Imaging to Enable the Next Generation of Chips

100nm Volume Manufacturing on 300mm wafers
100nm Applications

- Wireless PDAs with Enterprise Databases
- Real-time Language Translators
- 3D HDTV graphical images
- Complex vocal commands to computer
- 3D integrated images
  - Virtual shopping in 3D
  - Integrated composite images GPS/Radar/Weather/
  - 3D Medical composite imaging
- Dynamic event simulations
Performance scales with Process Generation

<table>
<thead>
<tr>
<th>Process Generation</th>
<th>1µm</th>
<th>800nm</th>
<th>600nm</th>
<th>350nm</th>
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Source: Intel
Performance Requires Higher Transistor Density

Transistor Count per Chip

Year


Source: Intel
Evolution of Leading Edge Lithography & Wafer Size

<table>
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<tr>
<th>Year</th>
<th>i-line</th>
<th>157nm</th>
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Milestones of Progress in Lens Technology

- **ASML Model #**
  - PAS 2500/40
  - PAS 5500/300
  - TWINSCAN AT:1100

<table>
<thead>
<tr>
<th>Model</th>
<th>Wavelength</th>
<th>g-Line</th>
<th># Pixels (E+6)</th>
<th>Pixel Factor</th>
<th>Price Factor</th>
<th>Weight (kg)</th>
<th>Yr of First Proto</th>
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High NA ArF System for 100nm Node

CD = \( k_1 \frac{\lambda}{NA} \)

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<th>λ (nm)</th>
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<th>CD (nm)</th>
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<th>248</th>
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<td>0.39</td>
<td>0.48</td>
<td>0.36</td>
<td>0.43</td>
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</tbody>
</table>

QUASAR
ANNULAR
Alt PSM
att. PSM
dipole
**Why 300mm?**

- 200mm
- 300mm

2.25 More Die per Wafer

**Why ArF?**

- 130nm node

1.7 More Die per Wafer

100nm node

100nm on 300mm

200mm

200mm

200mm

= 3.8 More Die per Wafer
Challenges for ArF & 300mm

**ArF**
- Lens Manufacturing with CaF2 Materials
- Mature Resist Processes
- High Power ArF Lasers
- Increase Focus Control

**300mm**
- Productivity
- Vibration Containment
- Tighter Overlay
- Increase Metrology Accuracy
Leading edge High NA 193nm Lens

- **Zeiss Starlith 1100 Lens:**
  - Variable Numerical Aperture 0.75 to 0.50
  - CaF2 for Critical Lens Elements Only
  - High Transmission Coatings
  - Control of Magnification, Field Curvature, 3rd Order Distortion, Coma and Spherical
  - Optimized Dynamics for Larger Lens Mass

*Projection Lens*
- High NA
- Low aberrations
ArF Imaging Results

ArF High NA Lens

- Lens Design/ Manufacturing + Set-up
- Laser Design
- Stage Design
- Illuminator Design
- Resists
- Reticles

Exposure Latitude
Depth of Focus
Low Proximity Effects
Low Line-end Shortening
Low Mask Error Factor
Linearity

- Low Aberration Level
- Narrow Bandwidth
- Low Fading (MSD)
- Illumination Uniformity
- Mature Processes
- Binary Chrome Reticles

ASML
ArF Imaging Results
100nm Dense Lines Through Focus

Binary Mask
Pitch = 200nm

NA = 0.75, σ = 0.85/0.55
Annular Illumination

Scanned Exposure Starlith™ 1100

E = 17.5 mJ/cm²
ArF Imaging Results
90nm Dense Lines Through Focus

Binary Mask
Pitch = 180nm

$NA = 0.75$, $\sigma = 0.85/0.55$
Dipole Illumination

Scanned Exposure Starlith™ 1100
ArF Imaging Results
Contact Holes with Binary Mask, 130nm, pitch 260nm

NA = 0.75, $\sigma = 0.85/0.55$
QUASAR Illumination
Scanned Exposure Starlith™ 1100
ArF Imaging Results
130nm Contact Holes

Top-Down 130nm
10nm Bias 53mJ

Cross Section 130nm
10nm Bias 53mJ
20 Watt 4 kHz ArF Laser for High Dose Levels

Increased Illumination Intensity Maintains Productivity for High Dose Levels

<table>
<thead>
<tr>
<th>Dose (mJ/cm^2)</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
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</thead>
<tbody>
<tr>
<td>10 Watt (2kHz)</td>
<td>93</td>
<td>76</td>
<td>64</td>
<td>55</td>
<td>48</td>
<td>43</td>
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<tr>
<td>20 Watt (4kHz)</td>
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<td>98</td>
<td>93</td>
<td>84</td>
<td>76</td>
<td>69</td>
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Productivity vs Laser Power

- 10 Watt (2kHz)
- 20 Watt (4kHz)
Measurement Position
Wafer Height Mapping

Level Sensor
Used As a Height Gauge
Experiment:

• Expose Wafer With IC Structures

• Measure Height Map

Accurate leveling data to wafer edge - no “Edge Die”

Resolution: 3 x 0.5 mm

300 mm

340 nm
Better Focus through Pre-Recorded Z-Map

- Optimum Focus & Tilt Setting of Exposure Slit
- Wafer Mapped in Z According to Exposure Field Size
- Z Positioning Optimised for Stage Servo Response
- Z Position Measured & Controlled With Interferometer Precision
TWINSCAN Platform Focusing Approach

- Wafer scanned at metrology position
- 9 spot focus sensor
- 8 axis interferometry for X, Y and Z, \(\theta X\), \(\theta Y\), \(\theta Z\)
- Perfect meander - alternating scan directions improves throughput
Challenges for ArF & 300mm

- **ArF**
  - Lens Manufacturing with CaF2 Materials
  - Mature Resist Processes
  - High Power ArF Lasers
  - Increase Focus Control

- **300mm**
  - Productivity
  - Vibration Containment
  - Tighter Overlay
  - Increase Metrology Accuracy
TWINSCAN™ Dual Wafer Stages

- Balance mass for 70 nm dynamics
- Separate metrology position: Full 3D wafer mapping
- Dual wafer stage: Parallel operation, 320mm Scan Speed

ASML
Dual Stage Elapsed time Improvement

**Single Stage Cycle**

Total time = 57 sec → 63 WPH

- **Expose**: 45 sec
- **Step**: 15 sec
- **Overhead** (Align + Wafer Swap): 15 sec

**ArF Example**: 20mJ/cm²

**Dual Stage Cycle**

Total time = 38.6 sec → 93 WPH

- **Expose**: 30 sec
- **Step**: 15 sec
- **Overhead**: 15 sec

6X more Alignment Data + Full Wafer Height Map

**Metrology Position**
Dual Stage Benefits for Alignment Metrology

No Throughput Penalty for up to 25 Alignment Marks with Dual Stage

Single Stage
Trade Off Between Alignment Information & Throughput

Number of Alignment Marks

Throughput %

Dual Stage

Single Stage
**ArF Productivity** -
Intensity, Scan Speed, Dual Stage vs. Field Size

**Increased Scan Speed & ArF Intensity**

**Single Stage System**

**Conditions:**
- Dose: 20 mJ/cm²
- Wafer: 300mm

**Graph:**
- Throughput (300mm WpH)
- Scanned Fields per Wafer

- 16x32mm: 109 fields
- 18x32mm: 95 scans
- 22x32mm: 73 scans
- 26x32mm: 63 scans
Imaged Pixels per Hour

Quantum jump in pixel transfer rate!

- 20 W ArF Source
- 320mm scan speeds
- Dual stage design
TWINSCAN Platform Roadmap

**Legend**
- 193nm
- 248nm
- 365nm

**1997 - 2005**
- **70nm**
- **100nm**
- **130nm**
- **150nm**
- **>250nm (non critical)**

- **NA\_max = 0.75** AT:1100 100nm
- **NA\_max = 0.70** AT:750 130nm
- **NA\_max = 0.65** AT:400 280nm

*ITRS Roadmap, 1999 Update*
TWINS CAN 1100
Key Specifications

- Variable NA: 0.75 → 0.50
- Resolution: ≤ 100nm
- Field Size: 26mm X 32mm
- Laser: 20Watt 4kHz
- Overlay: < 20nm
- Throughput: > 93 wph
Extends ASML’s TWINSCAN Product Family
with ArF Technology for 100nm on 300mm

TWINSCAN AT:1100
ArF Step & Scan

TWINSCAN AT:400
i-Line Step & Scan

TWINSCAN AT:750
KrF Step & Scan
Worldwide Demand for AT:1100

- Demand from Foundry, Logic and Memory

Shipment ramp commences end of 2001
100nm Volume Manufacturing on 300mm Wafers

- **Productivity for Volume**
  - New 320mm/sec dual stages
  - Highest utilization of optics
  - Parallel align metrology
  - 20W 4kHz Laser

- **100nm imaging**
  - A-A overlay <20nm
  - 0.75 NA ArF Optics
  - Vibration control to 70nm
  - Z-interferometry for focus control