The nanoworld of IC manufacturing:
smaller, faster, and more accurate

Patrick de Jager
Director New Business
Agenda

• Chips are everywhere
• Introducing ASML
• Business update
• ASML’s place in the industry
• Lithography, the driving force behind Moore’s Law
• Technology
• How do we do it?
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It’s hard to imagine a world without chips
More than 180 billion chips are made every year

IC units, in billions

In 2012, 185 billion chips were produced — 27 for every man, woman and child on the planet.

Global semiconductor industry sales were about $300 billion.

Data: WSTS
Content consumption drives traffic growth
> 100% CAGR since 1990
Content consumption drives traffic growth
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> 100% CAGR since 1990

80k Petabytes/month = 2 year of video content/s

Everything will be connected which will benefit from being connected

Source: Pieter Vorenkamp, Broadcom, IMEC Technology Forum, May 2012
Market driven by mobile devices and Solid State Drives

Mobile drives cloud, cloud drives infrastructure, driving servers and SSD

Bob Johnson, Gartner, ISS Jan 2012
A chip up close: smallest details <20nm
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ASML makes the machines for making those chips

- Lithography is the critical tool for producing chips
- All of the world’s top chip makers are our customers
- 2013 sales: €5.2 bln
- Payroll: about 10,400 FTEs
Founded in 1984 as a spin-off from Philips
A global presence

Over 70 sales and service offices located worldwide

Source: ASML Q4 2013
A global presence

Wilton (CT)

San Diego (CA)

Chandler (AZ)

Veldhoven

Korea

Taiwan
A market of 12 large ASML customers

For the 10th consecutive year, top five of VLSI’s “Best Wafer Processing” suppliers

<table>
<thead>
<tr>
<th>Company</th>
<th>2013 semi capex (estimate, $M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intel</td>
<td>10,500</td>
</tr>
<tr>
<td>TSMC Group</td>
<td>9,750</td>
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<td>Samsung</td>
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<td>STMicroelectronics</td>
<td>500</td>
</tr>
</tbody>
</table>

Source: Gartner, Q4 2013

Technology Collaboration Award
Preferred Quality Supplier Award
‘Good Partner’ Award

22 January 2014
Public Slide 16
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Total net sales M€

Numbers have been rounded for readers’ convenience.
Net system sales breakdown in value: Q4 2013
Total value is € 1,441 million

Technology
- KrF 19%
- ArF dry 3%
- EUV 4%
- ArF Immersion 74%

Region
- Taiwan 41%
- Korea 21%
- China 13%
- USA 16%
- Japan 3%
- Europe 5%
- Rest of Asia 1%

End-Use
- Memory 35%
- Foundry 46%
- IDM 19%

Sales in Units
- EUV: 1
- ArF i: 27
- ArF dry: 2
- KrF: 26
- I-Line: 0

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Moore’s Law:
The amount of transistors per given area doubles every 2 years at similar cost.
The industry is sustained by the need to make cheaper, smaller ICs that do more.

Factories and tools are more expensive, but:
Transistors can be made faster and more economical, so:
Electronics becomes cheaper, or has more functionality for the same price.
Driving the semiconductor industry: Moore’s Law

Gordon Moore (1965): Number of transistors per chip doubles every year. Later adjusted to two years, the trend has held for more than four decades.
Moore’s Law makes chips cheaper…

Source: Gartner. High quality Flash
... and more energy-efficient
Computations per Kilowatt hour double every 1.5 years

Regression results:
N = 76
Adjusted R-squared = 0.983
Comps/kWh = exp(0.440243 * year − 849.259)
Average doubling time (1946 to 2009) = 1.57 years

Source: Jonathan Koomey, Lawrence Berkeley National Laboratory and Stanford University, 2009
Moore’s Law means doing more with less

Cray 1: The first supercomputer

- 8 megabytes of memory
- 5.5 tons
- 150 kilowatt power supply
- “Innovative Freon cooling system”
- $8.8 million ($30 million in today’s dollars)
Moore’s Law means doing more with less

The supercomputer in your pocket: a fraction of the materials, price, power consumption
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Key to Moore’s Law: Making smaller transistors

The first integrated circuit on silicon, on a **wafer the size of a fingernail**  
(Fairchild Semiconductor, 1959)

Transistor length has shrunk by a million

Today: **More than a billion transistors on the same area**  
(Intel, 2012)
The manufacturing loop
How a lithography system works
Keeping up with Moore’s Law

**PAS 2500**
ASML’s first successful stepper, 1986

**NXT:1970Ci**
First shipped in Q3 2013
Keeping up with Moore’s Law

PAS 2500
ASML’s first successful stepper, 1986

NXT:1970Ci
First shipped in Q3 2013

Resolution:
900 nanometers

70 wafers per hour
(150mm wafers)

Overlay:
150 nanometers
Keeping up with Moore’s Law

Resolution:
38 nanometers

250 wafers per hour
(300 mm wafers)

Overlay:
As little as 2 nanometer

PAS 2500
ASML’s first successful stepper, 1986

NXT:1970Ci
First shipped in Q3 2013
Keeping up with Moore’s Law requires constant technology upgrades.
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The challenge of ASML engineers

- Make small structures that are all equal within nanometers
- Do that lightning fast
- And put 30 to 40 layers on top of each other within nanometers

AND all at the same time!
The basic rule of lithography

Resolution:

\[ R = k_1 \frac{\lambda}{NA} \]

Numerical aperture:

\[ NA = n \sin(\Theta) \]

State of the art in production
- Smallest feature: 38nm
- Wavelength: 193nm
- Increase NA: 1.35
- \( k_1 \): 0.265
Key innovation: TWINSCAN
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High R&D spending to sustain technology leadership

1984: PAS 2000
Resolution: >1µm
overlay: 250 nm

1989: PAS 5000
Resolution: <500 nm
overlay: 100 nm

1990s: PAS 5500 (step/scan)
Resolution: 400 to 90 nm
overlay: 100 to 12 nm

2000s: TWINSCAN
Resolution: 100 to 38 nm
overlay: 20 to 2 nm

2010s: NXE EUV systems
Resolution: 32 to <18 nm
overlay: <3 nm
Great people in an integrated supply chain

- 32,000 people
- +/- 10,000 payroll employees
  +/− 3,000 flex
- +/- 3,300 payroll
  +/− 1,400 flex
- >500 PhD/Dr.

Supplier and technology network:
Open Innovation makes complexity and cost manageable