450 mm Fab Cleanroom Design Challenges

M+W Group
December 2013
Contents

- Introduction

- The Transition - Investment Drivers
  - Tool Dimensions / Weight
  - Floor Load and Cleanroom Height
  - Manufacturing Area Sizing
  - Utility Consumption

- Sustainability - Operational Cost Considerations
  - Energy Conservation
  - Related M+W R&D Activities
  - Facilities Optimization

- Summary
Our Industries

Advanced Technology Facilities
- Semiconductor
- Flat Panel Display
- Photovoltaics
- Battery Cells

Life Science & Chemicals
- Pharma & Biotech
- Food & Nutrition
- Consumer Care
- Chemicals

Energy & Environment Technologies
- Renewable Energy
- Waste to Energy
- Power Plants
- Oil & Gas

High Tech Infrastructure
- Science & Research
- IT & Telecom
- Space & Security
- General Industries

Process Automation
- Chemicals
- Pharma & Biotech
- Food & Nutrition
- Automotive
- Semiconductor
- Oil & Gas, Paper

Products & Services
- Cleanroom Products
- Air Handling Units
- Contracting
- Controlled Environments
- Technology Center
- Operation & Maintenance
Enabling New Horizons

Leader
“Top 100” of Germany’s World Market Leaders

E-Mobility
Pioneer developing a modular facility concept for large-scale Li-Ion battery manufacturing

Nanotech Research
Appointed as leader of 450 mm Facility Technology Development at State University New York

Food Security
Infant nutritional production utilizing most advanced technology

Growth Company
Appointed as one of the “50 most important global growth companies 2011”

Pharmaceutical Engineering
“Facility of the Year 2011” Award for our Customer Novartis Vaccines

World Record Photovoltaics
We built more than 11 GW of production capacities

Corporate Social Responsibility
Founding Member of Dii Desertec Industrial Initiative
M+W Group in the Semiconductor Industry

Leading global engineering and construction company…

- More than 7,800 employees worldwide
- World-class Environmental Health & Safety standards
- Technical expertise in process and automation

… for semiconductor production facilities

- More than 200 semiconductor Fabs designed and built
- Over 4 million m² of manufacturing area designed and built
- Installed over 11,000 tools since 2003
- Constructed NanoFab Xtension (NFX) facility for G450C programme operations
The 450 mm Transition Will Facilities become a Scale-Up Limiter?

- Making 450 mm a reality is a monumental task.
- Merely scaling up the new facility is not a practical option.

“The size of the 450 mm facility infrastructure and associated utility consumption projections will simply exceed affordability realities or resource availability. Solutions to these challenges require collaboration with experts across the entire supply chain.”

Al Ware, Semicon West, July 2013

- Related discussions in the industry have resulted in the formation of the Facility 450 mm Consortium (F450C) partnership within the G450C Cooperative Model.

A partnership of select facility experts working in consultation with G450C to bring their collective expertise to bear on the most pressing 450mm facility issues.
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If…
- the first 450 mm Fab should come on line within the next 2 to 3 years there is already today a need to extrapolate 450 mm tool requirements to enable the design and construction of 450 mm capable HVM factories.

But…
- only a few 450 mm process tools are already available at SUNY or other R&D sites for evaluation of requirements (footprint, load impact, utility consumption, move-in etc.).

Therefore,…
- M+W Group developed a tool scaling methodology in order to extrapolate future 450 mm tool requirements. The modeling results are continuously updated with real data collected from international R&D projects as well as within the framework of cooperation with tool vendors.
Anticipating 450 mm Impact on Fab Design Targets & Challenges

- **Current IDM Targets**
  - Same process tool throughput rate for 450 mm as for 300 mm (in wafers per hour)
  - Same utility consumption per wafer pass

- **Examples of Sustainability Challenges**
  - **Power Consumption**
    - Increased power demand by Lithography tools (especially in case of EUV)
    - Increased power usage by single wafer processing (RTP)
    - Development of idle mode solutions to lower power consumption
    - Overall increase anticipated
  
  - **UPW Consumption**
    - Trend to single wafer wet processing
    - Tool drain segregation challenges
    - Overall increase anticipated
Preliminary 450 mm Process Equipment Scale-Up Model

- Model Assumptions
  - Same throughput data as for 300 mm (in wph)
  - Assumed changes in tool architecture
    - Linear architecture of cluster tools is likely
    - Shift from batch to single wafer wet processing
    - Trend to Rapid Thermal Processing

- Modeling Methodology
  - Estimation of chamber and bath volumes based on wafer and batch sizes
  - Estimation of dimensions of handling and loading stations based on wafer and batch sizes
  - Estimation of equipment utilities consumptions based on anticipated chamber and bath volumes
  - Extrapolation of overall area and utility demand based on generic HVM equipment list
## 450 mm Process Equipment Initial Scaling Results

- Average estimated change of Footprint and Utility Consumption

<table>
<thead>
<tr>
<th>Tool Type</th>
<th>Footprint</th>
<th>Power</th>
<th>UPW</th>
<th>Exhaust</th>
<th>Size Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Furnace Metrology</td>
<td>+ 40%</td>
<td>+ 50%</td>
<td>n.a.</td>
<td>+ 20%</td>
<td>S/M</td>
</tr>
<tr>
<td>Small Vacuum Cluster</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large Vacuum Cluster</td>
<td>+ 20%</td>
<td>+ 30%</td>
<td>+ 50%</td>
<td>+ 20%</td>
<td>L</td>
</tr>
<tr>
<td>CMP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implant</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wet Bench</td>
<td>+ 15%</td>
<td>+ 20%</td>
<td>+ 80%</td>
<td>+ 20%</td>
<td>XXL</td>
</tr>
<tr>
<td>Litho Track</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Litho Scan</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend: S/M = Small/Midsize Equipment, L = Large Equipment, XXL = Very Large Equipment
Fab Totals – Utility System Consumption

- Moderate change of utility system consumption expected

<table>
<thead>
<tr>
<th>Tool Type</th>
<th>Effective Average Change [%]*</th>
<th>Size Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Furnace</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metrology</td>
<td>+ 7%</td>
<td>S/M</td>
</tr>
<tr>
<td>Small Vacuum Cluster</td>
<td>n.a.</td>
<td></td>
</tr>
<tr>
<td>Full Vacuum Cluster</td>
<td>- 8%</td>
<td></td>
</tr>
<tr>
<td>CMP</td>
<td></td>
<td>L</td>
</tr>
<tr>
<td>Implant</td>
<td>+ 8%</td>
<td></td>
</tr>
<tr>
<td>Wet Bench</td>
<td>+ 5%</td>
<td>XXL</td>
</tr>
<tr>
<td>Litho Track</td>
<td>+ 60%</td>
<td></td>
</tr>
<tr>
<td>Litho Scan</td>
<td>+ 5%</td>
<td></td>
</tr>
</tbody>
</table>

*) = Ratio of Utility Change / Area Change

Exceptions:

- UPW consumption (when volume-based)
- Technology driven consumption increase (e.g. for EUV) of electrical power, Hydrogen, etc.

On an overall cleanroom area basis, the combined changes in tool footprint and utility consumption can compensate each other.
Process Equipment Scaling – Weight Critical Driver – EUV Lithography

- EUV Scanners will remain the key structural design driver regarding:
  - Distributed load
  - Vibration criteria
  - Stiffness
- Minor increase in load specification in other functional areas.
- Potential for implementation of 2 waffle table load specifications
- Estimation of waffle table floor load for 450 mm fabs:

<table>
<thead>
<tr>
<th>Actual</th>
<th>Estimated</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 mm Fabs</td>
<td>15 – 20 kN / m²</td>
</tr>
<tr>
<td>300 mm Fabs</td>
<td>18 – 25 kN / m²</td>
</tr>
<tr>
<td>450 mm Fabs</td>
<td>30 – 36 kN / m²</td>
</tr>
</tbody>
</table>

A loading contingency of 15% is recommended pending input data from OEM’s.
# Investment Cost Impact of 450 mm Capability for new Greenfield Fabs

<table>
<thead>
<tr>
<th>Tool-Related Fab Design Guidelines – Change from 300 mm to 450 mm Technology</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual Equipment Footprint</td>
<td>+ 20 to 40%</td>
</tr>
<tr>
<td>Specific Utility Consumption per m² of cleanroom (*)</td>
<td>+ 0 to 20%</td>
</tr>
<tr>
<td>Cleanroom Height (**)</td>
<td>+ 20 to 30%</td>
</tr>
<tr>
<td>Roof Truss Load (**)</td>
<td>Will Increase</td>
</tr>
<tr>
<td>Waffle Table Floor Load Capability (***)</td>
<td>+ 20 to 30%</td>
</tr>
<tr>
<td>Waffle Table Stiffness (***)</td>
<td>May Increase</td>
</tr>
<tr>
<td>Vibration Classification</td>
<td>No Change</td>
</tr>
<tr>
<td>Investment Cost Adder for 450 mm Capability (****)</td>
<td>10 to 20%</td>
</tr>
</tbody>
</table>

(*) Increase is mainly driven by new processes and equipment technology, e.g. EUV, single wafer processing etc.
(**) Pending AMHS concept and preference for floor mounted or ceiling suspended maintenance cranes
(***) Mainly driven by simultaneous introduction of new lithography technology, not by wafer size transition
(****) Calculated per m² Gross Manufacturing Area for full 450 mm capability (Building and Facilities)

Source: M+W Group, 2013
Evolution of Typical High Volume Manufacturing Fabs - Past, Present and Future

- **Fab Construction**
  - **1990**: First Concrete (FC) to Ready for Equipment (RFE), 18 Months
  - **Today**: Fast Track FC to RFE, < 15 Months
  - **Future**: Ultra-fast Track FC to RFE, < 12 Months

- **Wafer Size**
  - 200 mm
  - 300 mm
  - 450 mm

- **Manufacturing Area**

*The Oregonian, 02/06/12*
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- Summary
Energy Conservation for Wafer Fabs
Key Relationships

Energy conservation evaluation should consider:

Process equipment defines
- Environmental conditions
- Supply media
- Capacities and consumption rates

Energy supply

Impact to system capacities and annual energy consumption

Energy saving potential by
- Use of alternative supply sources (renewables, cogeneration)
- Co-design of generation and supply system to
  - Get maximum total performances

Heat Transfer
Lower heat input/output reduces energy consumption
Energy Efficiency During Design
Five Step Plan

1. **STEP 1:** Improve Process Equipment Energy Efficiency
2. **STEP 2:** HVAC and Process Systems (PCW, CDA) Optimization
3. **STEP 3:** Thermal Energy Supply System Optimization
4. **STEP 4:** Heat and Cold Supply Systems
5. **STEP 5:** Alternative Energy Supply Systems
Facilities Optimization Potential Through Cooperation with Process Equipment Vendors

- 10% decrease in process equipment power consumption would reduce Basebuild CAPEX by ~2% (~$20M for a $1B fab).

- 10% decrease in process equipment exhaust volumes would reduce HVAC costs by ~3% / Basebuild CAPEX by 0.2% (~$2M for a $1B fab).

- 10% decrease in process equipment UPW consumption would reduce UPW system cost by ~7% & Basebuild CAPEX by 0.3% (~$2.8M for a $1B fab).

PLUS: Reductions in Facility Operating Costs

Source: Sematech
Equipment Energy Efficiency Improvement within G450C Cooperative Model

- M+W Group is the selected G450C Associate Member to lead F450C and to direct the interface between the G450C and F450C member companies.

- List of current and planned F450C Activities
  - Current:
    - Utility demand validation and optimization
    - Component lift capability and dynamic loading
    - AMC monitoring and real time measurements
    - Pump system optimization
  - Planned:
    - Overhead & under-floor space use allocation
    - Aisle/bay dimensions & related items (maintenance, predictive carrier logistics)
    - Installation enhancements (templates, reduced POCs, supports)
    - Health and safety-related items
    - He (Backside Cooling) & H₂ (EUV) gas recycling
Equipment Energy Efficiency Improvement within EEM450PR (Pilot Line Readiness)

- Project partners include Intel, IMEC, ASML, Edwards etc.
- M+W Group appointed as Work Package Leader for WP 1.4 “Facilities, automation and wafer handling”.
  - Special Focus: Smart tool operation and consequential OPEX savings

M+W Group Utility Saving Model
Initial Results [US$]*

*(HVM, 40,000m² GMA, located in Europe;)

- Power
  - 17,200,000 kWh/a
  - 2,300,000 US$/a

- Water
  - 220,000 m³/a
  - 260,000 US$/a

- Waste Water
  - 180,000 m³/h
  - 260,000 US$/a

- Natural Gas
  - 2,250,000 m³/h
  - 1,200,000 US$/a
Selected Facility Optimization Measures
Optimize HVAC Systems and Process Systems

- Decentralized systems instead of centralized systems
- Piping and ductwork design for low pressure losses
- Low supply pressure
- Adiabatic (spray) humidification
- Heat exchanger optimization
- Lowest make-up air supply temperature to avoid re-heating and re-cooling
- General exhaust recycling to reduce make-up air flow
Selected Facility Optimization Measures
Example Cleanroom Recirculation Air

- **FFU & Filter Optimization**
  - Reduction of internal Pressure drop FFU
  - Adjustment of FFU size and Fan size
  - Reduction of Pressure drop at Particle Filter
  - Remove FFU Pre-Filter after Commissioning

- **Cleanroom Optimization**
  - Increase / Decrease C/R Temperature (Seasonal)
  - Increase / Decrease C/R Humidity (Seasonal)
  - Reduce C/R Classification
  - Usage of Enclosure to reduce FFU quantity
  - Verify Heat Load Design Data
Selected Facility Optimization Measures
General Exhaust Recycling

- Make-up airflow reduction by local removal of risk-free general exhaust
- Separation of risk-free GEX is required at tool level
- Already been implemented in flat panel and retrofit semiconductor fabs

**Alternative 1**
Decentralized Recycling Air Units in Subfab
Recycling Air Sampling of a Tool Group

**Alternative 2**
Recycling Air Units inside Tool
(Small Fan + Cooling Coil)

Reduced operational cost and investment for make-up air, chillers and cooling tower
Selected Facility Optimization Measures
Make-up Air – Reduced Supply Temperature

- Lower make-up air supply temperature to the cleanroom improves make-up air cooling capacity
  - Smaller cooling coils required
  - Lower chilled and cooling capacity

- Higher make-up air cooling capacity reduces recirculation air cooling demand
  - Smaller cooling coils required
  - Lower chilled and cooling capacity

- Make up air unit outlet temperature shall be as low as possible (relative humidity at MUA-Unit outlet 85%)

Lower recirculation air cooling capacity reduces chiller, cooling tower, piping and cooling coil investment and the energy consumption
Selected Facility Optimization Measures
Chilled Water - Temperature Optimization

- Supply temperatures adapted to process requirements
  - Low temperature chilled water (LTCW)
    - Used for dehumidification only
    - Supply temperature specification according dew point (air specification)
  - High temperature chilled water (HTCW)
    - Supply temperature chilled water shall be as high as possible
    - Higher supply temperature improves the free cooling capacity

- Higher chilled water / Hot water temperature differences (system and heat exchanger design)
  - Lower pump power ($\Delta T$ increase from 6K to 8K saves 25%)
  - Smaller pipes

Positive impact on both – investment and operational costs
Selected Facility Optimization Measures
Electrical Systems

- Use highest available voltage
  - Lower transformer and cabling losses

- Use energy-efficient motors, frequency inverters

- Lighting: use energy saving products only (power saving by LED up to 80%)

- Increase temperature and humidity specification in electrical rooms

- Reduce lighting level to the required minimum

- Use motion detectors for light control in areas with lower access (plenum area, toilets, staircases, etc.)
Waste Reduction Potentials = Introduction of Recycling Material

Today
Consumables & Utilities
Waste

Single consumable strategy!

Future
Consumables & Utilities
Waste

Hybrid strategy!

Recycling
Regeneration

Source: www.faithasia.com
Summary

- From a building and facilities perspective, the 450 mm transition is evolutionary not a revolutionary.

- The technology roadmap (EUV, single wafer clean, rapid thermal processing) may dominate the impact versus the wafer size migration.

- The transition provides the opportunity to re-think and optimize actual operational procedures, facility design criteria and system specifications.

- M+W Group is involved in major 450 mm R&D projects and initiatives across the globe in order to identify potential facility optimization measures and support their incorporation into 450 mm HVM.
Thank You!

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