

# **Rational Design in Cyclic Olefin Resists for Sub-100nm Lithography**

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# Acknowledgements

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## IBM East Fishkill

P. Rao Varanasi

Margaret C. Lawson

Ranee W. Kwong

Kuang-Jung Chen

Robin Keller

Timothy Hughes

## IBM Almaden Research Center

Hiroshi Ito

Hoa Truong

Robert D. Allen

Carl Larson

## IBM Yorktown Research Center

Arpan Mahorowala

## JSR (*193nm Resist Development*)

Masafumi Yamamoto

Eiichi Kobayashi

## JSR Micro

Mark Slezak

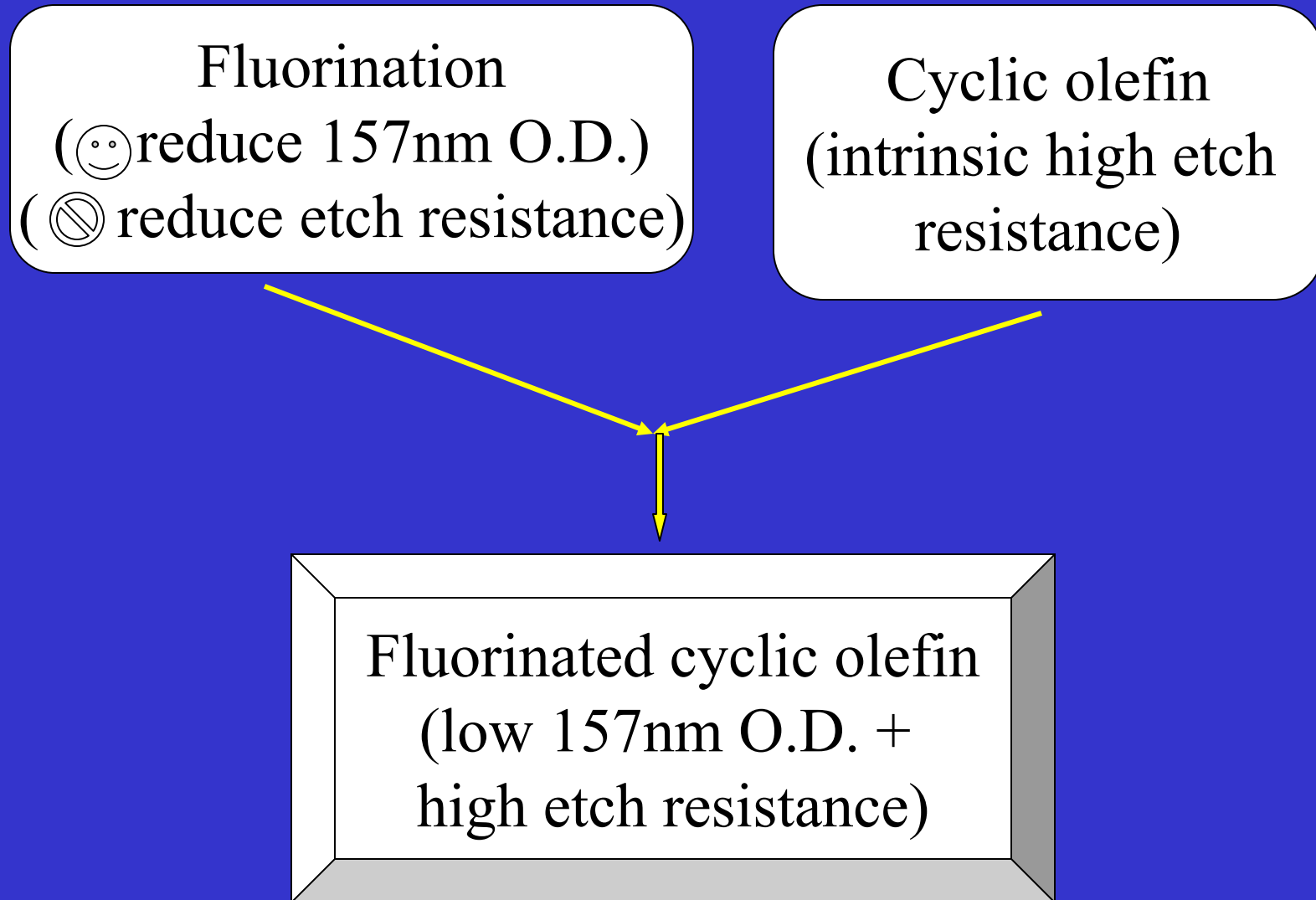
## Promerus (*CO polymer supplier*)

Larry Rhodes

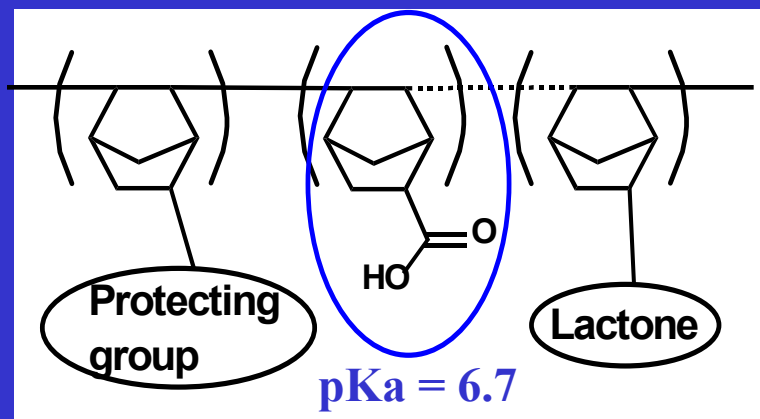
Leah Langsdorf

- Polymer design
- Material properties of Cobra 5K polymers
  - Optical density at 157nm and 193nm
  - Etch resistance and after etch surface roughness
  - Dissolution properties
- Lithographic performance of Cobra 5K resists (with 193nm exposure tool)
  - PEB sensitivity and CD uniformity
  - Line/space performance
  - Contact Hole performance
- Conclusions

# Design of resist for sub-100nm lithography

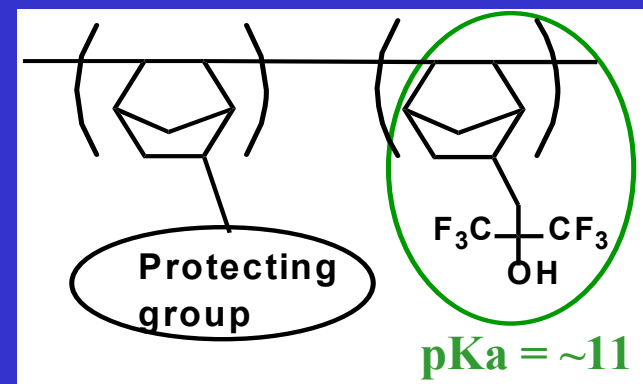


# New polymer design to improve dissolution properties

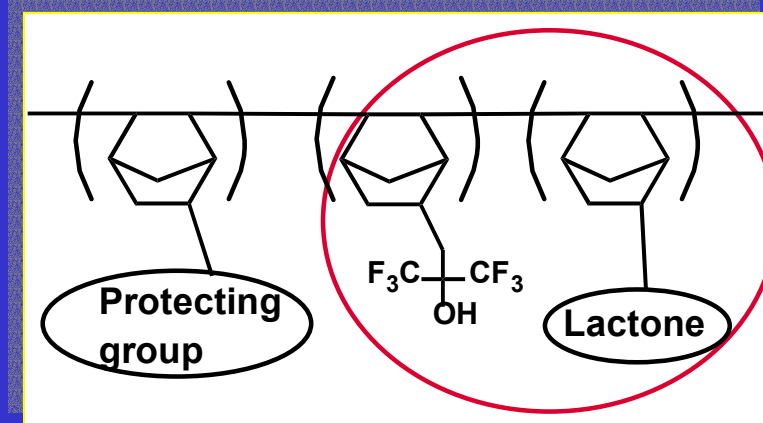


Cobra 1K-4K:  
Good etch resistance  
Swelling  
Limited resolution

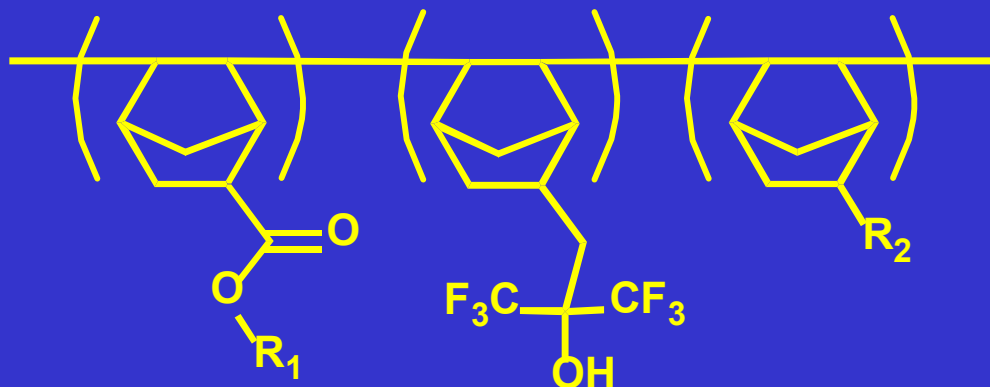
**Cobra 5K terpolymer:**  
**No swelling**  
**Much improved resolution**  
**Good etch resistance**



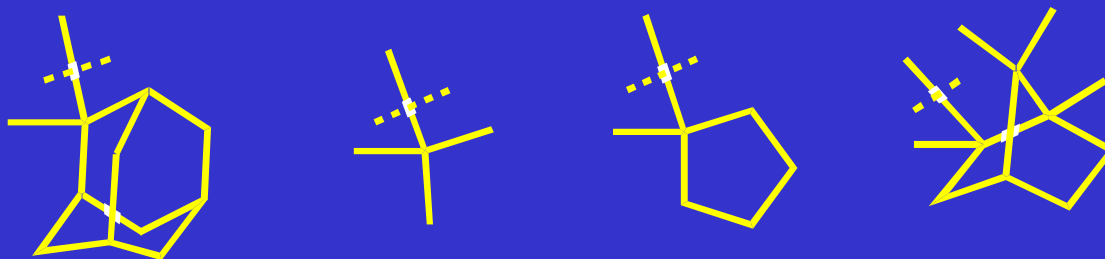
Cobra 5K copolymer:  
Low 157 nm O.D.  
Little swelling



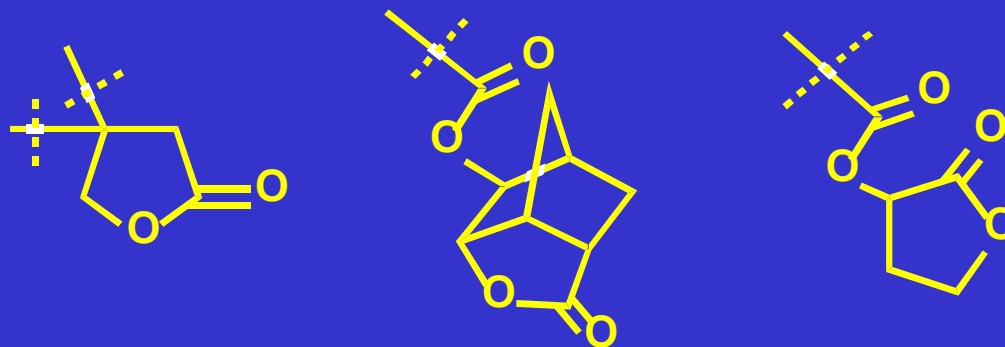
# Structures of Cobra 5K terpolymers



$R_1$ :



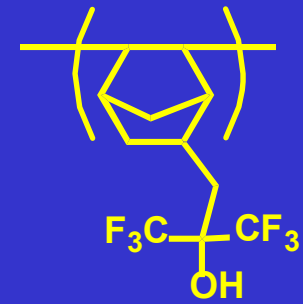
$R_2$ :



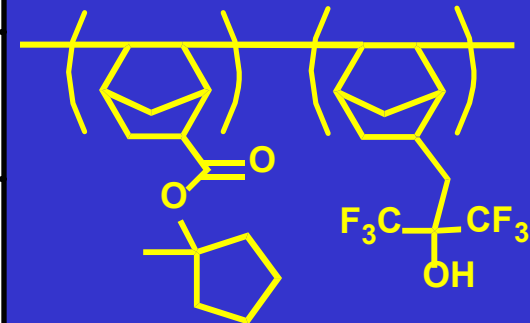
# Optical density and contact angle data of Cobra 5K polymers



Polymer	157nm O.D. ( $\mu\text{m}^{-1}$ )	193nm O.D. ( $\mu\text{m}^{-1}$ )	Contact Angle (H <sub>2</sub> O)
Polynorbornene			96°
PNBHFA	1.7	0.05	69°
NBMCP/NBHFA (20/80)	3.0	0.12	
NBMCP/NBHFA (30/70)	3.2	0.16	
NBMCP/NBHFA (40/60)	3.4	0.19	76°
NBMCP/NBHFA (50/50)	3.7	0.20	78°



PNBHFA

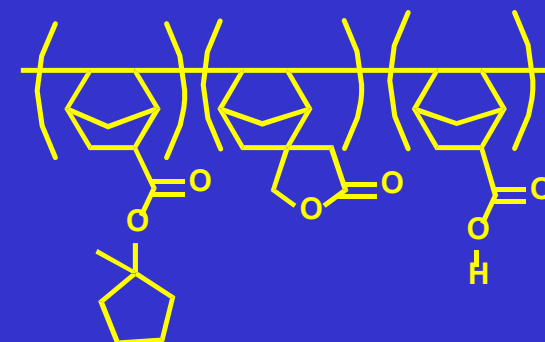


NBMCP/NBHFA

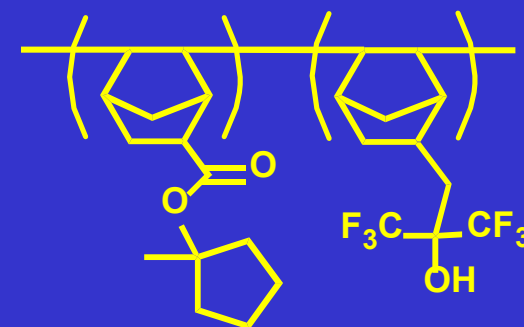
- *HFA effectively reduces the 157nm O.D. of CO polymers*
- *HFA effectively increases the hydrophilicity of CO polymers*

# Oxide etch rate of Cobra 5K copolymers

Polymer	Oxide etch rate (Å/min)	Relative etch rate (vs. PHS)
Poly(hydroxystyrene)	998	1
Poly(t-BOC hydroxystyrene)	1,147	1.15
Cobra 3K polymer	1,076	1.08
Cobra 5K (50/50) (NBMCP/NBHFA)	1,161	1.16
Cobra 5K (20/80) (NBMCP/NBHFA)	1,216	1.22



Cobra 3K



NBMCP/NBHFA

\* Etch chemistry: CF<sub>4</sub>/CF<sub>3</sub>H/O<sub>2</sub>/Ar

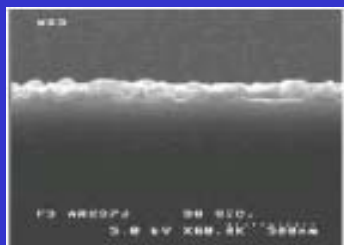
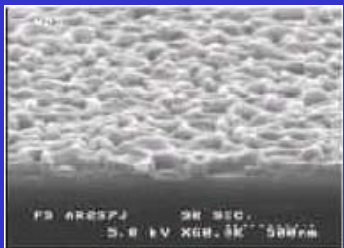
➤ *Fluorine-containing Cobra 5K polymers maintain good etch resistance*



# Cobra 5K has much better after etch surface roughness than acrylates



State-of-the-art  
193nm acrylate



Cobra 5K resist



Pre-etch

Post-etch  
(30s)

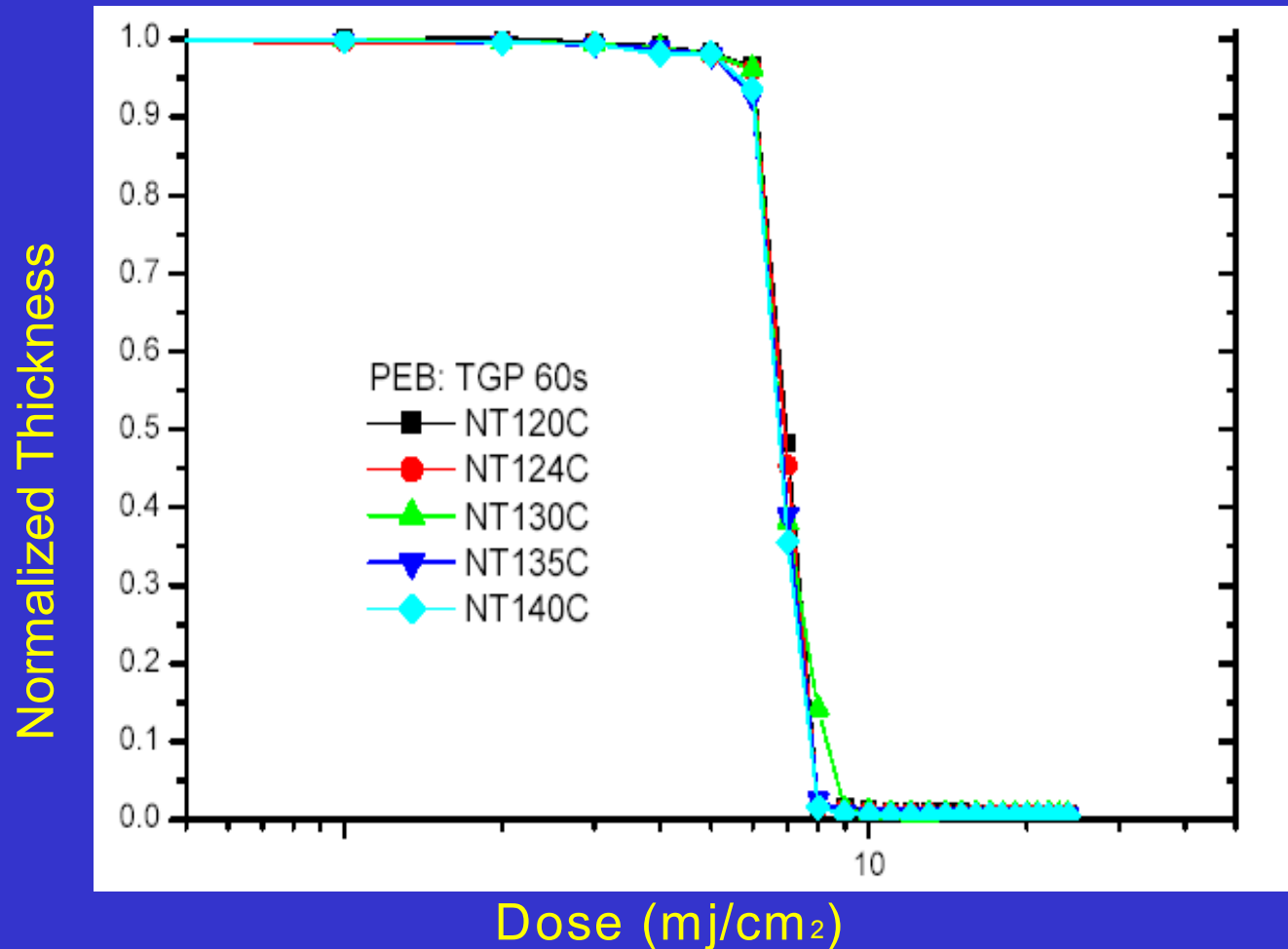
Post-etch  
(90s)

Post-etch  
(90s, 90° view)

Polymer	Dissolution rate (Å/s)
PNBHFA	1500-8000
NBMCP/NBHFA (20/80)	-2.0
NBMCP/NBHFA (30/70)	-0.9
NBMCP/NBHFA (40/60)	-0.6
NBMCP/NBHFA (50/50)	-0.5
Cobra 5K terpolymers	-0.2 ~ 0.2

- *Wide range of NBHFA concentration cause little swelling*
- *Terpolymers with HFA and lactone combination have better dissolution properties than copolymers*

# Contrast curve of Cobra 5K resist at different PEBs

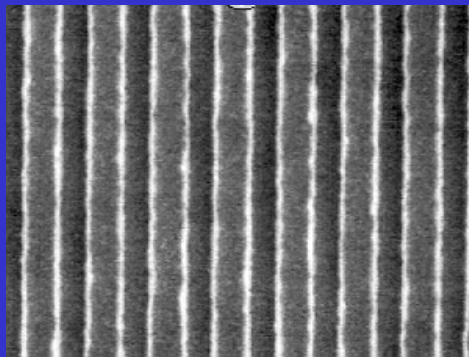


➤ *Little change in contrast curve with PEB temperature from 120 °C to 140 °C*

# Very low PEB sensitivity of Cobra 5K resists

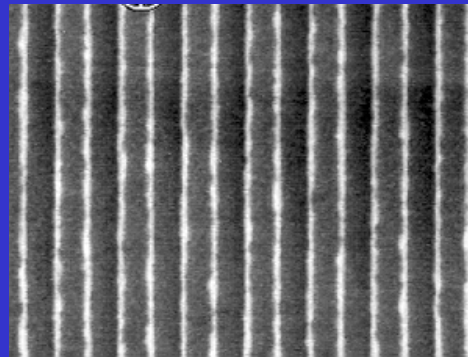


120 °C



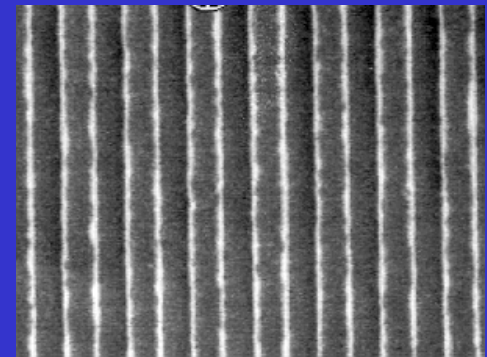
(138nm)

130 °C



(132nm)

140 °C



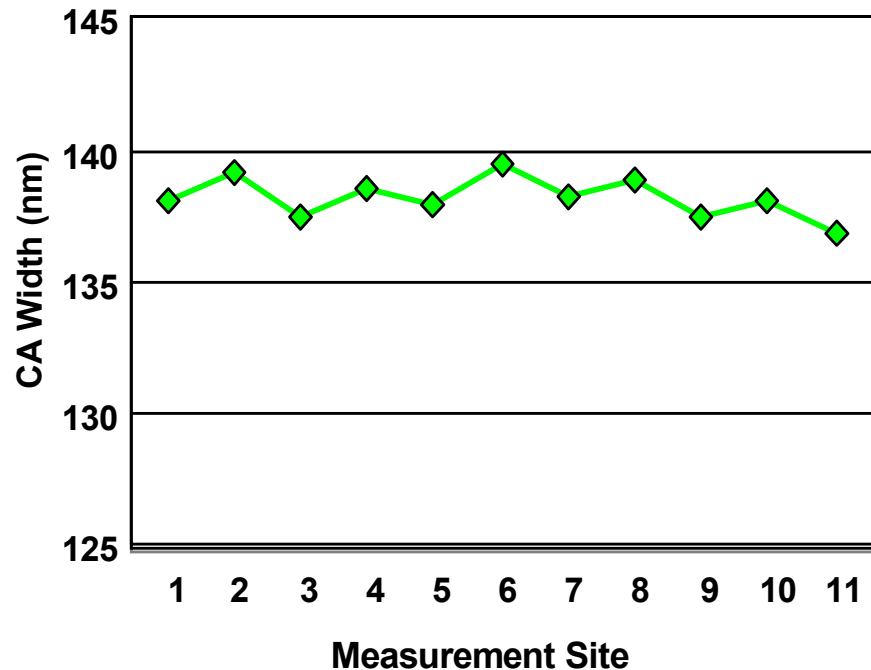
(130nm)

→ PEB sensitivity:  $<0.5 \text{ nm/}^{\circ}\text{C}$

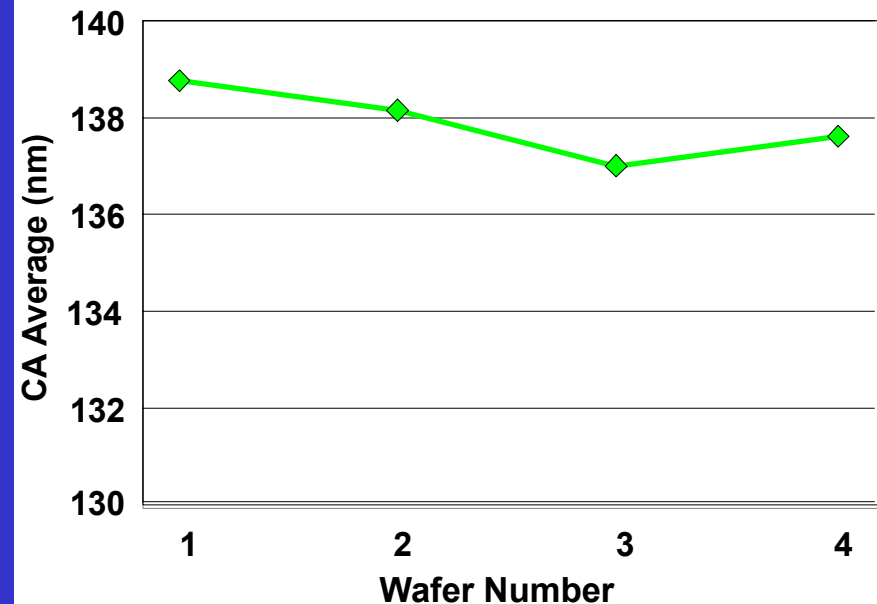
# CD uniformity of Cobra 5K resists



## CD Uniformity: across wafer



## CD uniformity: wafer to wafer



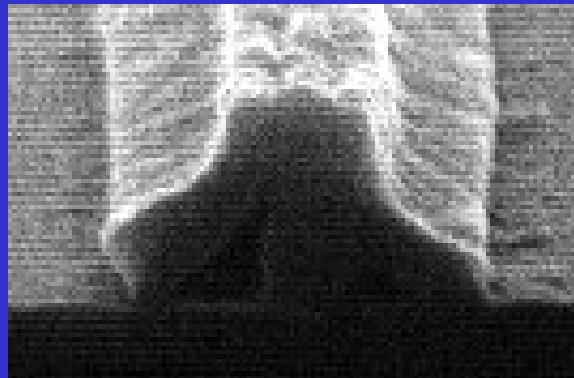
➤ *Good CD uniformity possibly due to low PEB sensitivity*

# Improved resolution over Cobra 1K-4K



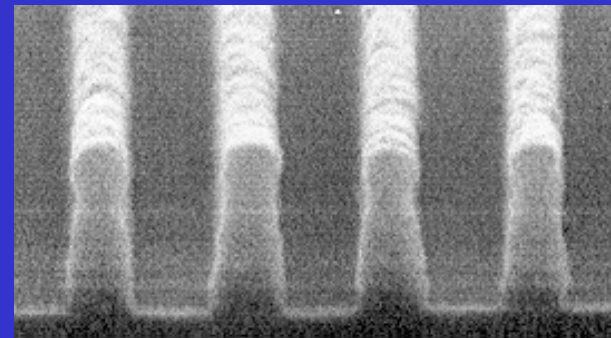
(193nm ASML tool, 0.75 NA, attn. PSM, 3000 Å resist thickness)

Cobra 3K  
(120nm 1:1)



(limited resolution due to swelling)

Cobra 5K  
(105nm 1:1)

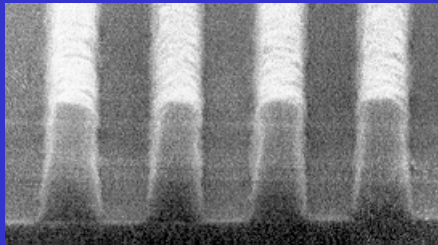


(improved dissolution properties leads to better resolution)

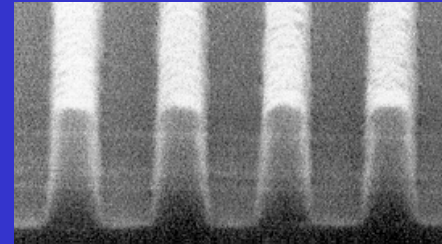
# 105nm 1:1 line/space exposure latitude



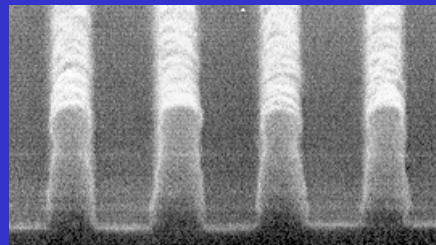
(193nm ASML tool, 0.75 NA, attn. PSM, 3000 Å resist thickness)



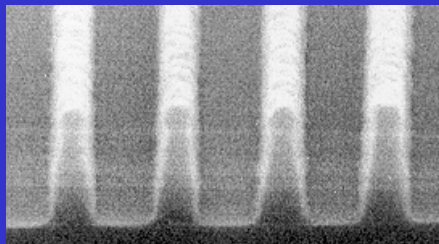
(118nm, 20mj)



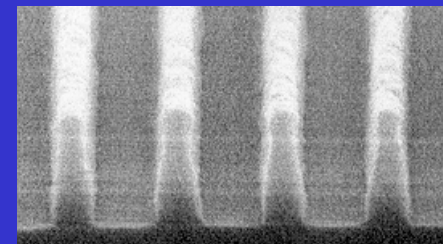
(113nm, 20.5mj)



(103nm, 21mj)



(101nm, 21.5mj)



(96nm, 22mj)

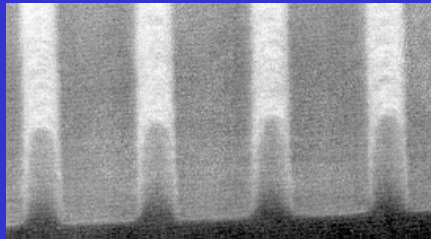
➤ ~10% exposure latitude



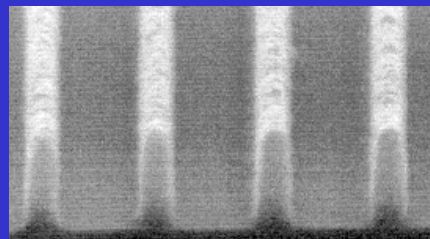
# 80nm line in 245nm pitch performance



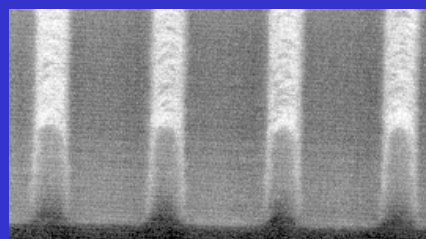
(193nm ASML tool, 0.75 NA, attn. PSM, 2700 Å resist thickness)



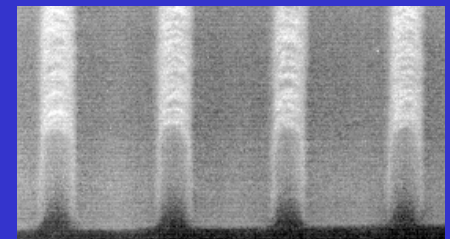
(88nm, 25.5mj)



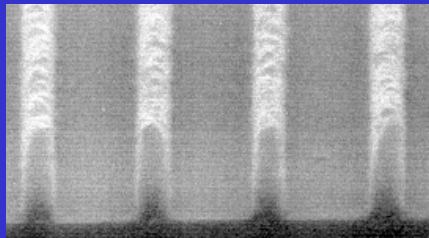
(84nm, 26mj)



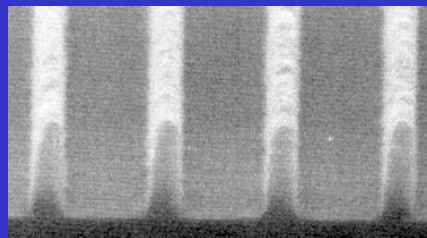
(81nm, 26.5mj)



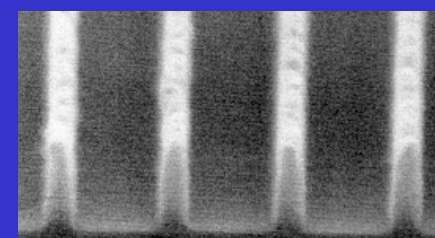
(74nm, 27mj)



(72nm, 27.5mj)



(72nm, 28mj)



(67nm, 28.5mj)

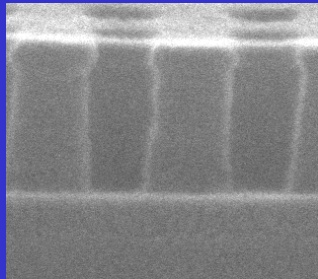
➤ *No line collapse to 67nm, indicating good adhesion to substrate*



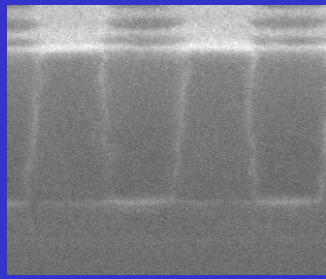
# Exposure latitude of 140nm dense and iso contacts



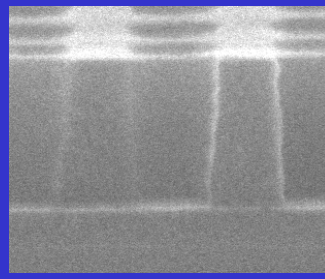
(193nm ASML tool, 0.75 NA, attn. PSM, 3000 Å resist thickness)



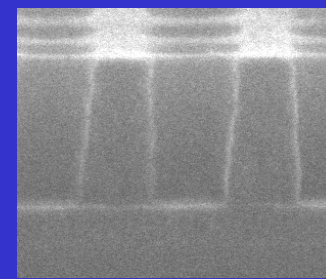
(120nm, 29mj)



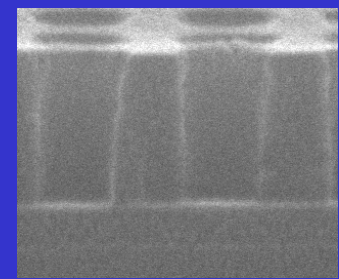
(134nm, 30.5mj)



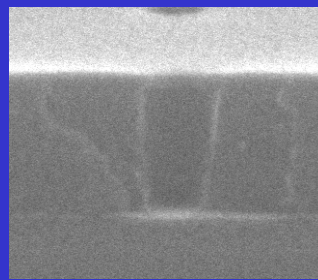
(142nm, 32mj)



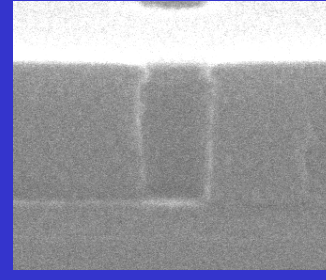
(144nm, 33.5mj)



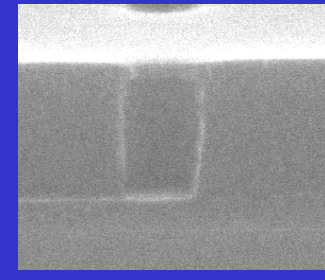
(155nm, 35mj)



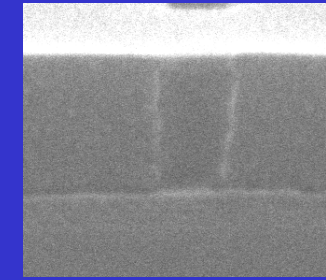
(121nm, 29mj)



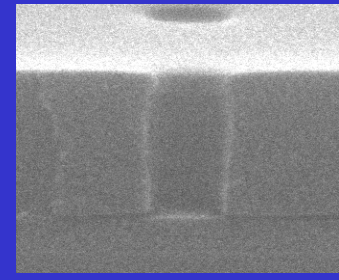
(129nm, 30.5mj)



(138nm, 32mj)



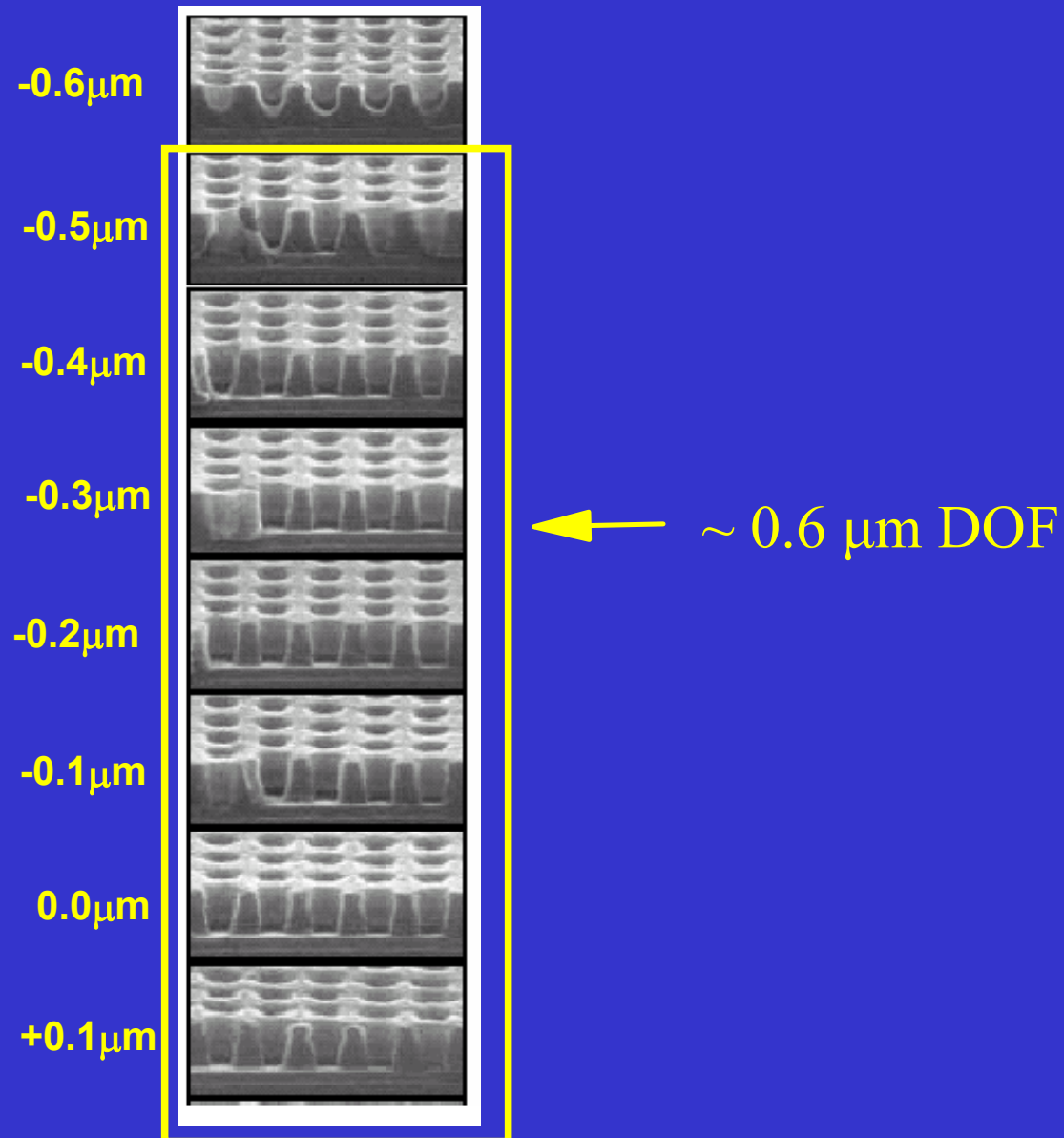
(144nm, 33.5mj)



(152nm, 35mj)

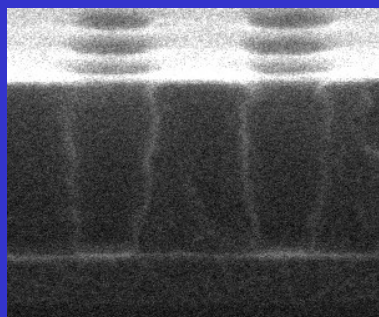
- *~20% exposure latitude for both dense and iso contacts*
- *Small dense-iso bias (< 5nm)*

# Focus latitude of 140nm dense contacts

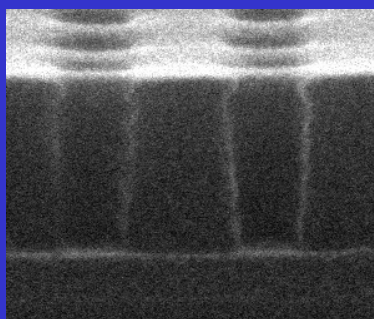


# 100nm contact holes in 280nm pitch

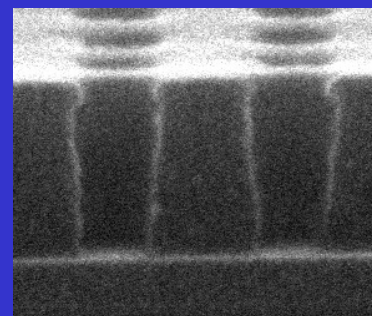
(193nm ASML tool, 0.75 NA, attn. PSM, 3000 Å resist thickness)



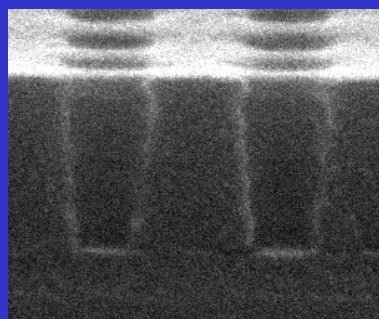
(88nm, 25.5mj)



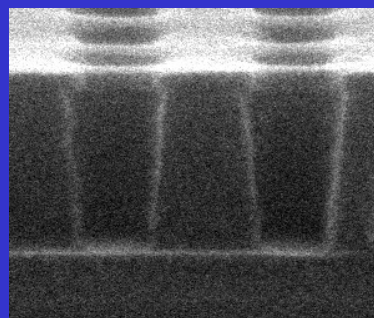
(95nm, 26mj)



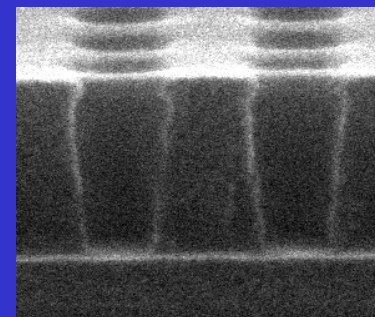
(106nm, 26.5mj)



(109nm, 27mj)



(111nm, 27.5mj)



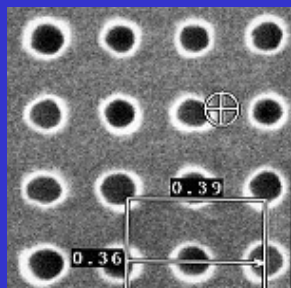
(115nm, 28mj)

➤ *~8% exposure latitude*

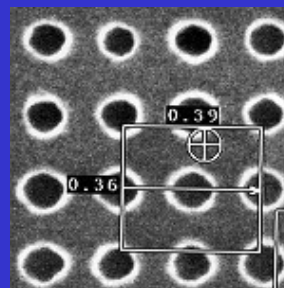
# 100nm dense contact holes



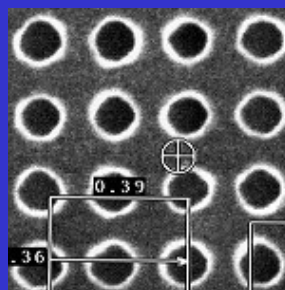
(193nm ASML tool, 0.75 NA, attn. PSM, 2300 Å resist thickness)



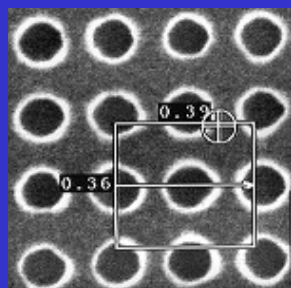
(84nm, 53.5mj)



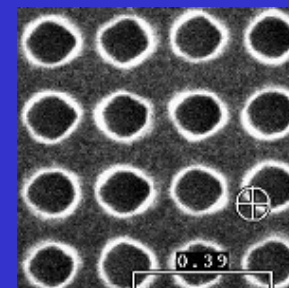
(99nm, 54.5mj)



(106nm, 55.5mj)



(117nm, 56.5mj)



(123nm, 57.5mj)

The combination of HFA and CO polymer backbone provides:

- Low 157nm and 193nm O.D.
- Good etch resistance and after etch surface roughness
- Improved dissolution properties (vs. COOH)

Cobra 5K resists (commercialized through JSR for 193nm application) demonstrated:

- Low PEB sensitivity ( $<0.5\text{nm}/^{\circ}\text{C}$ ) and good CD uniformity
- Good L/S performance
- Excellent contact hole performance
  - ✓ Large process window
  - ✓ Small dense-iso bias
  - ✓ Sub-100nm resolution capabilities