EUV Lithography
Towards Industrialization

Wim van der Zande, Director of Research, ASML

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Agenda

- EUV benefit and status at customers
- Towards higher productivity
- Summary
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• EUV benefit and status at customers
Multi-patterning complexity drives need for EUV

EUV Lithography will stop the strong increase of litho steps/masks needed
EUV status:
Demonstrated >500 wafers per day at customer sites

- More than 500 wafers exposed per day during endurance tests at 2 customer sites
- 7 NXE:3300B systems shipped to customers
- 4 more NXE:3300B systems being integrated
- 4th generation NXE system (NXE:3350B) integration ongoing
- EUV cleanroom extension is under construction
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Wafers per day program: Progress in major areas

- Improvement of Conversion Efficiency demonstrated
- Reduced dose margin with advanced controls
- Doubled source power to ~80 Watts demonstrated
- Improved optical design

- > 500 Wafers per day
- Automation
  - Collector lifetime
  - Drive laser reliability
  - Droplet generator reliability
- POWER
  - Drive laser power
  - Dose margin
  - Laser to droplet control
- SCANNER
  - Optical transmission
  - Exposure dose
  - Stage accuracy at high speed
  - Overhead optimization

4 Nov 2014
>40W rolled-out on customer NXE:3300B systems

Under clean collector conditions

NXE:3300B customer systems
Customer system continuous use at power level of >40W

System continuously used

Accumulated Gpulse count

Source power [Watt]

Power of >40W since start use system

Implying stable collector reflectivity

Stable power over 2 months period of time

4 Nov 2014
Continuous stable source operation at 80 W

excellent die yield, ~25% dose margin

24 hours continuous operation at 80W of EUV power with excellent simulated Die Yield

Die Yield = Simulated % of dies that meet the 1% dose requirement
An Intermezzo

- Towards an pSi pellicle for EUV tools
- Source aspects
The mask defect challenge
Challenging defect requirements on reflective EUV mask without pellicle

DUV Reticles (193nm)

EUV Reticles (13.5nm)

Pellicle

Transmitted illumination

Particle (μm size)

Reflective multilayer

Absorber pattern

Reflected illumination

Particle (nm size)
Scalability of free-standing pSi films demonstrated and prototype pSi pellicles successfully tested in EUV tools.

- 11mm x 11mm (~80% EUV transmission)
- 50mm x 50mm (~82% EUV transmission)
- 64mm x 106mm (~86% EUV transmission)
- 103mm x 122mm (~85% EUV transmission)

Open frames used for testing prototype pSi pellicles in EUV tools.

All reticles and frames courtesy of Intel.
Imaging testing of $\frac{1}{2}$ size pSi pellicle collaborative effort of ASML and customers
27 nm L/S features successfully exposed with half-size proto pellicle

SEM image at BE/BF w/o pellicle

SEM image at BE/BF w/ pellicle

Joint effort of NXE end users and ASML accomplished imaging results of half size pellicle

CD = 24.2 nm
LWR = 4.0 nm

CD = 24.0 nm
LWR = 3.7 nm

- NXE:3100, NA=0.25, Conventional Illumination
- CDU difference of 0.18 nm
- Pellicle EUV transmission confirmed in imaging data: 85.5% (single pass)

Reticles and frames courtesy of Intel
Scanner exposures courtesy of tsmc
Source Aspects

- Pre-pulse: Preparing Shape of Tin Target
- Main Pulse: Tin heating to proper state of matter (highly charged ions) and high temperature (200 kK) for continued EUV emission
- Pulse shaping in time and space for reduction of energy in particles and in ions and for increase of EUV radiation
- Protecting collector optics by hydrogen flow combining stopping and dynamic cleaning
Towards 250W EUV power with 4.5% CE CO₂ Drive Laser

Drive Laser Increase to more than 30 kWatt maintaining availability

In-situ collector cleaning towards a dynamic equilibrium Using hydrogen gas for stopping ions and cleaning collector

Increasing reliability of the droplet generator

Improved automation algorithms also for start-up
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Summary: EUV towards production insertion

- Two customers demonstrated 500 wafer per day capability in endurance tests.
- System performance well within target at >40W source power

- Half-size EUV pellicle prototype has been tested successfully

- >40W stable performance at customers, 80W performance shown at ASML and being transferred to customers
- EUV source: Continuous Improvements on conversion efficiency, dose margin, automation, collector lifetime, driving power. Increasing reliability and availability
The work presented today, is the result of hard work and dedication of teams at ASML, Cymer, Zeiss, and many technology partners worldwide including our esteemed customers.

Special thanks to our partners and customers for allowing us to use some of their data in this presentation.