Actinic Mask Defect Inspection

Specifications for Metrology Tools
EUV Sources for Metrology: 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

Outline

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Actinic Mask Defect Inspection Background

- Three type of actinic mask defection tools are needed by the industry for EUVL deployment
  - Aerial Imaging tool
  - Mask Blank Defect Inspection tool
  - Pattern Mask Defect Inspection tool
- Tools needed by 2010 to support beta scanners
- Present Technology Status
  - Mask Blank inspection tool operational at MIRAI with Energetiq DPP source
  - Mask Defect inspection capabilities available at LBNL with synchrotron
  - Metrology Suppliers are in the tool design phase and determining source requirements

Actinic Mask Defect Inspection Background

- As etendue of defect inspection system optics is small, only a small portion of light source is used
  - This makes HVM Source technology too costly
- Key parameter for EUV Sources for Actinic Inspection is source brightness (and not average power): W/mm2-sr
  - COO and technology readiness are important
  - Opportunity for alternative EUV Source Technologies
- Future Direction
  - Industry needs to develop unified requirements for EUV sources for Actinic Inspection -similar to Joint Requirements for EUV Sources

Mask Inspection Tools Represent Serious EUVL Infrastructure Gap

Mask Infrastructure Gaps

Gap	Suppliers building solution	Estimated cost for HVM solution	Time to HVM solution
Full-field production scanner	Yes	Funded	2012
Source	Yes	Funded	2011
Resist	Yes	Funded	2011
Mask substrate	Yes	Funded	See below
Mask substrate inspection	Yes	Funded by Sematech	2013?
Mask blank	Yes	Funded	See below
Mask blank multilayer deposition	Yes	Funded by Sematech	2013
Mask blank inspection	No	>$50M	2013?
Mask defect review	No	>$50M	2013?
Mask: patterned inspection	No	>$100M	2013?

Source: Bryan Rice, SEMICON West, July 15, 2009

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Current Technology Status

Source Brightness Calculations

- Brightness : $W/mm^2.sr$
- Example for a DPP Source
  - Source Power: P=10 W (at source)
    - Measured in 2% BW in 2π sr
  - Source Area: $A=0.07\ mm^2$
    - Diameter (FWHM)= 0.3 mm / Radius=0.15 mm
    - Etendue: $E= A/(2\pi)= 0.011\ mm^2.sr$
  - $B= P/(A*2*\pi) =P/E =22.5\ W/mm^2.sr$
- Source Power defined after Debris mitigation
- Brightness needs to be measured
  - Source Emission is non-uniform and shape may be ellipsoidal.
  - Not all EUV sources emit radiation in 2π

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Current Technology Status

EUV Source Brightness: Current Status

Technology	Power (W)	Viewing Angle (sr)	Source Radius (mm)	Area (mm2)	Etendue (mm2-sr)	Brightness (W/mm2-sr)
DPP	5	2 Pi	0.15	0.07	0.44	11.27
	15	2 Pi	0.15	0.07	0.44	33.81
	40	2 Pi	2.00	12.56	78.88	0.51
	100	2 Pi	2.00	12.56	78.88	1.27
	200	2 Pi	3.00	28.26	177.47	1.13
	0.1				1.00E-04	1.00E+03
	1				1.00E-04	1.00E+04
LPP	25	2 Pi	0.10	0.03	0.20	126.78
	50	2 Pi	0.10	0.03	0.20	253.56
	100	2 Pi	0.10	0.03	0.20	507.12
	200	2 Pi	0.10	0.03	0.20	1.01E+03
Alternate 1	1.00E-03	1.00E-04	0.01	6.15E-04	6.15E-08	1.62E+04
Alternate 2	1.00E-03	1.00E-04		3.00E-03	3.00E-07	3.33E+03

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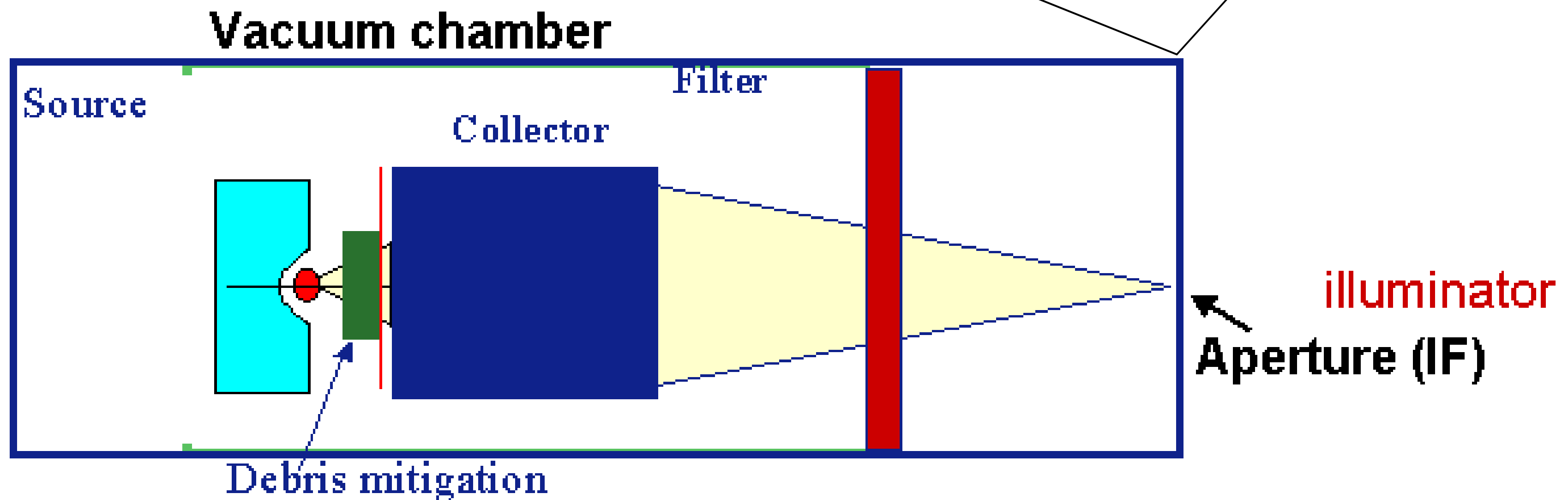
Lessons learned from the Selection of High Power Sources

- Need specs agreed by end customers
  - Throughput and defect size will drive the requirements, defined by end users
  - Need throughput model to drive the source requirements
- Need specs agreed by metrology tool suppliers
- Agreed Source and Tool Specs need to include
  - Location of Source specs (at IF or at source?)
  - Range of source parameters, e.g. etendue
- Who owns the collector : Source supplier or integrator?
  - Are source suppliers responsible to be a SoCoMo suppliers (as in the case of high power sources for scanners)?

High Power EUV Source Technology
EUV Source Definition for EUVL Scanners

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



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Joint Specifications for EUV Sources (For High Power Sources for scanners)

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)

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Wafer Throughput Model (EUVL Scanners)

Throughput drives Source Power Requirements

Throughput	wafers/h	100
Time per item		
Total time per wafer	sec	36.0
Stage overhead	sec	27.0
Exposure time	sec	9.0
Field and wafer parameters		
Wafer diameter	mm	300
Fraction of wafer exposed	%	78.7
Penalty for not using full field height	%	96.2
Resist Sensitivity	mJ/cm^2	5.0
Intermediate derivatives at wafer		
Total energy per wafer	J	2.9
Power at wafer	W	0.321
PO Box		
Reflectivity, mirror	%	67.5
Number of near-normal mirrors		6
Bandwidth mismatch loss	%	5.0
Polarization loss	%	5.0
Gas absorption PO	%	5.0
Total transmission PO	%	8.1
Reticle		
Reflectivity Reticle	%	65.0
Power at Reticle	W	6.1
Illuminator		
Total transmission	%	8.4
General		
Overall component degradation	%	37.0
Power: captured clean photons	W	115.2

Mask Blank Inspection Tool
Specs Proposal

			Mask Blank		
	Supplier A	Supplier B	Supplier C	Supplier D	Proposal
Wavelength	13.5				13.5
Source Power at plasma (2% BW in 2 pi)	>10				>25
Source Size at plasma (dia) mm	0.4				0.1
Source Size at plasma (area) mm2	1.26E-01				7.85E-03
Source Power at IF (2% BW in 2 pi)	>0.1	10	5.8		
Source area (mm2)	<0.12				
Etendue of source Output (mm2-sr)	<0.01	0.1	2.00E-03		4.93E-02
Max. Solid angle to system (sr)	<0.1				
Area of source at IF (mm2)	5.02E-01				
Source dia at IF (mm)					
Brightness (W/mm2-sr)	>14	100	2.90E+03		>500
Repetition Rate (K Hz)	>2				>5
Integrated Energy Stability (%)	1				1
Source Cleanliness (10% loss for B pulses)	30				100
Spectral Purity	N/A				N/A
Tool Specs					
Stage Velocity (mm/s)	5				
Inspection time for one blank	2		1		1
Defect Inspection Capability (Width) (nm)	40				Per Node
Defect Inspection Capability (Height) (nm)	1.5				
Field of view (FOV) mm x mm	0.5 x 0.5	1 x 1			
Number of Mirrors			4		

AIMS Tool
Specs Proposal

			AIMS		
	Supplier A	Supplier B	Supplier C	Supplier D	Proposal
Wavelength				13.5	13.5
Source Power at plasma (2% BW in 2 pi)				0.2	>10
Source Size at plasma (dia) mm				0.2	0.1
Source Size at plasma (area) mm2				3.14E-02	7.85E-03
Source Power at IF (2% BW in 2 pi)			0.25		
Source area (mm2)					
Etendue of source Output (mm2-sr)			2.90E-03		4.93E-02
Max. Solid angle to system (sr)				3.16E-02	
Area of source at IF (mm2)					
Source dia at IF (mm)					
Brightness (W/mm2-sr)			8.62E+01		>200
Repetition Rate (K Hz)					
Integrated Energy Stability (%)				1	
Source Cleanliness (10% loss for B pulses)					
Spectral Purity					
Tool Specs					
Stage Velocity (mm/s)					
Inspection time for one blank			1		1
Defect Inspection Capability (Width) (nm)				Per Node	
Defect Inspection Capability (Height) (nm)					
Field of view (FOV) mm x mm				0.05 x 0.05	
Number of Mirrors			4		

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Patterned Mask Inspection Tool Specs Proposal

	Supplier A	Supplier B	Supplier C	Supplier D	Patterned Mask Proposal
Wavelength					13.5
Source Power at plasma (2% BW in 2 pi)					>100
Source Size at plasma (dia) mm					
Source Size at plasma (area) mm2					
Source Power at IF (2% BW in 2 pi)					
Source area (mm2)					
Etendue of source Output (mm2-sr)					
Max. Solid angle to system (sr)					
Area of source at IF (mm2)					
Source dia at IF (mm)					
Brightness (W/mm2-sr)			2.51E+03		>2000
Repetition Rate (K Hz)					
Integrated Energy Stability (%)					
Source Cleanliness (10% loss for B pulses)					
Spectral Purity					
Tool Specs					
Stage Velocity (mm/s)					
Inspection time for one blank			1		
Defect Inspection Capability (Width) (nm)					Per Node
Defect Inspection Capability (Height) (nm)					
Field of view (FOV) mm x mm					
Number of Mirrors			4		

Summary

- Industry needs Actinic Mask Defect inspection tools by end of 2010 to support EUVL beta level scanners
- EUV Source with high brightness will be the key enablers of these metrology tools and these sources are not commercially available today
- We need to learn from the high power source development
  - Develop tool specs to provide clear guidance to source developers
  - Conduct independent assessment of source performance to understand technology readiness

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