie Fiol, without whose support our APC infrastructure would not exist

  - **The APC Team** – James Welsh, Matt England and Gary Skinner, whose support on application development made our ideas reality and opened our minds to new possibilities

  - **The Etch Cimco** – Dean Smith, who supported our tool server upgrades and maintained our connectivity to the production equipment

  - **IFX APC CoC** – Ralf Otto for FDC wisdom

  - **Ernst-Günter Mohr** for the inspiration to get started
References

1. Thomas Sonderman, AMD, “APC as a Competitive Manufacturing Technology: AMD’s Vision for 300mm”, Keynote Address, 3rd European AEC/APC Conference, April 2002
2. Brian Harrison, “Expanding the Control Paradigm by Excellence in Manufacturing Execution”, Keynote Address, AEC/APC Symposium XIV, September 2002