NGL

Resists for High Throughput Next Generation Lithographies

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157 EUV EPL
MEBDW EBDW X-ray IPL

gnt-091400

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IC Technology Roadmap

Year	2000	2002	2004	2007	2010
Node	130 nm	100 nm	70 nm	50 nm	35 nm
Technology	DUV	193 nm	157 nm, EPL, EUV	EPL, EUV, 157	EUV, MEBDW, EPL
A. Mask Making Resists					
157 nm (5X)	-	-	**120 nm**	100 nm	-
EPL (4X)	-		200 nm?	**160 nm**	100 nm ?
EUV(4X)	-	-	200 nm?	**160 nm**	**100 nm**
B. Wafer Patterning Resists					
157 nm	-	-	**60 nm**	40 nm ?	-
EPL	-	-	60 nm ?	**40 nm**	25 nm ?
EUV	-	-	60 nm ?	**40 nm**	**25 nm**
MEBDW	-	-	-	-	25 nm ?

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NGL Characteristics

Property\Technology	157	EUV	EPL
Type & Energy	Optical 7.89 eV (157 nm)	Optical 92.4 eV (13.5 nm)	Electron 100,000 eV 0.000124 nm
Electronic Excitations	Molecular, Rydberg	Atomic, Ionizing	Atomic, Ionizing
PDUV Resist Absorption	Very High	Mod. High	Very Low
Resist Thickness, T>45%	60 nm	120 nm	>1000 nm
PDUV Resist Chemistry	Similar	~ Same	~ Same
Sensitivity	<10 mJ/cm^2	<5mJ/cm^2	~3μC/cm^2
Resolution Target	60 nm	60 nm	60 nm
Depth-of-Focus	~300 nm	~800 nm	>10,000 nm
Anti-reflective Coating	Yes	No	No
Low Resist Outgassing	Yes	Yes	Yes
Hardmask Processing	Yes	Yes	Yes
Plasma Etch Resistance	= PDUV	= PDUV	= PDUV

EUV Resist Development

Principal Needs:

Resolution, Sensitivity, LER, Plasma Etching Resistance

Focus Areas

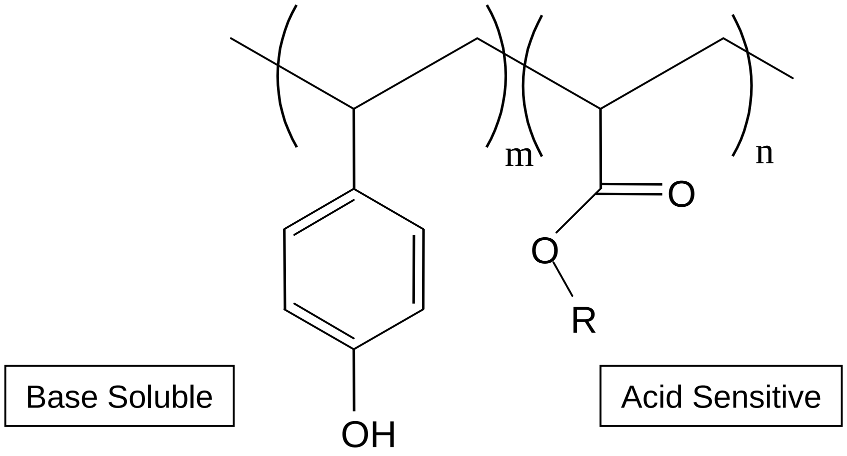
- Apply learning from DUV lithographic materials & processing.

- Phenolic resin materials
    - Modified high temperature resists based on hydroxystyrene.
    - Modified low temperature processed resists based on hydroxystyrene and new acid-sensitive blocking groups.

- Optimize performanceusing materials and processing DOEs.

Ultrathin Phenolic Resists

- Based on Positive DUV resist polymers



\+ Photo Acid Generator (PAG)

- Absorbance is ~ 6.8/um
- Thicknesses range from 60-85 nm
- Standard DUV processing
  - * PAB 110-140°C and PEB 130-150°C
  - * Development: aqueous 0.26N TMAH

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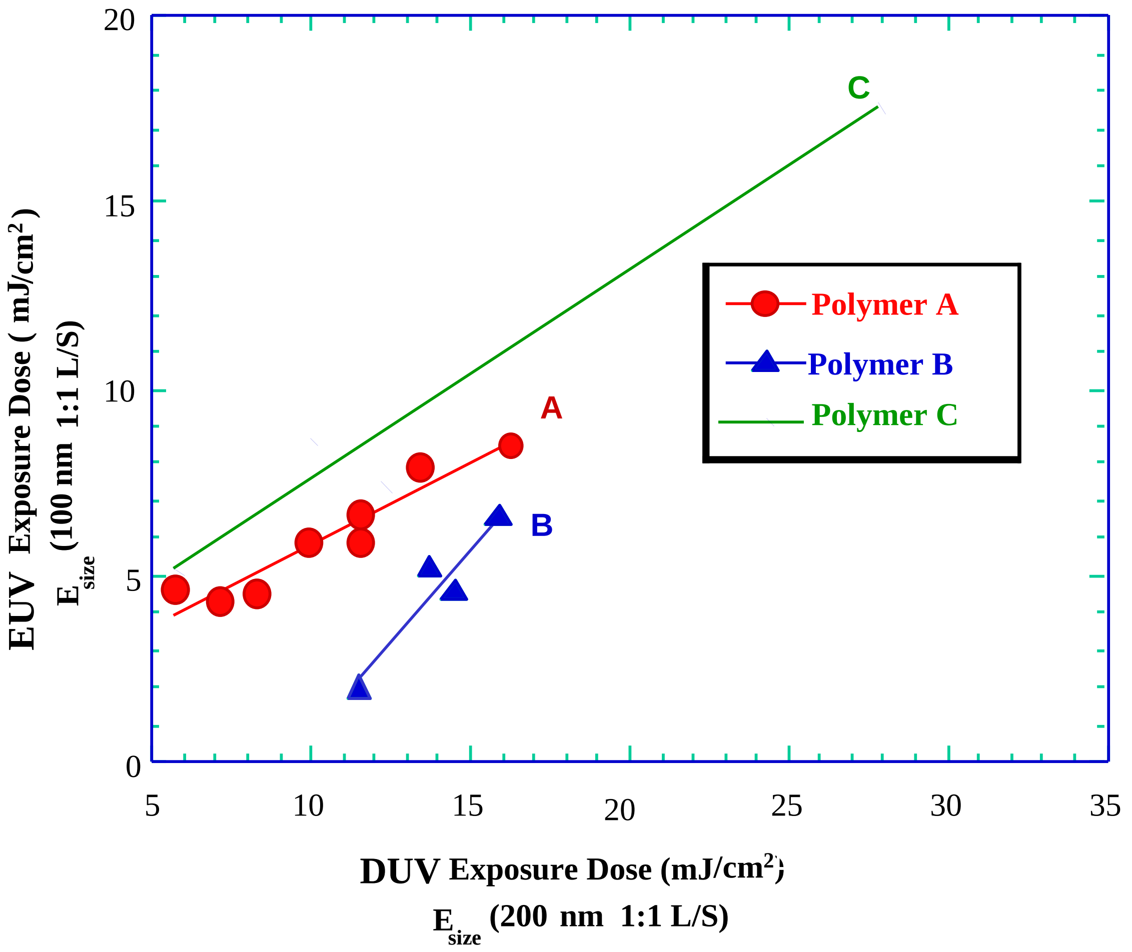
Comparison of EUV and DUV Doses @ 100 & 200 nm Size for Modified DUV Resists



- Linear correllations with polymers of a certain type.
- Standard polymer C has highest E_{size} & lowest intercept.
- Modified polymer A is similar to C.
- Modified polymer B has the steepest slope and highest sensitivity.

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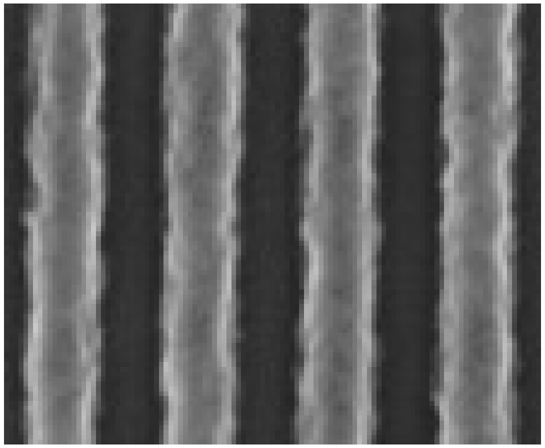
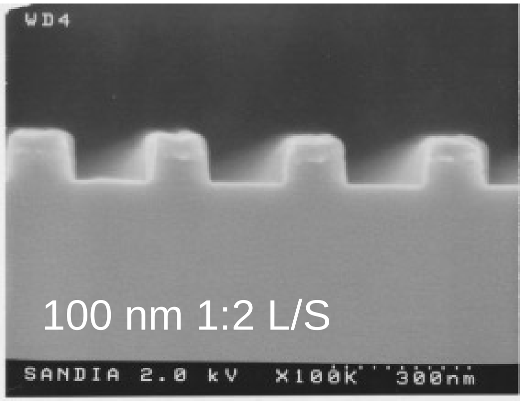
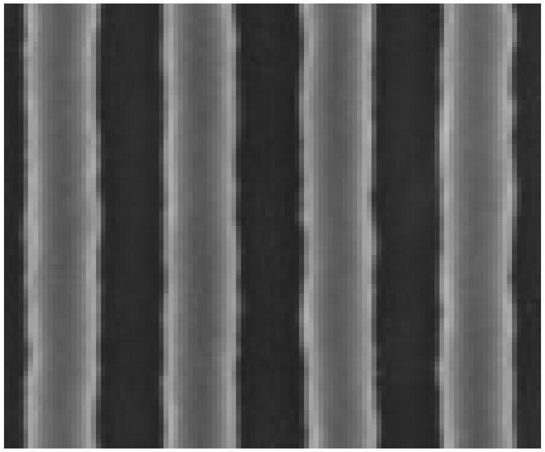
EUV Resist Lithography and Etch:
100 nm, I:1 L/S, T=85 nm, NA = 0.088



UV6
Dose >15 mJ/cm^2
LER = 9.4 nm

XP98248



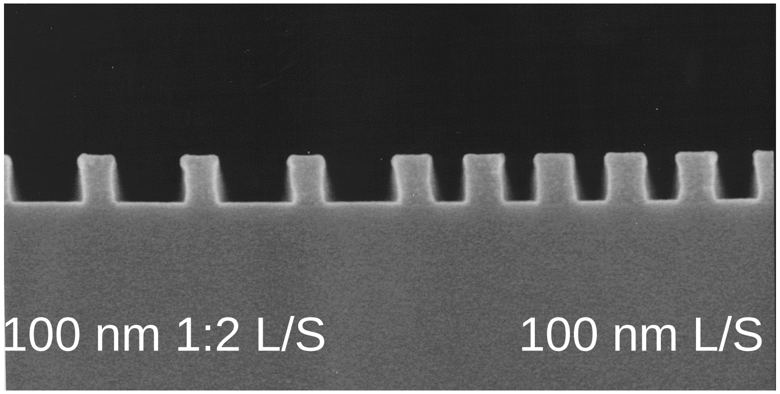


XP98248 (EUV 2D)
Dose = 5.6 mJ/cm2
LER = 6.0 nm

120 nm, 1:2 L/S
Transferred to
50 nm SiON
Hardmask, Resist
loss 37%

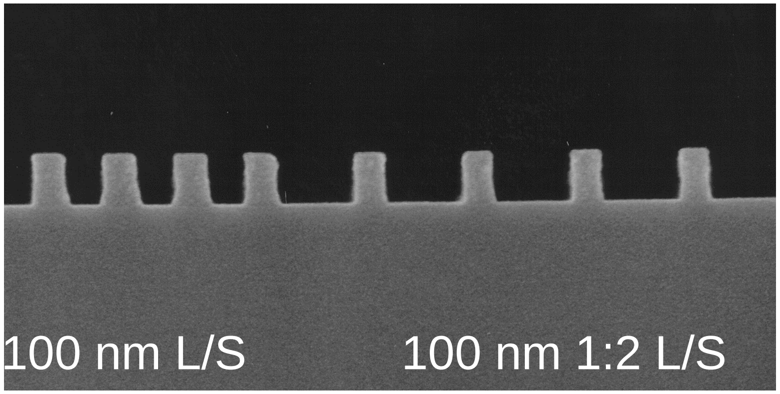
SEMs courtesy J. Cobb, C. Henderson,EUV-LLC & SNL

XP98248 Imaging in Thicker Films



T = 145 nm

7.5 mJ/cm^2



T = 120 nm

6.7 mJ/cm^2

SEMs courtesy of C. Henderson & J. Cobb, EUV-LLC

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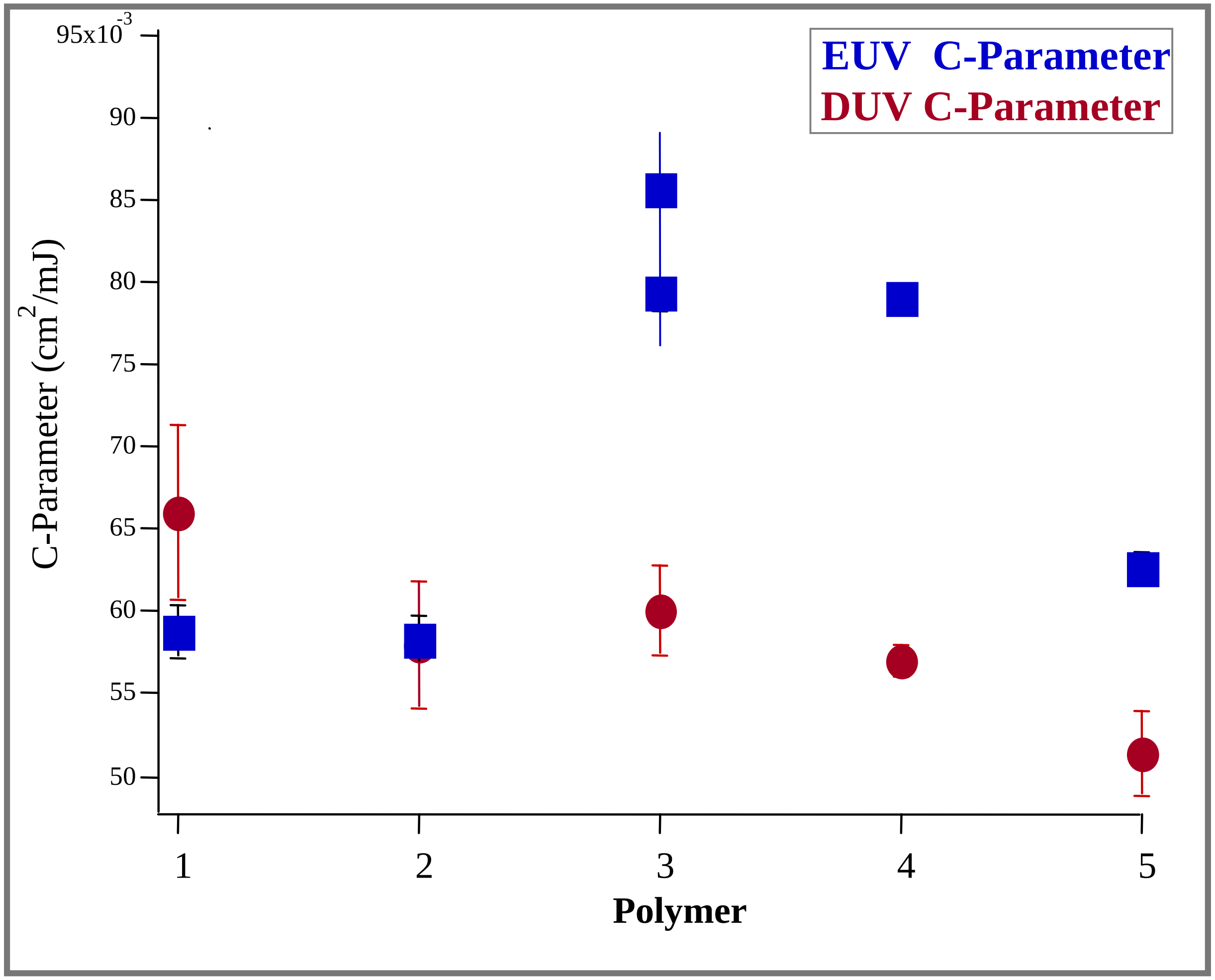
PAG Acid Generation Efficiency *vs.* Radiation Type and PolymerType



- *** Resists exposed with 248 nm light have a slight dependence on poylmer.**
- *** Resists exposed with EUV have a dramatic dependence on structure.**
- *** Polymer 3 has a large 30% increase in acid formation.**
- *** Employ Polymer 3 in sensitivity enhancement studies with other techniques.**

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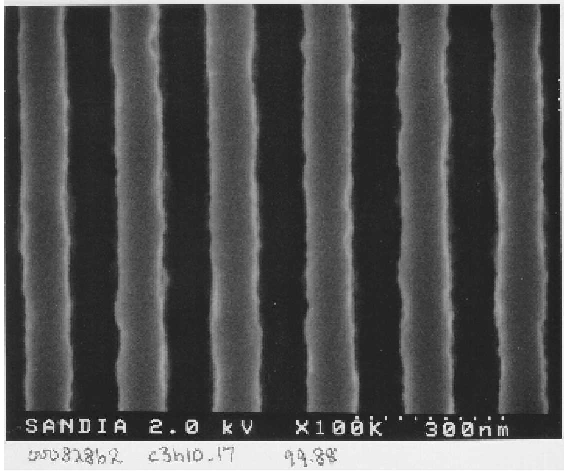
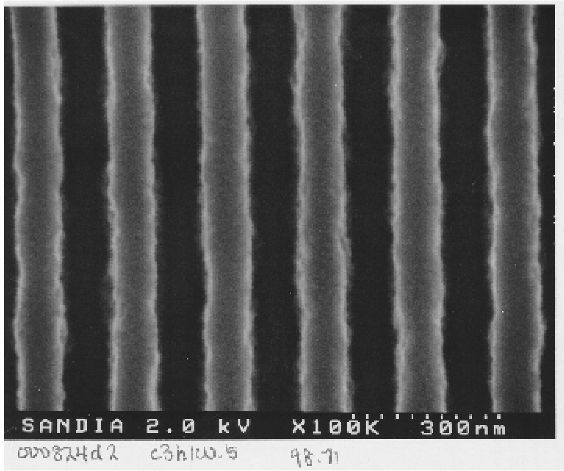
Recent High Sensitivity Resist Data

Resist	Sensitivity (mJ/cm^2)	Resol'n (nm)	LER (nm, 3σ)
A	1.6	90	7
B	1.7	90	7
C	1.6	100	7
D	1.7	100	10
XP98248	5.9	80	6



A

T = 120 nm
NA = 0.088
10X1
90 nm, 1:1 L/S



B

Data & SEMs courtesy G. Cardinale, EUV-LLC

E-beam Resist Development

Principal Needs:

Sensitivity, Resolution, LER, Exposure Latitude, Plasma Etching Resistance, Outgassing

Focus Areas

- Phenolic resin materials
    - Modified high temperature resists based on hydroxystyrene.
    - Modified low temperature resists based on hydroxystyrene inhibited by acid-sensitive blocking groups.
- Apply learning from EUV and DUV lithographic performance.
- Optimize performance by materials ansdprocessing DOEs.

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XP9947A E-beam Resist

Modified DUV chemically amplified resist, high temp process

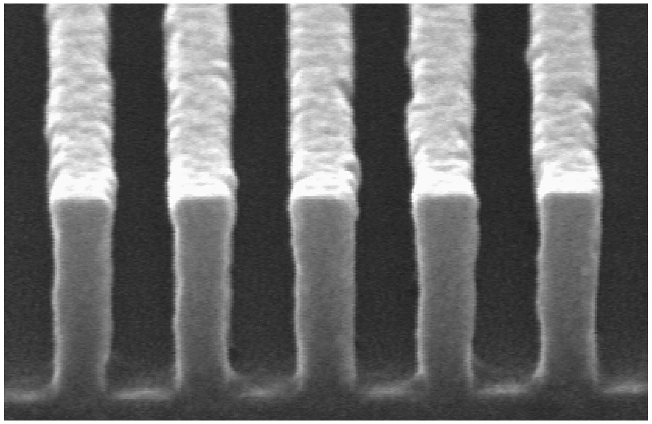
E_{size} (50 KeV) = 8.4 µC/cm^2

Thickness = 350 nm

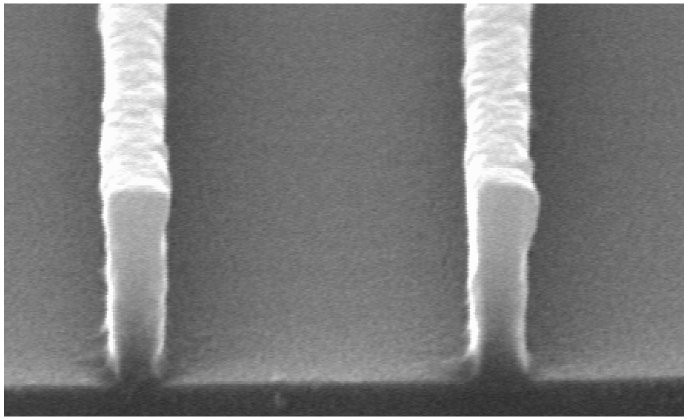
Contrast = 18 **Resolution = 100 nm 1:1 & 1:3 L/S**

Exposure Latitude: >25% Dense, >15% Iso

Coated Shelf-life = > 3 Months



100 nm 1:1 L/S



100 nm 1:3 L/S

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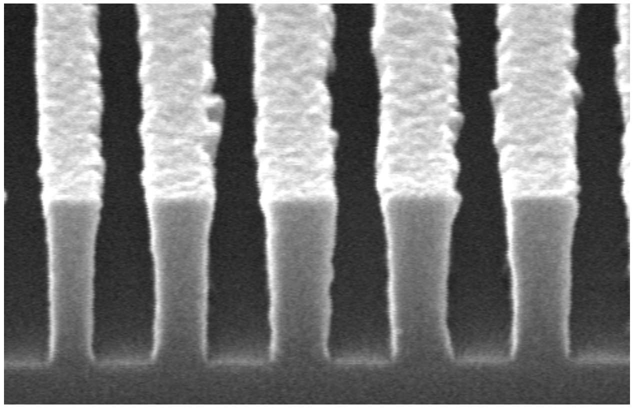
XP9947A Soft-Bake Study: 100 nm L/S

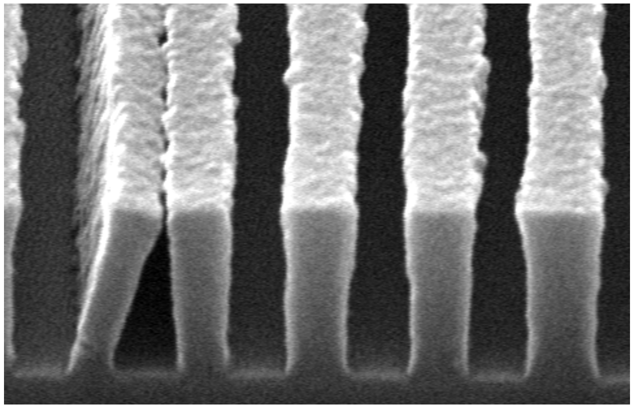
60 sec **Baking Time** **90 sec**

Temp

130°C

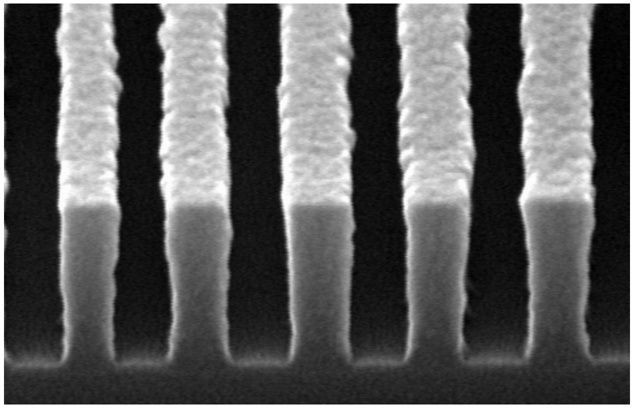


7.3 μC/cm^2

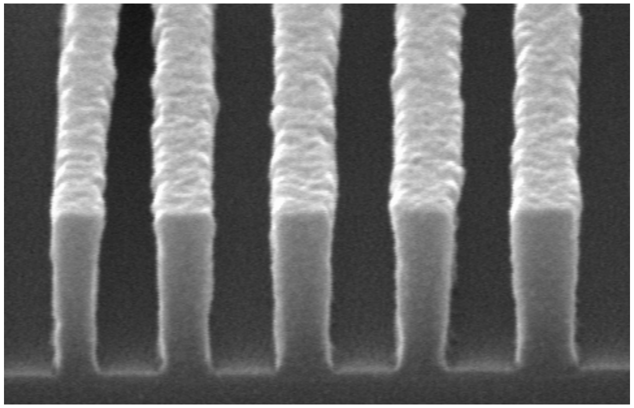


8.0 μC/cm^2

140°C



7.7 μC/cm^2



8.4 μC/cm^2

PEB = 130°C

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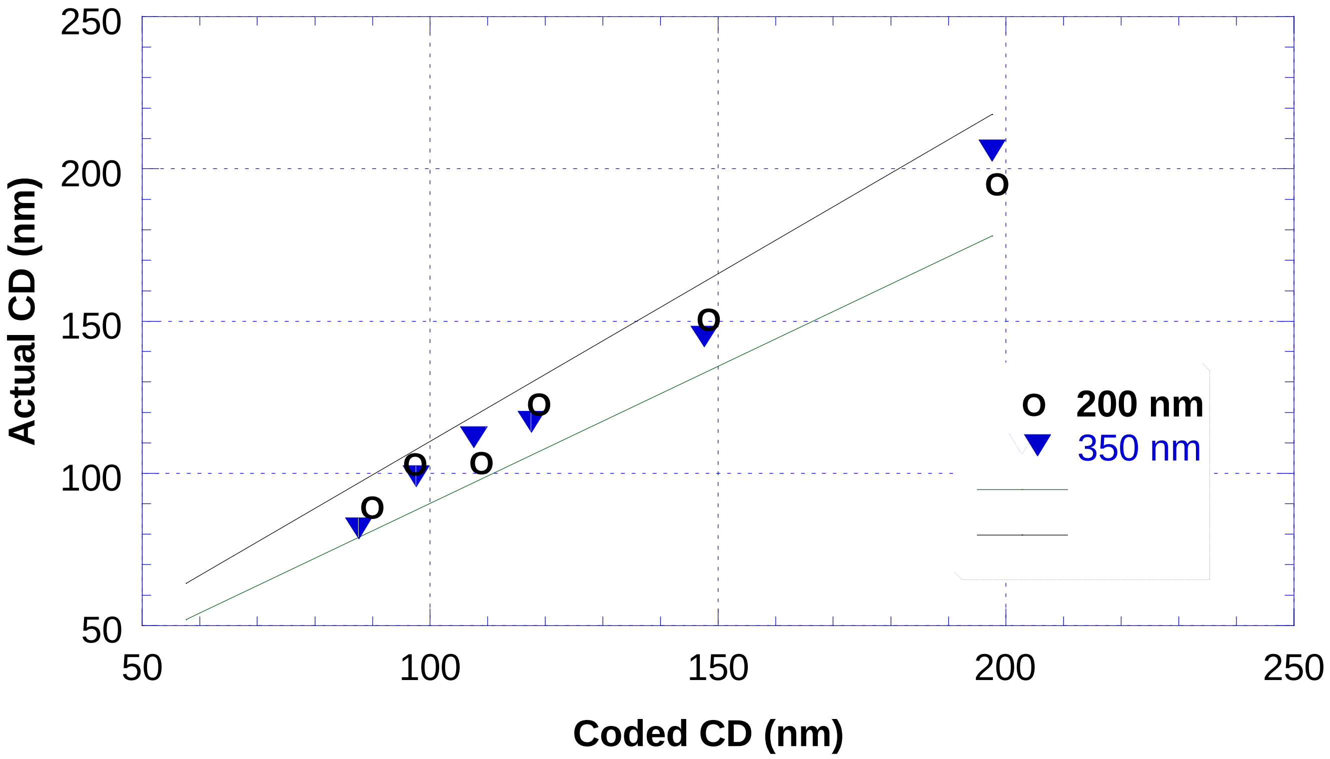
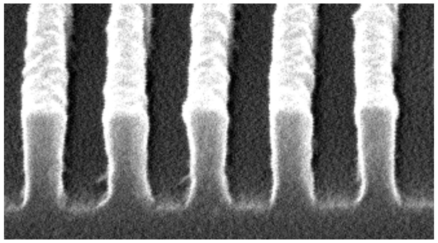
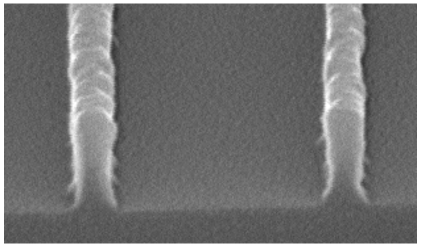
Actual vs Coded 1:1 Feature Size Linearity for 350 & 200 nm Thickness L/S, IL & CH



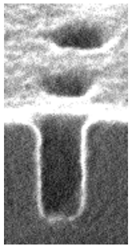
200 nm Films



80 nm



80 nm



90 nm

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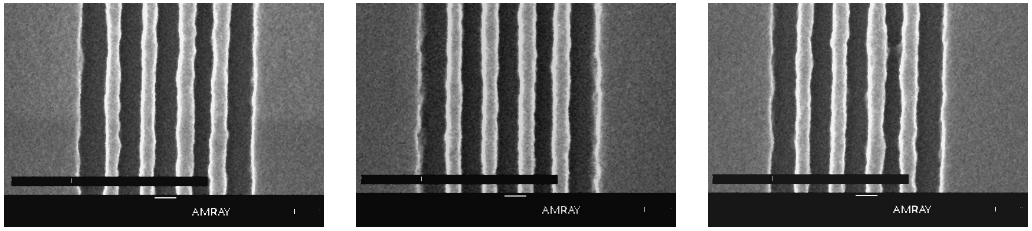
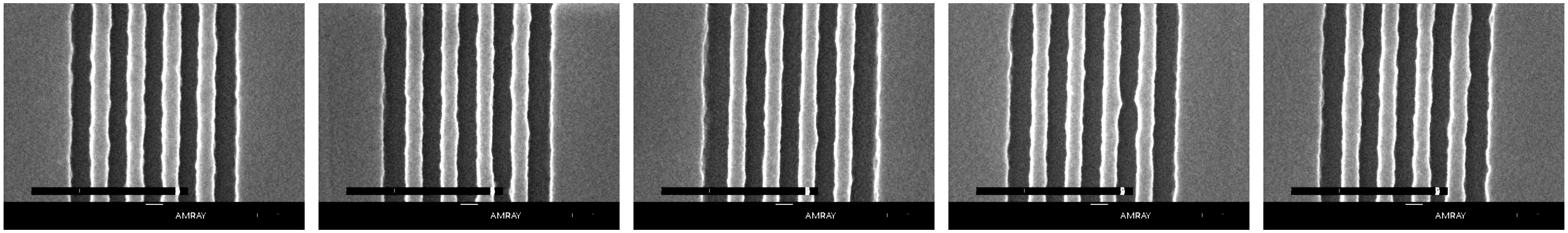
XP9947A Focus Latitude @ 100 kV, 350 nm Film Thickness & 11 µC/cm²

SCALPEL Exposures

80 nm L/S



-20 µm **-10 µm** **0 µm** **+10 µm** **+20 µm**



100 nm L/S

SERMs courtesy L. Ocola &A. E. Novembre, Lucent Technologies

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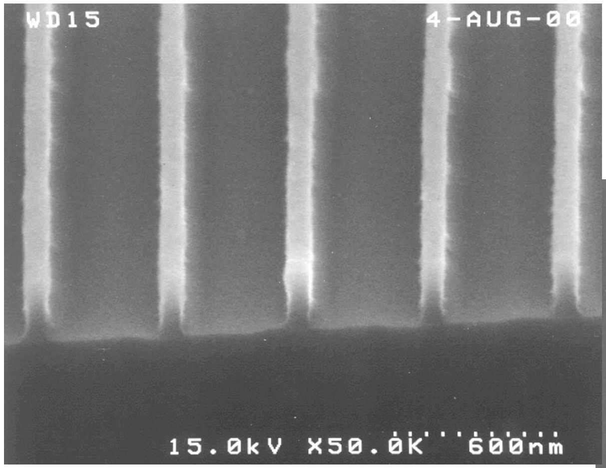
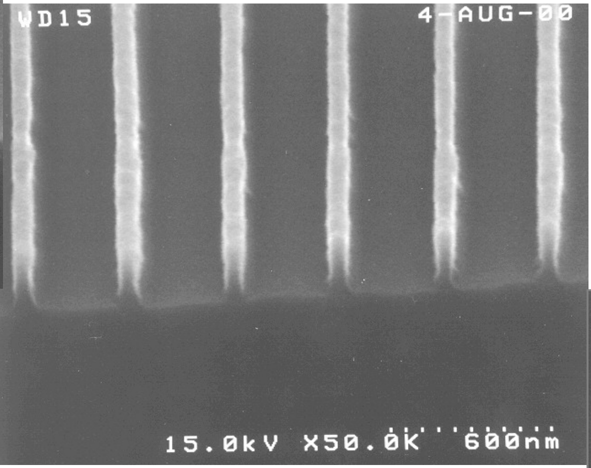
High Sensitivity Results with XP2009-M

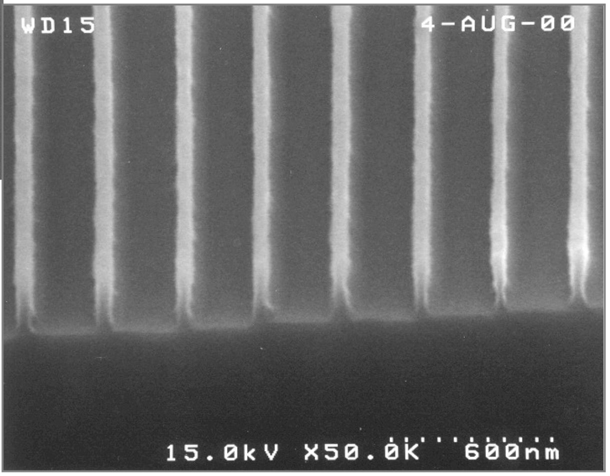
2 µC/cm^2 @ 50 kV
JEOL 9300
(4 µC/cm^2 @ 100 kV)
PAB 130°C/60sec
PAB 140°C/60sec



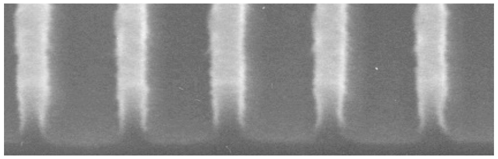
100 nm



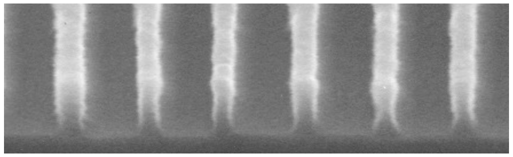
80 nm



60 nm



100 nm



80 nm

Courtesy, L. Ocola & A. E. Novembre, Lucent Technologies

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157 nm Resist Development

Principal Needs:

Absorption, Thickness, Resolution, Outgassing, LER, Plasma Etching Resistance, Sensitivity

Focus Areas

F
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A
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e
a
s

- **Apply learning from DUV, EUV and E-beam lithographic materials and extend their use to UTRs for 157 nm tool testing.**
- **UTR phenolic resin materials**
  - **Modified high temperature resists based on hydroxystyrene.**
- **Prepare resins with lower absorbance using fluorine incorporation.**
- **Study the influence of groups and structure on absorption.**
- **Optimize lithographic performance using materials, formulation and processing DOEs.**

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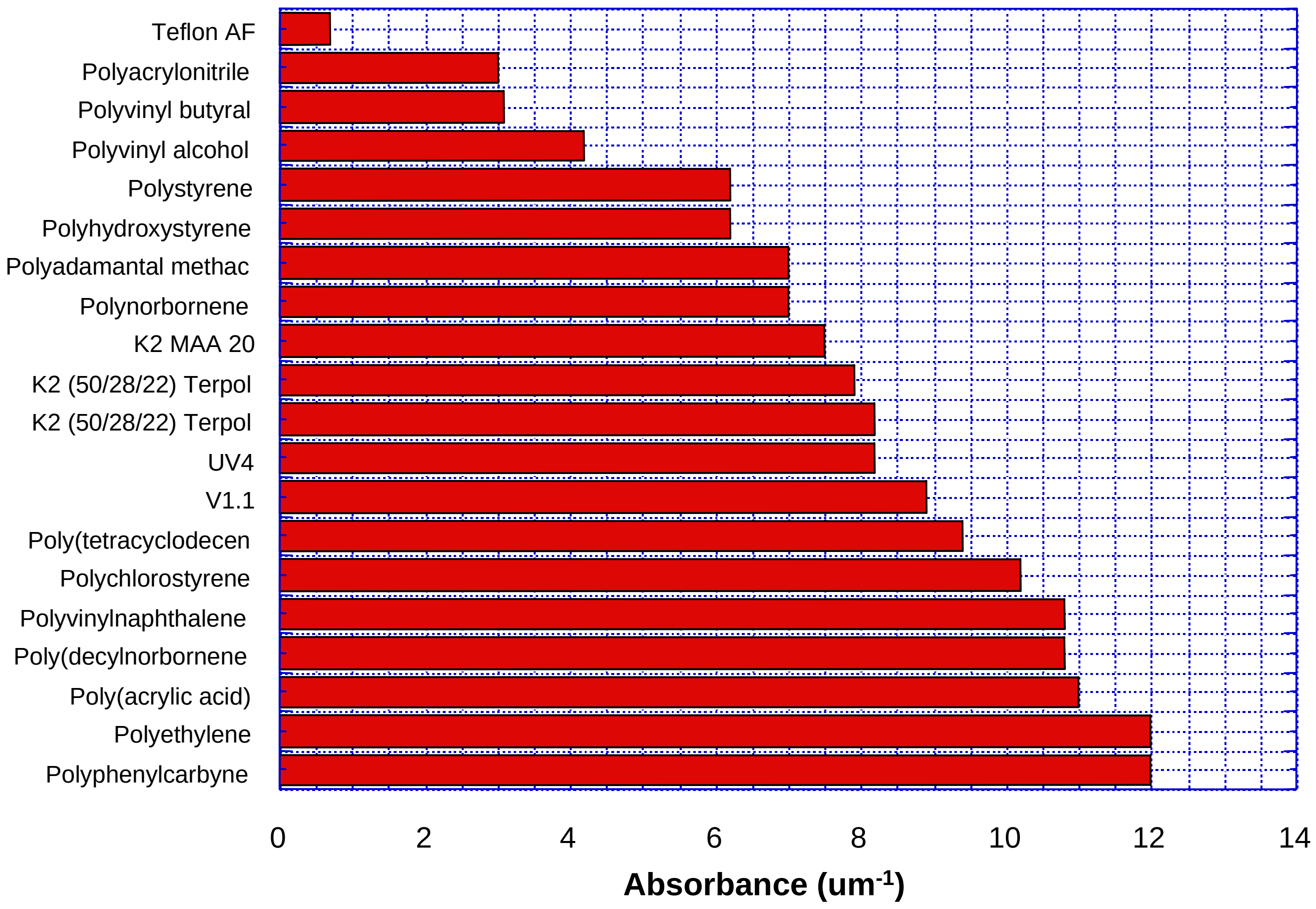
Polymer Absorbance @ 157 nm



R. Kunz, T. Bloomstein, et al, MIT-LL

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Thickness Targets for 157 nm Resists

Dense Features		
% Trans	**Thickness**	Abs/um
45%	**0.100**	**3.468**
45%	**0.125**	**2.774**
45%	**0.150**	**2.312**
45%	**0.175**	**1.982**
45%	**0.200**	**1.734**
Isolated Features		
% Trans	**Thickness**	**Abs/um**
30%	**0.100**	**5.229**
30%	**0.125**	**4.183**
30%	**0.150**	**3.486**
30%	**0.175**	**2.988**
30%	**0.200**	**2.614**

- Resist absorbance <3.0/um is difficult.
- Fluorine or other electron withdrawing groups needed.
  - Lower etching resistance
  - Softer resists will have more pattern collapse
- Resist thicknesses using hardmask technology may range from 120-200 nm.

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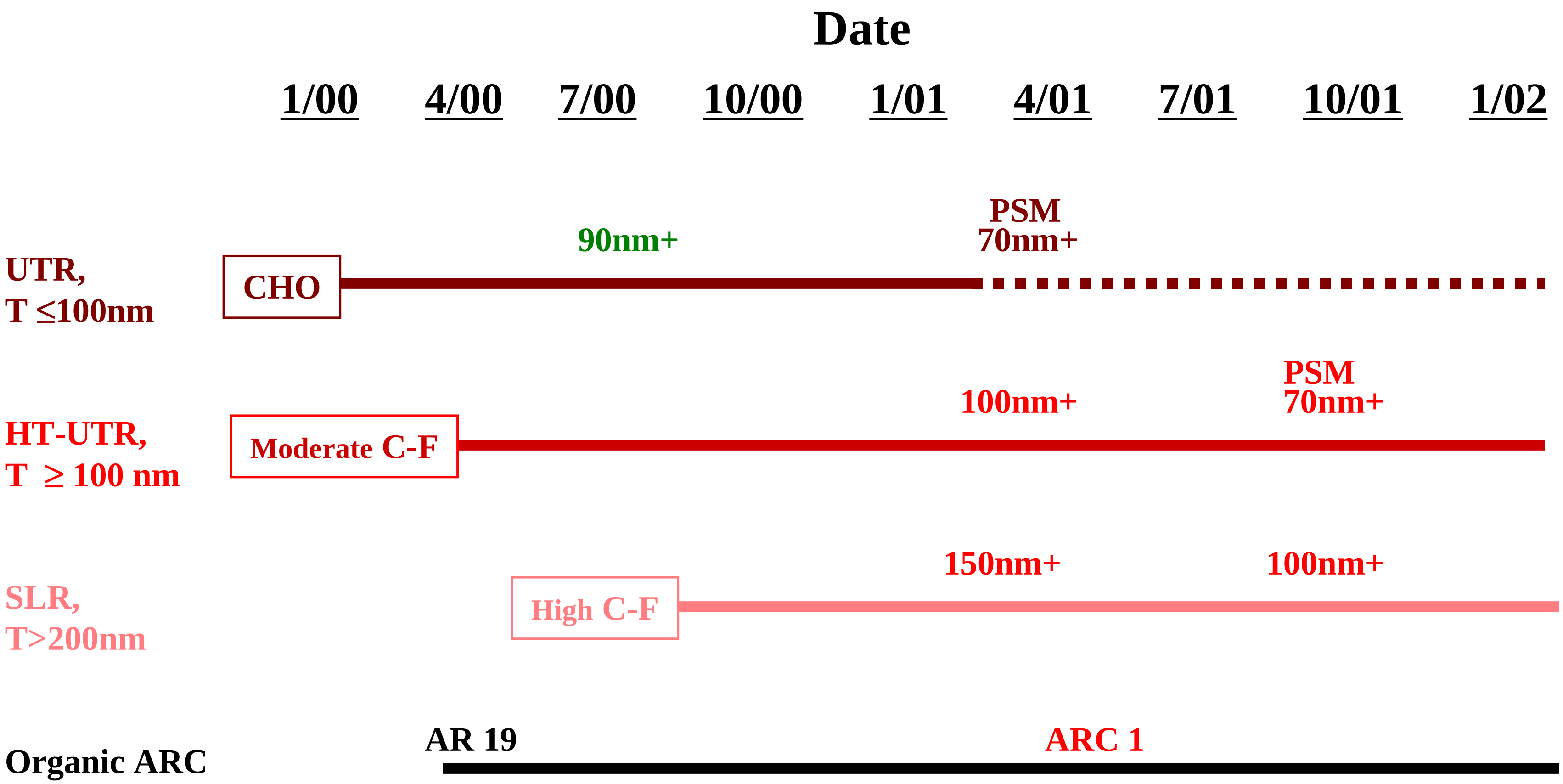
157 nm Resist Timeline



Date

1/00 4/00 7/00 10/00 1/01 4/01 7/01 10/01 1/02

UTR,
T ≤100nm

CHO — 90nm+ — PSM 70nm+

HT-UTR,
T ≥ 100 nm

Moderate C-F — 100nm+ — PSM 70nm+

SLR,
T>200nm

High C-F — 150nm+ — 100nm+

Organic ARC

AR 19 — ARC 1

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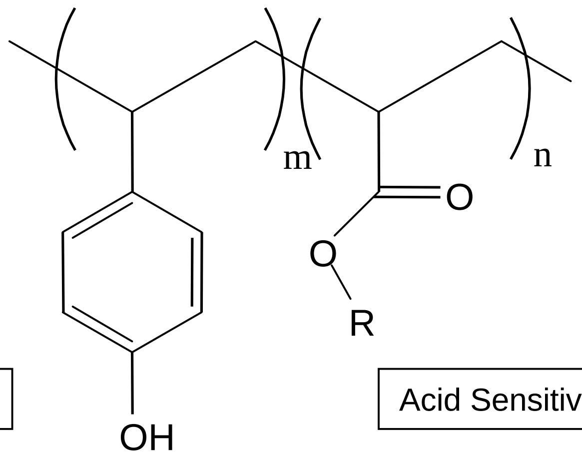
Ultrathin Phenolic Resists

- Based on Positive DUV resist polymers



Base Soluble

Acid Sensitive

+

Photo Acid
Generator
(PAG)

- Absorbance is ~ 6.8/um
- Thicknesses range from 60-85 nm
- Standard DUV processing
    - * PAB 110-140°C and PEB 130-150°C
    - * Development: aqueous 0.26N TMAH

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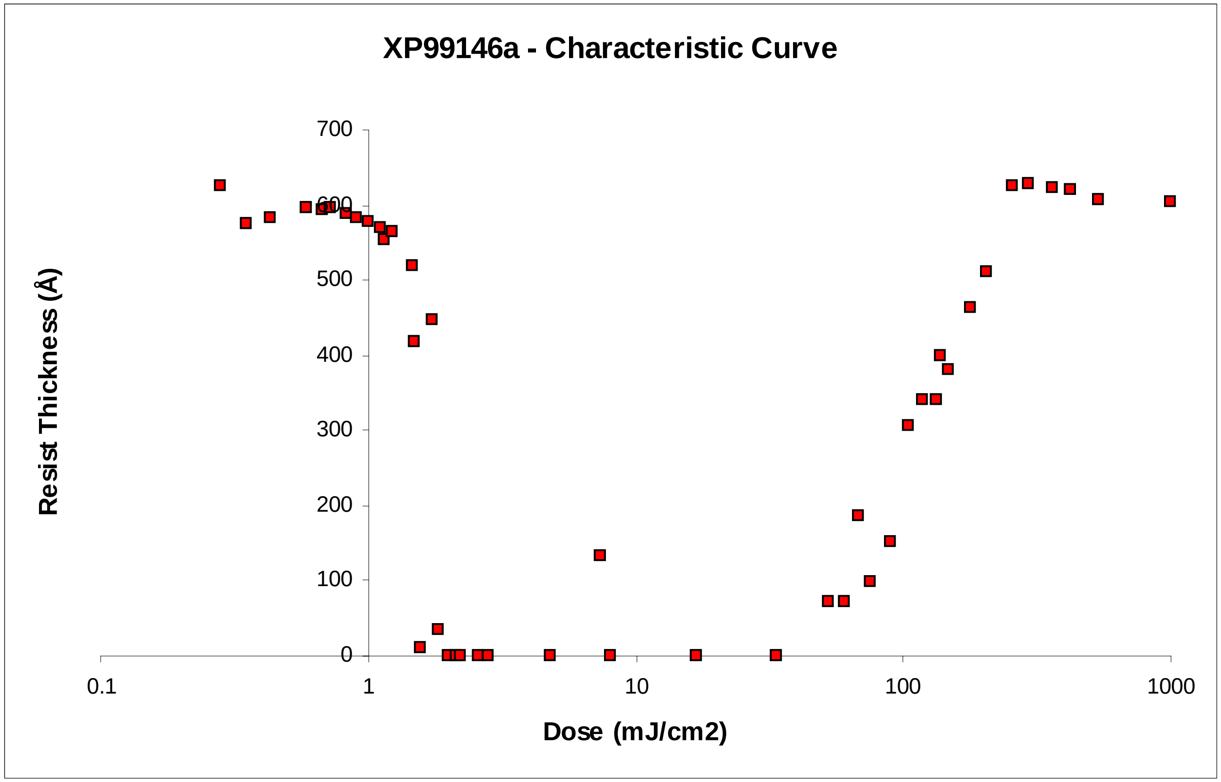
Contrast Curve: Crosslinking Effect



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Factors Involved in UTR Resolution

- Modified Phenolic Resins
  * Monomers with low crosslinking.
  * Optimum dissolution properties, low UFTL.
- Modified Formulations
  * Revised to give enhanced deprotection.

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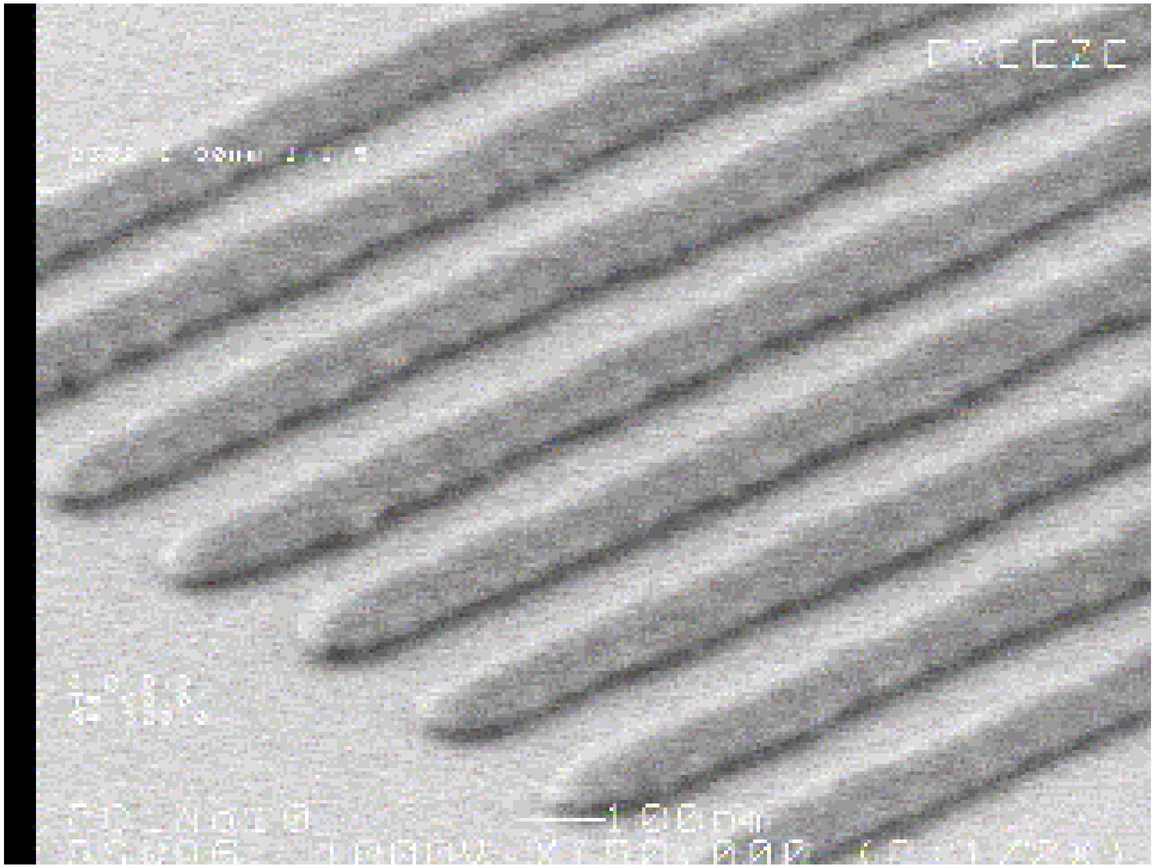
XP2332C Imaging @ 4 mJ/cm^2



70 nm Thick
NA = 0.6
Binary Mask
90 nm, I:I.5 L/S
PAB = 130°C/60sec
PEB = 130°C/90sec
0.26N TMAH/45sec

SEM courtesy Georgia Rich, SEMATECH

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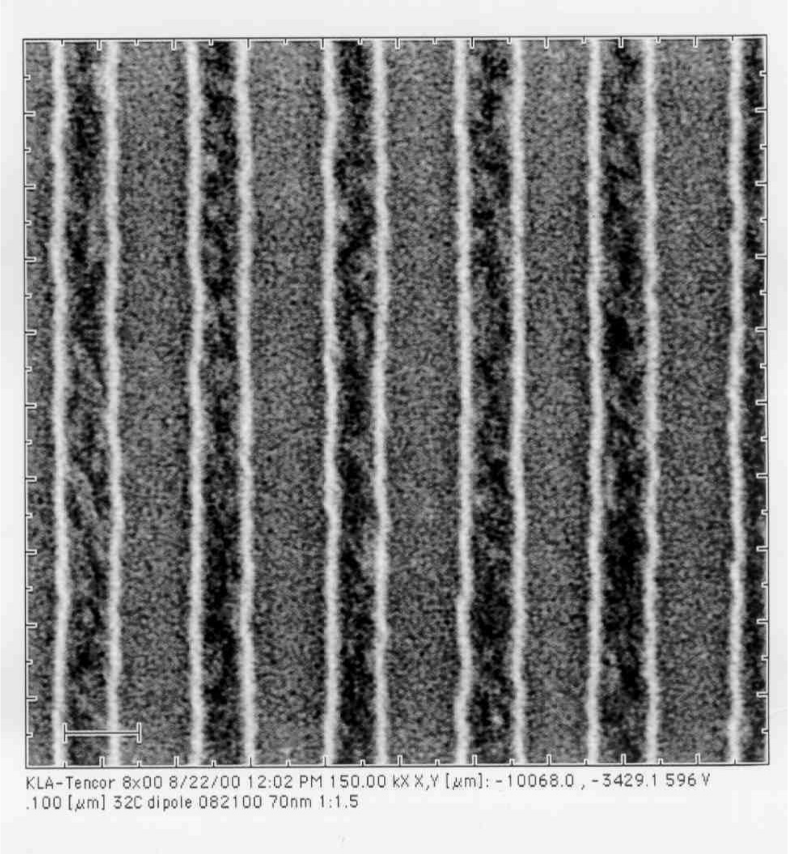
Ultrathin Film Imaging of XP2332C



Thickness = 70 nm
NA = 0.60, dipole
70 nm, l:1.5 L/S
PAB = 130°C/60sec
PEB = 130°C/90sec
0.26N TMAH/45sec
LER ~ 7 nm, 3σ

SEM courtesy Stephan Hien, SEMATECH

Resist Outgassing

Resist	Type	Outgassing Rate @ 6 mJ/cm^2 (Molecules/cm^2-sec)
UV6	DUV	2.0E11
XP2452D	157	2.0E11
XP98248D	EUV	6.0E10
XP2332B	157	4.0E10

Measurement by R. Kunz & D. Downes, MIT-LL

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Conclusions

- Making progress in the three NGL resist technologies targeting the 70 nm node for production.
- Some achievements.

157

- * Sensitive UTR XP2332C resolves 70 nm in 70 nm films.
- * Work just being initiated on lower absorbance polymers for157

EUV

- * XP98248 resist has best resolution (80 nm) and LER.
- * XP2008B resist is 3X faster at almost equal performance.

E-beam

- * XP9947A resist has excellent overall properties, but is somewhat insensitive for optimum EPL throughput.
- * New XP2008A has 100 kV sensitivity of ~4μC/cm^2 and resolution approaching 60 nm for isolated lines.

Future focus: 50 nm resolution and improved processes & characteristics

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Acknowledgments

- Shipley

  Jeff Calvert, Robert Brainard, Chuck Szmanda, Jay Mackevich, George Mirth, Xin Zhu, Thinh Nguyen, Jeffrey Guevremont, Scott Reeves, Tony Zampini, Sungseo Cho, Axel Klauck-Jacobs, Kirk Brown

- EUV

Craig Henderson, Paul Detinger, Scott Gunn	Sandia National Labs
Greg Cardinale, Jonathan Cobb, Veena Rao, Uzodinma Okoroanyanwu	EUV-LLC

- E-beam

Juan Maldonado, Zoilo Tan, Kim Lee	Etec Systems
Erik Anderson	LBNL
Etec Subcontract N66001-99-C-8624	DARPA/SPAWAR
Leo Ocola, Anthony Novembre, SCALPEL	Lucent Technologies
Ted Lyzarczyc,	MIT-LL

- 157 nm

Kim Dean, Georgia Rich, Stephan Hein	SEMATECH
Ted Fedynyshn, R. Kunz	MIT-LL
Olga Vladimirsky, Chen Lu	SVG-L