450 mm Lithography Development Update

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Executive Vice President
Overview

• 450 mm Motivation
• The Path Forward
• Litho Requirements
• Nikon 450 mm Program
• Summary
Demand Keeps Growing

- Growth in mobility followed by IoT will drive continued growth for transistors
- ...which in turn will drive device and Si growth

Demand for transistors and devices will drive Si demand

Ref: Gartner Q1’14, ITU, ARM  * 10 year growth 2003-2013

Ref: KITGRU (For Intel at ISSCC), Wagner Consulting
Moore’s Law has enabled tremendous growth through scaling and transistor cost reduction.

To maintain this trend, combination of scaling and wafer size change will ultimately be needed to keep costs in check – as done historically.

Wafer size change will be needed to maintain Moore’s Law.
### 450 mm: Economics and Technology

#### Economics

<table>
<thead>
<tr>
<th>Wafer Area +2.25X and Effective Chip Area +2.4X:</th>
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<tbody>
<tr>
<td>• Reduces increase in per unit area process costs associated with the technology evolution</td>
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**Greater Economies of Scale for Chip Manufacturing:**

| Boost property, plant, equipment (PPE) and employee productivity, and reduce associated costs |

#### Technology

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<th>Stimulate Industry Creativity and Innovation:</th>
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<td>• Designers have the chance to think outside of the box</td>
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**Opportunities for Invention and Expanded Collaboration:**

| Tooling, automation, IC manufacturing processes, green tech, etc. |

- 450 mm is about economics – 30% die cost saving
- Also presents tremendous opportunities for innovation
Lessons Learned at 300 mm

- Industry focus and management required for successful transition
- R&D investment must be optimized and shared across the chain
- Must avoid false starts experienced with 300 mm
- Alignment on industry timing is imperative

300 mm took about 20 years for payback
Is 450 mm Affordable?

- Expected 450 mm development cost ~$14B best case
- Assuming 3.8% average revenue growth rate for equipment companies, **payback occurs 22 years after initial spending**…

Payback equivalent to 300 mm if development spending is in check
Comparison – Boeing 787 Dreamliner

- A massive, globally-coordinated supply chain effort to design and build – in order to achieve 20% efficiency improvements

- Program start: 2004
- Development cost: $15B
- First commercial flight:
  - Planned: May 2008
  - Actual: October 2011
- Plane sales needed to break even: 2150 units
- Net order received (mid 2013): 979 (almost half way there…)
- Boeing manufacturing capacity: 120 (now)
- *Estimated year to break even: ~ 2025*

Payback: 22 years from initial funding…sound familiar?
Transition Management

• Timing Alignment
  • Initial statements calling for pilot lines as early as 2013…now “latter part of the decade” for 450 mm
  • Industry consensus should be reached “soon” to keep “latter part of the decade” intact
  • Must avoid the double peak…

• R&D Spending and Risk Management
  • Simultaneous development of 300 and 450 mm technology
  • Sharing risk/reward between device makers and equipment suppliers
  • Collaboration on standards, components, etc.

• Importance of G450C:
  • Focused on optimizing timing, cost, consensus building, risk sharing, and collaboration
  • Doing a good job in coordinating and communication

Effective management essential in balancing risk and reward
450 mm Litho Requirements

Must simultaneously satisfy scaling and wafer size transition requirements

- Productivity (m²/hr > 300 mm)
- Cost (< gained productivity)
- Optimized Footprint
- Performance
  Overlay, imaging, focus, and defectivity meet aggressive scaling roadmap

- Extending 193i, proven core technology, provides solid foundation
- Wafer size transition creates the opportunity to develop innovative technologies to ensure litho meets die cost reduction goals

450 mm litho readiness through ArF immersion extension
# Lithography Technology Trends

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<tr>
<th>Year</th>
<th>DRAM (1/2pitch)</th>
<th>Logic (M1 1/2Pitch)</th>
<th>NAND (1/2pitch)</th>
<th>3D NAND (1/2pitch)</th>
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### Scaling
- **ArFi(SE)**
- **ArFi (SADP/LELE)**
- **ArFi (SAQP/LE³)**
- **DSA (assist to ArFi and EUVL)**
- **EUVL (SE)**
- **EUVL (NA0.33 SADP or NA~0.4 SE)**

### Wafer Size Increase
- 450 mm

### Integration
- 3D NAND, TSV etc.
Nikon Lithography Product Roadmap

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<td><strong>ArF Immersion 450 mm</strong></td>
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<td>Development</td>
<td>Patterning</td>
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Enabling 450 mm HVM at the latter part of the decade

Some Say: *Benefit from 450 Lithography is Limited*

- Reduced acceleration
- Decreased stiffness
- Added heat dissipation
- Poor overlay?
- Low productivity?

Some don’t see the benefits…
Opportunities for Innovation

**Nikon innovation will meet new process node requirements in either environment**

**World-class Accuracy**
- Minimized Aberrations
- Enhanced Overlay and AF
- Source Mask Optimization

**Ultra-high Productivity**

**Cost Innovation**
- Collaboration
- Reliability/Uptime
- Productivity & Yield

**Advanced Stage**
- Increased Throughput
- Defectivity Reduction
Nikon 450 mm Program

- Customer orders in place
- Several tools undergoing manufacturing at our factory
- Advanced litho patterning for G450C in 2014

And now??
450 mm Patterning is Underway

- Nikon development continues per committed plans
- Patterning 450 mm wafers for G450C from Kumagaya started as scheduled
- Nikon 450 mm immersion scanner will ship to Albany on time in April 2015
Summary

• Motivations for next wafer size transition are present – economics and opportunity for innovation

• Industry consensus and commitment for HVM start are paramount – should be done “soon” to intercept “latter part of the decade”

• Nikon innovations in immersion extension will meet litho process requirements regardless of wafer size

• Nikon 450 mm program is progressing on schedule and per commitments made

• 450 mm litho patterned wafers are already here – patterning for G450C started

• Nikon 450 mm immersion scanner will ship to G450C in Albany on schedule in April 2015

Nikon 450 mm will be ready when the industry makes transition