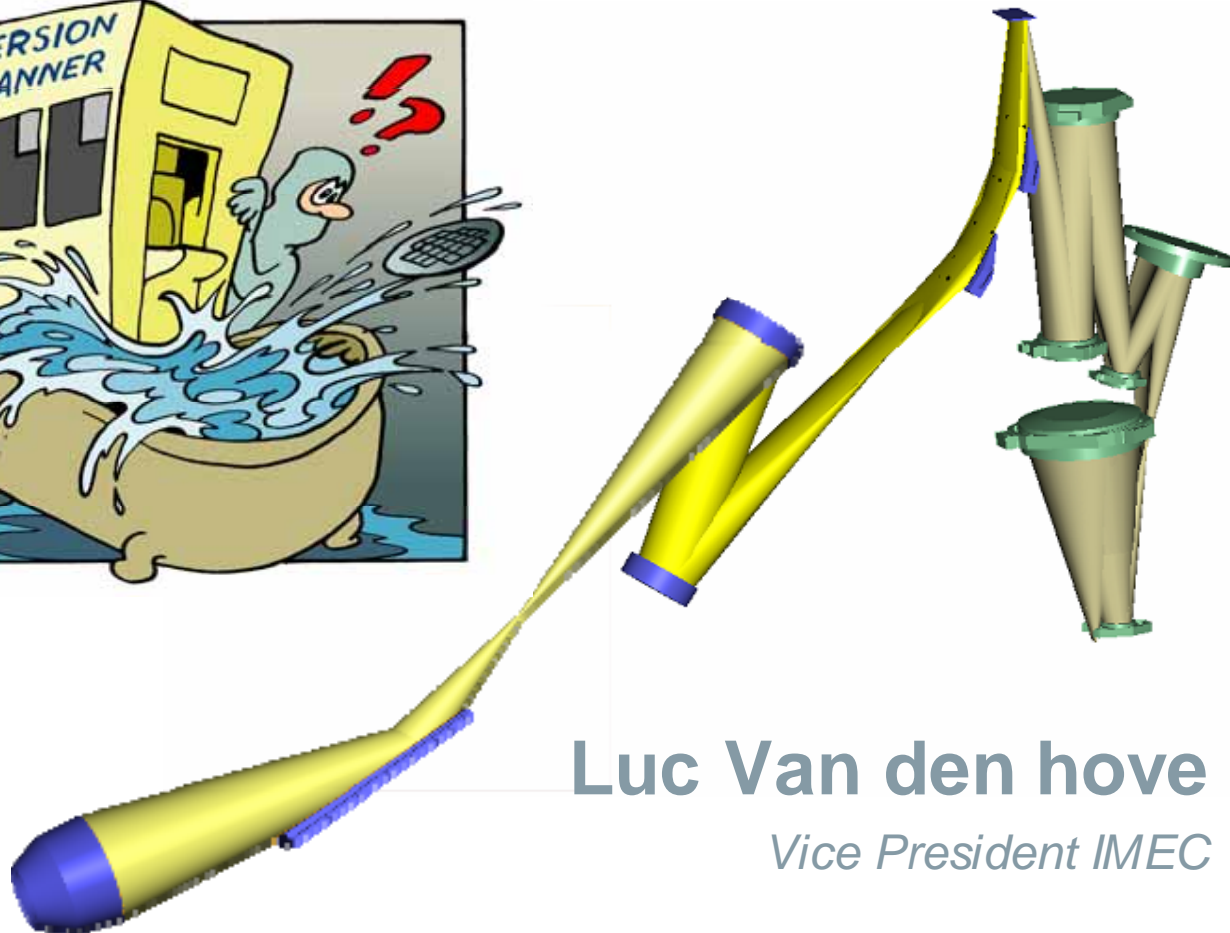


From ArF Immersion to EUV Lithography



Luc Van den hove

Vice President IMEC



Outline

Introduction

193nm immersion lithography

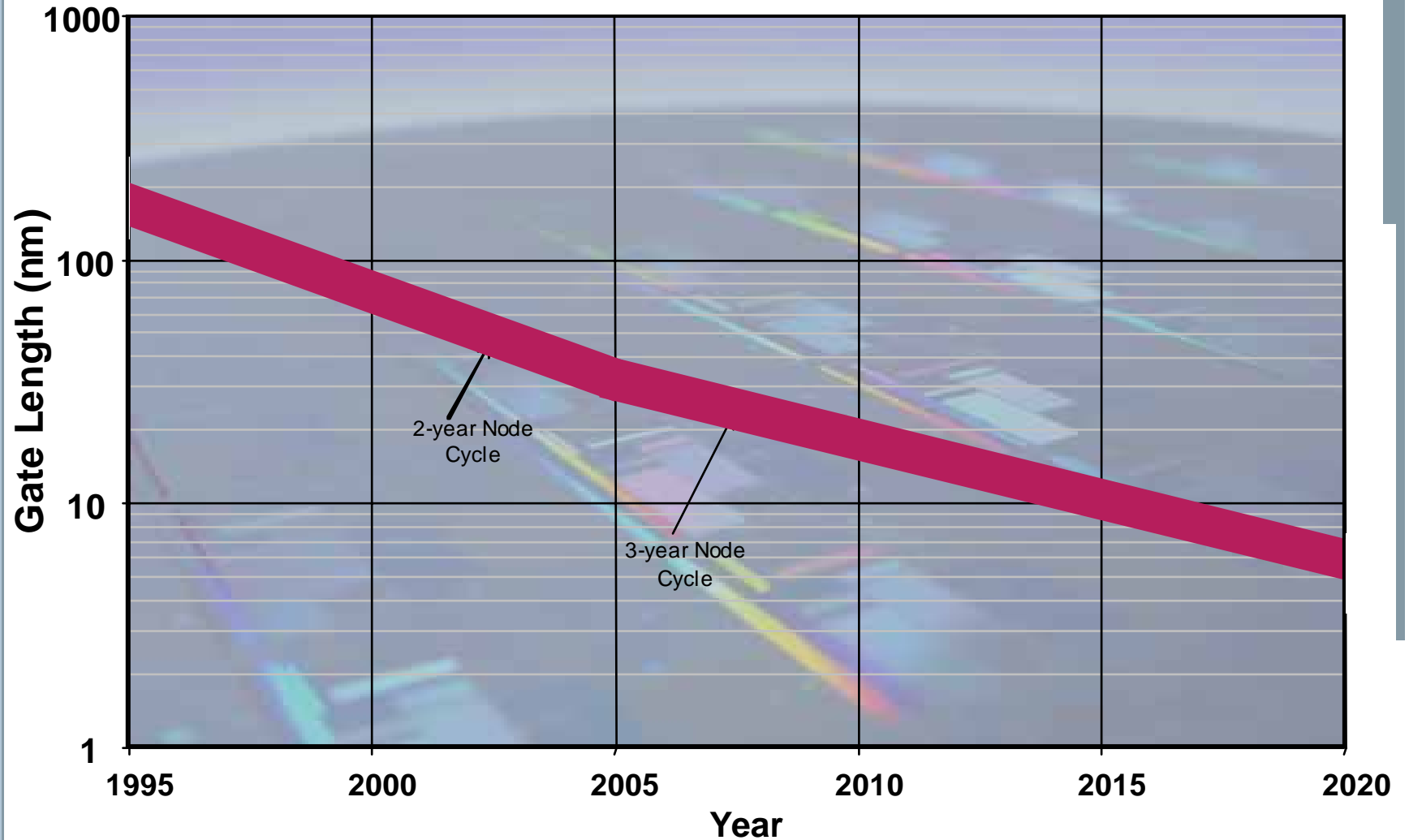
EUV lithography

Global collaboration

Conclusions

Lithography is enabling...

ITRS Technology Trends – MPU Gate Length





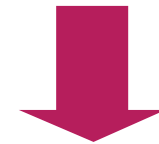
Lord Rayleigh

Rayleigh equation

Wave length scaling

$$resolution = k_1 \cdot \frac{\lambda}{NA}$$

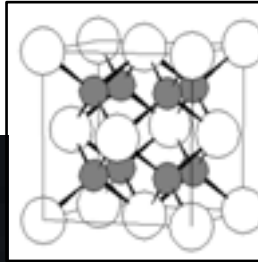
193nm



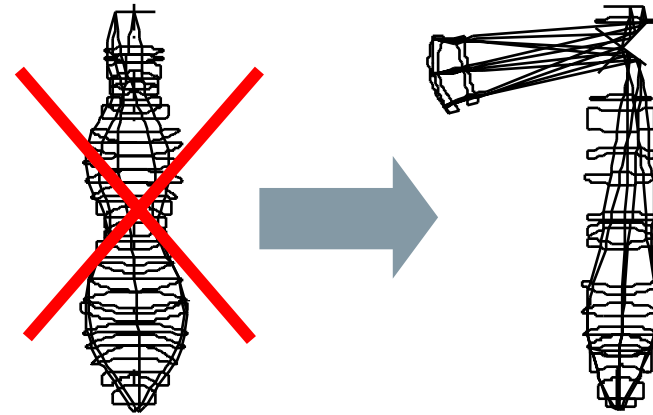
157nm

157nm Challenges

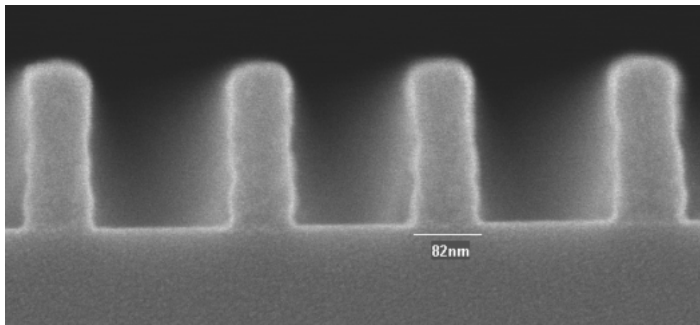
CaF₂ lens material



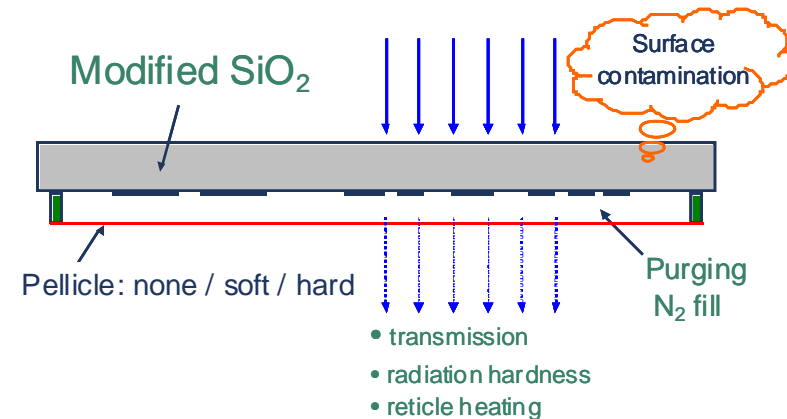
Catadioptric lens design



Fluorinated resist materials



Mask technology





Outline

Introduction

193nm immersion lithography

Status, Challenges, Outlook

EUV lithography

Global collaboration

Conclusions



Lord Rayleigh

Rayleigh equation

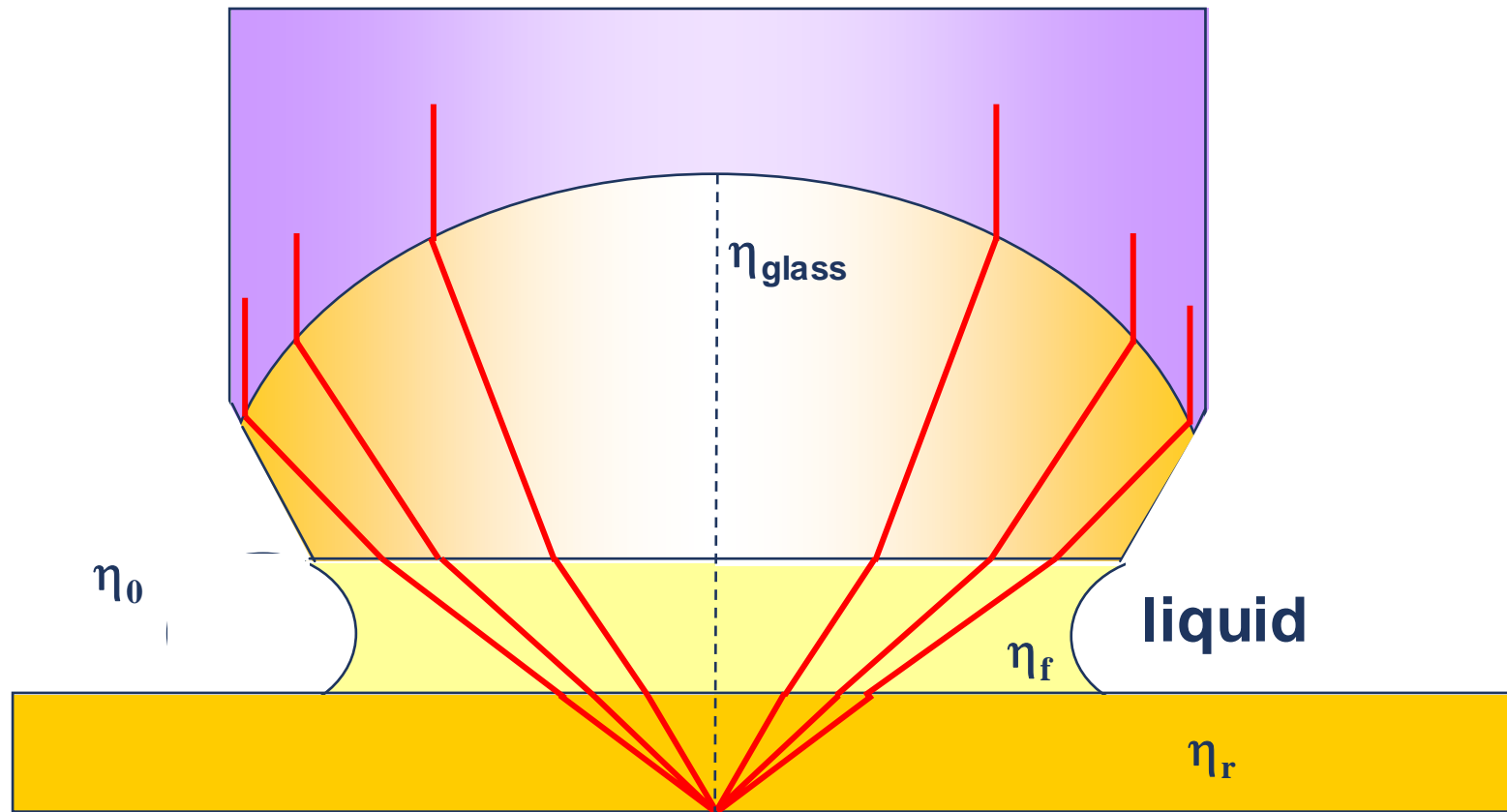
$$\textit{resolution} = k_1 \cdot \frac{\lambda}{NA}$$

NA scaling

Immersion Lithography

Improvements in resolution

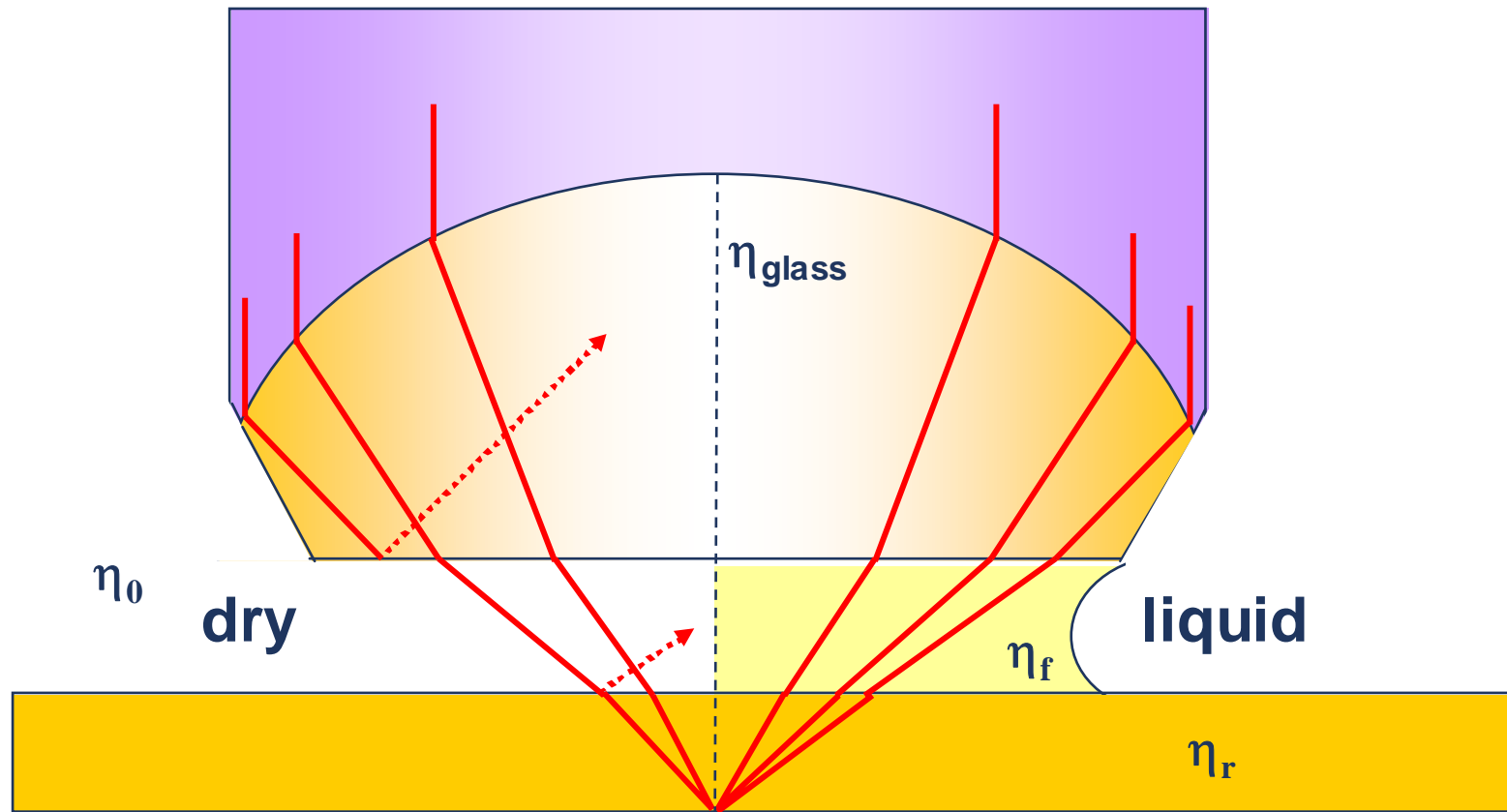
Snell's law : $NA = \eta_0 \sin \theta_0 = \eta_f \sin \theta_f = \eta_r \sin \theta_r$



Immersion Lithography

Improvements in resolution

Snell's law : $NA = \eta_0 \sin \theta_0 = \eta_f \sin \theta_f = \eta_r \sin \theta_r$



Immersion Litho

**Extremely short
introduction time**



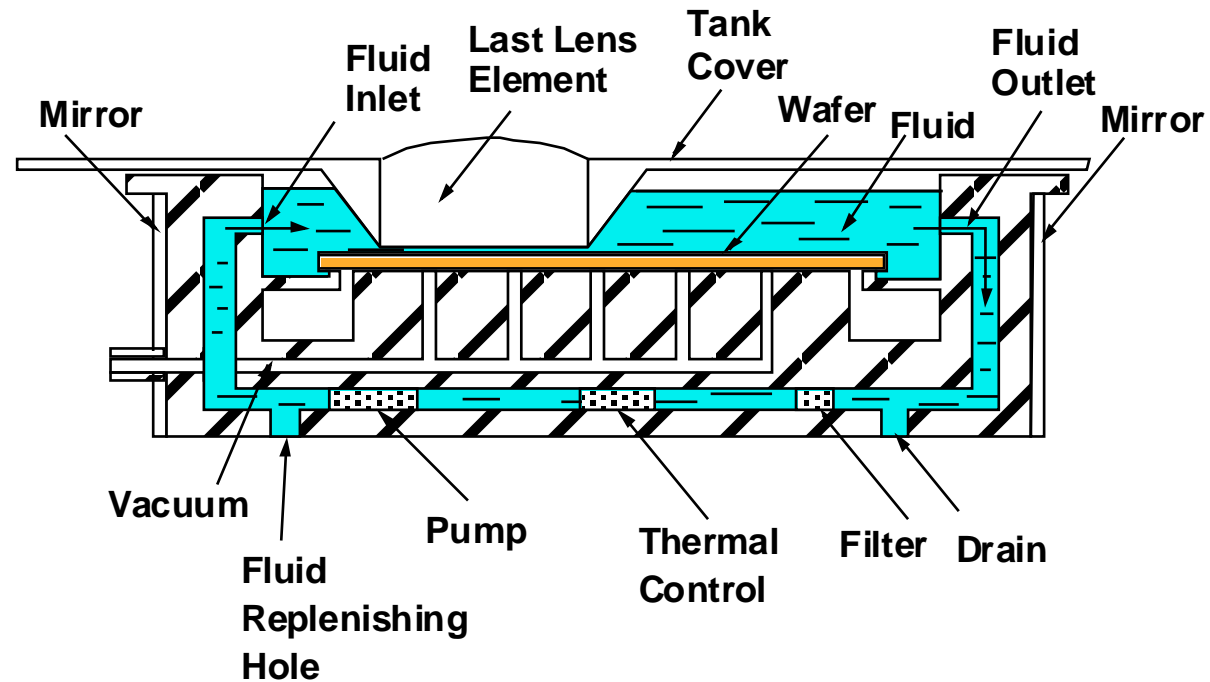
Immersion demonstration in record time

March 2002: Key note presentation @ SPIE Santa Clara
Burn Lin (TSMC): First suggestion to consider immersion lithography

2002

2003

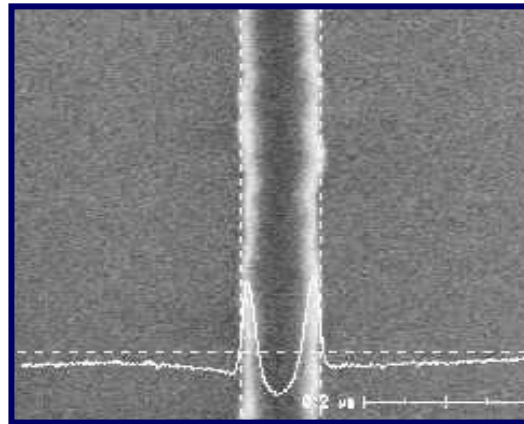
2004



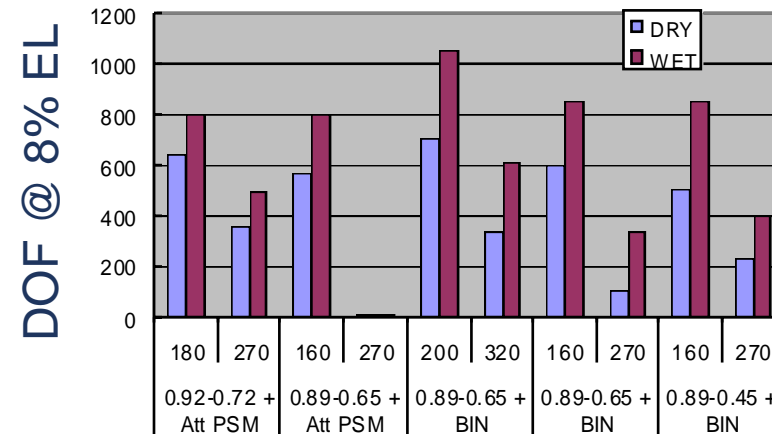
Immersion demonstration in record time

March 2002: Key note presentation @ SPIE Santa Clara
 Burn Lin (TSMC): First suggestion to consider immersion lithography

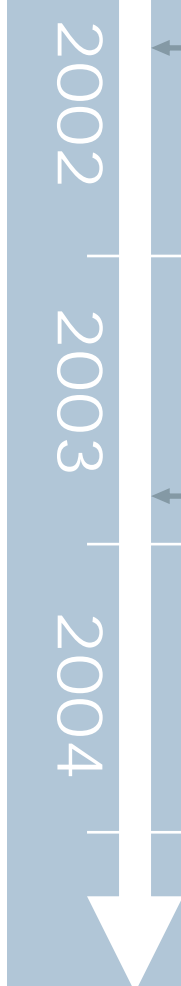
October / November 2003:
 ASML and IMEC demonstrate feasibility on 0.75NA immersion prototype scanner



First immersion scanning image on Oct 7, 2003



> 50% DOF gain demonstration





Immersion demonstration in record time

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World momentum shifts entirely from 157nm to immersion lithography





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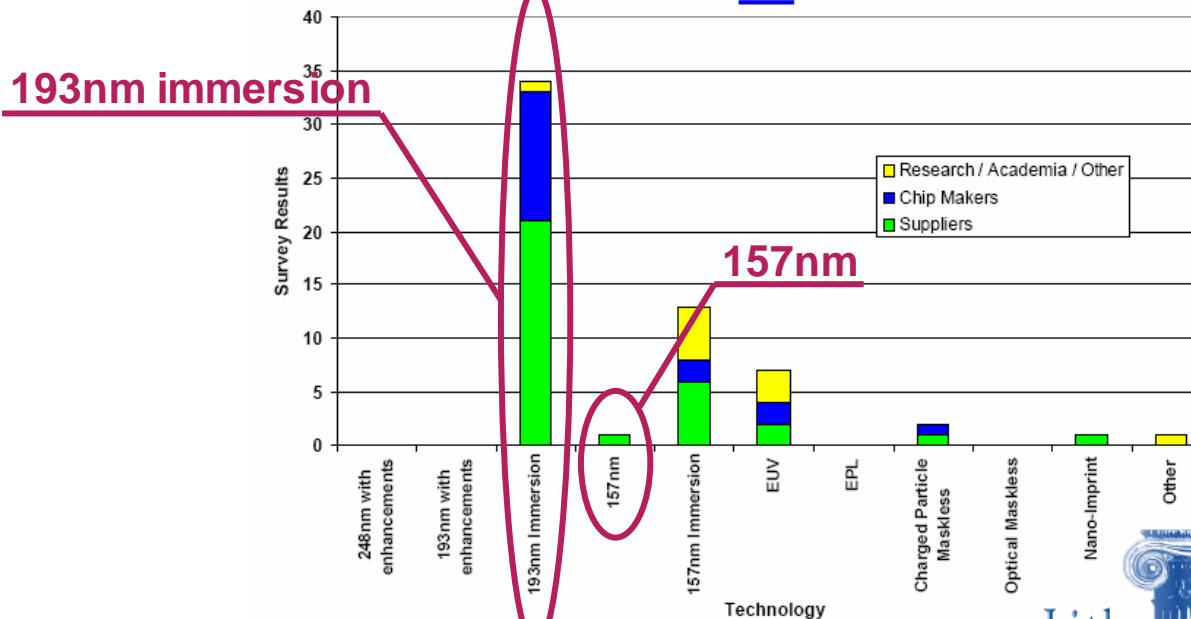
January 2004: Sematech Lithography Forum Los Angeles
World momentum shifts entirely from 157nm to immersion lithography

2002

2003

2004

What Technology will you employ for leading edge gate manufacturing in 2009?



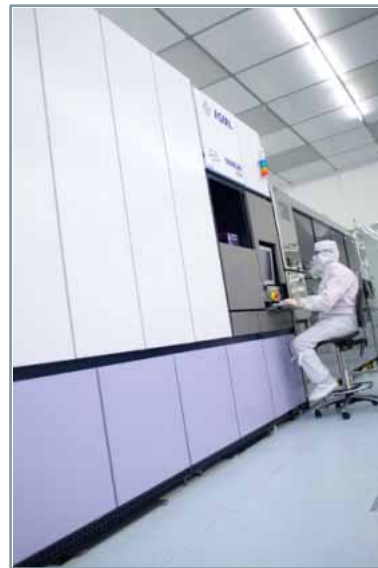


Immersion demonstration in record time

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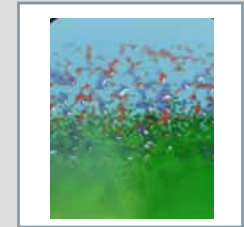


End 2004:
multiple 2nd generation 0.85 NA immersion scanners have been shipped (TSMC, IMEC)

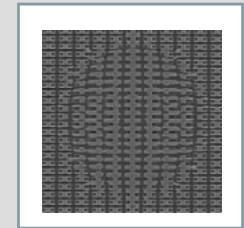
Immersion Lithography

A few challenges

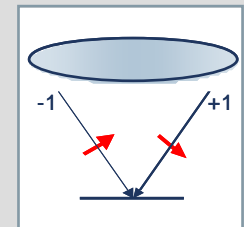
Process interactions



Defectivity



Polarization effects



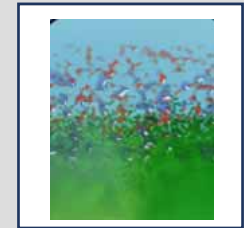
Lens dimensions



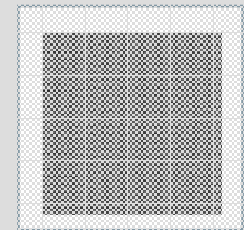
Immersion Lithography

A few challenges

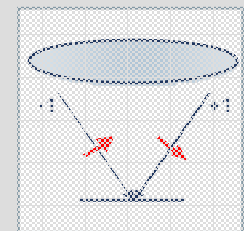
Process interactions



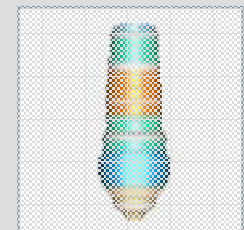
Defectivity



Polarization effects

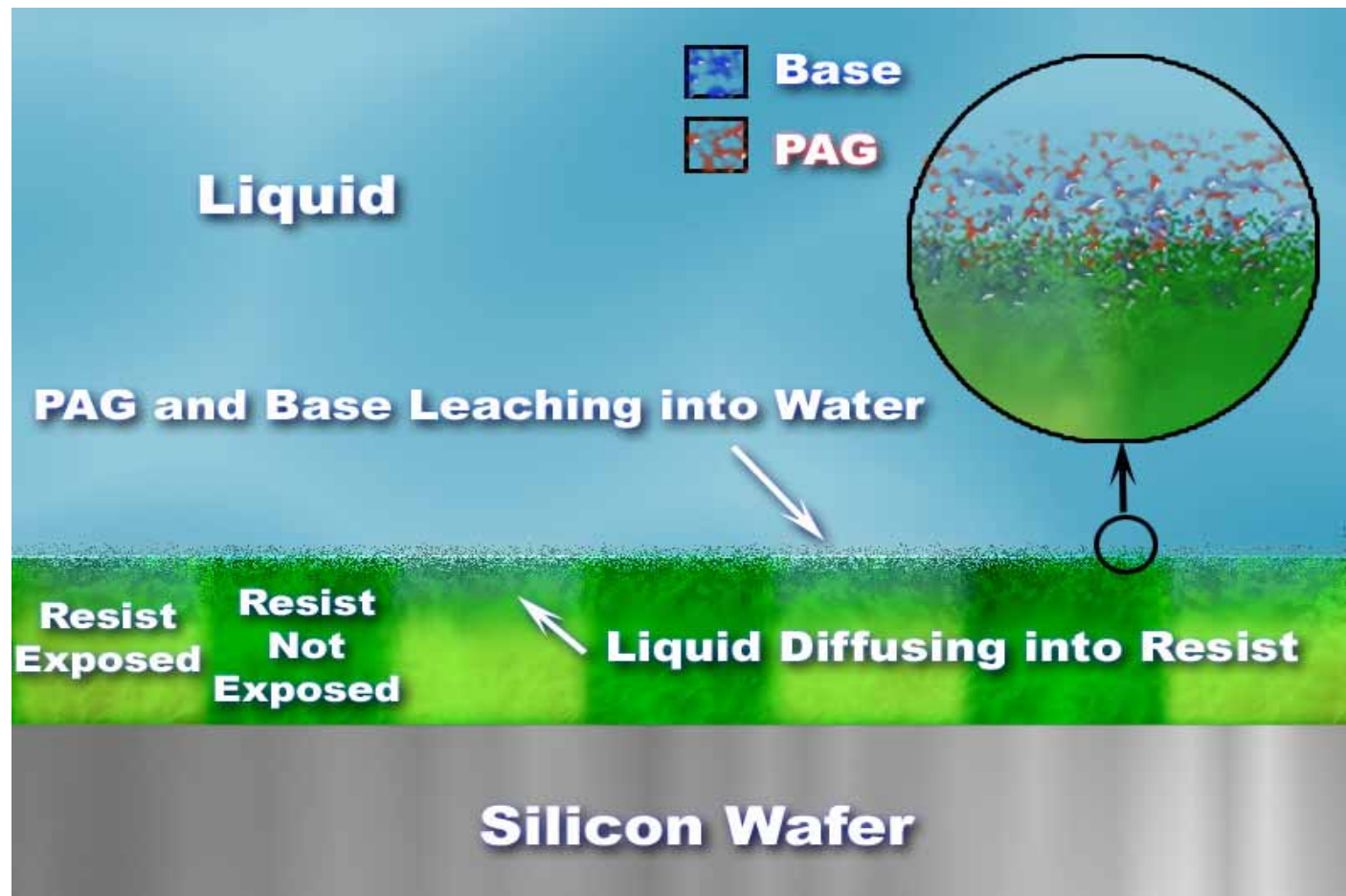


Lens dimensions



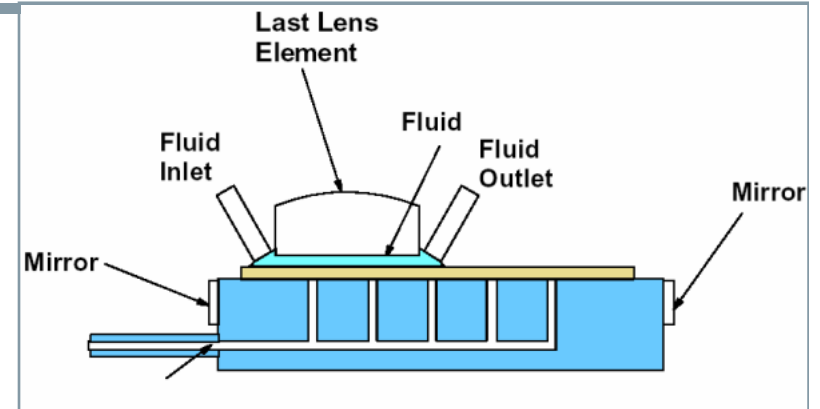
Process Interactions

Interaction of resist/top coat with water

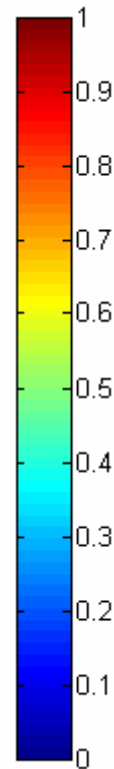
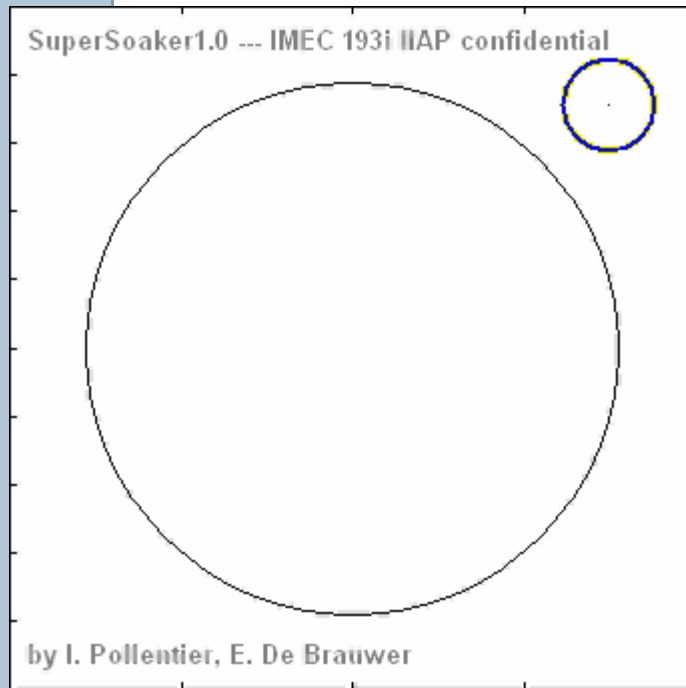


Process interactions

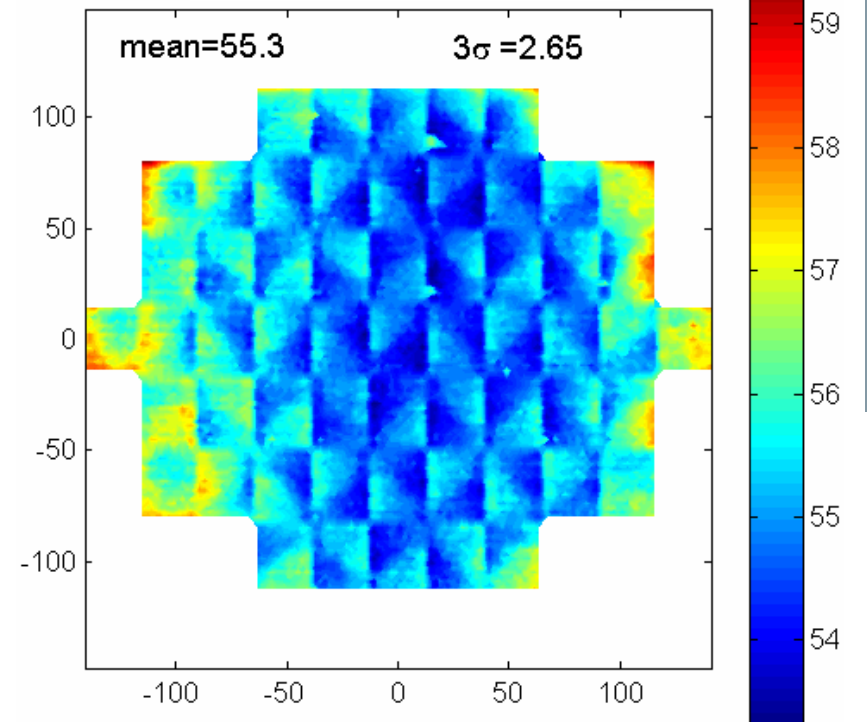
Some topcoats reveal an intrafield CD fingerprint similar to the soak simulations



Soak simulation



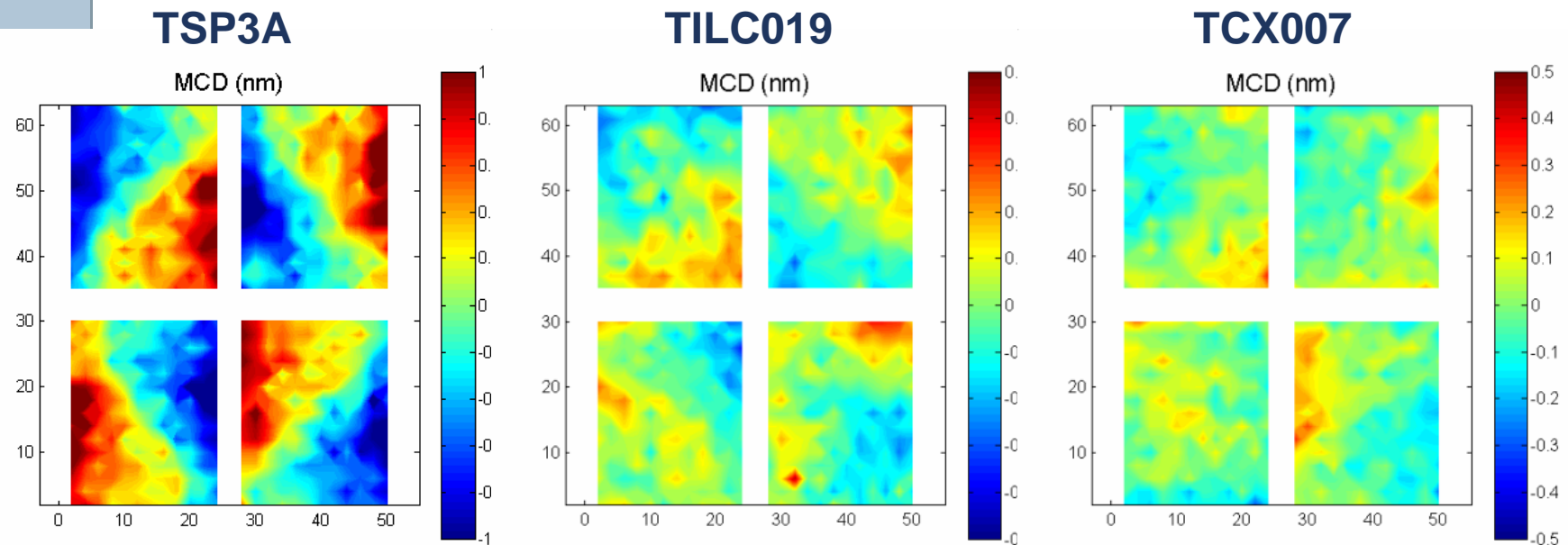
CD fingerprint



Process interactions

CD soak fingerprint using new developer soluble topcoats is significant reduced compared to TSP3A (but still visible)

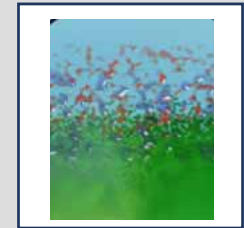
New developer soluble topcoats



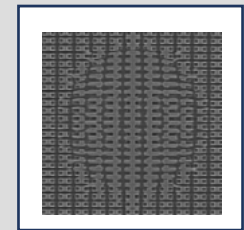
Immersion Lithography

A few challenges

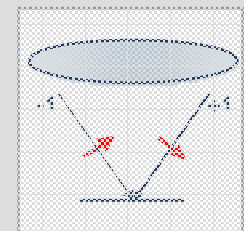
Process interactions



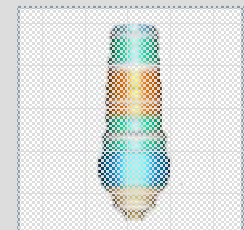
Defectivity



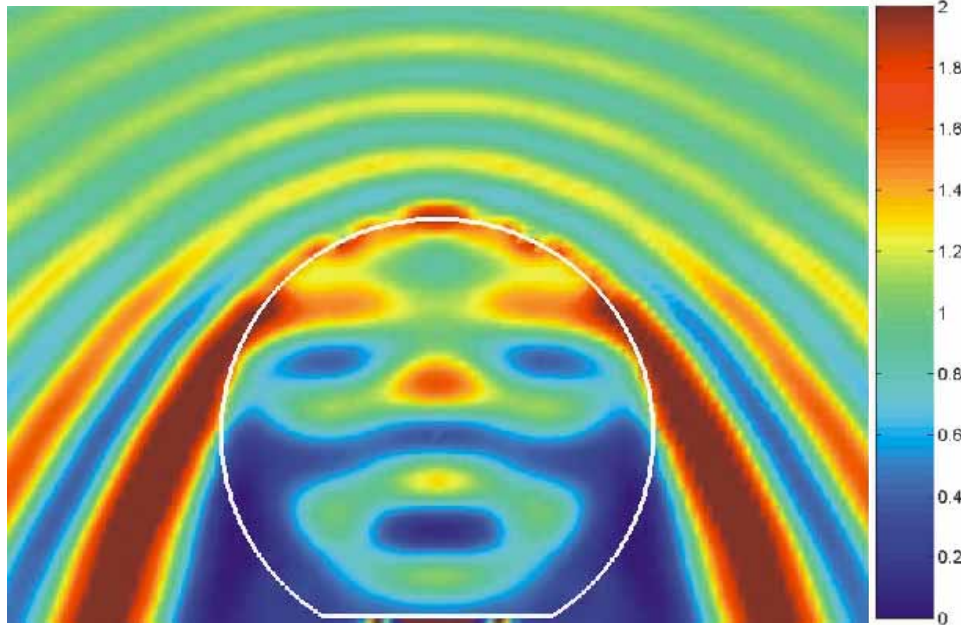
Polarization effects



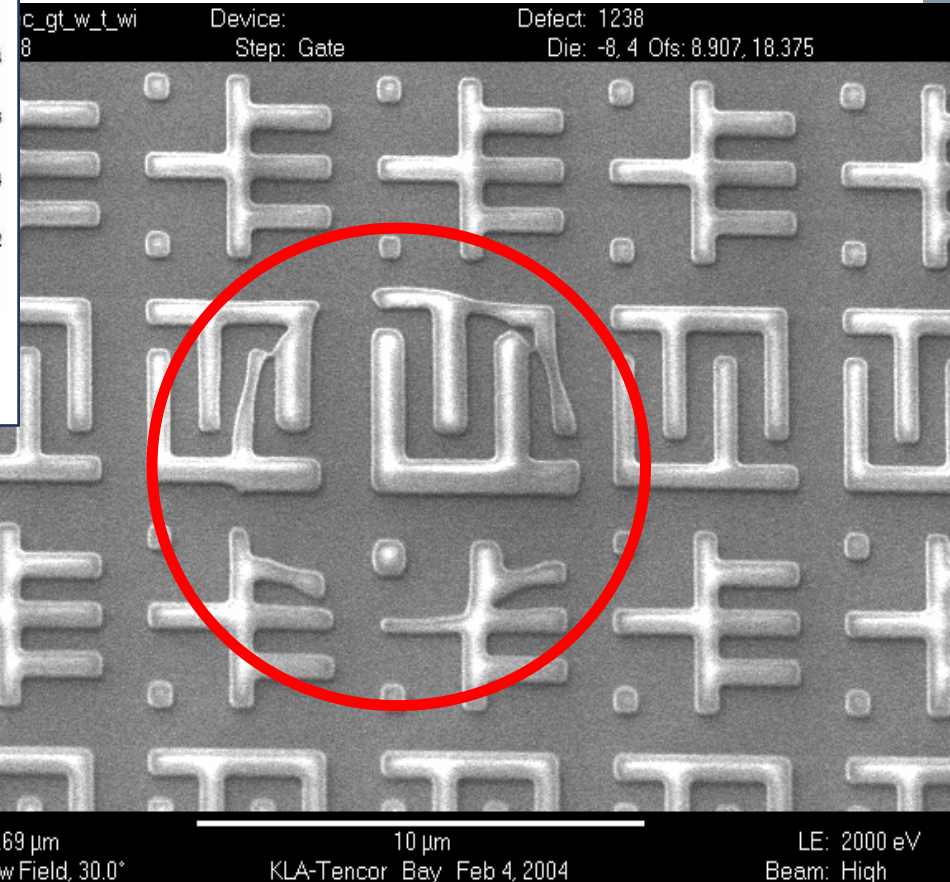
Lens dimensions



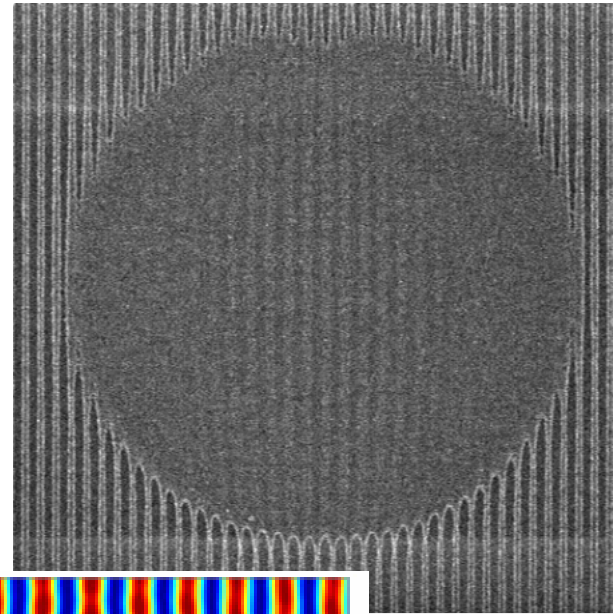
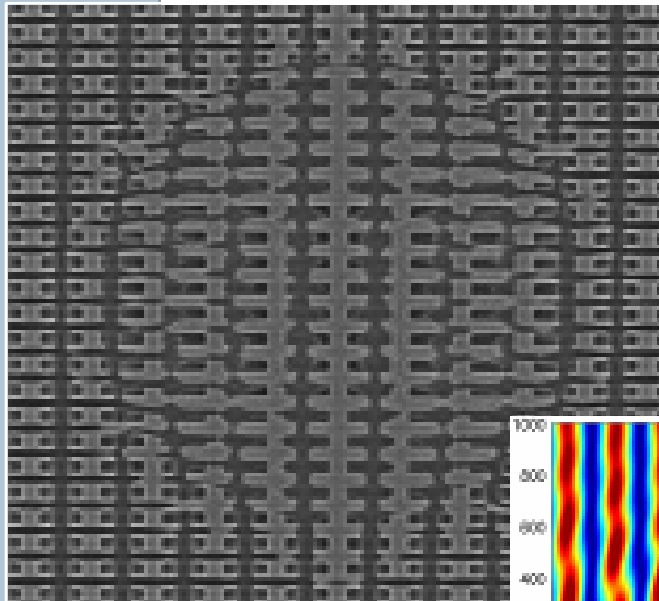
Immersion defectivity



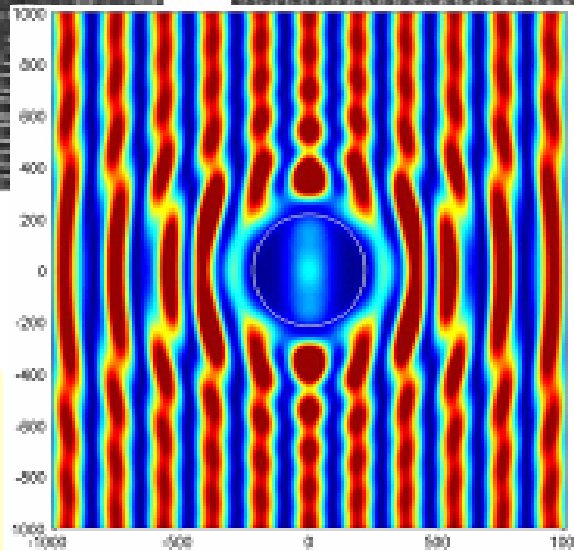
A spherical air bubble casts a shadow



“Bubble Defects”



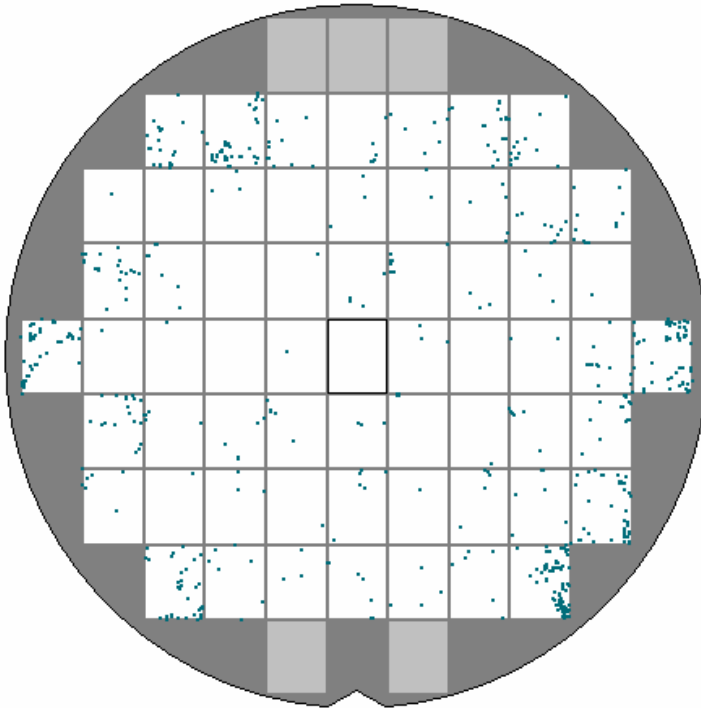
Defect: 2261 ADC, Class 81
Die: -7, 4 Of: 0.859, 1.665



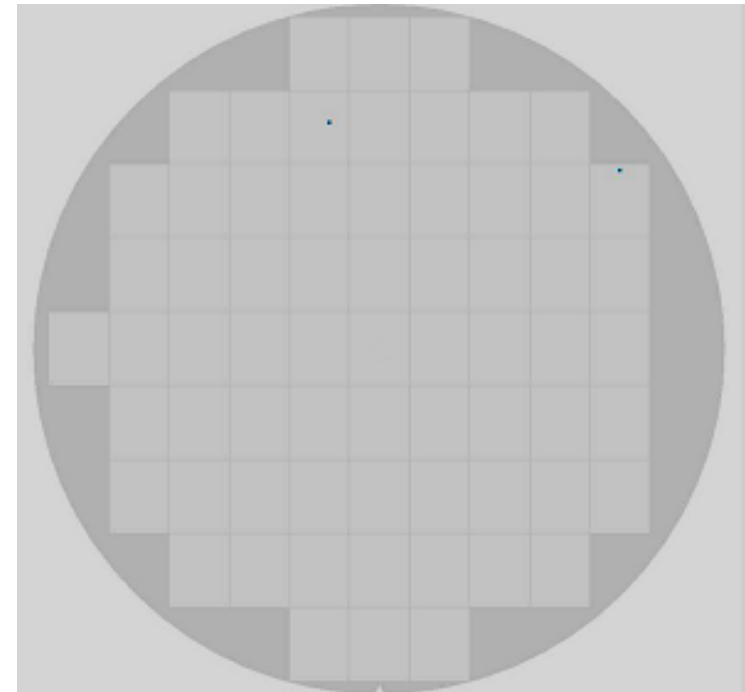
Simulated (2-beam imaging) aerial image of 500nm bubble defect on 100nm L/S pattern

Bubble improvement (/1250i)

Non-optimized conditions



After optimization



Immersion specific defects

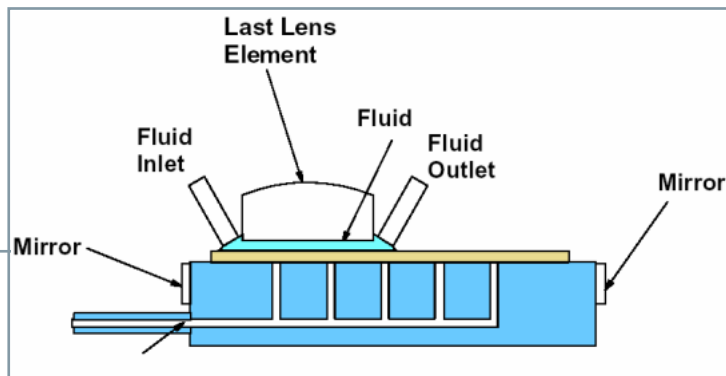
Scanner contributions

Bubbles

(related to shower head design, wafer chuck design, ...)

Defects

(related to water residues, related to chuck/head design, ...)



Resist/process contributions

Resist leaching

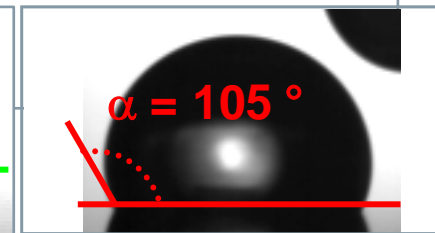
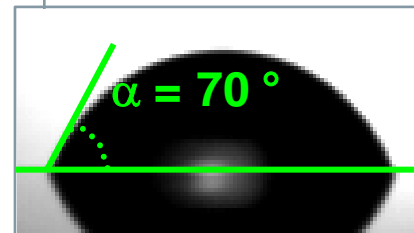
(resist composition, use of top coat, ...)

Hydrophobicity

(material contact angle, material response to water droplets, ...)

Water quality

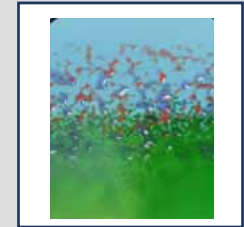
(particles, bacteria, TOC, ...)



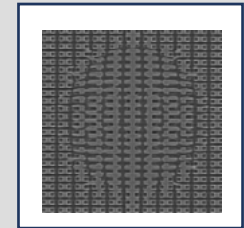
Immersion Lithography

A few challenges

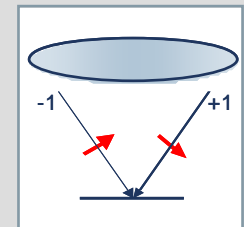
Process interactions



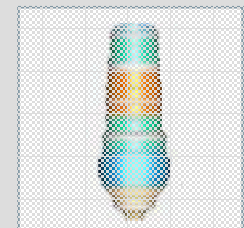
Defectivity



Polarization effects



Lens dimensions



Polarization at high NA

X-polarized (TM)

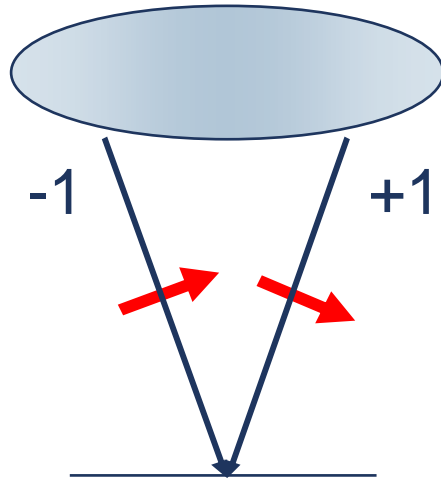


Image contrast 70%

NA=0.6

Angle of incidence
in resist
 20°

Y-polarized (TE)

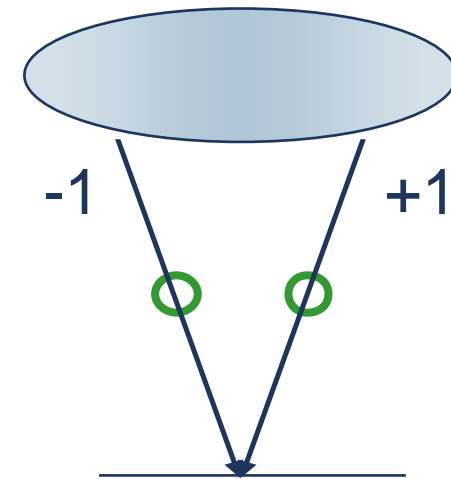
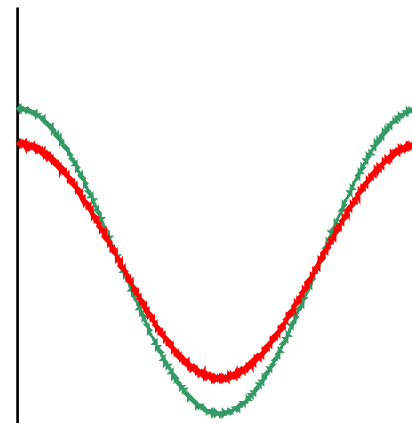


Image contrast 92%



Medium NA (0.6)
in resist ($n=1.7$)

Polarization at high NA

X-polarized (TM)

NA=0.85

Y-polarized (TE)

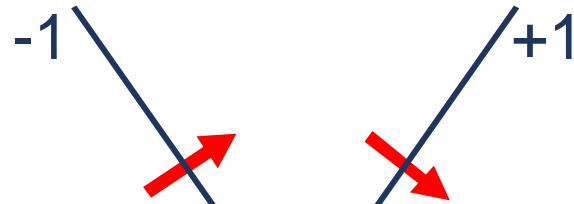
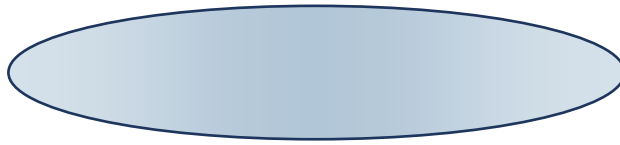


Image contrast 49%

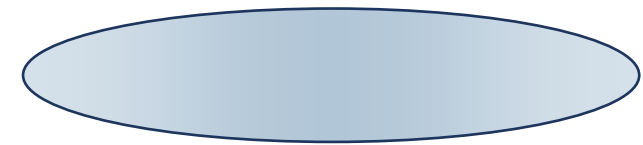
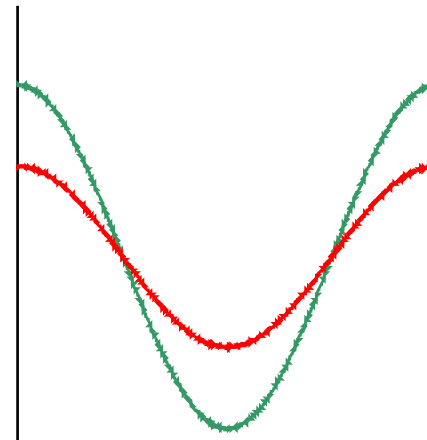


Image contrast 92%

Angle of incidence
in resist
 30°



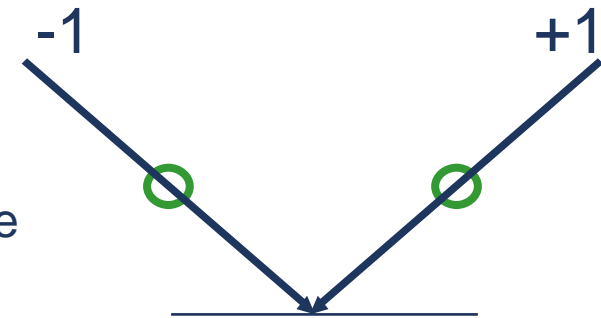
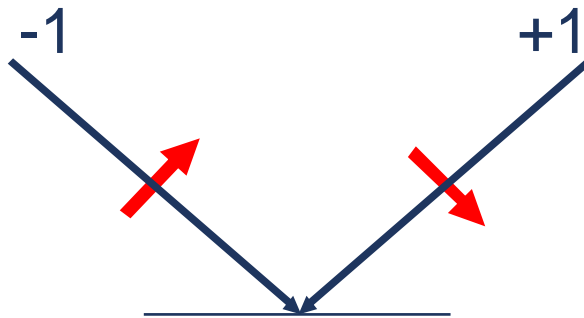
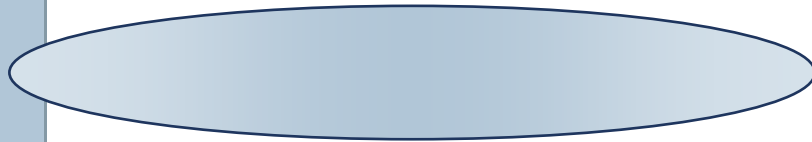
High NA (0.85)
in resist (n=1.7)

Polarization at high NA

X-polarized (TM)

NA=1.3

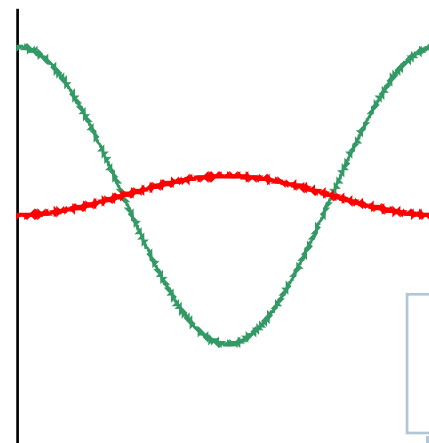
Y-polarized (TE)



Angle of incidence
in resist
50 °

Image contrast -8%

Image contrast 59%



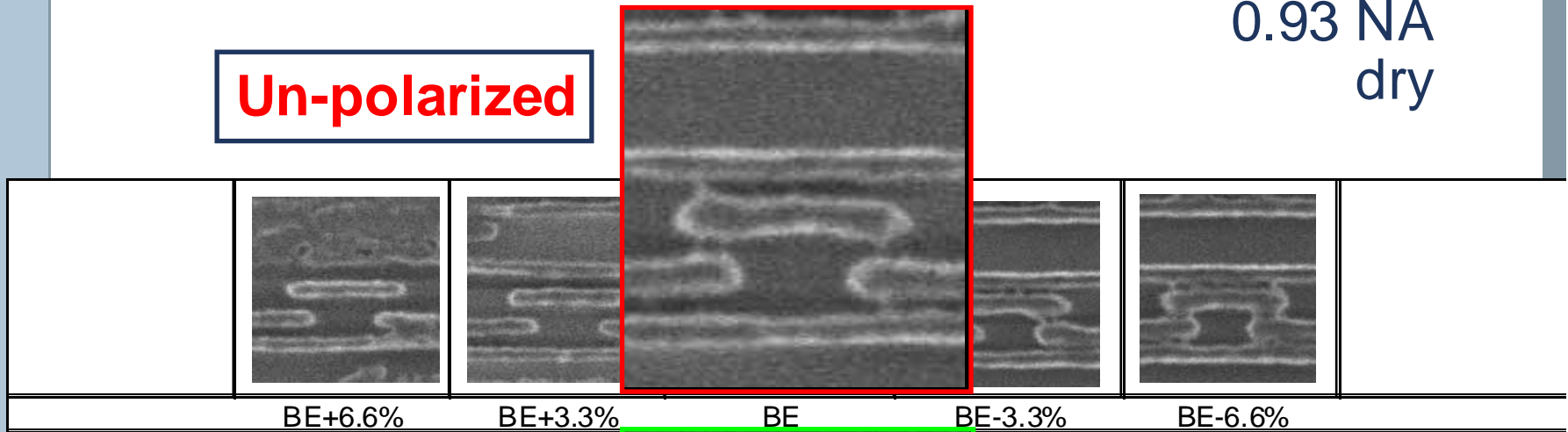
Very High NA (1.3 immersion)
in resist (n=1.7)

Contrast enhancement with polarization

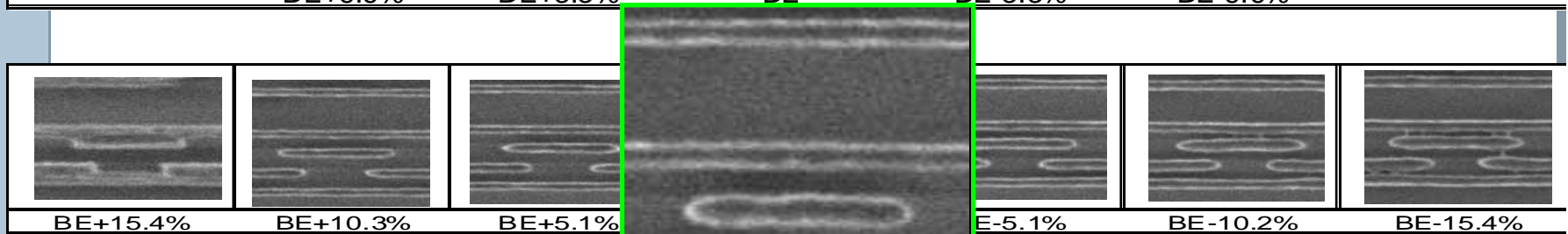
SRAM, half pitch 55 nm, pitch 110 nm, 6% att PSM, dipole Y

0.93 NA
dry

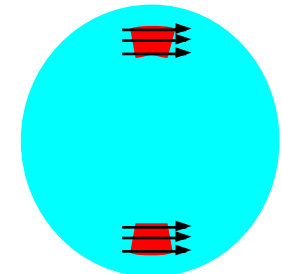
Un-polarized



Polarized



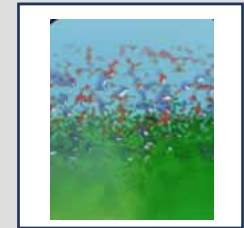
Design adjustments



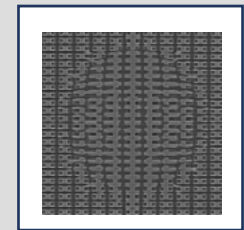
Immersion Lithography

A few challenges

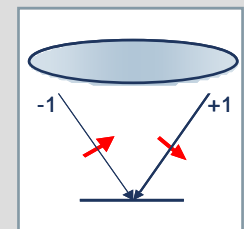
Process interactions



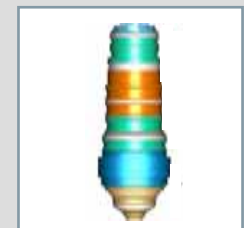
Defectivity



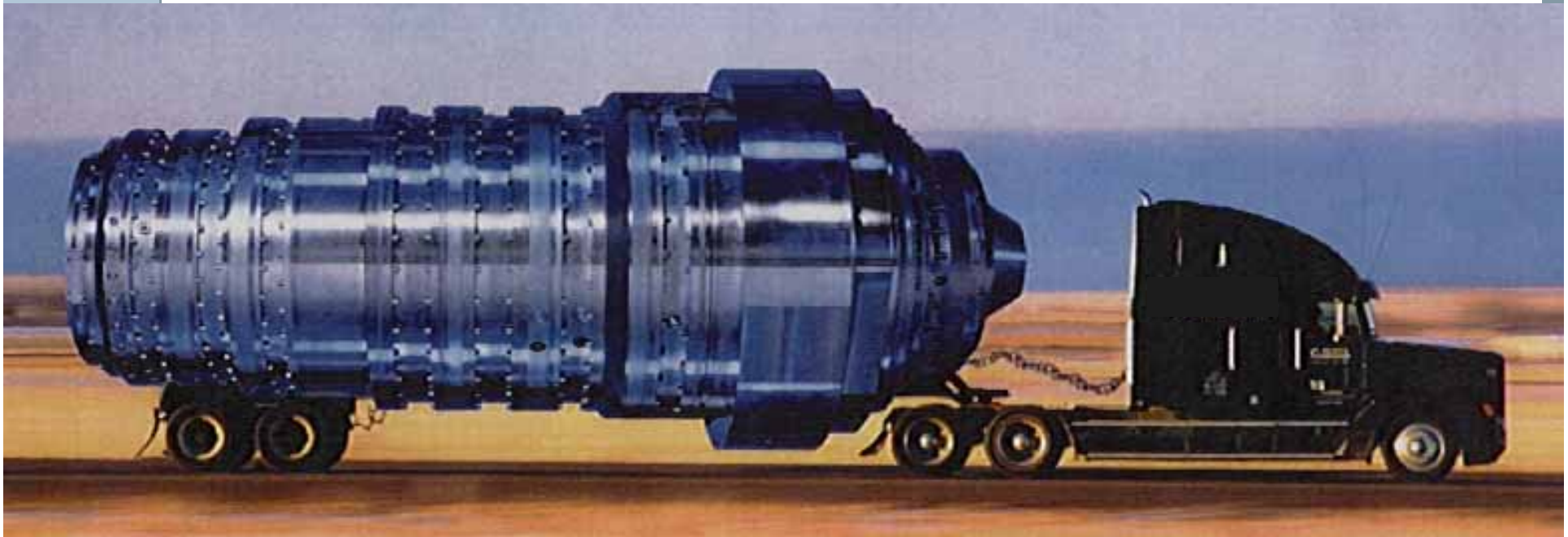
Polarization effects



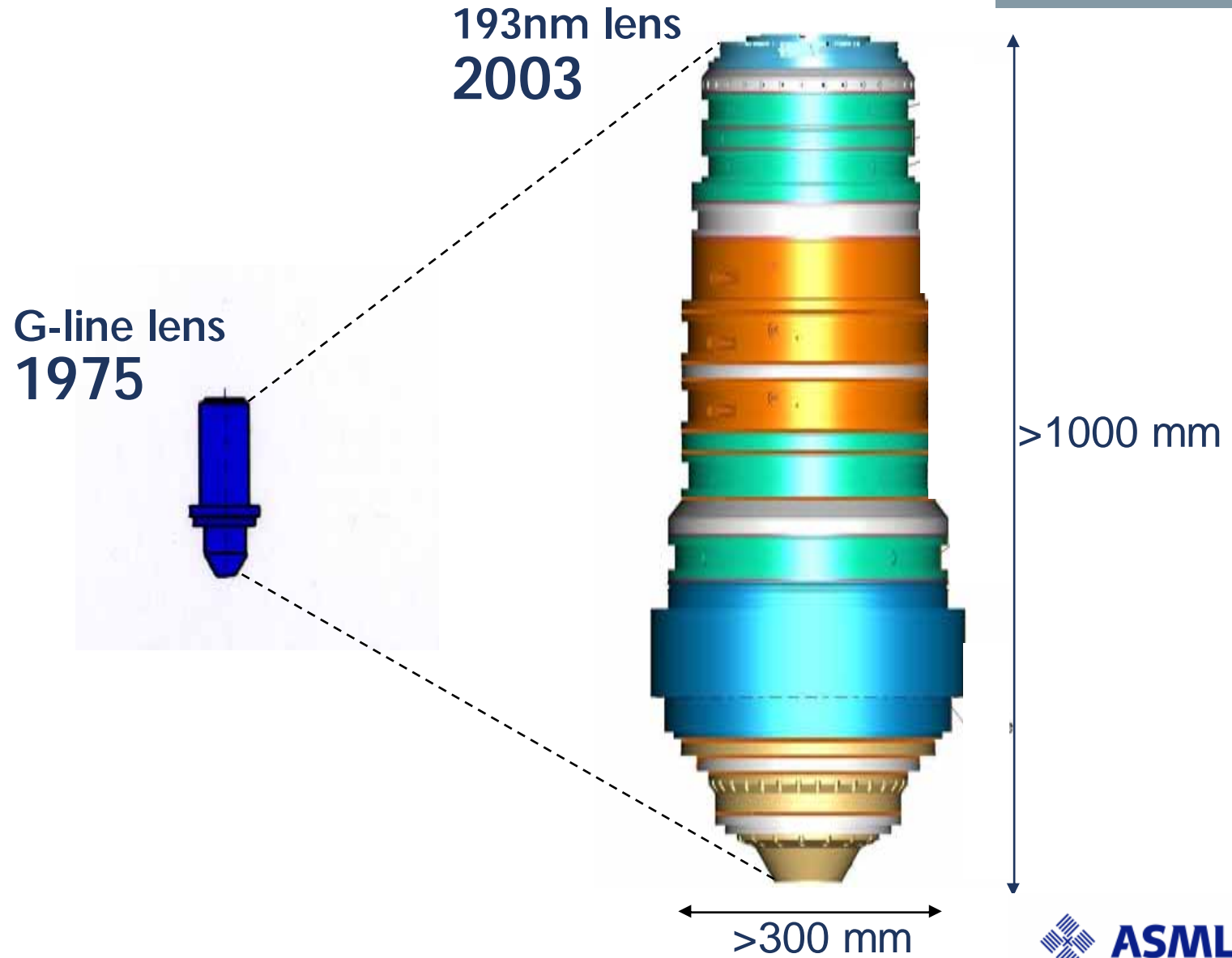
Lens dimensions



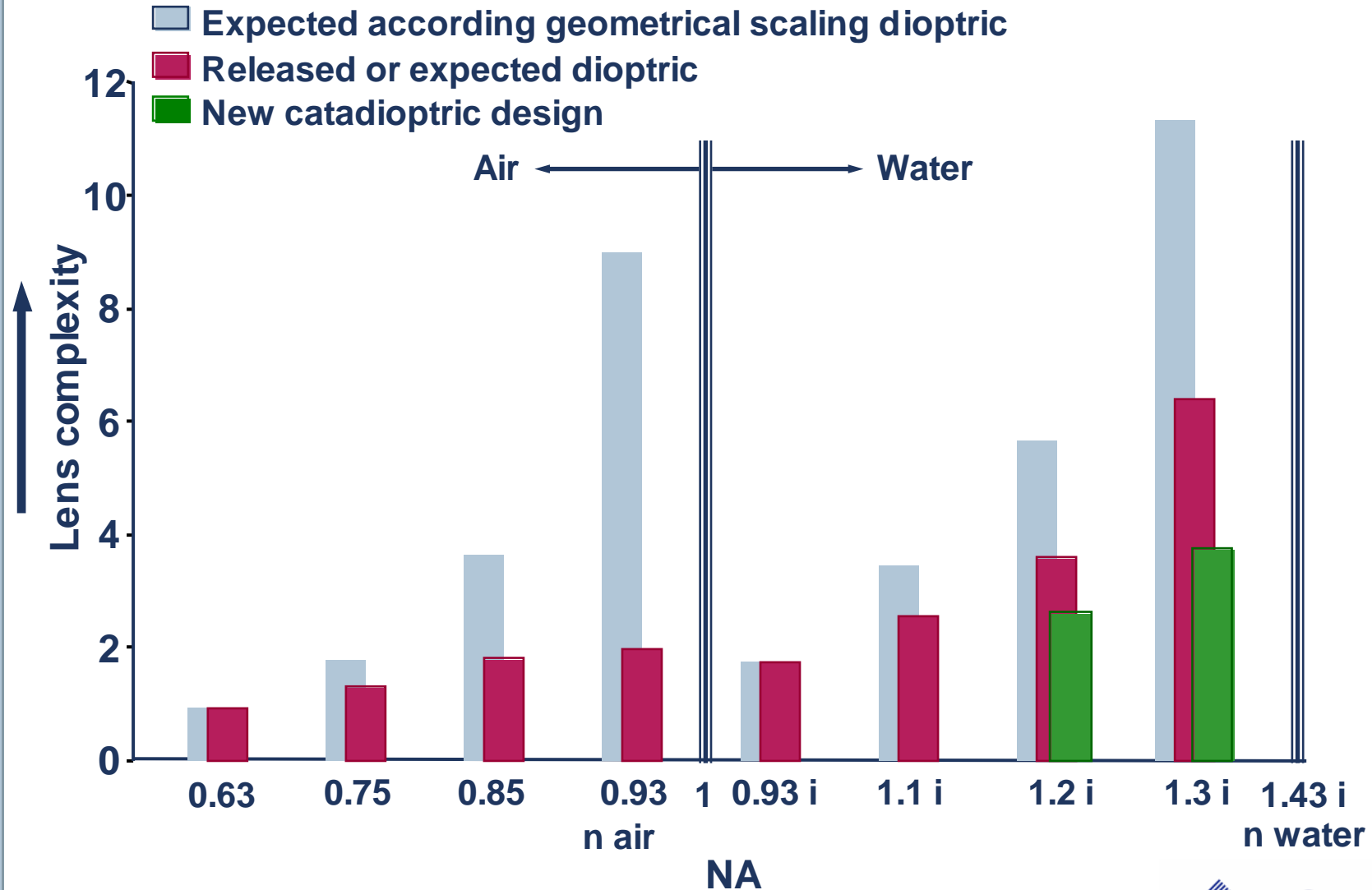
Hyper NA: lens cost



Hyper NA: lens cost



Cost innovations in Optics for hyper NA





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