Lithography ITWG Update

ITRS Conference

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Highlights of the 2002 Lithography Update

- There were very few changes compared to earlier years.
  - Greater stability in the roadmap.
    - At least for the moment!
- The changes for the 2002 update.
  - Lithography Requirements Table.
    - Yellow cells for 2002 have been changed to white except for 1/2 pitch and MPU CD control.
  - 157 nm, Ion Projection Lithography and Proximity X-ray Lithography have been removed from 90 nm node as potential solutions in 2004.
  - Differences between the lithography and metrology tables for overlay and CD control at wafer level have been corrected.

Highlights of the 2002 Lithography Update

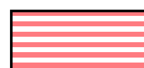
- More changes for the 2002 update.
  - Pellicle solutions for 157 nm lithography have been recognized.
  - Interim solutions coloring has been adopted for several parameters in 2002 and later years.
    - Recognition that products are being produced or will be produced, but yield and productivity may not be at the desired level.

Lithography Requirements

Year of Production	2002 115 nm	2003 100 nm	2004 90 nm	2005 80 nm	2006 70 nm	2007 65 nm
DRAM						
Half pitch (nm)	**115**	**100**	**90**	**80**	**70**	**65**
Contacts (nm)	**130**	**115**	**100**	**90**	**80**	**70**
Overlay (nm, mean + 3 sigma)	**40**	**35**	**31**	**28**	**25**	**23**
CD control for critical layers (nm, 3 sigma, post-etch, 15% of CD) litho contribution, only	**11.0**	**10.0**	**9.0**	**8.0**	**7.0**	**7.0**
MPU/ASIC						
Half pitch	**130**	**107**	**90**	**80**	**70**	**65**
Gate length (nm, in resist)	**75**	**65**	**53**	**45**	**40**	**35**
Gate length (nm, post-etch) (physical length)	**53**	**45**	**37**	**32**	**28**	**25**
Contacts (nm, in resist)	**130**	**115**	**100**	**90**	**80**	**70**
Gate CD control (nm, 3 sigma, post-etch, 10% of CD, litho only)	**4.3**	**3.7**	**3.0**	**2.6**	**2.3**	**2.0**

Updated Optical Mask Table

	Year of Production	2002	2003	2004	2005	2006	2007
		115nm	100nm	90nm	80nm	70nm	65nm
Was	Mask minimum image size (nm) [C]	300	260	212	180	160	140
Is	Mask minimum image size (nm) [C]	300					
Was	Mask OPC feature size (nm) Clear [D]	230	200	180	160	140	130
Is	Mask OPC feature size (nm) Clear [D]	230					
Was	Mask OPC feature size (nm) Opaque [D]	150	130	106	90	80	70
Is	Mask OPC feature size (nm) Opaque [D]	150					
Was	Image placement (nm, multi-point) [E]	24	21	19	17	15	14
Is	Image placement (nm, multi-point) [E]						
	CD uniformity (nm, 3 sigma) [F] @						
Was	Isolated lines (MPU gates) Binary	6.1	5.1	4.2	3.7	3.4	2.5
Is	Isolated lines (MPU gates) Binary	6.1					
Was	Isolated lines (MPU gates) ALT	8.5	7.2	5.9	5.1	4.8	4
Is	Isolated lines (MPU gates) ALT	8.5					
Was	Contact/vias	6.9	6.1	5.3	4.8	4.3	3.2
Is	Contact/vias	6.9					
Was	Linearity (nm) [G]	17.5	15.2	13.7	12.2	10.6	9.9
Is	Linearity (nm) [G]	17.5					

 = interim solution

Updated EUV Mask Table

	CD Uniformity (nm, 3 sigma) [E]					
Was	Dense lines DRAM (half pitch)	11	10	7	5	3.5
Is	Dense lines DRAM (half pitch)	11	10			
Was	Linearity (nm) [F]	11	10	7	5	3.5
Is	Linearity (nm) [F]	11	10			
	EUVL-specific Mask Requirements					
Was	Mean peak reflectivity	65%	65%	66%	67%	67%
Is	Mean peak reflectivity			66%		
Was	Reflected centroid wavelength uniformity (nm 3sigma) [M]	0.06	0.05	0.05	0.04	0.03
Is	Reflected centroid wavelength uniformity (nm 3sigma) [M]					0.03

- The same change in the linearity spec occurs for the EPL mask tables.

Potential Solutions

Technology Options at Technology Nodes (DRAM Half Pitch, nm)	First Year of IC Production	
130	248 nm + PSM 193 nm	2001
90	193nm + PSM *PEL*	2004
65	157 nm EUV, EPL ML2 *IPL, PEL, PXL*	Narrow Options	2007
45	EUV EPL ML2 *IPL, PEL, PXL*	Narrow Options	2010
32	EUV EPL *ML2* *IPL, PEL, PXL*	Narrow Options	2013
22	EUV, EPL ML2 Innovative technology *IPL, PEL, XPL*	Narrow Options	2016

DRAM Half Pitch (Dense Lines)

Research Required — Development Underway — Qualification/Pre-Production

This legend indicates the time during which research, development, and qualification/pre-production should be taking place for the solution.

EUV = extreme ultraviolet

EPL = electron projection lithography

ML2 = maskless lithography

IPL = ion projection lithography

PXL = proximity x-ray lithography

PEL = proximity electron lithography

Technologies shown in italics have only single region support

Difficult Challenges - Short Term

Five difficult challenges ≥ 65 nm before 2007.	Summary of issues
Optical mask fabrication with resolution enhancement techniques and post-optical mask fabrication	• Registration, CD control, defectivity, and 157 nm films; defect free multi-layer substrates or membranes. • Equipment infrastructure (writers, inspection, repair).
Cost control and return-on-investment (ROI)	• Achieving constant/improved ratio of tool cost to throughput over time. • Cost-effective resolution enhanced optical masks and post-optical masks. • Sufficient lifetimes for the technologies,
Process control	• Processes to control gate CDs to less than 2 nm (3σ) • New and improved alignment and overlay control methods independent of technology option to < 23 nm overlay.
Resists for ArF and F_2	• Outgassing, LER, SEM induced CD changes, defects ≤ 32 nm.
CaF_2	• Yield, cost, quality.

Difficult Challenges - Long Term

Five difficult challenges < 65 nm beyond 2007.	Summary of issues
Mask fabrication and process control	• Defect-free NGL masks. • Equipment infrastructure (writers, inspection, repair). • Mask process control methods.
Metrology and defect inspection	• Capability for critical dimensions down to 9 nm and metrology for overlay down to 9 nm, and patterned wafer defect inspection for defects < 32 nm.
Cost control and return on investment (ROI)	• Achieving constant/improved ratio of tool cost to throughput. • Development of cost-effective post-optical masks. • Achieving ROI for industry with sufficient lifetimes for the technologies.
Gate CD control improvements; process control; resist materials	• Development of processes to control gate CDs < 1 nm (3 sigma) with appropriate line-edge roughness. • Development of new and improved alignment and overlay control methods independent of technology option to < 9 nm overlay.
Tools for mass production	• Post optical exposure tools capable of meeting requirements of the Roadmap.

Litho ITWG proposal for 2003 revision

- CD control needs to be revisited.
  - Discussion requires an agreed-upon CD control model.
    - Must include LER and lens flare.
  - Budget allocation lithography/etch should be reconsidered.
- Half-pitch values need review.
  - This is a critical parameter for lithography and affects which potential solution is used.
- More discussion of 2 year / 3 year per node implications for lithography is required.
  - Get a better understanding of the business issues.

Litho ITWG proposal for 2003 revision

- Improve the definitions of line edge roughness (LER) and make consistent with metrology tables.
- Lens flare (scattered light) is being considered as a critical parameter.
- Review method for determining potential solutions and revise potential solutions figure.
- Consider measuring contact holes as areas, not diameters.
- Insert hard pellicle requirements.

Litho ITWG proposal for 2003 revision

- Tendency of chemically amplified resists to form defects as difficult challenge for sub-90 nm lithography.
- Higher refractive index resists needed for ultra-high-NA optical lithography.
- Revisit minimum resist sensitivity for EUV lithography.
  - Shot noise issue.
- Issue: compatibility between chemically amplified resists and low-k materials.