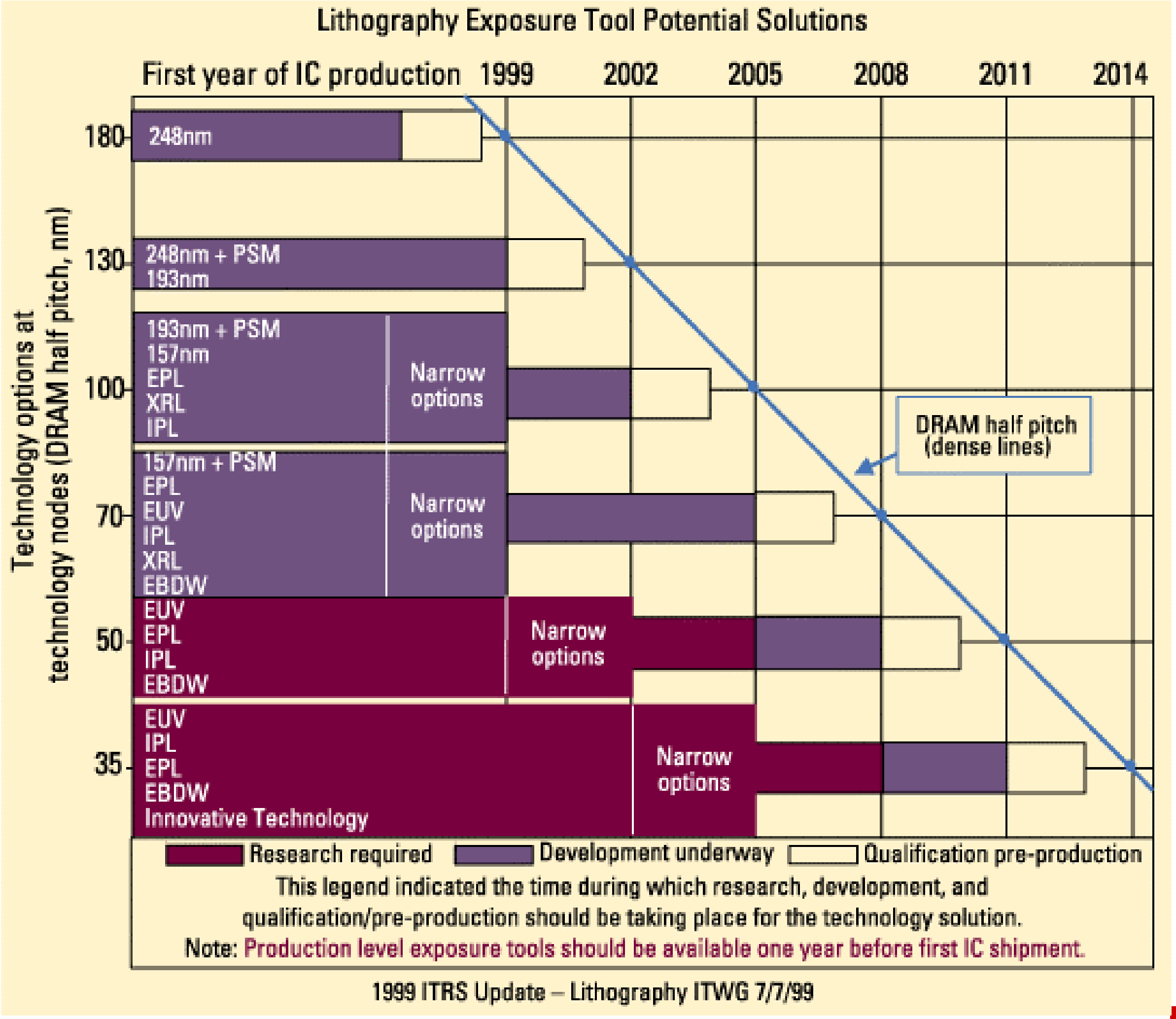
Resist Platforms for 157 nm Lithography

Christopher K. Ober

Department of Materials Science & Engineering,

Cornell University, Ithaca, NY 14853

Lithography Requirements



The Technical Challenges

A high resolution, single layer resist sensitive to 157nm light with adequate etch resistance and low defect density and low out-gassing;

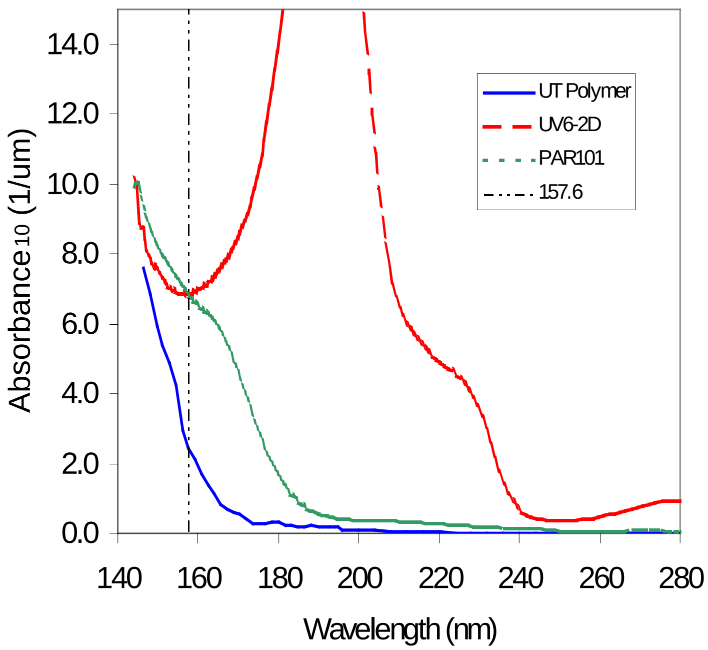
- "high resolution" means <100 nm dense features and <70 nm isolated features;
- "single layer resist" means <300 nm thickness dictated by depth of focus, resist collapse, and resist transparency;
- "sensitive to 157-nm light" i-line, 248 nm, and 193 nm resins are opaque to 157 nm light at thickness >80 nm; new resins and new amplification mechanisms may be necessary;
- "adequate etch resistance" means as or more resistant to etch than thicker 193 nm resists;
- "low defect density" is especially important for the thinner films; and
- "low out-gassing" means no redeposition on critical optical surfaces.

Other approaches, e.g. bilayer, hard mask, and CARL are attractive only because they may meet the technical challenges better or sooner than single layer resist.

Courtesy, Gene Feit (Sematech)

Problems with Using Existing Resist

- High absorbance at 157 nm requires using thin resists.
  - Thin layers have more defects.
  - Etch resistance is questionable
    - Hard masks may offer solution.
    - EUV ultra-thin resist studies have provided useful data
- Resist contrast may be affected by cross-linking.
  - Positive 248 nm resists turn negative at ~10x clearing dose



Courtesy, Gene Feit (Sematech)

Target Properties

☞*Positive-Tone Single Layer Resists for 157 nm Lithography*

Requirements	***Targets***	***Strategies***
Transparency	**A < 2 μm^{-1}**	**Hydrofluorocarbon >30% fluorination**
Acidic group for base solubility	**pK_a ~ 10**	**Fluorocarbinols**
Etch resistance	**Comparable to Novolac system**	**Alicyclic structures**
Imaging group	**Cleavable by PAG**	**Alkoxy alkyl ethers**

Absorption Coefficients of Various Polymers at 157 nm and Corresponding Film Thickness with OD = 0.4

Polymer	A, μm^{-1}	L (OD = 0.4), nm
Si–O backbone		
Poly(hydrosilsesquioxane)	0.06	6667
Poly(dimethylsiloxane)	1.61	248
Poly(phenylsiloxane)	2.68	149
Carbon backbone		
Fluorocarbon	0.70	571
Hydrofluorocarbon, 30% F	1.34	298
Poly(methylmethacrylate)	5.69	70
Poly(norbornylmethacrylate)	6.67	60
Poly(adamantylmethacrylate)	6.73	59
193 nm Cyclo-olefin resist	8.0	50
193 nm Acrylic resist	8.7	46
248 nm Phenolic resist	8.3	48

From Kunz et al. *J. Vac. Sci. Technol. B* **1999**, *17*, 3267

World Wide Interaction

Global Linkages
157 nm Research & Development

Fused Silica

Asahi Glass	Nikon
Corning	NSG
Heraeus	Shin-Etsu

Resist

ARCH Chem.	Shin-Etsu
Clariant	Shipley
DuPont	Sumitomo
JSR	TOK
OHKA	

Coatings

Acton	LaserOptik
Alpine	Nikon
CANON Inc.	SVGL
Fraunhofer	Zeiss

Government Labs

Fraunhofer Gesellscheft

NIST	SANDIA

Consortia

ASET
German Initiative
IMEC
International SEMATECH

SELETE	SRC

Exposure Tools

ASML	Nikon
CANON	SVGL
Exitech	Ultratech

F2 Excimer Laser

Cymer Inc.
Gigaphoton Inc.
Komatsu
Lambda Physik

Lenses

CANON Inc.	SVGL
Nikon	Zeiss
Tropel	

Pellicles

DuPont	Shin-Etsu
Mitsui Chemical	

Universities

Berkeley	CalTech
Clemson	Cornell

Massachusetts Institut Technology/Lincoln La
Pacific Northwest National Labs
Rochester Institute of Technology
University of Texas at Austin
University of Wisconsi

Calcium Fluoride

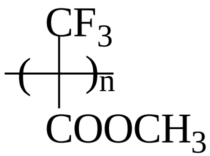
Bicron	Korth
Corning	Schott

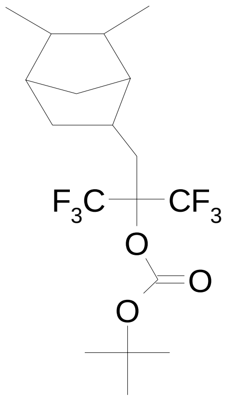
Barium Fluoride

Bicron	Korth
Corning	

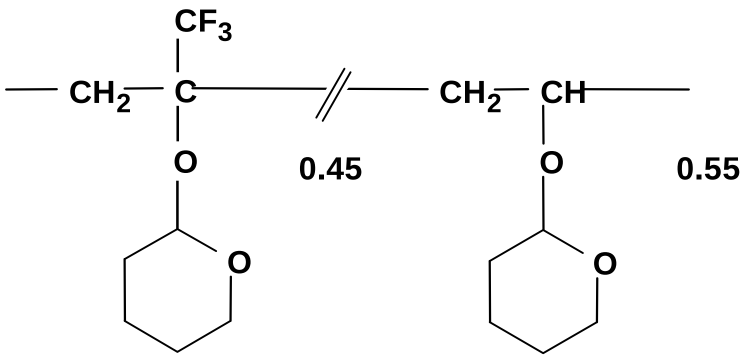
Some Candidate Platforms

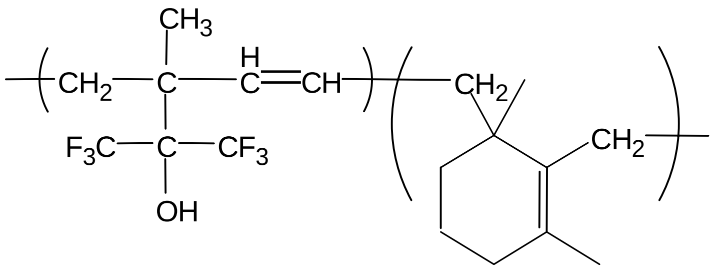
University of Texas



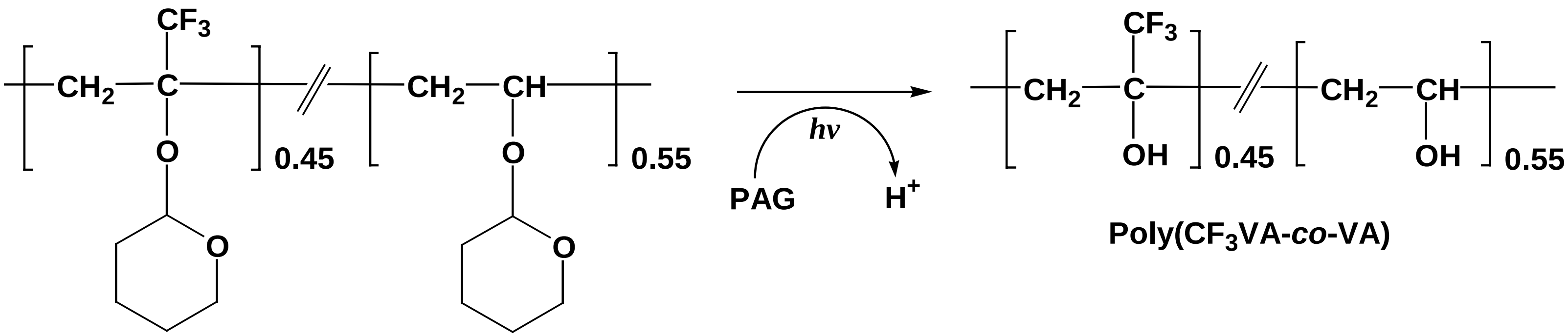


Cornell University

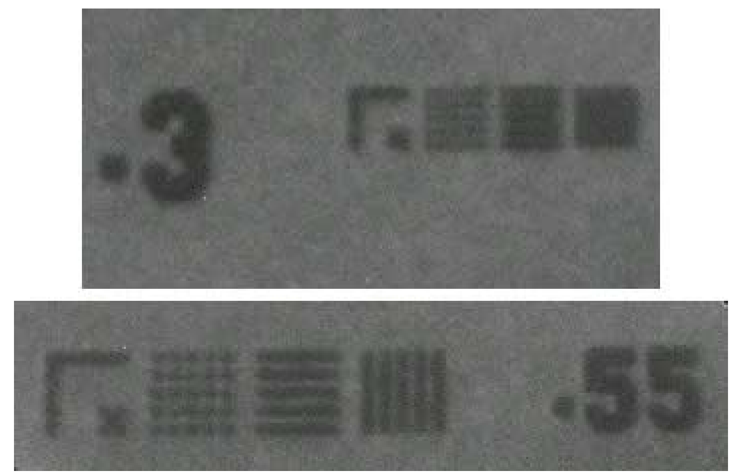




Exposure Results Using a 248 nm Stepper



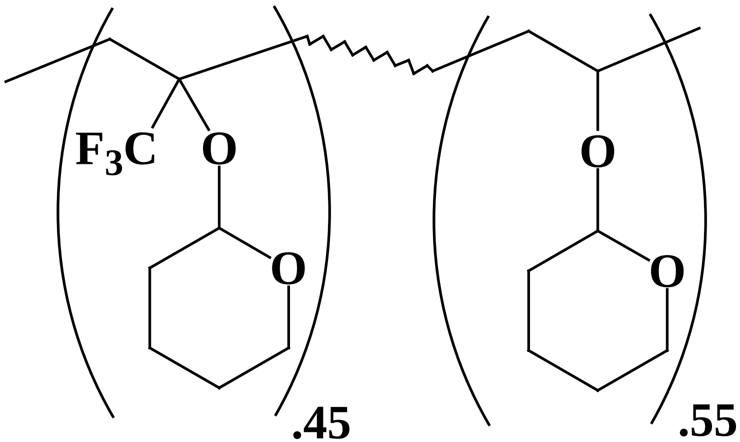
THP-Protected Poly(CF_3VA-*co*-VA)



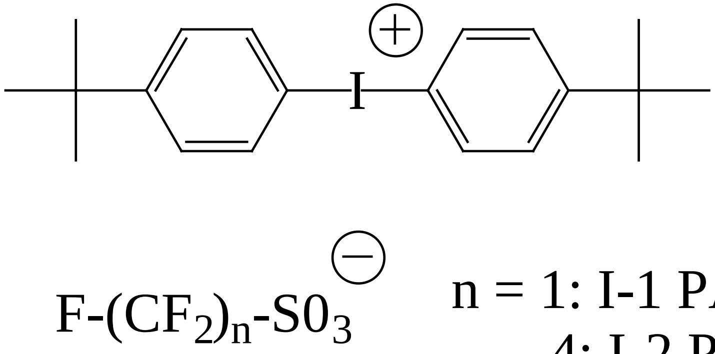
A **= 3.2 μm^{-1}***
- **10 wt% Polymer in PGMEA**
- **1 wt% TASHFSb PAG**
- **PAB 90 °C for 60 sec**
- **PEB 110 °C for 60 sec**
- **0.262 *N* TMAH for 60 sec**

Suitable as a tool-test resist with FT ~130 nm (OD = 0.4)

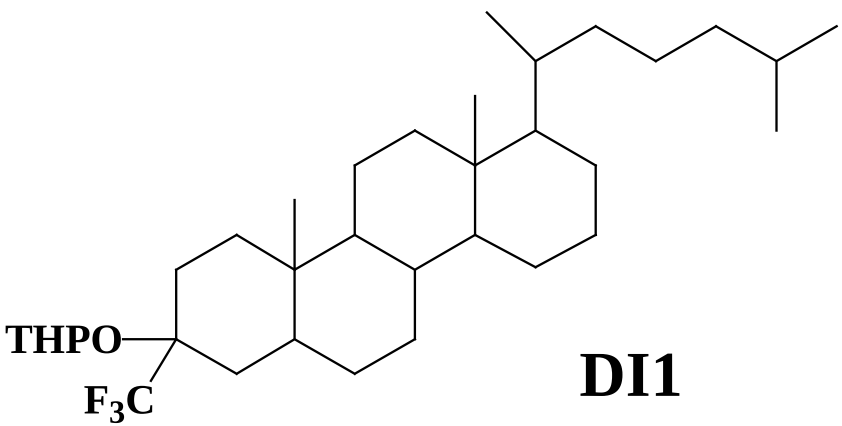
Dissolution Inhibitors



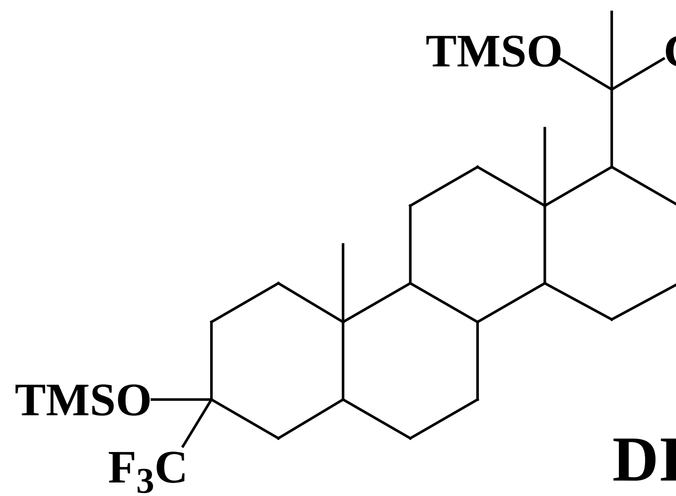
P1-OTHP



n = 1: I-1 PAG
4: I-2 PAG
8: I-3 PAG

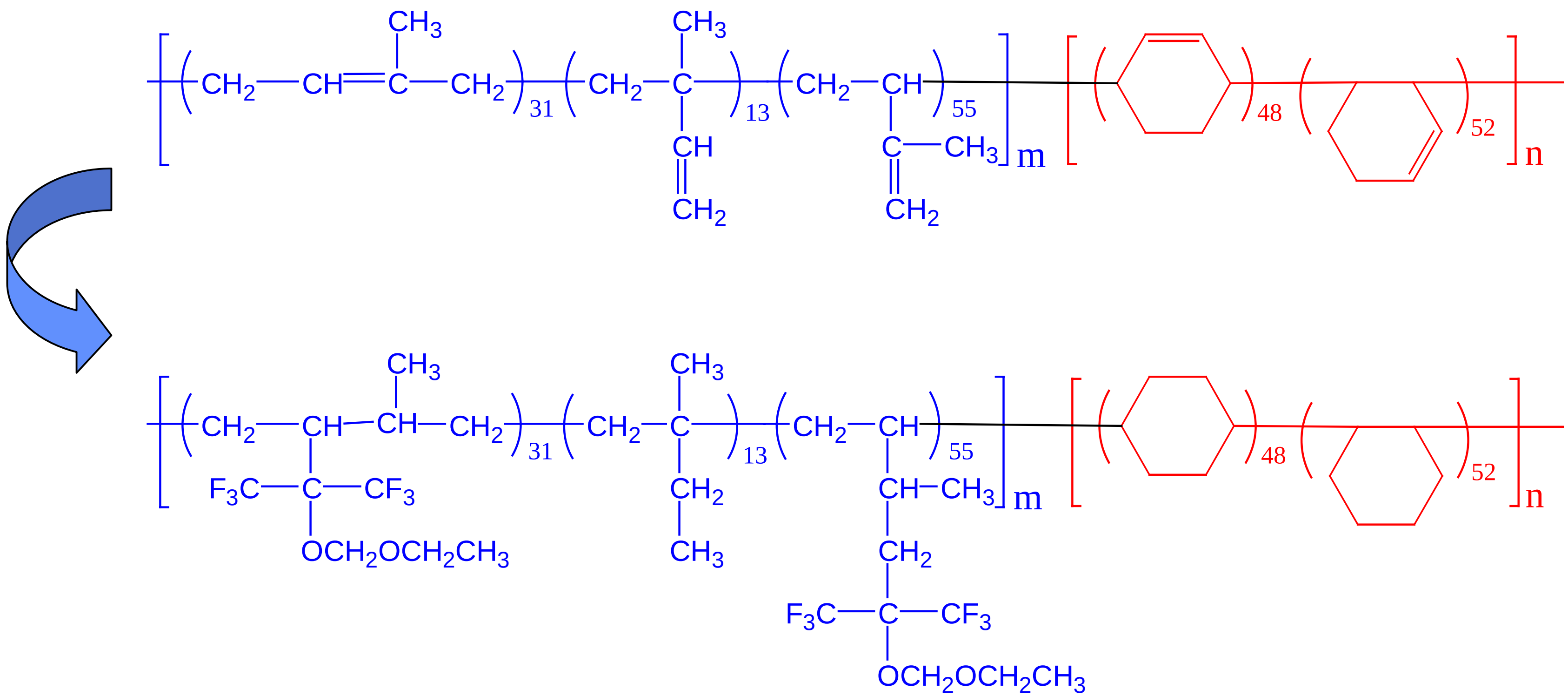


DI1



DI2

Design of Block Copolymer Resists as Model Cyclized PIP Resists



PIPF Block
– Transparency
– Aqueous base solubility
– Solubility switch by CA

+

PCH Block
– Etch resistance
– High Tg
– Dissolution inhibition

PIPF-*b*-PCH
– Good model for cyclized PIP
– Easy for characterization

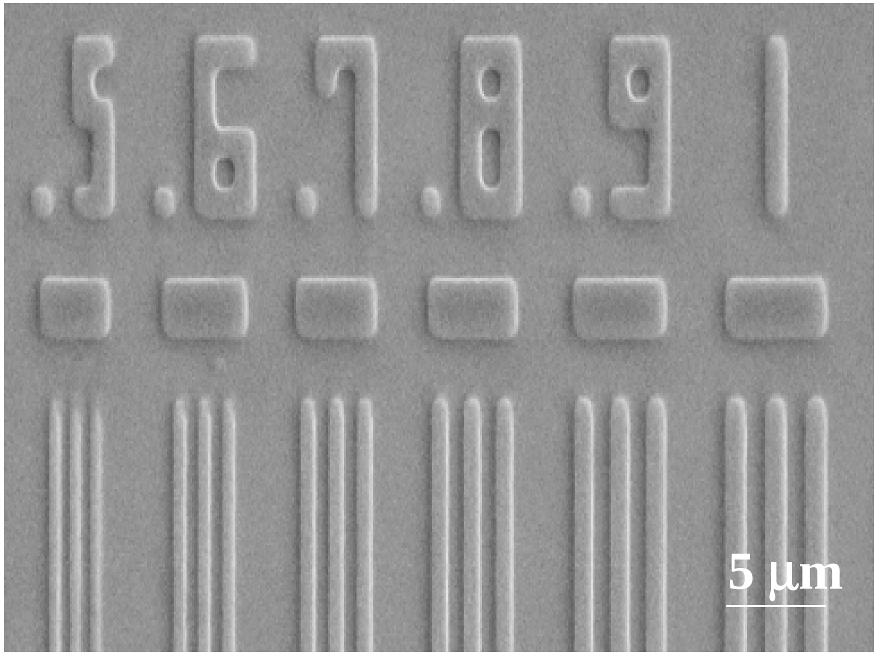
Etch Studies of Cyclized PIP-F$_6$OH

Polymer	Etch Rate (vs. Novolac Resin)	
	CHF_3/O_2 †	CF_4 ‡
Linear PIP-F$_6$OH	1.88×	1.53×
Cyclized PIP-F$_6$OH	1.19×	1.06×

†Thermo oxide etching: 40 mtorr/200 W/ CHF_3 (50 sccm) + O_2 (2 sccm)
‡Nitride etching: 40 mtorr/150 W/CF_4 (30 sccm)
(Measured on *Plasma Therm 72 RIE System* at CNF)

- ☞**Identified a polymer backbone with tunable properties**
- ☞**Cyclized PIP-F$_6$OH: T_g and Etch resistance**

Lithographic Results Using a 248 nm Stepper

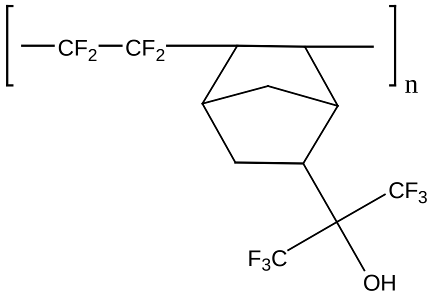


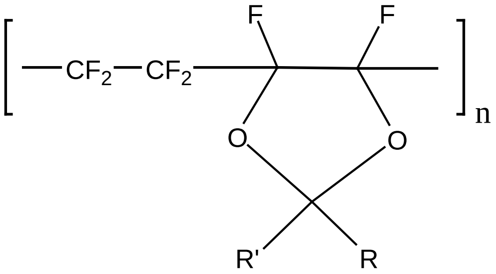
Film thickness: 325 nm
– 12 wt % Polymer in PGMEA
– 2% Triphenylsulfonium nonaflate
– PAB 90 °C/ 60 sec
– 30 mJ/cm^2
– PEB 115 °C/ 60 sec
– 0.26N TMAH + 17% IPA/150 sec

☞**Image obtained before the optimization of processing conditions**
☞**157 nm Exposure at Intel and International SEMATECH**

Outlook For Other 157nm Resists

- Tetrafluoroethylene chemistry
  - DuPont, Universities
- Siloxane chemistry
  - Japan, Shipley
- Nitrile chemistry
  - Universities





Future ESH Issues for Lithography

- Radiation
  - 50-100 KeV from Electron Projection Lithography (EPL)
  - 11-14nm X-rays from Extreme Ultraviolet Lithography (EUVL)
  - 157nm vacuum ultraviolet light for 157nm Lithography
- Materials
  - Passive materials of construction
  - Active materials of construction, e.g. lenses, mirrors, masks, etc.
  - **Disposable materials, e.g. resists, pellicles, etc.**
- Processes (***"cradle to grave"***)
  - at the fabricators
  - **at the semiconductor manufacturers**
  - in disposal

Courtesy, Gene Feit (Sematech)

Resists and Pellicles for Post-193nm Lithography

- 157nm Resist
  - likely to be very unfamiliar materials
  - less likely to be thinner versions of familiar DUV resists
- EUVL Resist
  - likely to be thinner versions of familiar materials
- EPL Resist
  - likely to be refinement of existing e-beam resists

- Pellicle
  - likely to be a very unfamiliar material
  - less likely to be a thin glass plate
- Pellicle
  - not invented yet
- Pellicle
  - not invented yet

Courtesy, Gene Feit (Sematech)

Acknowledgments

Intel Corporation

Dr. Susan Holl

Dr. Raghu Balasubramanian

Ms. Janet Chambers

International SEMATECH

Mr. Will Conley

Cornell University

Dr. Young Bae

Dr. Dirk Schmaljohann

Dr. Hilmar Koerner

Sandi Hamad

Cornell Nanofabrication Facility

Garry Bordonaro