The Challenge and Opportunity of More-Than-Moore (MTM) Technology Transitions

Rossella Mininni
Strategic Marketing Manager, 200mm Equipment Product Group
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Outline

- Changing Semiconductor Landscape
- Applied Materials ≤200mm MTM Portfolio
- Manufacturing Challenges
- Example 200mm/300mm Transition Technologies
- Conclusion
Semiconductor Market Evolution

PC + Internet
Av. WFE = $25.5B*

Mobile + Social Media
Av. WFE = $32.3B**

Artificial Intelligence + Visual Computing
VR / AR
IoT / Smart devices
Big Data
AI / Machine learning
Smart vehicles
Industry 4.0
Additive manufacturing

Semiconductor Market Outlook

- **Smart Phone**: rising units number and need for new technologies – despite overall growth slow down
- **Automotive**: ADAS, Electrification, Telematics (4G/5G), Infotainment, miniaturization key factors
- **Datacenter/Server**: IoT / Increased ‘Cloud’ presence - onsets of photonic technology inflection
- **Communication Infrastructure**: 5G at the Base Station & the Node
- **Industrial**: Industry 4.0, Building Automation and Control, Robotics & Drones for industrial applications
- **Consumer**: IoT, 4G/5G, Virtual & Augmented Reality (VR/AR), Artificial Intelligence (AI), Drones & Robotics, Wireless Charging
- **Markets post-2021**: Automotive; 5G; Mobile Health; Next generation Virtual and Augmented Reality; Robotics & Drones

Gartner Forecast; Dec 2016
Emerging/MTM Application Technologies on 200mm

End Market Drivers

- Smartphone, Tablet & PC
- Communication
- Consumer
- Industrial Application
- Automotive (Safety, Navigation, ECM, Etc.)

Enabling Devices (Nodes)

- Advanced Logic
- Advanced Memory
- Packaging: Fan-out
- Image Sensor (28nm - 180nm)
- Analog Device (90nm - 180nm)
- Power IC (130nm - 350nm)
- MEMS, Sensors, RF (0.5μm - 5μm)
- Packaging Fan-in

Today ≤200mm represent > 70% of all IC content across all major market segments
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MTM Device Technologies: Opportunities for ≤200mm

- Additional tools
  - State of the Art Manufacturing Facility for New and Refurbished Tools

- Productivity
  - Spare Solutions for guaranteed availability, Value and Parts supply

- On wafer performance
  - Service solutions to Enhance Tool Capability & Improve Fab Efficiency

- New materials & Technologies
  - Product Development and Customer Demo Center

Extending Tool Lifetimes & Enabling New Technologies
MTM Device Technologies: Challenges for ≤200mm

- 200mm Equipment Availability
- Supply Chain
- Improve Performance
- New HW and Process Development

Extending Tool Lifetimes & Enabling New Technologies
≤ 200mm Manufacturing Facility - Austin, TX

- 92,000 sq ft. of manufacturing and warehouse, with 22 Test Bays (full final test)
- In-house component repairs/testing
- Capability to ramp up to 50 tools / quarter
- Manufacturing services for all Applied Materials product lines
- Supply chain and direct materials management, Obsolescence Protection
≤200mm Equipment Portfolio

Supporting the MTM evolution with innovative ≤200mm platform technologies
Key 200mm Upgrades

PVD
- Source Magnet Tachometer
- EZ LCF (Local Center Finder)
- MCA E-chuck

CVD
- Ultima to Ultima Plus
- Ceramic Clean Gas Manifold
- Slit Valve Door
- Vita™ Controller (Centura & Producer)

Etch
- Ceramic and EP E-chucks
- Black jacket turbo pump
- High temp. throttling gate valve
- $Y_2O_3$ Kit coating
- Slit Valve Door

CMP
- Multi-Zone Heads
- EZ UPA
- PM Reduction Kit
- Distributed Slurry Delivery Arm

Implant
- E2/E5: 1GHz Control System
  - Productivity Plus
  - Thin Wafer
- VIISion: Memory Upgrade

Thermal
- Motorized lift
- Radiance WRLD Upgrade
- High growth rate Epi

PDC
- SEMVision “Plus” Upgrades
- ComPlus Generation Upgrades
MTM Product Demo & Development
Xi’an, China based Customer Demo and Product Development Facility

- New products and applications development, customer demos
- Product enhancements, material & software testing and qual
- R&D Testing
Key Market Opportunities based on Technology Inflections

Device Application
- Fingerprint Sensor
- RF Filter
- Next Gen Microphone

Chamber Technology
- Soliton™

On Wafer Technology
- AIN / ScAIN / PZT
- ATM Blanket Epi

- EPI Wafers Power / MEMS
- IGBT / SJM Power Device
- High Power MOSFETs
- Next Generation MEMS Gyroscopes
- ≤12µm Al
- Critical Etch For MEMS
Committed to New Product Development Execution

**Deliverables:**
- Pilot capability
- Producibility engineering
- Low cost sourcing
- Testing strategies
- Lead time reduction
- DFX

**R&D**

New Products
Revised HW Designs

Clear ownership with strong ties to Business Unit

**MFG**

Performance Feedback

**Customer**

**Deliverables:**
- Meet Customer needs
- New product designs
- Prototypes
- Mfg support

Increased new products customization drives need to rapidly commercialize through manufacturing
AGS Service & Spares Portfolio

What We Offer - Service

► Flexible portfolio for custom solutions
► Advanced predictive and diagnostic technologies
► Innovative technology extension and conversion
► World-class expertise and knowledge-base systems

What We Offer - Spares

► Broad portfolio with focus on value and parts availability
► Steady stream of available parts including CIP
► Solution to refurbishment and quality issues
► Performance guaranteed on new or refurbished parts

Work with customers to boost Fab operational excellence

Draft
Manufacturing Challenges

Overcoming The Supply Chain For ≤200mm
Cores scarcity on the open market driving up the cost of used 200mm equipment
EPG building more 200mm new tools to be able to fulfill customer demand
150mm/200mm Core Market ASP Trends

Scarcity of cores on the open market increasing ASP pressure for specific tool or chamber
Refurbished vs. New Tool Builds

Core Refurb vs. New Mainframe Builds

- Core Refurb
- New Mainframe Builds
- % of New Mainframe Builds

Increasing percentage of new tools adding pricing challenges AND parts supply issues
Used vs. New Content Utilization

QoQ Material Utilization

- From Core Value
- Used Content Value
- New

Material:
- Q2'14
- Q3'14
- Q4'14
- Q1'15
- Q2'15
- Q3'15
- Q4'15
- Q1'16
- Q2'16
- Q3'16
- Q4'16
- Q1'17
- Q2'17
- Q3'17
Example 200mm/300mm Transition Technologies

MTM Defined As ≥45nm Technology Node
200mm to 300mm Transition

Drivers for 300mm transition

- Available Depreciated 300mm Line
- Opportunity For Disruption
- More Sophisticated ASIC
- WLCSP Required
- Technology Existing on 300mm
- Volume / ASP Pressure

The 200mm/300mm transition will occur in MTM on an opportunistic basis

Examples of device transitioned to 300mm
- CIS
- MCU
- Analog

Examples of device that may transition to 300mm
- Disruptive Technologies
- RF AIN / ScAIN Based Devices
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The 200mm/300mm transition will occur in MTM on an opportunistic basis
End User Application Market IC Revenue - by Wafer Size

- 300mm IC Revenue increasing in all application markets through 2020 and representing ~70% of the total IC revenue
  - 300mm legacy IC revenue growing ~3x faster than 300mm leading edge IC revenue driven
- 200mm IC Revenue flat to slightly up through 2020 in application markets reflecting increased wafer starts and capacity adds
  - Eroding ASPs and profits shifting up the supply chain negatively impacting 200mm IC Revenue despite increased wafer demand

**IC Revenue ($B) 2016 - 2020**

<table>
<thead>
<tr>
<th>Application</th>
<th>2016</th>
<th>2020</th>
<th>CAGR 2016-2020</th>
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<tbody>
<tr>
<td>Smart Phone</td>
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<tr>
<td>Other</td>
<td>4</td>
<td>6</td>
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</tr>
</tbody>
</table>

**300mm Legacy**

- 200mm: 0.5%
- 300mm Legacy: 10.8%
- 300mm Leading Edge: 3.5%
- Total IC Revenue: 3.7%

**Source**

EPG marketing, Gartner 2016, Yole Developpement 2016; Data Beans Est. (TI, 2013)
* Consumer includes PC and Tablets

CMOS: Memory 300mm & 30% of total CMOS revenue; Logic revenue @ 200mm 30% of total logic
CIS, Analog and Power revenue would be either 200mm or 300mm (legacy), MEMS all 200mm
YoY % of 300mm revenue +2% for CMOS and CIS / +6% for Analog and 9% Power 1% 300mm revenue by 2020 for MEMS
Advanced RF/pDC PVD Chamber For MTM Films

- Soliton serves a broad variety of PVD films: **Piezo-Films, AlN, Sc:AlN, VOx, Mag. Aligned Films**, Others ($\text{Al}_2\text{O}_3$, Ta)
- Application segments include **MEMS & Sensors**, **Power Device & LEDs** (e.g., GaN on Si)

Next Generation RF/pDC PVD
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Key Challenge: Transfer High Temp (800°C) capability
High Deposition Rate Thick Aluminum (Al)
For Applications In Power and MEMS Devices

- Single pass solution for ≤12µm films
- High productivity <3µm/min deposition rate
  - (2x) productivity of standard Al chamber
  - > 50% improvement compared to the available solutions in marketplace
- Defect free films, no whiskers, hillocks
- Production proven at an automotive customer site
- Lowest CoO – available as an upgrade or chamber add to existing platforms, no need to introduce a new platform
High Deposition Rate Thick Aluminum (Al)
200mm/300mm Transition

key challenge: match power density and wafer temperature control

200mm HDR Al

300mm Alexandria
Advanced Deep Reactive Ion Etch (DRIE)

DRIE for Power, MEMS and Packaging Technologies

Transitioning MTM Technologies to 200mm/300mm Capable Tools

DPS-DTM (≤200mm)  DPS II – Silvia / Silvia-N (200mm/300mm)

High Aspect Ratio (>110:1)  Sub-Micron CD (<< 200nm)  High Etch Rate (>25µ/min)

New Etch Processes for SiC and GaN Applications

GaN Etch  SiC Etch
High Growth Rate Epi-Silicon
Power Device, MEMS & Wafering Applications

Improved Productivity
Tighter Process Control
New Software Capability
Hardware

Growth Rate Profile

Thickness Profile (nu. <0.7%)

Resistivity Profile (nu. < 2.0%)
Summary: MTM Opportunities & Challenges

- MTM applications are growing surely driving up demand for ≤200mm and potentially boosting legacy 300mm (≥45nm tech node) production technologies.

- There are both HW and process challenges fostered by this increasing demand at 200mm and below …. and migrating even existing MTM processes from 200mm to 300mm will pose additional one.

- Refurbished tool market slowly drying up leading to increasing ASPs of the legacy tools and higher percentage of new tool builds.
Conclusion

Applied Materials Supports MTM Device Technologies by:

- **Continued Investments** to enhance productivity and develop new materials and process addressing the latest requirement and inflections in MEMS, Power, Analog, CIS, Packaging & CMOS

- Working with **leading R&D organizations** to ensure our film and technologies are demonstrated at the device level

- Constantly looking for new ways to **grow our portfolio** of advanced tools and comprehensive service— we’re eager to **collaborate with you**!

**Applied Materials - Your trusted Partner for ≤200mm and 300mm Technology and Equipment**