SEMATECH EUV Resist Benchmarking Results

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Outline

- Introduction
- Objective
- Methodology
- Benchmarking Data
- Effects of illumination conditions on <25nm imaging
- Summary

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Introduction

- Extreme Ultraviolet Lithography (EUVL) is one of the leading candidates for next generation lithography technology for the 32 nm HP and beyond.
- The availability of EUV resists is one of the most significant challenges facing its commercialization.
- To accelerate EUV resist development, SEMATECH provides access to two exposure tools:
  - The EUV Resist Test Center (RTC) at SEMATECH at the University at Albany, SUNY, NY.
  - The SEMATECH microexposure tool (ALS-MET) at Lawrence Berkeley National Laboratory (LBNL).
- The results in this report were collected on the SEMATECH Berkeley MET.

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Objective

- Evaluate resist samples from commercial suppliers with well-defined protocols and specification targets.
  - Provide benchmarking data package using consistent protocol to supplier for feedback and improvement.
  - Focus on Resolution, LWR and Photo speed.

Specifications	2007 Goals
Resolution lines1:1 (nm)	32
Resolution lines 1:5 (nm)	25
Resolution contact holes 1:1 (nm)	45
Resolution contact holes 1:5 (nm)	45
Low frequency LWR (nm, 3 σ)	<2.5
Photospeed, EUV (mJ/cm^2)	10
Outgassing (molecules/cm^2)	6.5E+14

Assumptions: Resolution results confirmed with cross-sectional SEM. Resolution targets can be met with Y-monopole illumination. Photospeed target is for 1:1 lines. Outgassing spec is for 35-200 AMU excluding 44 AMU.

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Resist Benchmarking protocol Procedure

Sample

↓

Resist Outgassing

↓

FD Matrix Exposure (Top down)

- EL, DOF at E_{size} for 1:1 (40 & 30 nm L/S) LWR on 40 nm & 30 nm
- LWR vs dose (top down)

Contact (top down)- No data available at this time

- EL, DOF at E size for 1:1 (45 nm contact CD)
- EL, DOF at E size for 1: 5 (45 nm contact CD)
- Proximity Bias

↓

SEM cross-section Confirm profile

- Resist top loss
- EL,DOF at E size for 1:1 (40 nm L/S)
- EL,DOF at E size for 1:1 (30 nm L/S)
- Ultimate Resolution (1:1)

→ Data Base

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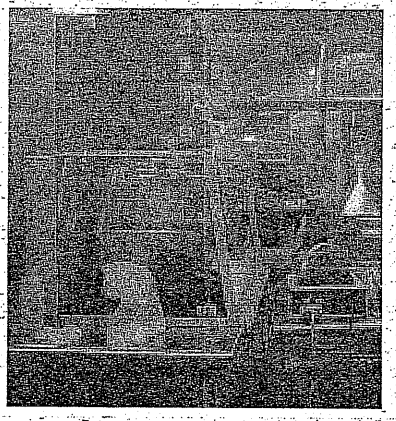
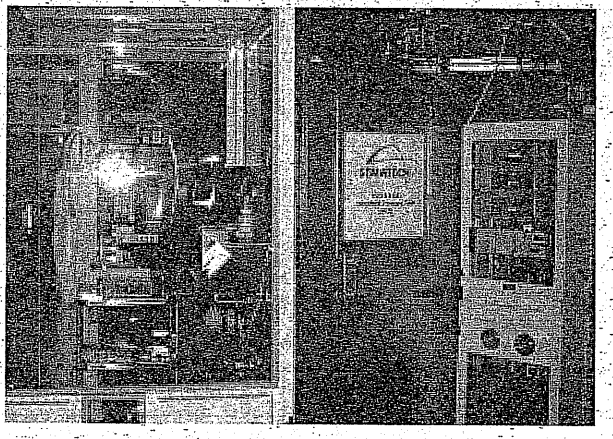
Toolset used for Benchmarking at LBNL (4" wafer)

Resist outgas screening (SUNY)

Resist coat

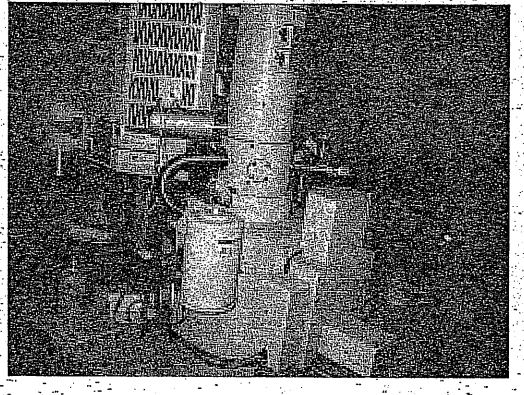


Resist Expose

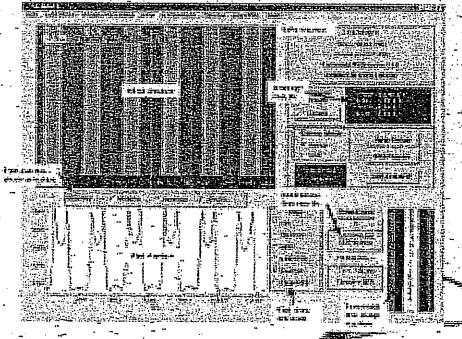


Resist Develop

SEM- Hitachi-S4800 (4")



CD/ LWR measurement (SEMCD- SuMMit) SEMATECH-RTC



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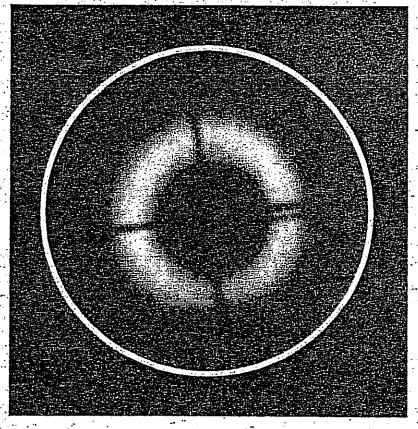
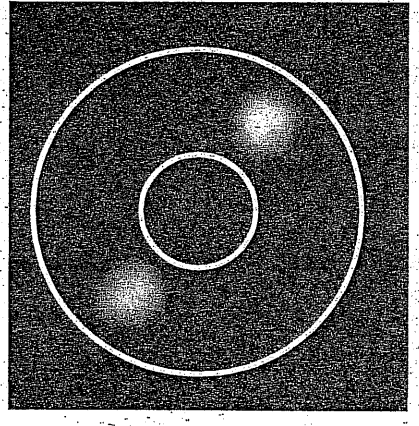
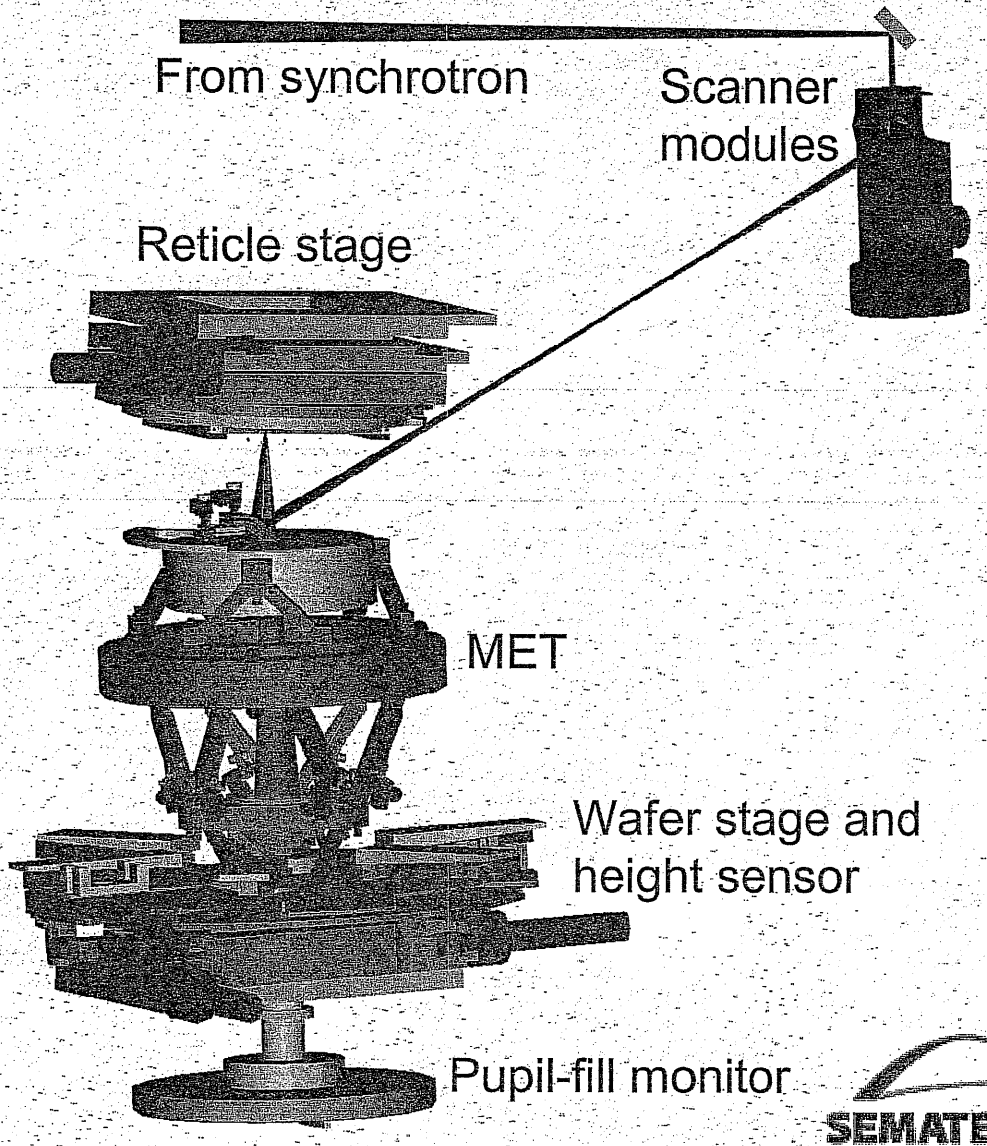
SEMATECH MET printing station at Berkeley supports advanced resist testing with unique low-k_1 capabilities



Examples of lossless programmable pupil fills





Benchmarking Data From Five Resists

- Top down SEMs of resist images
- Dose/ Focus process latitude on 40 nm HP
- CD & LWR vs Dose matrix @ 40 nm HP
- Ultimate resolution images
- SEM cross-section images

NOT SURE YOU NEED THIS SLIDE

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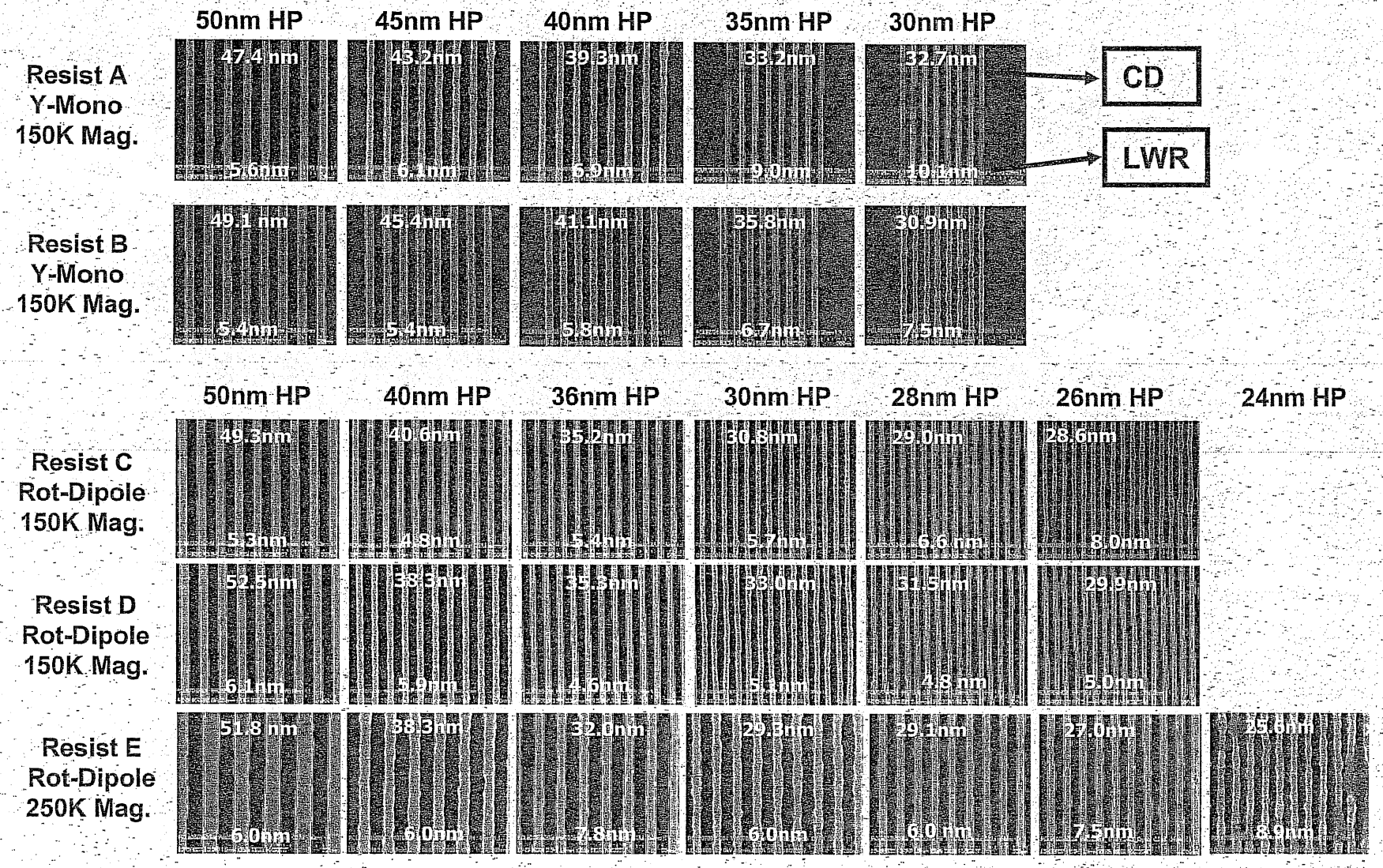
Printing down to 24-nm achieved



- Resist D demonstrated lowest LWR.
- Resist E demonstrated best resolution

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Up to 18% exposure latitude @ 40nm HP

Resist A Y-Mono Best Focus	20.3mj 46.8/ 9.2	21.2mj 43.4/ 8.7	22.2mj 42.0/ 7.6	23.2mj 39.3/ 6.9	24.1mj 36.5/ 7.3	25.1mj 36.4/ 8.6
Resist B Y-Mono Best Focus	19.9mj 44.2/6.2	20.9mj 44.2/4.7	21.9mj 44.8/5.6	22.9mj 41.4/5.3	23.9mj 37.3/5.8	24.9mj 38.2/5.2
Resist C Rot-Dipole Best Focus	15mj 47.6/5.8	16mj 43.2/5.5	17mj 40.6/4.8	18mj 36.3/5.7	19mj 32.1/5.7	20mj 32.0/13.3
Resist D Rot-Dipole Best Focus	21.6mj 43.5/5.0	23.0mj 40.1/5.6	24.3mj 39.2/5.0	25.7mj 35.7/4.9	27.0mj 33.0/4.6	
Resist E Rot-Dipole Best Focus	14.5mj 43.3/7.9	15.3mj 40.9/8.7	16.2mj 39.5/7.3	17mj 38.3/6.0	17.9mj 33.9/7.8	18.7mj 33.8/7.2

Dose

CD/LWR

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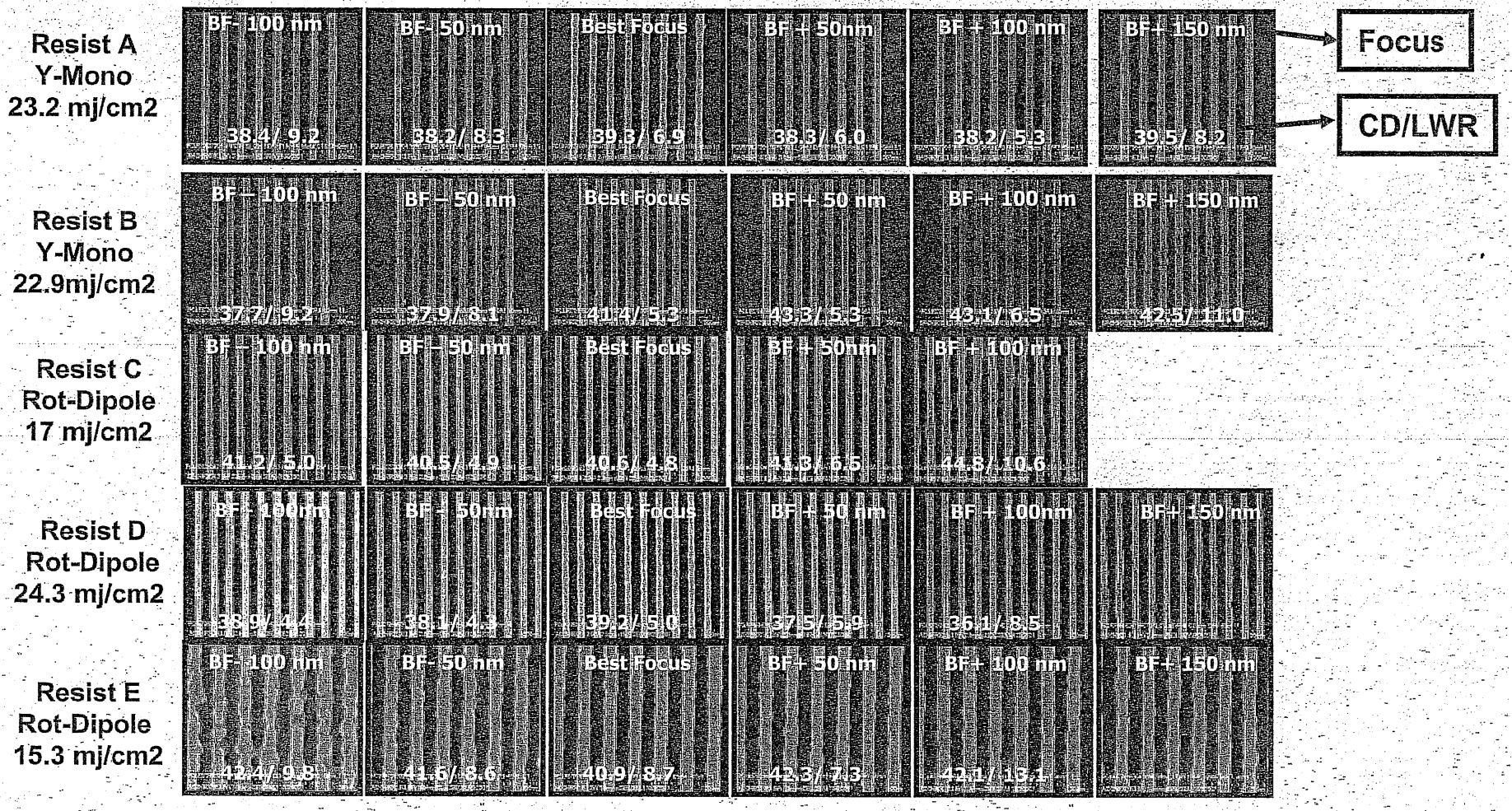
Up to 250-nm focus latitude at 40nm HP



- Resist A and B demonstrated 250nm of DOF on 40 nm HP

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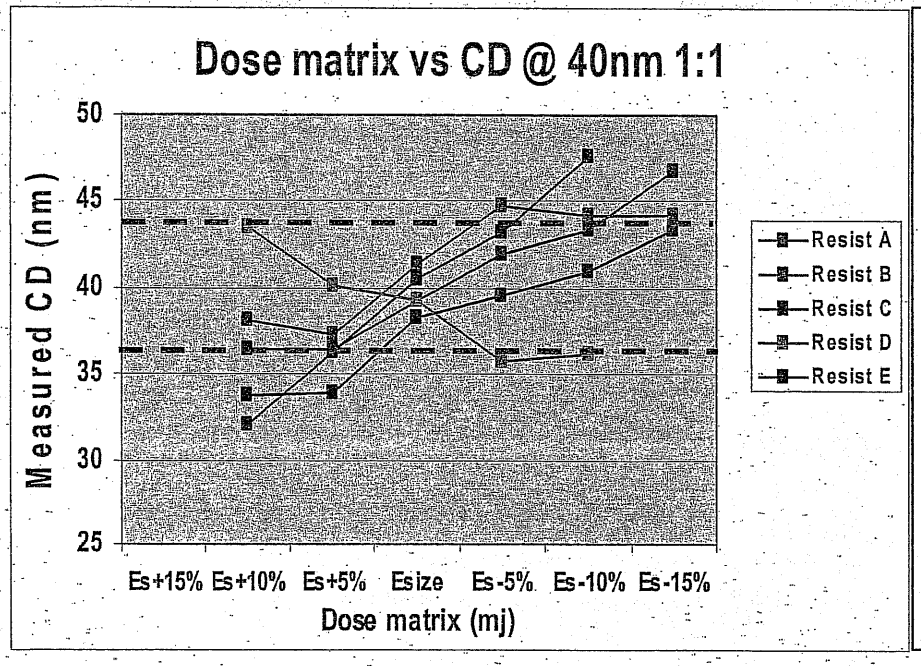
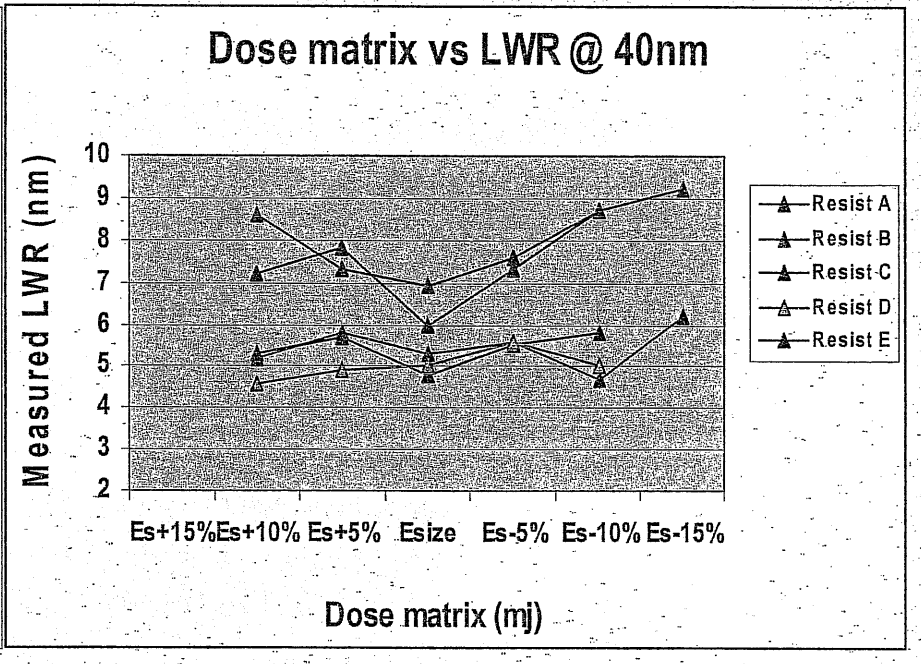
CD & LWR vs Dose matrix @ 40nm HP





- **Resist A demonstrated 18% of EL and 250nm of DOF @ 40nm HP**

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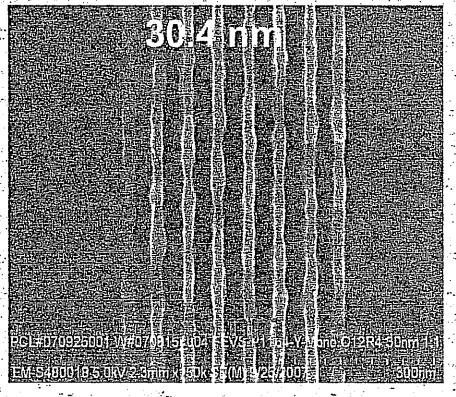
Ultimate Resolution Images

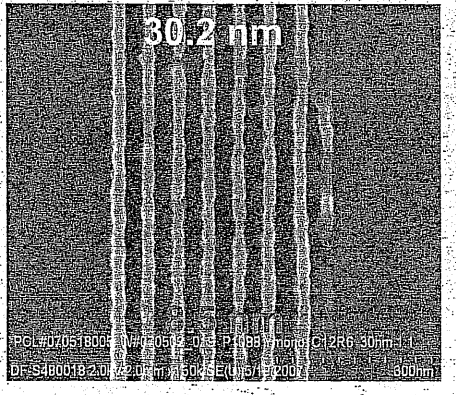
Resist A
Y-Monopole

30nm HP



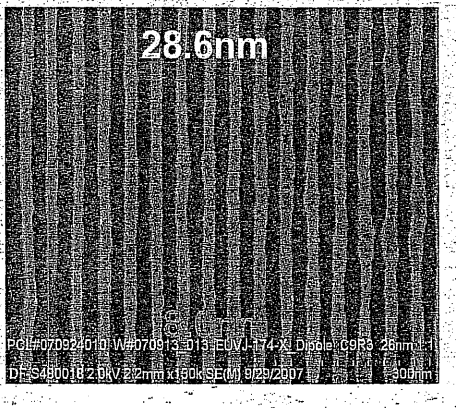
Resist B
Y-monopole

30nm HP



Resist C
Rot-Dipole

28nm HP

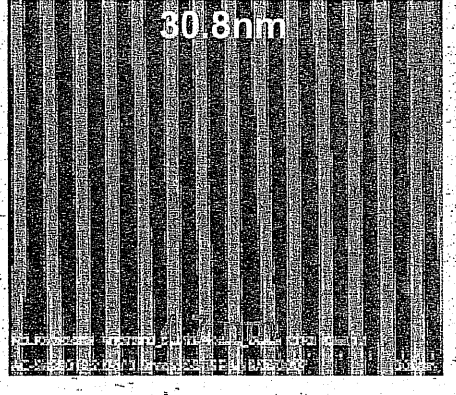


CD

LWR

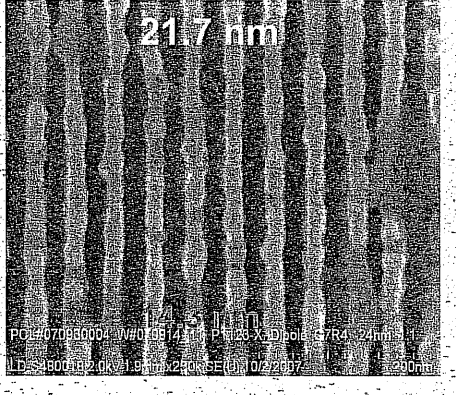
Resist D
Rot-Dipole

30nm HP



Resist E
Rot-Dipole

24nm HP



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Summary of Dose/Focus process latitude at 40nm HP

Resist Name	Resist THK (nm)	Illumination	Mask	Esize (mJ/cm^2)	Exposure Latitude (%)	DoF (nm)	Ultimate Imaging (CD/LWR)
Resist A	80	Offset Y-monopole	A Vertical Cleave	23.2	18	250	30.4/8.3
Resist B	50	Offset Y-monopole	A Vertical Cleave	23.9	10	250	30.2/8.5
Resist C	70	Rot-Dipole	B Horizontal Cleave	19.0	10	150	28.6/8.0
Resist D	80	Rot-Dipole	B Horizontal Cleave	25.7	10	150	30.8/4.7
Resist E	50	Rot-Dipole	B Horizontal Cleave	17.0	15	150	21.7/14.3

- Resist A had largest process latitude EL (18%) and DOF (250nm)
- Resist E has best photospeed (17.0 mJ/cm^2)
- Resist C has the lowest LWR at 40nm HP (4.8 nm)
- Resist E demonstrated best resolution

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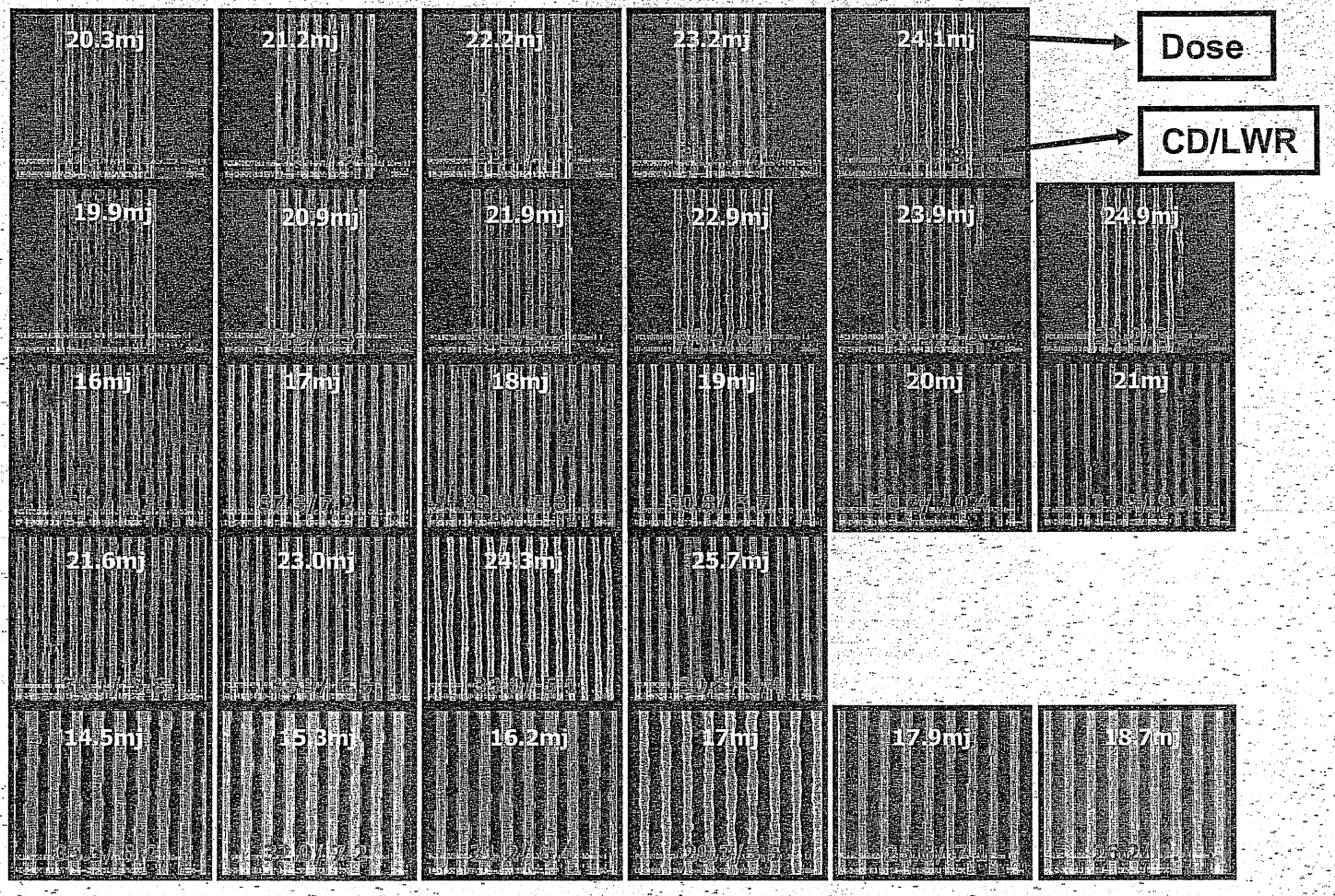
Exposure Latitude at 30nm HP



- Resist E demonstrated 10% EL @ 30nm HP.
- Resist A, B, and C have 2.5% EL @ 30nm HP.

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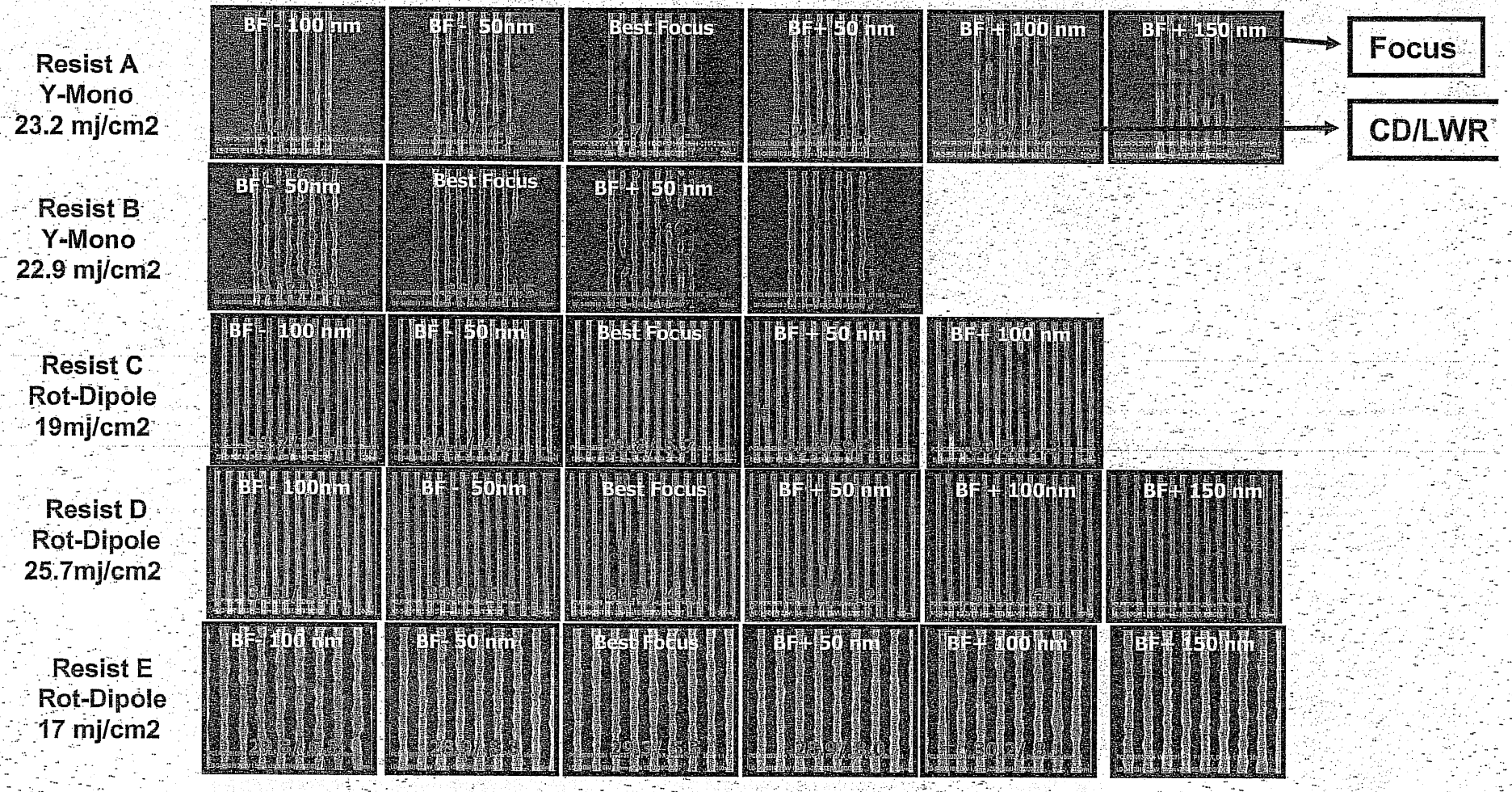
Focus Latitude at 30nm HP (1:1)



- Resist E demonstrated 150nm of DOF.
- Resist C had 50nm of DOF.

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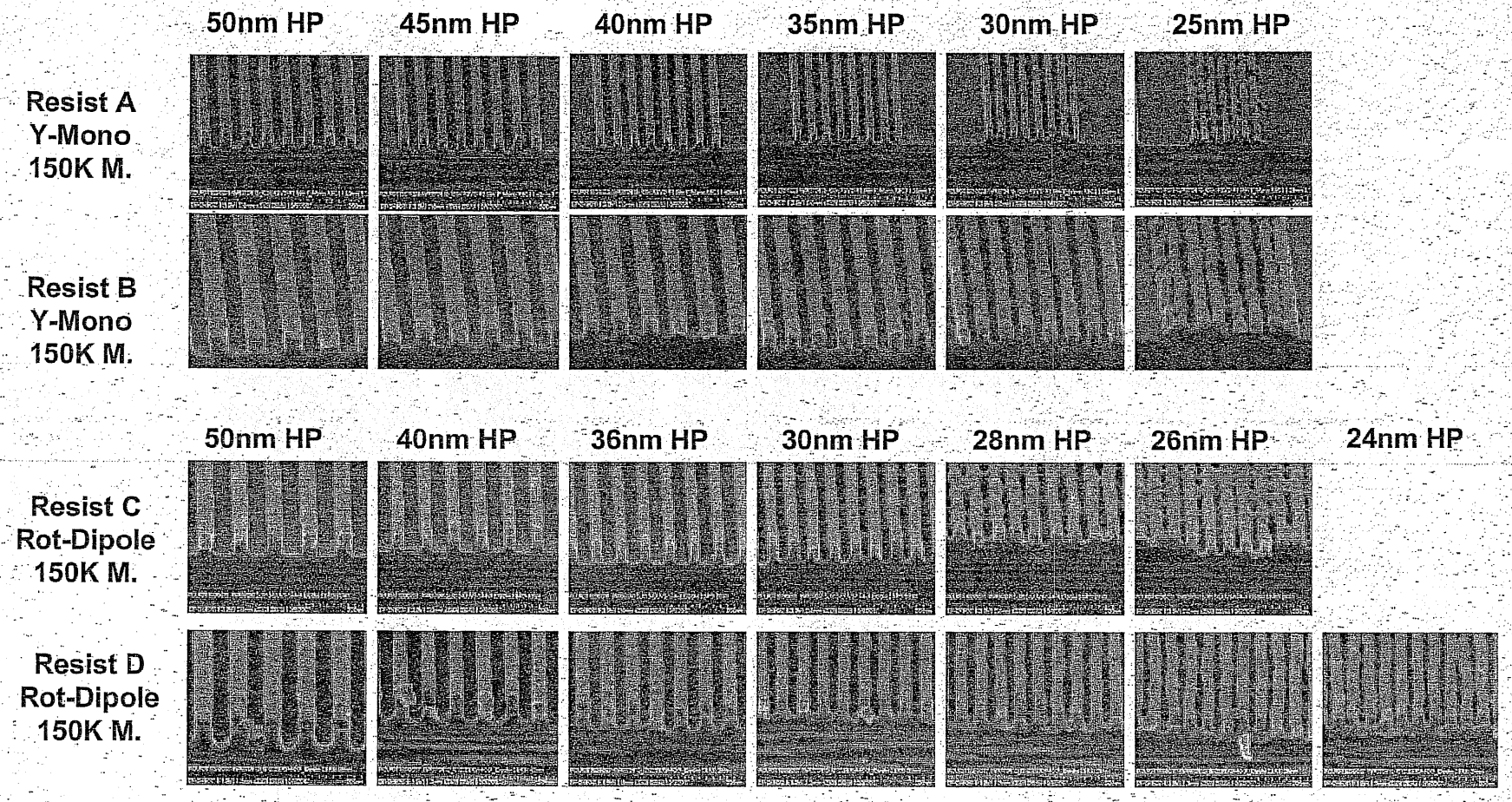
SEM Cross-section Images



- All resists demonstrated 35 nm resolution and printing capabilities below 30nm

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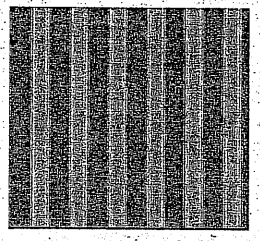
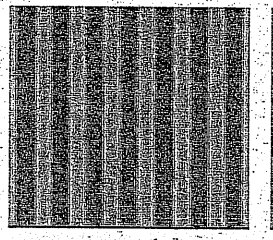
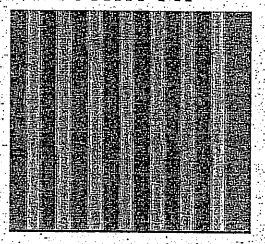
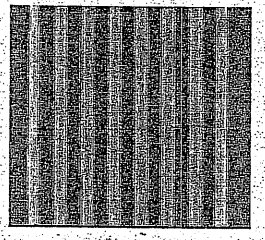
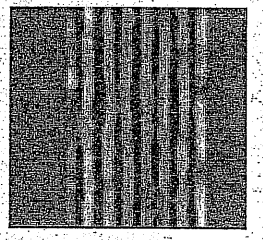
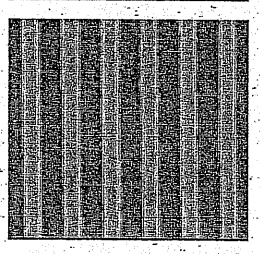
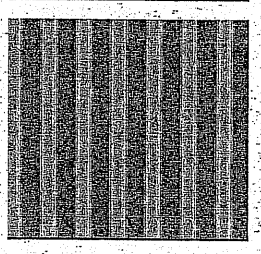
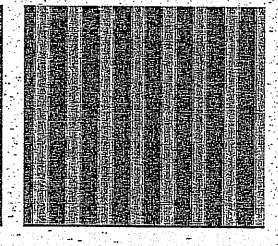
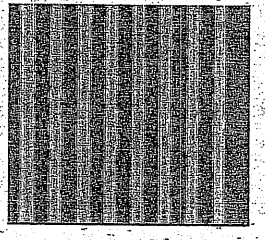
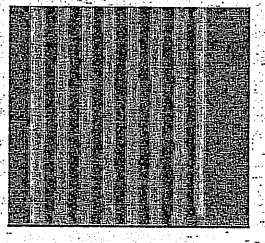
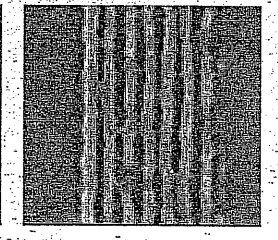
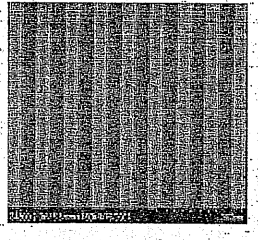
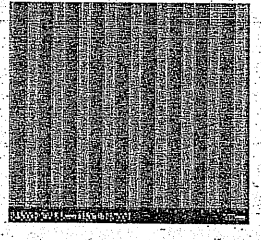
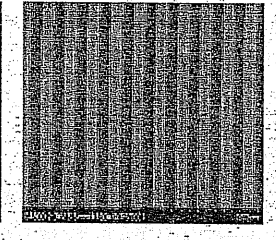
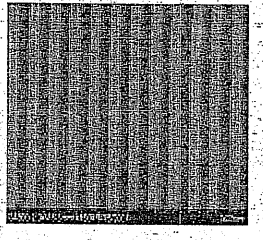
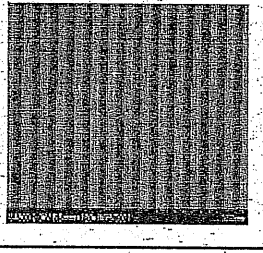
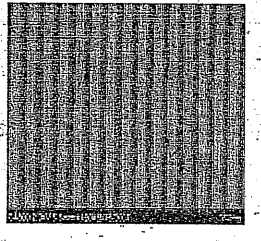
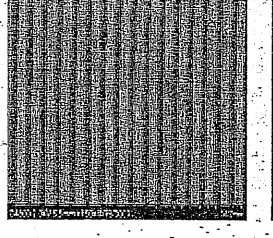
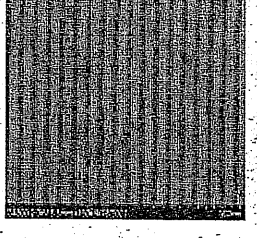
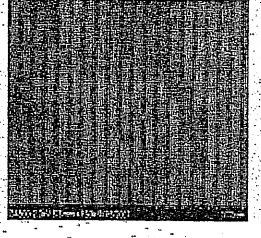
Different Illumination Conditions vs images

	50nm HP	45nm HP	40nm HP	35nm HP	30nm HP	25nm HP
Resist B Annular Mask A 23 mj/ cm2						
Resist b Y-monopole Mask A 24 mj/ cm2						

	50nm HP	46nm HP	40nm HP	36nm HP	30nm HP	28nm HP
Resist B Rot-Dipole Mask B 19.55 mj/ cm2						

26nm HP	24nm HP	22nm HP
		

Annular	Annular (0.35~0.55) Mask: LBNL, Vertical cleave Pseudo Dark
Y-Monoplole	off-set Y-Monopole, d-0.3, x-0.25, y--0.4) Mask: LBNL, Vertical cleave Pseudo Dark
Rotate diople	Dipole- 45, σ =0.175, off-set-0.53 Mask: Custom mask: SPDR30

- Rot-Dipole illumination has better image modulation than Annular and Y-monopole illumination.

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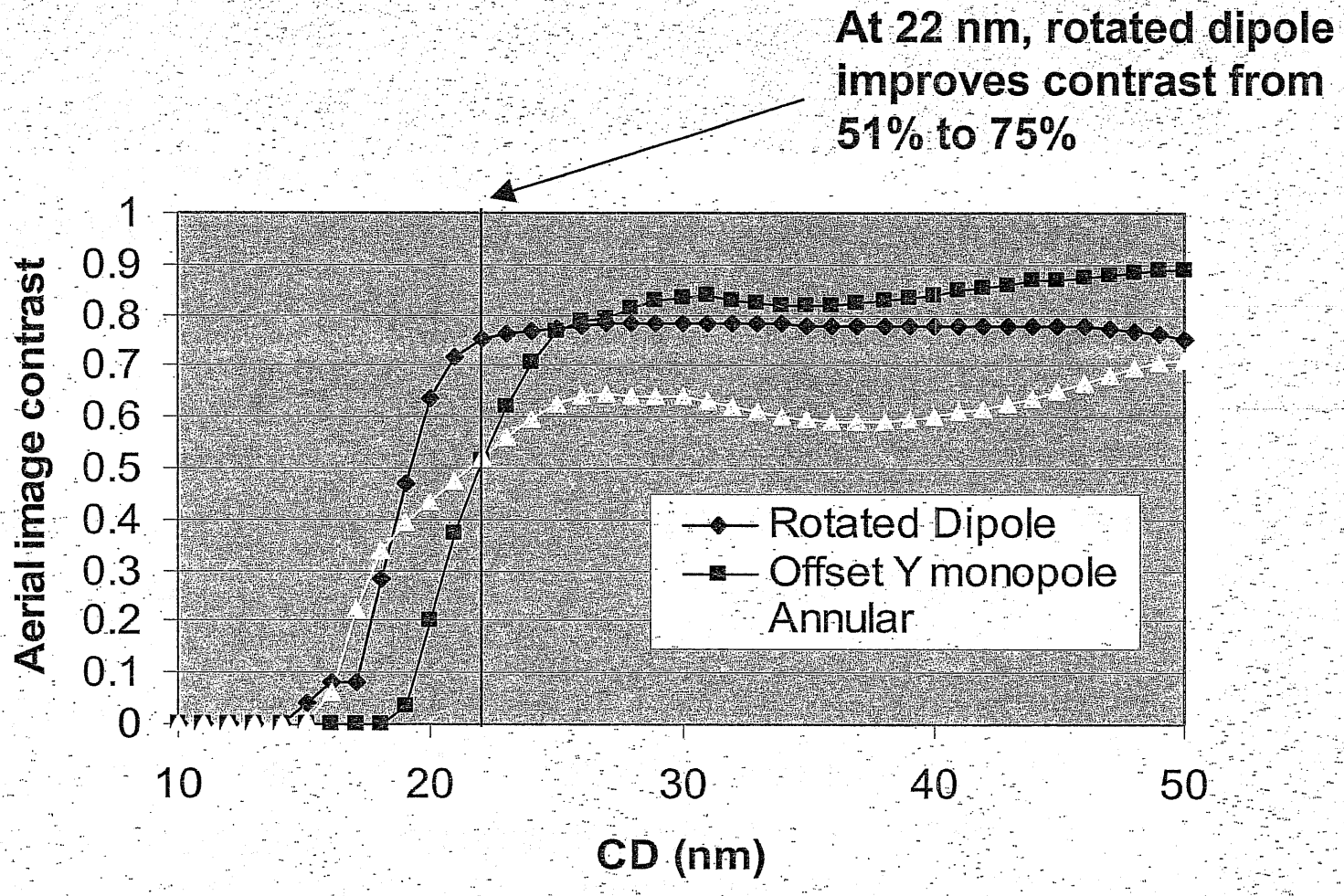
Rotated dipole on the Berkeley MET predicted to provide enhanced performance for CDs below 26 nm



Note: Prolith Aerial image modeling includes full measured wavefront data and assumes ideal thin mask

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Conclusion

- Total of 21 resist have been benchmarked since May 2007, the benchmarking results are being furnished to suppliers.
  - Demonstrate printing capability down to ~ 22 nm.
  - Demonstrate 10.0% of EL & 150 nm of DOF at 30 nm HP.
  - Thinner resist (50nm) and rotated dipole illumination are important factors to increase imaging capability.
- LWR and photospeed are still the most critical challenges for 32 nm node.
- The current benchmarked resist process window is not sufficiently to support 32nm pilot line. (please review backup slides)
- The best performing resist:
  - Resist A has the largest process latitude with 18% of EL and 250nm of DOF @ 40nm HP.
  - Resist D has lowest LWR of 4.7 nm at 30 nm HP
  - Resist E has fast photospeed of 17mJ/cm^2 with 10% of EL and 150nm of DOF @ 30 nm HP.
  - Resist E demonstrate ~ 22nm of printing images capability with rot-dipole illumination.

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Acknowledgement:

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