International EUV Initiative

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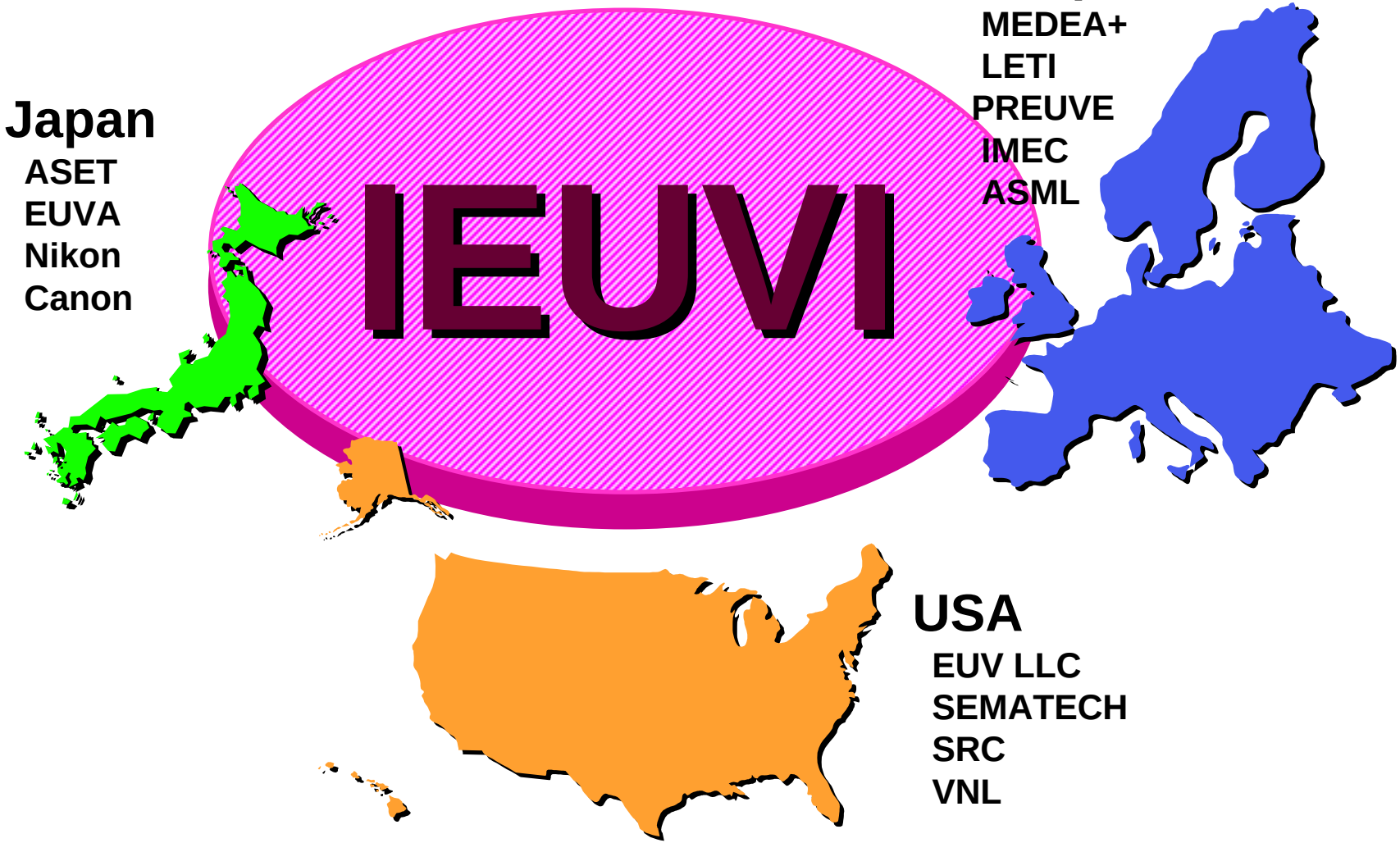
SEMATECH

IEUVI: A forum for international cooperation



http://www.ieuvi.org

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- **IEUVI background**
- **IEUVI TWGs**
- **EUVL status**
  - How can we measure progress?

IEUVI

THE CHALLENGE: International Collaboration on Extreme Ultraviolet Lithography

- Technical challenge: Radical departure from current optical lithography
  - All reflective optics, 13nm source, multilayer, atomic precision mask blanks, vacuum operation
- Required in manufacturing by 2009
- No single consortium, organization or country can bear the entire cost

Extreme Ultraviolet Lithography
=
The Prime Candidate for Collaboration

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WSC 2004 Joint Statement

Joint Statement on The Eighth Meeting of World Semiconductor Council (WSC)
May 13, 2004 - Busan, Korea

Future Semiconductor Technology Development

Much of the growth in productivity gained by our economies has been the result of advances in semiconductor technology…The WSC recognizes that making these advances requires ever increasing investments and wide-ranging skills. In order to properly assess these issues, ***international collaborative and cooperative efforts are necessary****...*

The ITRS identifies a number of challenges that must be overcome to continue the pace of technology advances, including the introduction of new materials, new lithography technology, and new device structures. The Members of the WSC unanimously agree that solutions to these challenges are vital to the continued growth and development of the semiconductor industry and that additional resources are needed. For example, while ***projects are currently underway in several WSC member geographies to develop EUV and other advanced lithography technology*** *to follow after 157nm,* ***the task is beyond the capabilities of any single geography*** *due to the significant cost and complexities involved.* ***The WSC encourages researchers in all regions to further cooperate on this pre-competitive technology.***

European Semiconductor Industry Association (EECA-ESIA)
Japan Electronics and Information Technology Industries Association (JEITA)
Korea Semiconductor Industry Association (KSIA)
Semiconductor Industry Association (SIA)
Taiwan Semiconductor Industry Association (TSIA)

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IEUVI Goals

- **To coordinate collaboration among world EUVL consortia by:**
  - Aligning R&D activities to the International Technology Roadmap for Semiconductors (ITRS)
  - Coordinating R&D collaboration activities among consortia
  - Facilitating dissemination of knowledge of EUVL IP

2. To encourage coordination among suppliers by sharing progress reports

3. To identify implementation issues by:

- Identifying potential "show stoppers" for EUVL implementation
- Communicating implementation issues (e.g., to consortia, IC manufacturers, suppliers, and governments)

IEUVI* Projects and Accomplishments

Status June 2003

Topic	Status	Japan	Europe	USA
1. Multi-layer reflectivity round robin #1	Completed	✓		✓
2. Multi-layer reflectivity round robin #2	Starting	✓	✓	✓
3. Multi-layer development & characterization		✓	✓	✓
4. Resist LER		✓	✓	✓
5. Sensor		✓		✓
6. Mask blank inspection	In progress			✓
7. Mask modeling	In progress	✓	✓	✓
8. Defect metrology	In progress		✓	✓
9. Optics metrology		✓	✓	
10. Source development			✓	✓

**includes EUVLCC activities prior to 2/2003*

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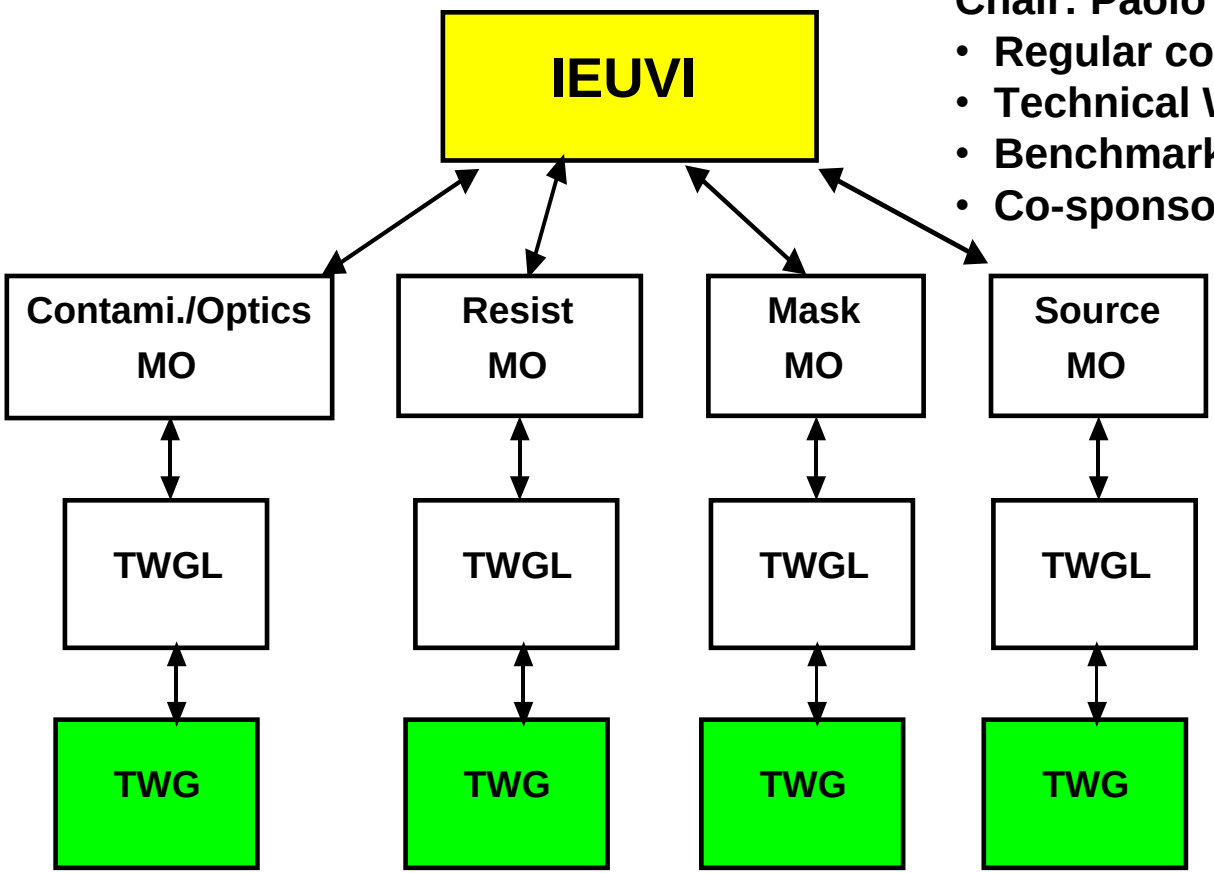
IEUVI Organization



Chair: Paolo Gargini

- **Regular coordination meetings**
- **Technical Working Groups**
- **Benchmarking data exchange**
- **Co-sponsorship of workshops**

MO = Meeting Organizer (IEUVI member)

TWGL = Technical Working Group Leader (Technical expert)

TWG = Technical Working Group (technical contributors from all regions)

- IEUVI meetings held 3 times per year (SPIE, SEMICON West, EUV Symposium)
- TWG meetings held 3 times per year + regular teleconferences

IEUVI

IEUVI TWG Updates

IEUVI

IEUVI Source TWG

- Meeting Organizers: Dieter Goetz (MEDEA+) and Masashi Ogawa (EUVA)
- TWG Chair: Koichi Toyoda (EUVA)
- TWG Co-Chair: Stefan Wurm (Infineon/SEMATECH)
- TWG Facilitator: Vivek Bakshi (SEMATECH)
- Members:
  - EXULITE: Magali Davenet
  - ASML: Rob Hartman, Hans Meiling
  - Canon: Yutaka Watanabe
  - EUVA: Akira Endo, Naomichi Abe
  - Intel: Christof' Krautschik, Giang Dao
  - Nikon: Hiroyuki Kondo, T. Asami
  - Philips Extreme: Joseph Pankert
  - Cymer: Igor Fomenkov, Bruce Bolliger
  - PLEX LLC: Malcolm McGeoch
  - Xtreme technologies: Uwe Stamm, Jürgen Kleinschmidt

EUV Source Technology Status

IEUVI Source TWG

EUV Source Specifications	Best Reported Values				Requirements		
	Xe GDPP	Sn GDPP	Xe LPP	Sn LPP	Alpha	Beta	Production
Status as of	Q2 2004	Q2 2004	Q2 2004	Q2 2004	2005	2007	2009
Wavelength	**13.5 nm**	**13.5 nm**	**13.5 nm**	**13.5 nm**	**13.5 nm**	**13.5 nm**	**13.5 nm**
Throughput WPH					20	60	**100**
EUV Power (at IF)	**10 W**	**20W**	**2 W**		**10 W**	**30 W**	**115 W**
Repetition Frequency	**2 k Hz**	**6.5 k Hz**	**4.5 k Hz**		**2 k Hz**	**5 k Hz**	**7-10 k Hz**
Integrated Energy Stability	**2%**		**5%**		**5%**	**1%**	**0.3%**
Source Cleanliness					**TBD**	**TBD**	**>30,000 hours**
Collector Lifetime	0.5 B	0.2 B	0.1 B		5 B (1 Month)	40 B (3 Month)	100 B (6 month)
Electrode Lifetime	0.6 B		n/a	n/a	5 B (1 Month)	40 B (3 Month)	100 B (6 month)
Projection Optics Lifetime							30000 Hours
Etendue of Source Output			**<1mm2sr**		**TBD**	**TBD**	**max 1-3.3 mm2 sr**
Max. Solid angle to illuminator					**TBD**	**TBD**	**0.03-0.2 sr**
Spectral Purity (130-400 nm)	**10-12%**				**TBD**	**TBD**	**<= 3-7%**
Spectral Purity (>400 nm)	**2-6%**				**TBD**	**TBD**	**TBD**
Spectral Purity (20-130 nm)					**TBD**	**TBD**	**TBD**
First Mirror Lifetime					**TBD**	**TBD**	**TBD**

Source performance is reported by suppliers and is not independently verified

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IEUVI Resist TWG

- Meeting Organizer: Serge Tedesco (CEA/LETI)
- Meeting Chair: Kim Dean (SEMATECH)
- Meeting Co-chair: Wolf-Dieter Domke (Infineon)
- TWG Members:

  IMEC: Mieke Goethals

  ASET: Iwao Nishiyama

  Intel: Wang Yueh, Heidi Cao

  AMD: Adam Pawloski

  Freescale: Richie Peters

  Philips: Peter Zandbergen

  IBM: Carl Larson, Greg Walraff

Status/Schedule of 0.3 NA Exposure Tools

IEUVI Resist TWG

- **SEMATECH Berkeley MET**
  - In operation, 35nm images obtained using Rohm & Haas resist MET-1K
  - Added reticle load lock; implemented improvements in dose control and field uniformity
- **ASET HiNA**
  - Set 3 optics results to be presented at EUVL Symposium
- **LETI BEL**
  - Under development
- **Intel MET**
  - In operation
- **SEMATECH Albany MET**
  - Tool installed, in start-up
  - Scheduled for operation Q4 2004

EUV Resist Performance Roadmap

IEUVI Resist TWG

Specifications	Alpha (2005)		Beta (2007)		Gamma (2009)	
	Spec	Comment	Spec	Comment	Spec	Comment
Resolution 1:1	45nm		32nm		32nm	
Resolution contacts	55nm		45nm		45nm	
Resolution Isolated Lines	32nm		22nm		22nm	
Depth of Focus	200nm	Dense and isolated; DOF at best exposure latitude	225nm	Dense and isolated; DOF at best exposure latitude	225nm	Dense and isolated; DOF at best exposure latitude
Photospeed (mJ/cm^2)	< $5mJ/cm^2$	Assuming 10 wph	< $4mJ/cm^2$	Assuming ~30 wph	< $3mJ/cm^2$	Assuming > 100 wph if 5 mJ/cm^2, 115W intermediate focus
Line Width Roughness (3 σ)	< 4 nm		< 3nm		< 1.6 nm	LWR < 8% etched gate length; gate length = 20 nm
Wall Profile Angle	>85º		> 85º		> 85º	
Outgassing	Similar to ESCAP@ EUV		TBD		TBD	
Pattern Collapse	>3	Aspect ratio 3:1 for all structures	>3	Aspect ratio 3:1 for all structures	>3	Aspect ratio 3:1 for all structures
Unexposed Film Thickness Loss	< 10%		< 5%		< 5%	
PEB Sensitivity	< 2.5 nm/deg C		<1.5 nm/deg C		< 1 nm/deg C	
Delay Stability @ < 1ppb amine	30min	a) pre-exposure, b) under vacuum, c) post-exposure	30 min	a) pre-exposure, b) under vacuum, c) post-exposure	30 min	a) pre-exposure, b) under vacuum, c) post-exposure
Etch Resistance	Similar to novolak		Similar to novolak		Similar to novolak	

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IEUVI Mask TWG

- Meeting Organizer: Shinji Okazaki, ASET
- International Chair: Scott Hector, Freescale/SEMATECH (acting)
- Regional Chairs
  - Japan: Takeo Hashimoto, ASET
  - Europe: Jan-Hendrik Peters, AMTC
- Members:

Brian Blum	Mike Sogard	Phil Ware	Larry Zurbrick
Pei-Yang Yan	John Maltabes	Laurent Dieu	Scott Mackay
Bruno LaFontaine	Ken Racette	Rod Kendall	Dick Eandi
Tom Kielbaso	Brion Hoffman	David Navan	Chris Walton
Lennie Klebanoff	Eric Gullikson	Iwao Nishiyama	Tsukasa Abe
Hisatake Sano	Tadashi Matsuo	Tsutomu Shyoki	Jin-Ho Ahn
Seong-Sue Kim	Masayuki Sengoku	Soichiro Mitsui	N. Yamamura
Osamu Okabayashi	Kazuya Ohta	Yoshihiro Nakamura	Kouji Ohtsuka
Toshihide Nakajima	Motoyuki Yamada	Mutsumi Asano	Shinichi Kondo
Yasuaki Fukuda	Tsuneo Terasawa	Frank Sobel	Hans Meiling

EUV Mask Technical Issues

IEUVI Mask TWG

- Multilayer defectivity (mask blank).
- Metrology / defect inspection (actinic?).
- Handling & protection.
- Substrate defectivity.
- Mask cleaning.
- Mask repair.
- Tool throughput.
- Mask flatness / thickness variation.

Status	Comment
	MBDC key issue.
	Push existing technology; ebeam option.
	Pursuing carrier; need molecular contamination.
	Investigating several options.

Status colors per ITRS

solution known - development required

no known solution

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EUV Mask Performance Roadmap

IEUVI Mask TWG

	Current	Alpha (2005)		Beta (2007)		Gamma (2009)	
parameter	Status	specification	comment	specification	comment	specification	comment
Added defects (/cm^2)		0.050	10 defects in max Quality Area (142 mm x 142 mm)	0.010	2 defects in max QA	0.005	1 defect in max QA
Adder rate - handling		per 1 handling operation	trigger level for cleaning operation	per 10 handling operations	trigger level	per 100 handling operations	trigger level
Adder rate - shipping		10	trigger level	2	trigger level	0	trigger level
Adder rate - storage (1 per)		30 days	trigger level	90 days	trigger level	180 days	trigger level
Max particle (nm, pattern side)		60	limit of metrology	32	ITRS 45nm	22	ITRS 32nm
Max particle (nm, backside)		60 (major reduction)		32		22	
Surface flatness (nm P-V, pattern side)		100		70		50	SEMI P37, Class C
Surface flatness (nm P-V, backside)		100		70		50	SEMI P37, Class C
Low order thickness uniformity (um)		1000					
Surface flatness outside QA (nm, both sides)		1000		500		??	Exclude areas of no interest based on practical designs?
HSRF (nm, within QA)						0.15	SEMI P37
Local slope (mrad)		3.0		2.0		< 1.0	SEMI P37
Maximum Legendre mode		(2,2)		(2,3), (3,2)		(3,3)	relaxed by HVM
Mask Lifetime			Cumulative exposure energy? Cleaning cycles?				

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EUV Optics Contamination and Lifetime TWG

- Meeting Organizer: Giang Dao, SEMATCH/ Intel
- Chair: Ginger Edwards, SEMATECH/ Freescale
- Members:

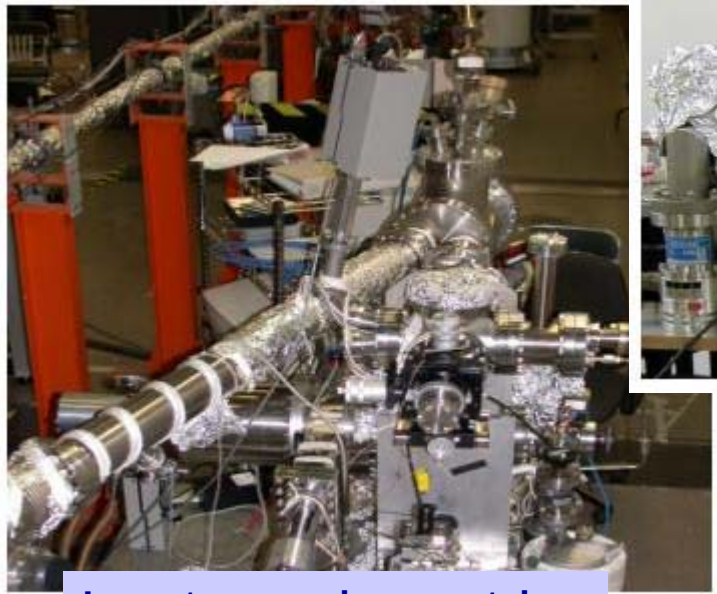
Iwao Nisiyama, ASET
Tom Lucatorto, NIST
Hiroyuki Kondo, Nikon
Frank Scholze, PTB
John Goldsmith, Sandia
John Taylor, Lawrence Livermore
David Ruzic, University of Illinois
Thomas Stein, Zeiss
Hiroshi Komori, EUVA

Obert Wood, SEMATECH / AMD
Hans Meiling, ASML
Yasuaki Fukuda, EUVA
Julia Simon, CEA/ LETI
Bas Mertens, TNO-TPD
Stefan Wurm, SEMATECH / Infineon
Vivek Bakshi, SEMATECH
Ted Madey, Rutgers U.
Peter Kuerz, Zeiss

Facilities for EUV optics lifetime and contamination testing

IEUVI Optics Lifetime TWG

Acceleration test of contamination study at LASTI Univ of Hyogo



Long term environmental test chamber on NIST Surf III synchrotron

Cleaning study of contaminated surface At NTT Atsugi SBL-2

GDPP condenser erosion test chamber at University of Illinois

Not shown:

- Lifetest facility at PTB, Munich
- Analysis of depositions by EUV irradiation at NTT Atsugi SBL-2

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EUV Optics Lifetime Roadmap

IEUVI Optics Lifetime TWG

	Alpha Spec (late 05/ early 2006)	Beta Spec (2007)	Gamma Spec (2009)
Optics Lifetime (nonconsumable)	1 year	3 years	5 years
"Light on Hours" (nonconsumable)	1000-3000 hrs (ASML)	none given	30,000 hrs (ASML) / 20,000 hrs (EUVA)
Pulse Lifetime (nonconsumable)	5.0E+09 (ASML)	2.9 E+10 (EUVA)	7.0E+11 (EUVA)/ 5.0E+11 (ASML)
Optics Lifetime (consumable)	3 months	3 months	3 months
Pulse Lifetime (consumable)	1.3E+09	2.4E+09	3.0E+10

Lifetime for projection optics means time to 10% total lens system reflectivity loss
Lifetime for condenser optics means time to 10% reflectivity loss
Input provided by EUVA assumes:
Gamma: 100WPH Tput; exposure time ~10sec wafer; 10kHz rep rate; exposure time for 10M wafers = 7E7 sec or 20,000hrs
Beta: 7kHz rep rate; wafer exposure time 30- 50 sec; 0.23- 0.35 Mpulses per wafer

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How can we measure progress?

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EUV Lithography Critical Issues*

- Source power and lifetime, including condenser optics lifetime.
- Availability of defect free masks.
- Reticle protection during storage, handling and use.
- Projection and illuminator optics lifetime.
- Resist resolution, sensitivity and LER.
- Optics quality for 32-nm node.

Key Tracking Metrics

Parameter	Metric	Goal	3Q-02	1Q-03	3Q-03	1Q-04	3Q-04
Source Power	Power @ Intermediate Focus [W]	>115	4	6	~20		
Critical Comp. Lifetime	Number of Pulses	$>7.6\times10^{11}$	1.0×10^{8}		5.0×10^{8}		
Condenser Optics Lifetime	Pulses to 10% refl. Loss	$\sim 7\times10^{12}$	1.0×10^{8}			5.0×10^{8}	
Mask Blank Defectivity	Defects/cm^2 @ PSL equiv. Size [nm]	< 0.003 @ 32	1 @ 150	0.2 @ 150		0.771 @ 80	0.32 @80
Mask Substrate Flatness	P-V [nm]	< 50	300	250	< 100	~ 70	
Reticle Protection	Added def./cm^2 @ PSL equiv. Size [nm]	< 0.003 @ 32				0.142 @ 100	
Projection Optics Lifetime	Time to 1% reflectivity loss [h]	30,000	1,000				
Resist Sensitivity	Sensitivity [mJ] / LER [nm]	2 / 4	5 / 7				
PO Box WFE (Figure)	RMS System WFE [nm]	0.25	0.67	0.48		0.68	

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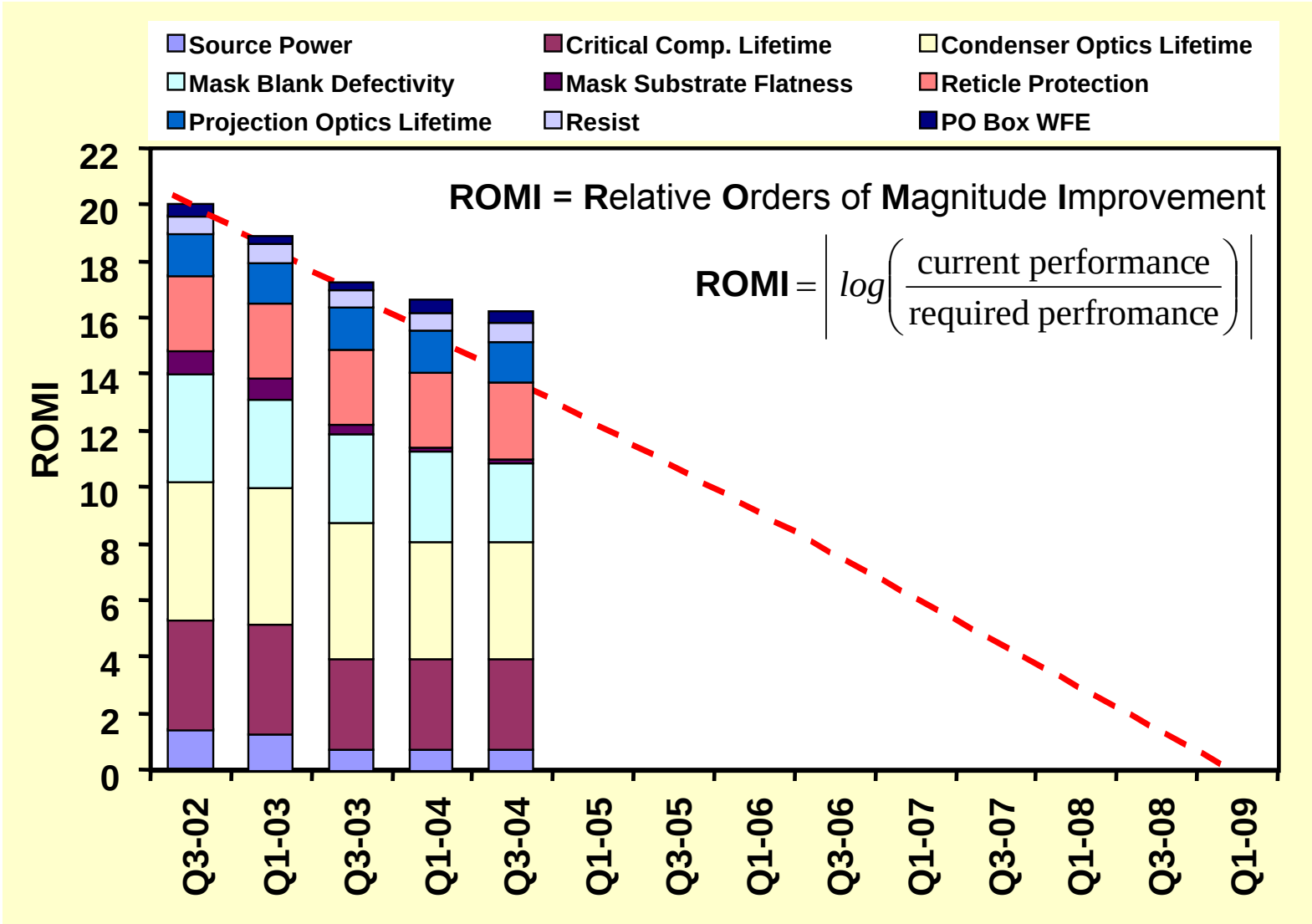
* *From 2nd International EUV Symposium Steering Committee, October 2003*

EUVL Progress



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Observations

- We need more sharing of data
  - To demonstrate that we are making adequate progress…
- We must collaborate closely to resolve the critical issues
  - Consolidate and focus resources on the most difficult problems
  - Reduce the total development cost of EUVL

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Summary

- The successful development of EUVL requires international collaboration and cooperation
  - Technical challenges demand worldwide effort to resolve
  - No single consortium, organization or country can bear the entire cost
- IEUVI membership and TWG activity is driving coordination, collaboration and common goals
- Our challenge together is to achieve and demonstrate aggressive progress toward these goals
  - **I hope to see lots of good progress this week!**

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