Presentation to IEUVI Board
July 20, 2007

EUV Source Joint Requirements Update

and

EUV Source Workshop Summary
(May 7, 2007, Baltimore, MD)

Dr. Vivek Bakshi
Senior Member Technical Staff
EUV Strategy, Lithography Division
SEMATECH

Presentation outline

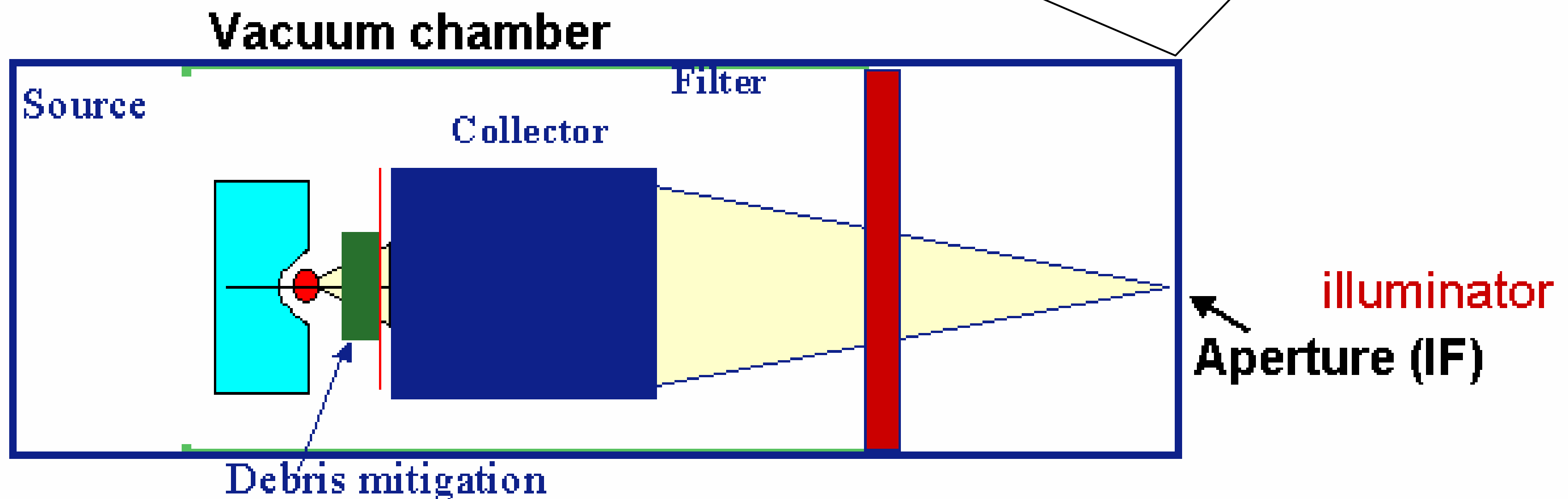
- EUV Source Joint Requirements Update
- EUV Source Workshop Summary

EUV Source Joint Requirements

ASML, Canon, Nikon

Definition of clean photon spot at intermediate focus (IF)

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



Joint Requirements for EUV Source- NO CHANGE *since last EUV Source Workshop (Barcelona, October 19, 06)*

SOURCE CHARACTERISTIC	REQUIREMENT
•Wavelength	13.5 [nm]
•EUV Power (in-band)	115 W *@ 5 mJ/cm2 115 W* @ 5 mJ/cm2 – 180 W* @ 10 mJ/cm2
•Repetition Frequency	>7-10 kHz *** There is no upper limit.
•Integrated Energy Stability	0.3%, 3σ over 50 pulses
•Source Cleanliness	Reflectivity degradation ≤10 % (in relative) after 30,000 light -on hours **
•Etendue of Source Output	max 3.3 mm^2sr ***
•Max. solid angle input to illuminator	0.03 - 0.2 [sr] ***
•Spectral Purity:	
130-400 [nm] (DUV/UV)	<1% at wafer, values at IF-design dependent
≥ 400 [nm] (IR/Vis) at Wafer	<10 – 100% at wafer, values at IF-design dependent

*** At IF**
**** After IF**
***** Design dependent**

EUVL Source Workshop

Baltimore, Maryland

May 6, 2007

7:00	Breakfast	
8:30	Welcome and Introduction	Vivek Bakshi
8:40	**Session 1: Technology Update**	Session Chair: Kurt Kimmel / IBM
15 min each	❖ Cymer Laser	David Brandt
	❖ GigaPhoton	Hakaru Mizoguchi
	❖ Philips Extreme UV	Marc Courthout
	❖ Xtreme technologies	Uwe Stamm
9:40	**Panel Discussion 1**	Moderator: Vivek Bakshi
Panelists		
10 min each	❖ Canon	Miyake Akira
	❖ Nikon	Katsuhiko Murakami
	❖ AMD	Obert Wood
	❖ IBM	Kurt Kimmel
	❖ Intel	Yashesh Shroff

Break

EUVL Source Workshop (cont'd.)

❖ Cymer	Igor Fomenkov
❖ GigaPhoton	Hakaru Mizoguchi
❖ Philips Extreme UV	Marc Courthout
❖ Xtreme technologies	Uwe Stamm
❖ Media Lario	Konrad Knapp

Panel Discussion 2

(A) **High Power CO_2 Lasers**

Co-chair: Eric Mueller (Coherent)

Co-chair: Kurt Weingarten (Time-Bandwidth Products, Inc.)

Panelists

❖ Coherant	Eric Mueller
❖ Cymer	Igor Fomenkov
❖ EUVA	Akira Endo

12:10 **Lunch** Grand Ballroom East

13:10

(B) **High power Nd: YAG lasers**

Co-chair: Samir Ellwi (Powerlase)

Co-chair: Hiromitsu Kiriyama (Japan Atomic Energy Agency)

EUVL Source Workshop (cont'd.)

Panelists

❖ Powerlase	Samir Ellwi
❖ Fraunhofer – Aachen / Edgewave	H.D. Hoffman
❖ General Atomic	Mike Campbell
❖ Osaka University	Hisanori Fujita
❖ Japan Atomic Energy Agency	Hiromitsu Kiriyama

(C) **High Power fiber based lasers**

Co-chair: Fabio Di Teodoro (Aculight Corporation)

Co-chair: Almantas Galvanauskas (University of Michigan)

Panelists

❖ Aculight Seattle	Fabio Di Teodoro
❖ Fraunhofer Institute Jena	Jens Limpert
❖ University of Central Florida	Martin Richardson
❖ University of Michigan	Almantas Galvanauskas

14:40 **Break**

15:00 **Report Out from Panel Discussion 2** Session Chair: Chris Krautzchik / Intel

10 min each

(A) High Power CO_2 Lasers

(B) High Power Nd: YAG lasers

(C) High Power fiber based lasers

EUVL Source Workshop (cont'd.)

Technical Presentations Session Chair: Obert Wood AMD

15 min each

Presentation	Speaker
❖ Temporal and Spatial Multiplexing Approaching for LLP	Martin Richardson, University of Central Florida
❖ Modeling with the Code Z* of EUV Emission and Fast Particles Generation in DPP and LPP Sources	Sergey V. Zakharov, EPPRA
❖ Review of Tin Debris Mitigation Technology Status and Future Challenges (LPP/DPP)	David Ruzic, University of Illinois at Urbana Champaign
❖ Update of EUV Source Requirements and EUV Source Workshop Summary	Vivek Bakshi, SEMATECH

16:30 Break

17:00 Poster Session and Reception Grand Ballroom East

19:00 Adjourn

Accelerating the next technology revolution.

EUV Source Supplier Update

- **Cymer (Sn LPP)**
  - **7 kW Pulsed CO_2 laser (50 K Hz), 6 % Duty Cycle**
  - **x W at Source, 25 W (Calculated at IF)**
  - Tin droplet target (1L of tin/yr @ 50 K Hz), 3.5 % CE
  - Higher CE from CO_2 laser (compared to YAG laser)
  - 120 μ droplet size
- **Gigaphoton (Sn LPP)**
  - **7 kW Pulsed CO_2 laser (22 ns, 100 K Hz), 10 % Duty cycle --Modules scalable to 20 kW**
  - **130 W at Source, IF Power 47 W (calculated)**
  - Rotating tin plate target, 2.2 % CE, 8 % stability (3 sigma)
  - Little or less tin debris from pulsed CO_2 laser as compared to from YAG laser operation

EUV Source Supplier Update

- **Philips Extreme UV**
  - **6 W demonstrated at IF**
    - **500 M shots without IF power degradation**
  - Foil trap can sustain 50 kW input source power
  - 35% transmission for foil trap
    - For HVM “foil trap to IF” 15 % transmission predicted
  - **Reliability improving towards 1 B shot MTBF**
- **Xtreme technologies**
  - Xe DPP
    - 150 W at Source (XTS 13-150 IF), dose stability of 0.25%
    - >10 B collector lifetime and 300 M electrode lifetime
    - **OOB radiation :3.9 % 160-300 nm, 300-1500 nm 0.9%, and 1500-4000 nm 3.3.%)**
  - **Sn DPP – 200 W at source** (1.4 KHz operation)
    - 85 μ dia 105 K Hz droplet operation

Panel Discussion 1:

- What are the urgent issues that need to be addressed to ensure timely delivery of SoCoMo (Source collector module) to support beta level EUVL scanners due for delivery in 2009?
- In your opinion, who owns the timely delivery of SoCoMo?

Panel Discussion 1: Discussion Summary

- Canon
  - SoCoMo for LPP and DPP are quite different
  - **Schedule is tight and time is short. Source shakedown / evaluation should be performed quickly**
  - **SoCoMo should be owned by source suppliers**
- Nikon
  - Urgent Issues: Power, short and long term stability and reliability, short downtime
  - Usable power is limited by etendue
  - **SoCoMo should be owned by source suppliers and Nikon will collaborate with source and collector suppliers**

Panel Discussion 1: Discussion Summary continued….

- **AMD**
  - DPP SoCoMo: Power scaling, debris mitigation and lifetime
  - LPP SoCoMo: Potentially higher cost and power at IF not demonstrated
  - **Initial EUVL scanners may not meet reliability goals** (based on lessons learned from Excimer laser based scanners)
  - **Ownership: Source companies cannot solve this problem themselves and will need help from entire community**
- **IBM**
  - We need proof of viable path to > 100 W with clean photons
  - **Ownership: All EUV stakeholders own SoCoMo**
  - **EUV is in survival phase as an overall technology. Open problem debate and solution consensus is at best the only path to success and at worst the lowest risk path to success**
  - **Need for 100 W – 7 mJ, 200 W <15 mJ, 300 W < 23 mJ for EUVL to be more cost effective than DE 193 nm**

Panel Discussion 1: Discussion Summary continued….

- **Intel**
  - Issues
    - Reliability (demonstration of sustained power levels > 60 W, tool uptime)
    - CoO (capital cost, consumables)
    - Component Lifetime (Collector, Electrode, DMT)
    - Meeting specs on time is critical
  - **Continued need for innovative solutions**
  - **For success need viable EUVL infrastructure and supplier ownership of SoCoMo**

Panel Discussion 1: Discussion Summary continued….

- **Cymer**
  - Issues:
    - **Power at IF (100W) needs to be demonstrated**
    - Collector performance and lifetime (50% reflectivity, 5 sr and full scale demo) and
    - Integration
  - **Ownership: Cymer plans to deliver SoCoMo**
- Gigaphoton
  - **At least 3-4 years of R&D needed before commercialization. Expect it to be economically competitive with DPP after 2010**
  - **5.3 M $ /100 W capital cost and CoO 1-2 M $ / year**
  - SoCoMo is needed before demonstration
  - Market size several dozens units /year

Panel Discussion 1: Discussion Summary
continued….

- **Philips Extreme UV**
  - Key success factors for SoCoMo (source, collector, thermal management, debris mitigation, SPF) are all linked to each other
  - **Power and reliability needs to improve by a factor of 10x in the next two years**
  - Performance and CoO needs overall optimization
  - **Ownership: Teamwork of Source, collector and scanner suppliers (source makers should take lead)**

Panel Discussion 1: Discussion Summary continued….

- **Xtreme technologies**
  - Challenges:
    - **Demonstrate beta level power (600-800 W)**
    - Debris Mitigation
    - Collector Mirror
  - **Ownership: Scanner manufacturers need to take lead. Xtreme is ready to deliver SoCoMo for beta level scanners**
- Media Lario
  - Challenges: Time to market and CoO demands integrated development
  - **Ownership: Litho system supplier owns time to market and integrated development**

Panel Discussion 2:
High Power Laser Feasibility

Laser Technology: Company:		Performance Today	Roadmap				
			2008	2009	2010	2011	Limit
Performance data	**Units**						
Average Power	W						
Length of operation for above reported power (*)	Hours						
Duty Cycle for above reported power (*)	%						
Pulse Energy	mJ						
Pulse to Pulse Energy Stability	%						
Pulse Width	ns						
Operation Frequency	K Hz						
Beam Quality (M^2)							
Mean Time Between Failures (MTBF)	Hours						
Length of operation for reported MTBF (*)	Hours						
Input Power	kW						
Wall plug to laser light conversion efficiency	%						
Foot print	m^2						
Dimensions (L x W x H)	mxmxm						
Clean room foot print	m^2						
Sub- floor foot print	m^2						
Weight	Kg						
Capital cost	US $						
Operation Cost /Maintenance cost	US $						
Estimated Development Cost **	US $						

Feasibility of High Power Lasers:
Pulsed CO_2 Lasers

- **Power (Today)**
  - **6-7 kW (6-10% Duty Cycle)**
  - Very reliable seed laser technology available today –**Specs for final lasers need to be finalized for development of reliable seed lasers for LPP (Coherent)**
- **Power (Near Future)**
  - **15 - 20 kW**
- Operation Frequency
  - 50-100 kHz
- **Efficiency**
  - **Today: 2.5% - 4%**
  - **Future: 5%**
- **Remaining challenges are Engineering challenges and not a physics based showstopper.**
- **Cost and timing of development?**

Feasibility of High Power Lasers:
Nd: YAG Lasers

- **Power (Today)**
  - 362 W, **1.5 k W (100 % Duty Cycle) -3.5 kW (30 % Duty cycle)**
  - **Nd : YAG lasers have warranty of > 10 K Hours**
- **Power (Near Future)**
  - **2.5 - 20 kW**
- Operation Frequency
  - 1-6 kHz (Today) and 10 K Hz (Future)
  - 50 -100 K Hz operation today (Fraunhofer)
- **Efficiency**
  - **Today: 6.25-13%**
  - **Future: 13%**
- **Cost 3-4 M$ for 10 kW**

Feasibility of High Power Lasers:
Fiber Lasers

- **Power (Today)**
  - **45 - >100 W**
  - **Good candidates for multiplexed systems**
- Power (Near Future)
  - 1 - 10 k W
- Operation Frequency
  - 100 kHz (today), MHz (future)
- **High wall plug efficiency**
  - **Today: < 10-30%**
  - **Future: > 40 %**
- **Further R&D needed**
- **Supplier and timing issues**

Technical Presentations

- Temporal and Spatial Multiplexing
  - Allows use of commercially available YAG lasers
  - Two lasers have been temporally multiplexed
  - Designs for spatial multiplexing shown
- Modeling Update
  - Simulation of fast ions in DPP
  - Benchmarking of code with UCD Sn LPP experiment
    - For gaussian distribution of laser power by radius, reabsorption of EUV in beam wings takes place
    - CE vs delay between pre-pulse and main pulse
- Debris Mitigation Technology Review
  - Neutral debris is very important
  - Neutral debris measurement detector proposed

EUV Source CoO (SEMATECH Model)

- Ultimate source market prices will depend largely on R&D, market size, market share, and required supplier ROI models
  - Reasonable understanding of EUV source cost of Bill of Materials (BOM)
  - R&D and ROI business models will affect more of ultimate price
- **EUV CoO of ~ $73 / GWLE is estimated for one 32nm HP critical level**; this is a **$11 increase from 2005 analysis due to the increased capital cost of stepper and source ~ $60 M**.
- **Collector lifetimes need to be at least ≥ 20 B pulses** based on replacement running costs to maintain a 15% contribution to overall CoO
  - EXAMPLE: $5M source capital cost with $1M collector replaced at 20 B pulses = $11.50 / GWLE; (this is ~15% of total CoO for cluster cell of $73 / GWLE)
- **Source reliability (MTBF) of ≥ 400 hrs needed** in linked exposure cell to support > 100 hr system MTBF (assuming equal subsystem MTBF partitioning)
- **A high reliability source of 400 MTBF with a capital cost of $5M (with a $500k collector replaced at 40 B pulses) supports a $8.57 / GWLE CoO contribution. A $10M source costs drives a $ 11.10 / GWLE CoO contribution**
- **Please see poster by Phil Seidel for further details.**

EUV Source Utility Requirements:
Wall Plug- Laser Light Laser Efficiency is an important Consideration

Power Consumption by Ten Scanners in a 300 mm HVM Fab			% of Total Fab Power Consumption
Present Technology			
193 nm Scanner	**0.75**	**MW**	**2%**
EUV (Sn Based)			
EUV (DPP)	**1.845**	**MW**	**3.6%**
EUV (LPP)			
Laser Effficiency	(MW)		
0.5%	36.23		42.4%
1.0%	18.87		27.7%
5.0%	4.97		9.2%
10.0%	**3.24**		**6.2%**
15.0%	2.66		5.1%
20.0%	2.37		4.6%
25.0%	2.19		4.3%
30.0%	2.08		4.1%