High Power EUV Sources

Technology Status

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Vivek Bakshi, Ph.D.
EUV Litho, Inc.
10202 Womack Road, Austin, TX 78748 USA
www.euvlitho.com vivek.bakshi@euvlitho.com

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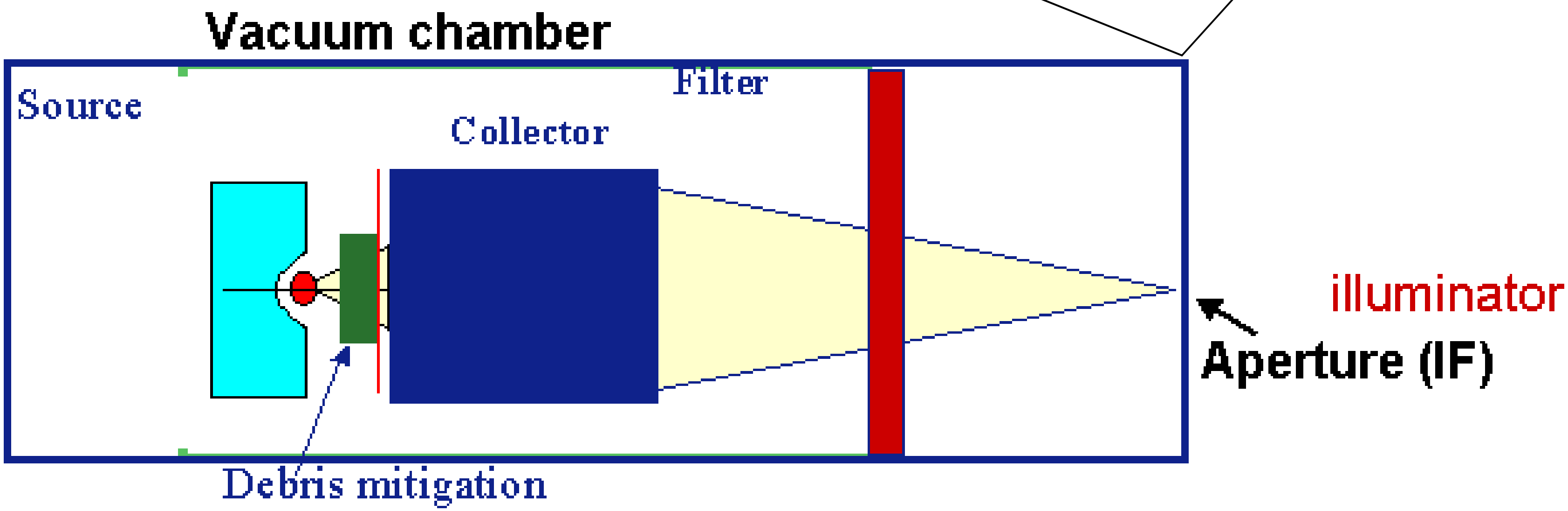
Presentation Outline

- Introduction
- EUV High Power Source Requirements
- EUVL Technology Status Overview
- Summary

EUV Source Technology

Introduction: EUV Source Definition

Source specifications are defined at intermediate focus (IF), which is the illuminator entrance



Joint Specifications for EUV Sources

Source characteristics	Requirements
Wavelength (nm)	13.5
EUV power (inband) (W)	**115 W *@ 5 mJ/cm2** **115 W* @ 5 mJ/cm2 – 180 W* @ 10 mJ/cm2**
Repetition frequency (kHz)	*>7-10 kHz* *** *There is no upper limit.*
Integrated energy stability (%)	±0.3, 3σ over 50 pulses
Source cleanliness (hours)	*Reflectivity degradation ≤10 % (in relative) after 30,000 light -on hours* **
Etendue of source output (mm2 sr)	*max 3.3 mm2sr* ***
Max. solid angle input to illuminator (sr)	*0.03 - 0.2 [sr]* ***
Spectral purity:	
130–400 nm (DUV/UV) (%) *values at IF-design dependent*	*<1% at wafer,*
>400 nm (IR/visible) at wafer (%) *values at IF-design dependent*	*<10 – 100% at wafer,*

At intermediate focus (IF).
**After IF.*
***Design dependent.*

Table 3.1 Joint requirements for EUV sources (November , 07)

EUVL Critical Issues

High power source & Collector Module (SoCoMo) Continues to be the leading challenge for HVM application of EUVL

2003	2004	2005	2006	2007	2008
Source power and lifetime including condenser optics lifetime	Availability of defect free mask	Resist resolution, sensitivity & LER met simultaneously	Reliable high power source & collector module	Reliable high power source & collector module	Long term source operation with 100 W at IF and 5 mJ resist
Availability of defect free mask	Lifetime of source components & collector optics	Collector lifetime	Resist resolution, sensitivity & LER met simultaneously	Resist resolution, sensitivity & LER met simultaneously	Defect free mask through lifecycle and inspection / review and inspection infrastructure
Reticle protection during storage, handling and use	Resist resolution, sensitivity & LER met simultaneously	Availability of defect free mask	Availability of defect free mask	Availability of defect free mask	Resist resolution, sensitivity & LER met simultaneously
Projection and illuminator optics lifetime	Reticle protection during storage, handling and use	Source power	Reticle protection during storage, handling and use	Reticle protection during storage, handling and use	Reticle protection
Resist resolution, sensitivity and LER	Source power	Reticle protection during storage, handling and use	Projection and illuminator optics quality & lifetime	Projection and illuminator optics quality & lifetime	Projection and illuminator optics and mask quality & lifetime
Optics quality for 32-nm half-pitch node	Projection and illuminator optics lifetime	Projection and illuminator optics quality & lifetime			

Source: EUVL Symposium, September 2008

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EUV Source Update (Cymer):
Sn LPP based on 10 k W CO_2 laser source

- **Cymer (Sn LPP)**
  - **10 kW Pulsed CO_2 laser**
    - **50 K Hz, 10 % Duty Cycle**
  - **Measured EUV Power (IF Equivalent) of 20 W – 50 kHz, 80% duty cycle and 400 ms burst duration for 18 hours**
    - **Assumed 5sr collector, 50% collector transmission and 90% optical transmission**
  - 1 MJ of accumulated dose over 18 hours
    - **Dose enough to expose 250 wafers of 300 mm**
  - **No reflectivity loss of collector optics in far field shown for operation with IF Equivalent EUV power of 40W and 25% duty cycle during 51 hours of exposure of 1.6 sr collector**
  - **1.6 sr collector operational. 5 sr collector with >650 mm dia with 47% average reflectivity and 0.2 nm roughness**
  - 3 % CE demonstrated
  - 50 μ droplet source operational. 30 μ droplet source ready and 10 μ droplet source planned.
  - **EUV Source Delivered to ASML for beta level scanner!**
  - Reported in press release (July 13, 2009), 75 W power with possibility of 100W in Q3 2009.

Source: SPIE 2009

EUV Source Update (Gigaphoton):
Sn LPP based on 13 k W CO_2 laser

- **Gigaphoton (Sn LPP)**
  - **13 kW Pulsed CO_2 laser (22 ns, 100 K Hz) -3.4 kW demonstrated at 30 % duty cycle with 1% stability**
  - **Measured power: 330 W at source (10% burst mode measured)**
    - **Collectable power at IF 25 W (for 100% duty cycle, current cycle 10 %).**
    - **CE of 2.5 %**
    - **Previously Measured IF Power 16 W (Burst mode measured with 1 sr collector)**
    - IF Image size 3.6 mm x 3.3 mm
    - Energy stability 3.8 %
    - Rotating solid tin target
  - **Continuous operation for 60 m droplet, 5 kW laser at 2.4 % duty cycle, using 0.6 T magnetic field for debris mitigation without any degradation of components. Average CE 1.5%.**
  - Droplets 20 μ with 142 to 500 K Hz with 20 m/s injection velocity

Source: EUVL Workshop, June 2008 and EUVL Symposium , February 2009

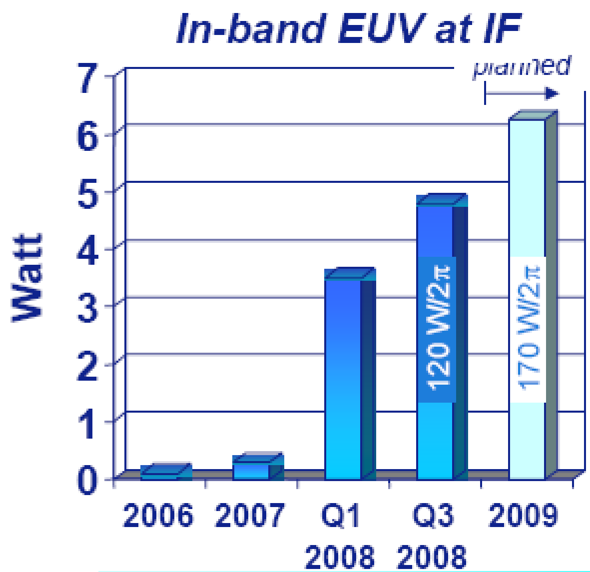
EUV Source Update (Philips Extreme UV): Sn DPP

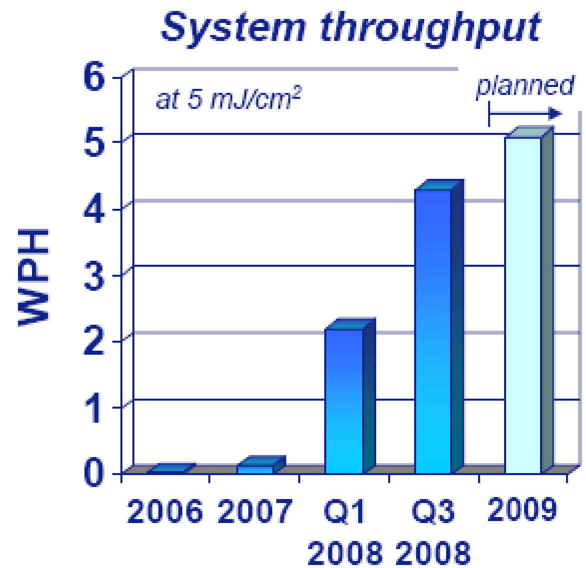
- **Philips Extreme UV**
  - **7.2 W at IF (Full collector) – 100% Duty cycle for 120 Hours**
    - **Corresponding to 90 W at Source**
    - **120 Hours operation, 3 MJ delivered at IF**
  - **170 W at source demonstrated -100% duty cycle for 2 B shots**
  - **Collector lifetime: 60 B shots or 0.6 year**
  - Source size 1.3 mm
  - MTBF ~ 10 MJ
  - Tin consumption: 25 g/ MJ in 2 p
  - **Proof of principal of 40 K Hz operation in burst mode (500 W in 2 π for 5500 continuous pulses)**
  - **CE (intrinsic) 3-4% demonstrated**

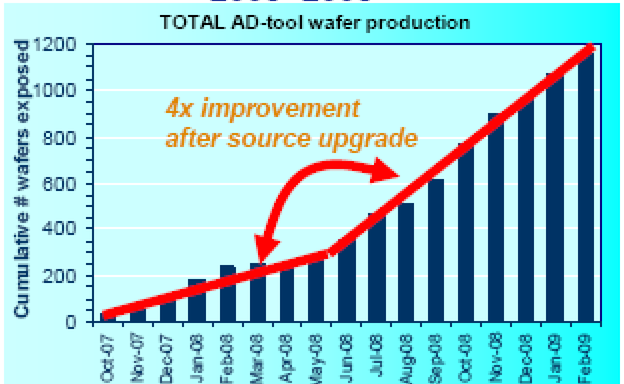
Source: EUVL Workshop, June 2008

Measured system throughput has improved >10×

and wafer output improved 4x; ~1200 300-mm wafers for R&D exposed







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- Throughput potential to be further improved with 170 W/2π source upgrade.
- Also system availability scheduled to improve.

ASML

SPIE 2009, *Alternative Lithographic Technologies*, San José, CA, USA.

Source: Hans Meiling, ASML

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EUV Source Update (Xtreme technologies):
Xe DPP

- **Xtreme technologies**
  - **Xe DPP**
    - **4 W at IF (100 % duty Cycle)**
    - 225 W at Source (XTS 13-150 IF)
    - Dose stability of 0.25%
    - SoCoMo Integrated with EUVL alpha level scanner
    - No plans to further pursue high power source technology

EUV Source Technology
Summary / Highlights

- EUV Source Technology decisions need to be based on integrated SoCoMo performance and not on the source performance alone

- DPP Technology Status
  - DPP Sources are being used today to support EUV patterning at pre-α and α level and Metrology tools
  - **Current power level ~ 7 W at IF (Sn DPP)**
  - Need improvement in the integration of DPP based SoCoMo so that all of the power delivered to scanner can be utilized
  - Main Challenge for meeting 50 W power level at IF for long term operation is thermal mitigation
  - **50 W at IF (500 W at source) demonstrated in proof of principal for Sn DPP**
  - Future of this technology is bit uncertain as Sn LPP has been chosen by ASML for beta tools. Still considered a candidate for beta and HVM scanners by scanner manufacturers?

EUV Source Technology
Summary / Highlights

- LPP Technology Status:
  - Continuous improvement :
    - Increased CO_2 laser power and duty cycle
    - Increased Burst mode and CW power at source / IF
  - Current power ~ 20 W at IF (80% duty cycle) for long term
  - Main Challenge for meeting 50 W power level at IF for long term operation is debris mitigation
- **Beta Level Source Roadmap**
  - **ASML has chosen Sn LPP based sources and the source has been delivered for integration with scanners**
  - **HVM level source technology selection not made**
- Solutions to scanner throughout /source power issue needs help from work on additional technical fronts:
  - Higher throughput scanner designs
  - Resist sensitivity improvement

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