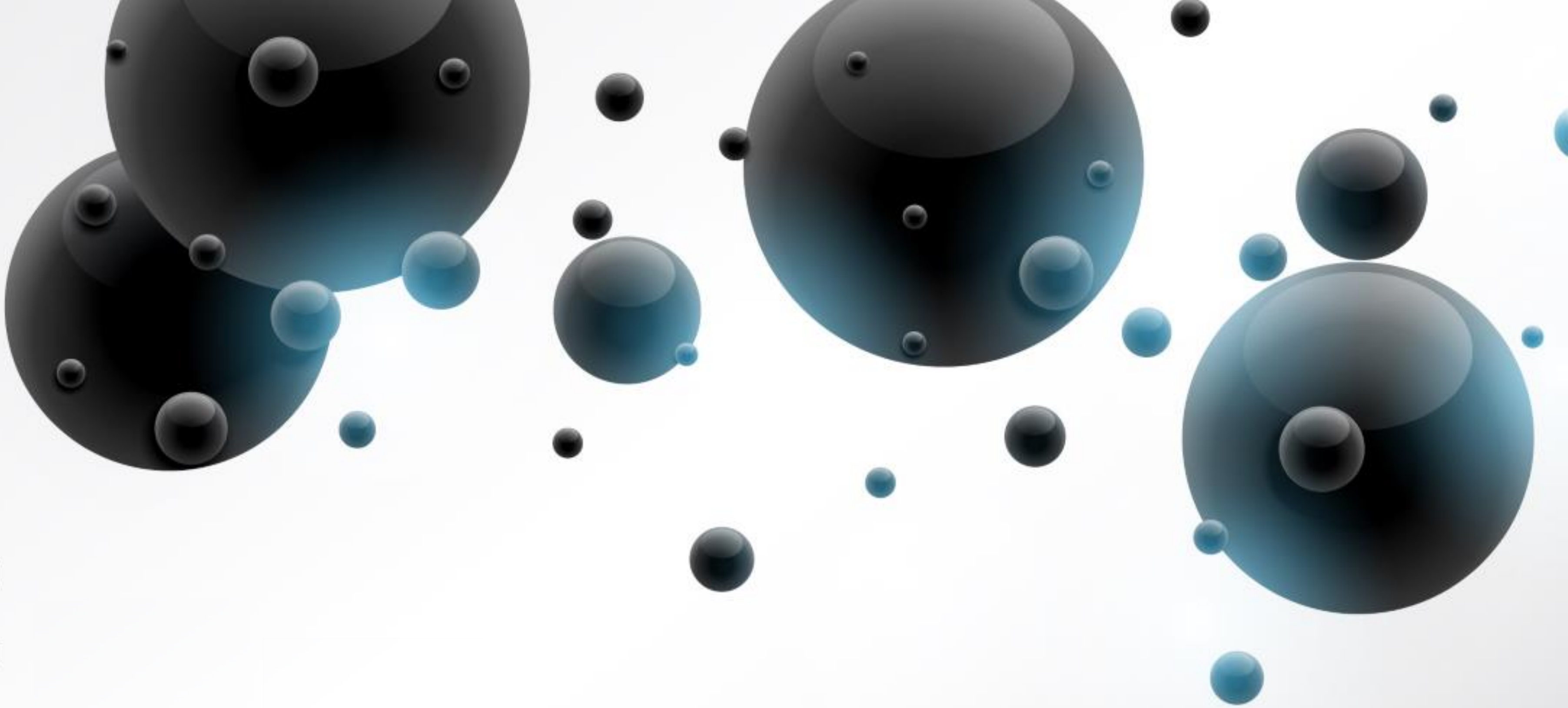


EUV DEVELOPMENTS AT IMEC

DANILO DE SIMONE, PETER DE BISSCHOP, IVAN POLLENTIER, WAIKIN LI, EMILY GALLAGHER, VICKY PHILIPSEN, VINCENT WIAUX, RYOUNG-HAN KIM, ERIC HENDRICKX, GEERT VANDENBERGHE, KURT RONSE, GREG MCINTYRE

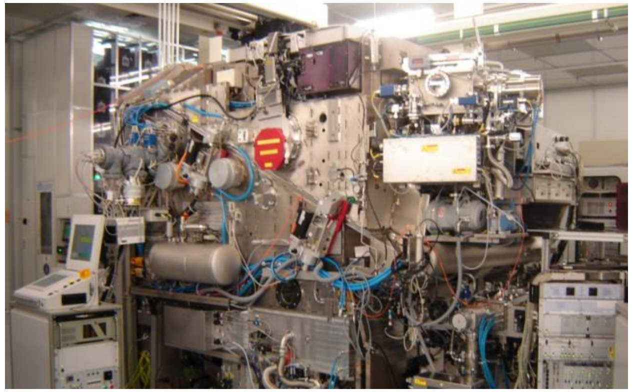
ON BEHALF OF IMEC PATTERNING

15 JUNE 2017, EUVL WORKSHOP, BERKELEY, CA

EUV HISTORY AT IMEC

OVER 10 YEARS OF EUV

EXPOSURE TOOLS AT IMEC



2006 - 2011	2011 - 2015	2014 - present
ASML Alpha-Demo tool 40nm → 27nm LS 0.25 NA	ASML NXE:3100 27nm, 22nm, 18nm LS 0.25 NA	ASML NXE:3300 22, 16, 13nm LS 0.33 NA

NXE:3300
+ TEL Lithius ProZ EUV

NXT:1970i
+ TEL Pro-Zi

NXT:1950i
+ Screen DUO

IMEC ADVANCED PATTERNING ECOSYSTEM…

COLLABORATION HUB FOR THE INDUSTRY

Advanced patterning ecosystem around all sectors essential to advanced patterning

NXE:3300
+ TEL Lithius ProZ EUV

NXT:1970i
+ TEL Pro-Zi

NXT:1950i
+ Screen DUO

ASML
ZEISS
CYMER
TEL
SCREEN
Entegris
EDWARDS
SUSS MicroTec

ASM
SCREEN
Lam RESEARCH
TEL
APPLIED MATERIALS

Exposure clusters

Unit process

Materials
Resist, DSA, Mask

Metrology & inspection

Comp litho

Design & DTCO

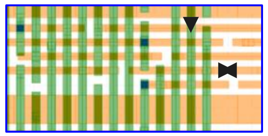
Integration
Logic, Memory

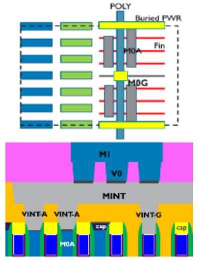
ASML
KLA Tencor
Park SYSTEMS
Hitachi High-Tech
NOVA partnering for process control

Panoramic Technology
Mentor Graphics
NCS
AGC
ASML
SYNOPSYS
KLA Tencor
cadence
COVENTOR

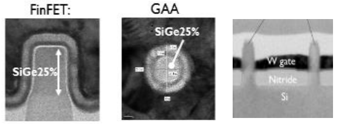
THE UNIVERSITY OF CHICAGO
SUMITOMO CHEMICAL
tok
Shin-Etsu
Brewer Science
MERCK
DNP
SUSS MicroTec
JSR
FUJIFILM
inpria
TOPPAN
ZEISS
NUFLARE
NISSAN Chemical
DONGJIN
RAVE
Micron
GLOBALFOUNDRIES
ADVANCED MASK TECHNOLOGY CENTER

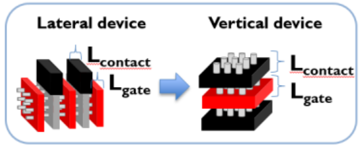
imec

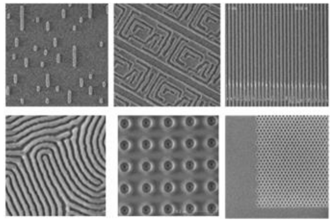


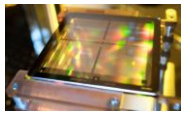


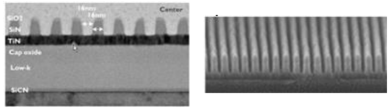
imec



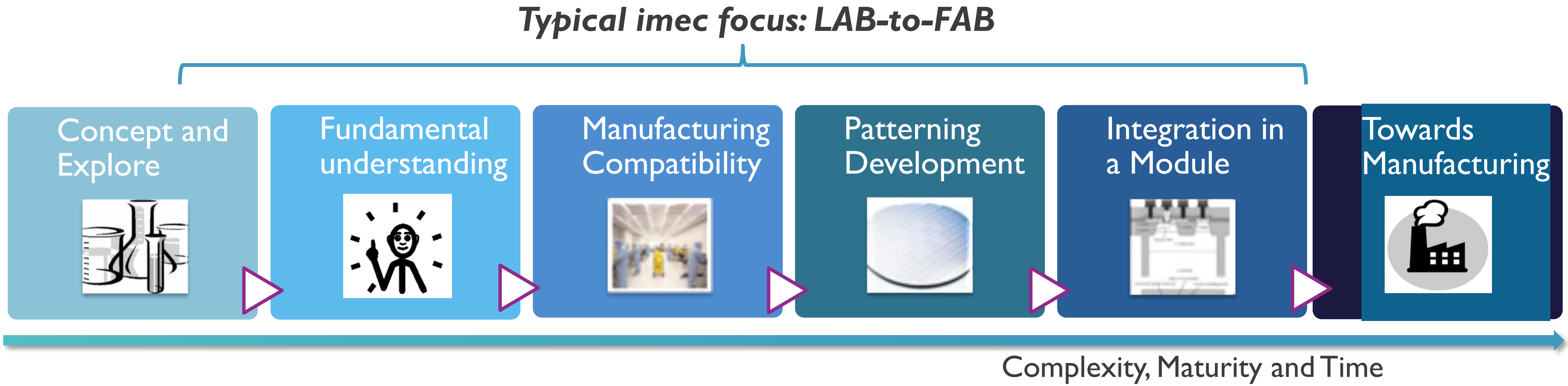








EUV ACTIVITIES AT IMEC: LAB-TO-FAB



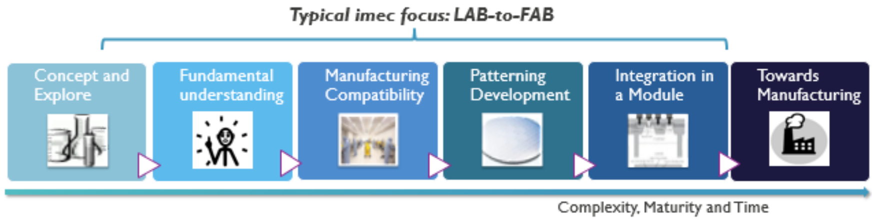
Typical imec focus: LAB-to-FAB

- Concept and Explore
- Fundamental understanding
- Manufacturing Compatibility
- Patterning Development
- Integration in a Module
- Towards Manufacturing

Complexity, Maturity and Time

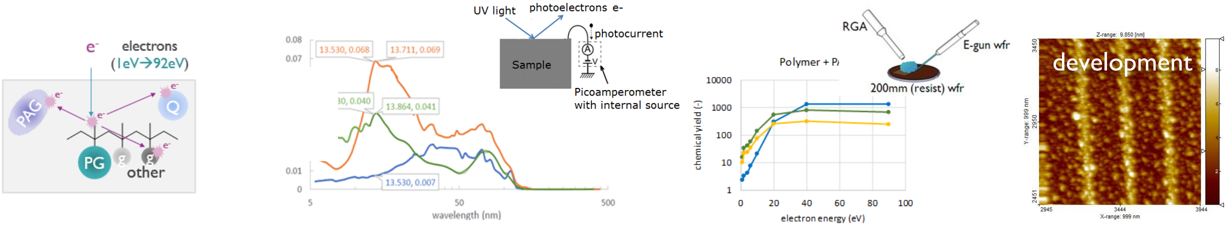
OUTLINE

EUV DEVELOPMENTS AT IMEC

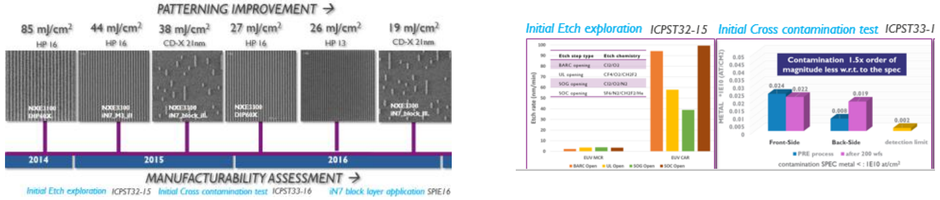


EUV materials and patterning

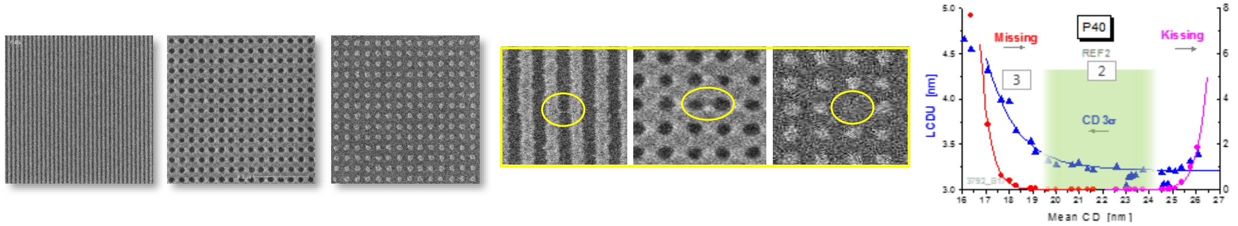
Fundamental understanding



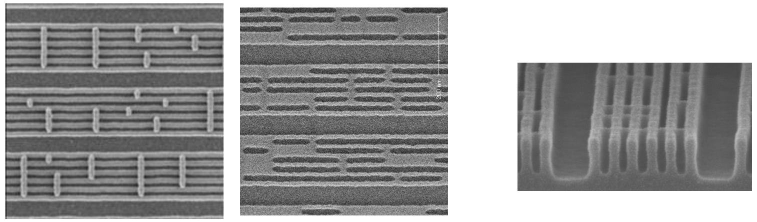
Manufacturing Compatibility



Patterning Development

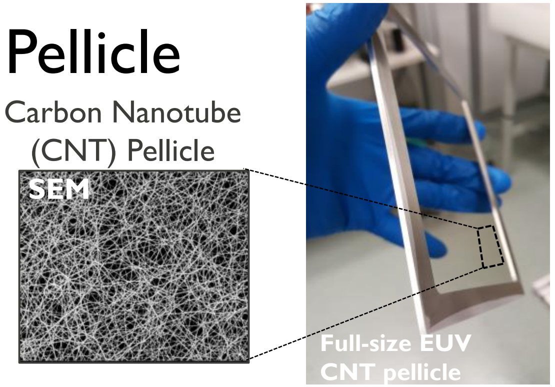


Integration in a Module

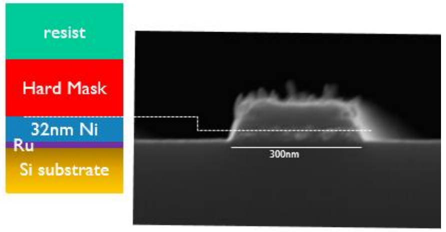


CNT Pellicle

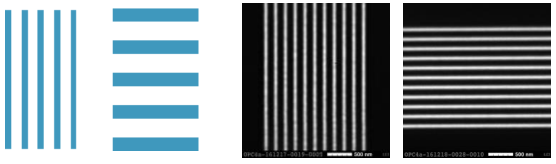
Carbon Nanotube (CNT) Pellicle



Alternate mask absorber



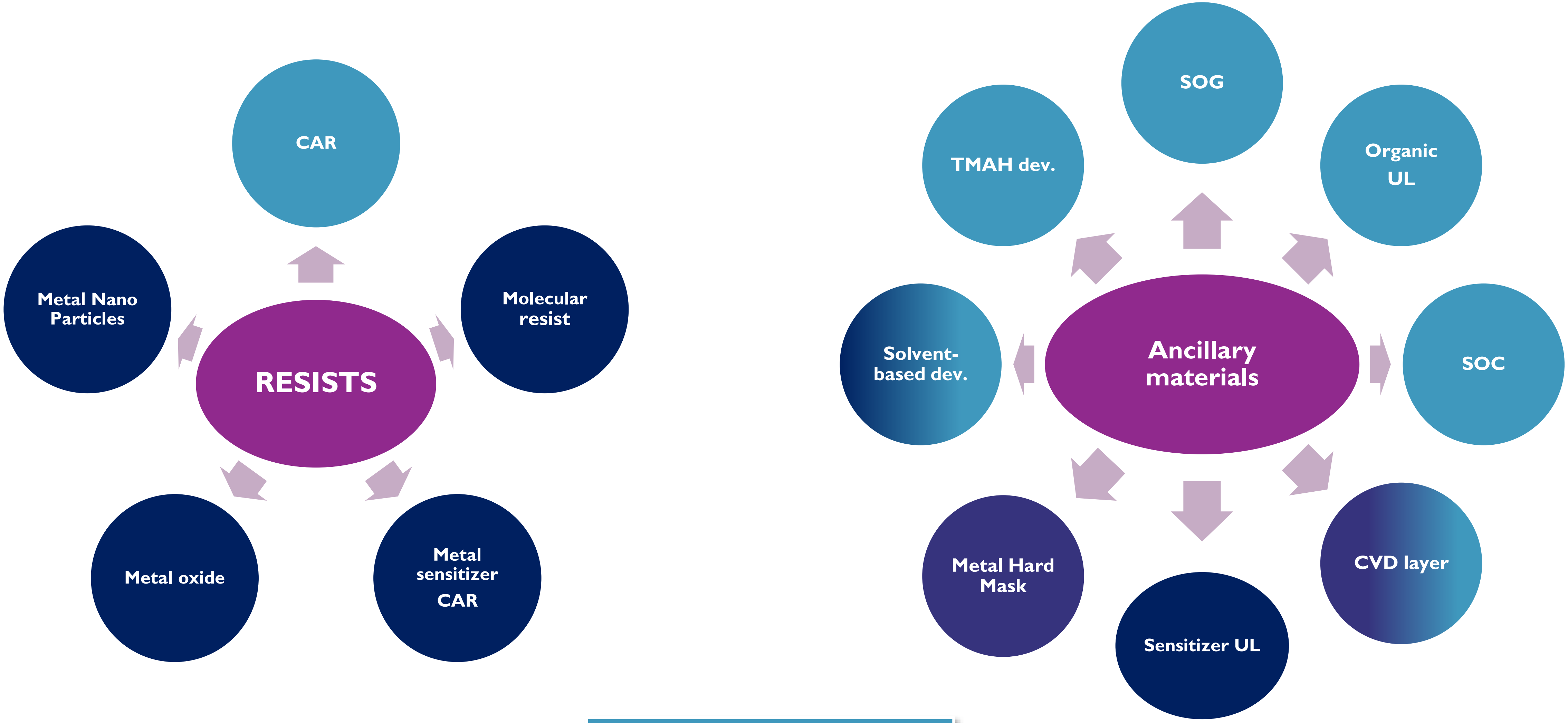
High-NA 3D-mask effects



MASK (4X8) **SHARP (1X1)**

EUV MATERIALS

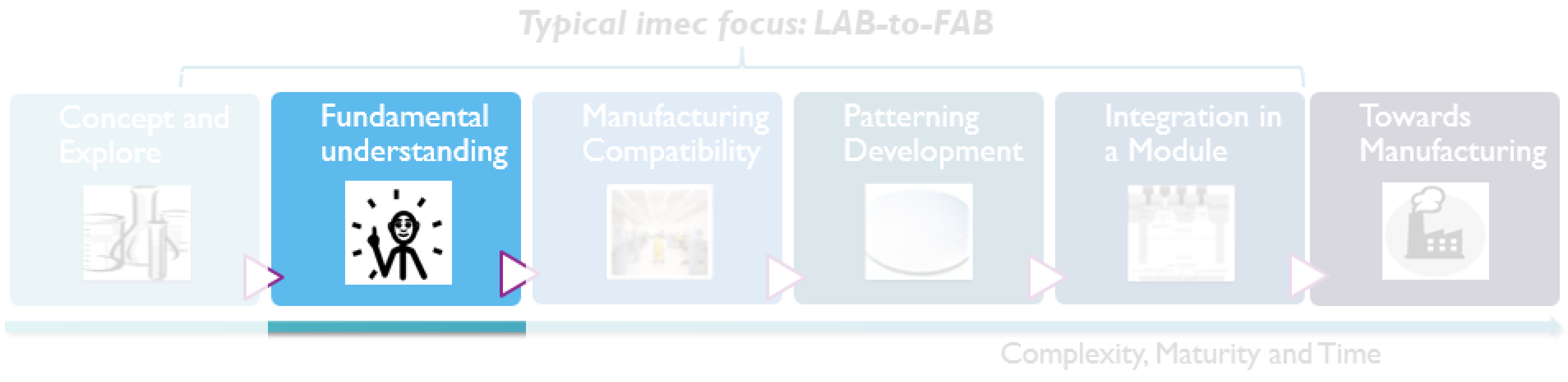
EUV MATERIAL LANDSCAPE TODAY



CAR = Chemically Amplified Resist
MCR = Metal containing Resist
PTD = Positive Tone Developer
NTD = Negative Tone Developer
SOC = Spin On Carbon
SOG = Spin On Glass
UL = underlayer

Legend
Traditional materials
Not traditional materials

FUNDAMENTAL UNDERSTANDING



Typical imec focus: LAB-to-FAB

Concept and Explore

Fundamental understanding

Manufacturing Compatibility

Patterning Development

Integration in a Module

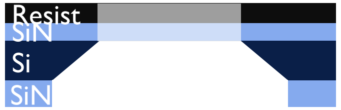
Towards Manufacturing

Complexity, Maturity and Time

FUNDAMENTAL UNDERSTANDING: MEASUREMENT TECHNIQUES

- EUV absorbance
- Total Electron Yield
  Photon emission
- Secondary Electrons, Quantum Efficiency
- Chemical reactions
- Solubility switch

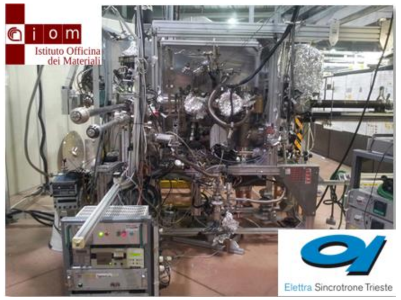
Absorption & Electron Yield Measurements at Elettra Synchrotron



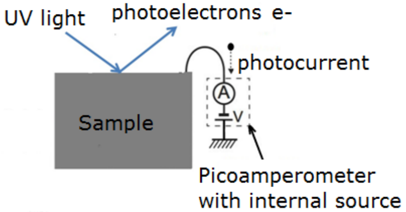
membrane sample prep. with resist on top

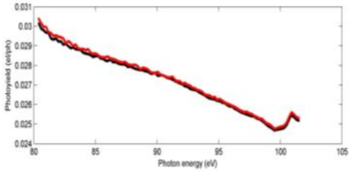
resist on bare silicon

Resist characterization



Bear line: XAS 85eV – 110eV

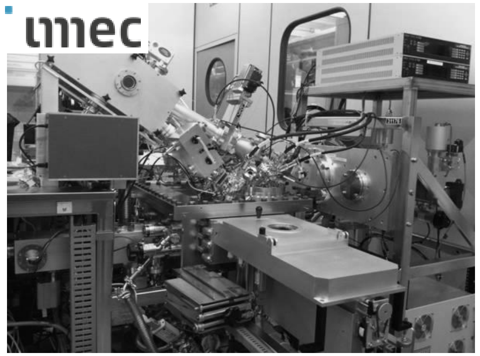


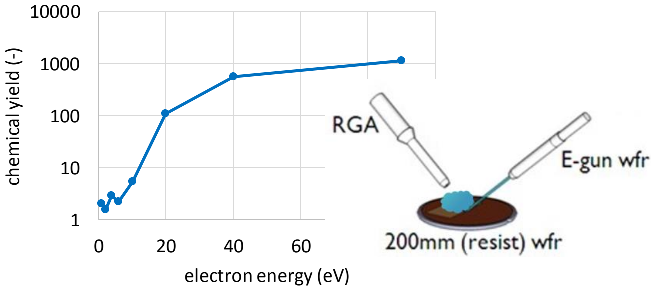


D. De Simone et al. Photopolymer conference 2016

High-Speed Atomic Force Microscope

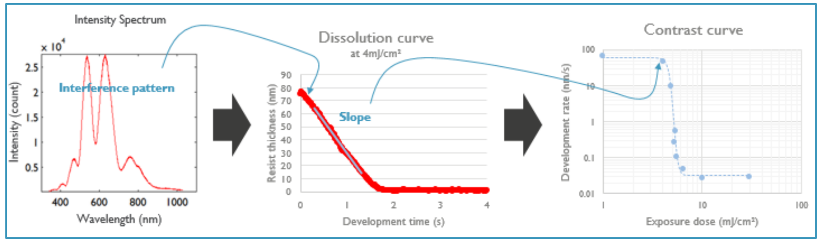
Chemical reactions with low-energy electron gun





I. Pollentier et al. upcoming EUVL symposium 2017

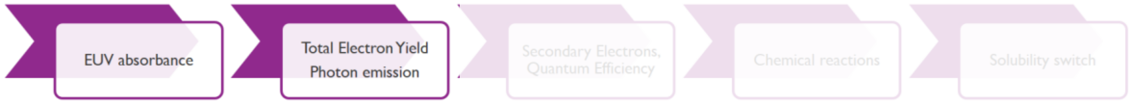
Dissolution Rate Monitor



Y. Vesters et al. EUVL symposium 2016

FUNDAMENTAL UNDERSTANDING

LIGHT-RESIST INTERACTION



EUV absorbance

Total Electron Yield Photon emission

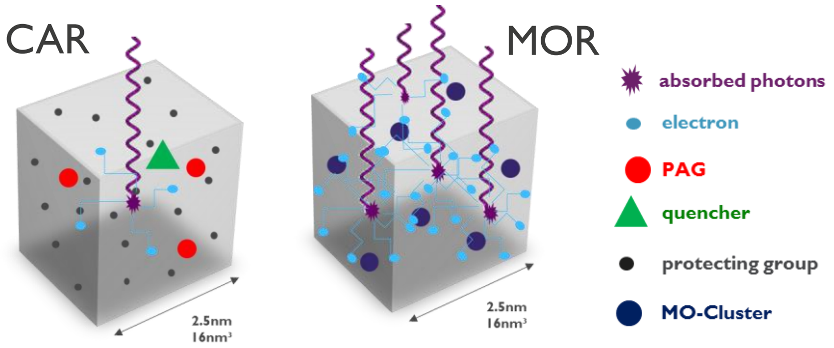
Secondary Electrons, Quantum Efficiency

Chemical reactions

Solubility switch

More photons are absorbed and more total electrons are generated within Inpria resist than with CAR

However, CAR electron efficiency looks higher

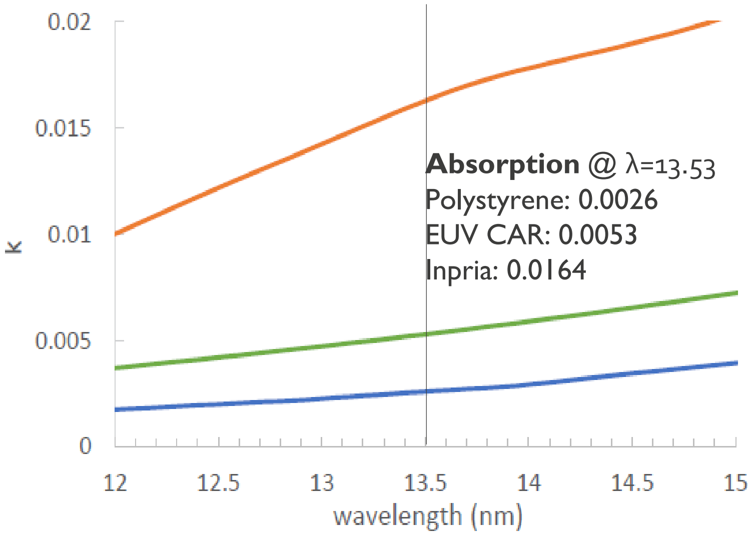


Polystyrene (control)

INPRIA

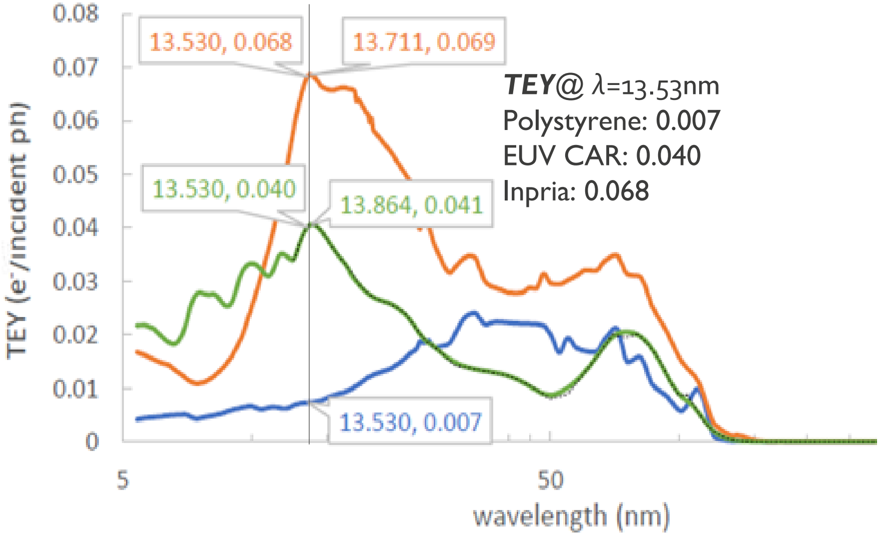
EUV CAR

Absorption



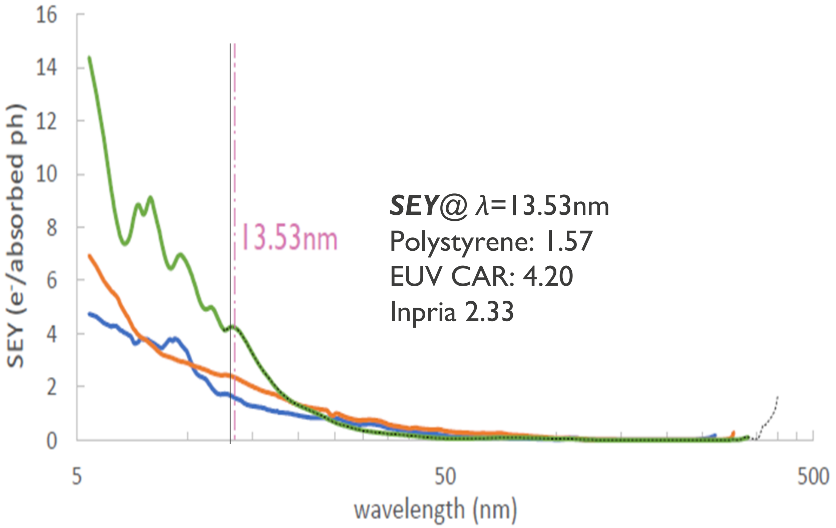
Absorption @ λ=13.53
Polystyrene: 0.0026
EUV CAR: 0.0053
Inpria: 0.0164

Total Electron Yield



TEY@ λ=13.53nm
Polystyrene: 0.007
EUV CAR: 0.040
Inpria: 0.068

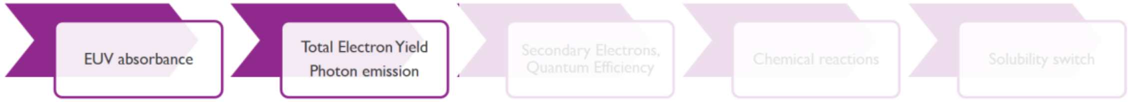
Secondary Electron Yield



SEY@ λ=13.53nm
Polystyrene: 1.57
EUV CAR: 4.20
Inpria 2.33

FUNDAMENTAL UNDERSTANDING

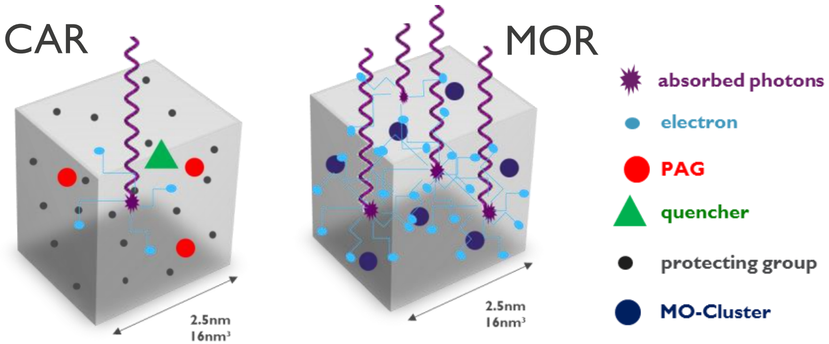
LIGHT-RESIST INTERACTION



More photons are absorbed and more total electrons are generated within Inpria resist than with CAR

However, CAR electron efficiency looks higher

... so, the chemistry matters

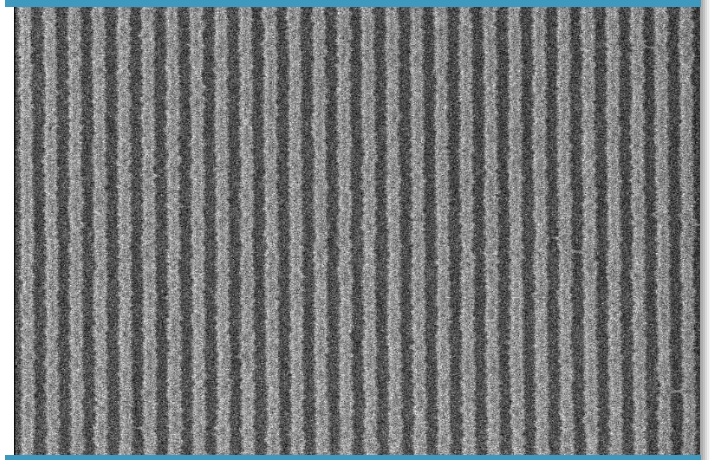


comparable Dose-to-Size (~21mJ/cm^2), 32nm pitch

CAR

LWR 5.4nm

$\alpha = 3.6\ \mu m^{-1}$

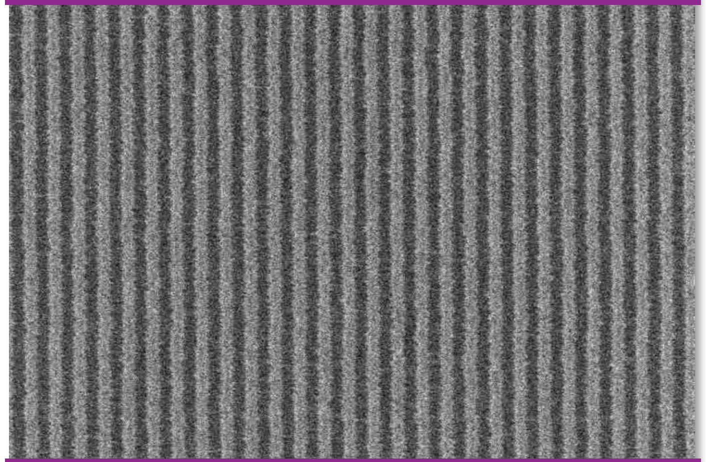


Chemically Amplified

MOR

LWR 5.2nm

$\alpha = 14.6\ \mu m^{-1}$



Not Chemically Amplified

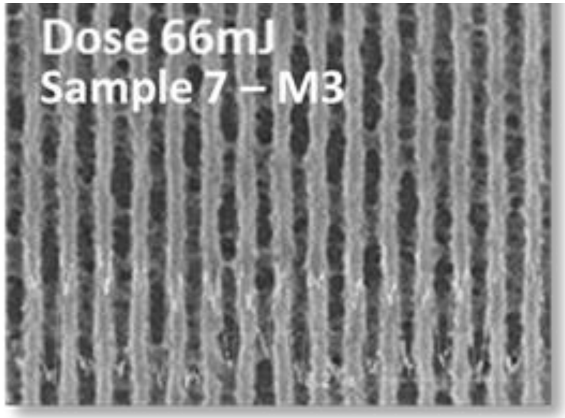
FUNDAMENTAL UNDERSTANDING
LIGHT-RESIST INTERACTION

EUV absorbance
Total Electron Yield
Photon emission
Secondary Electrons,
Quantum Efficiency
Chemical reactions
Solubility switch

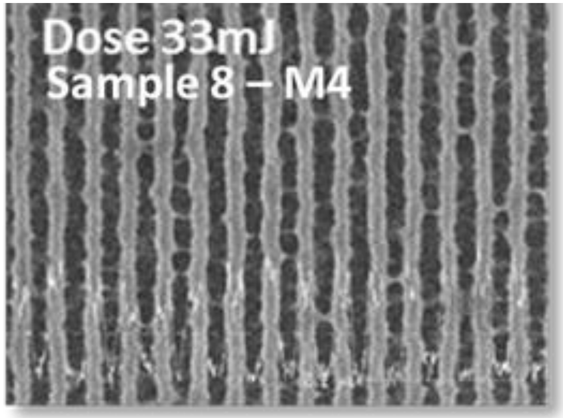
… so, the chemistry matters

other metal containing resists have shown very poor patterning performance

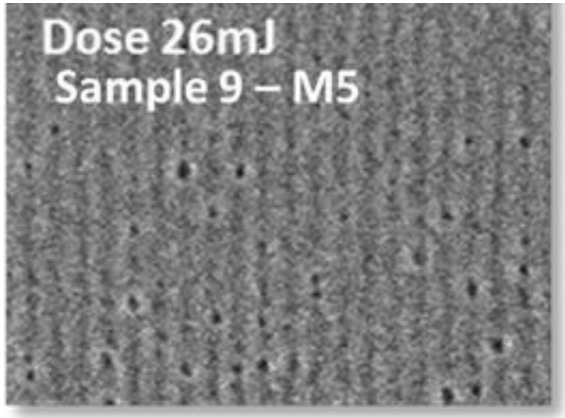
44nm pitch



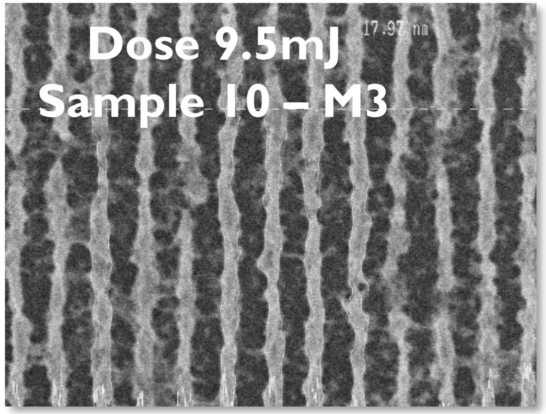
44nm pitch



44nm pitch



54nm pitch



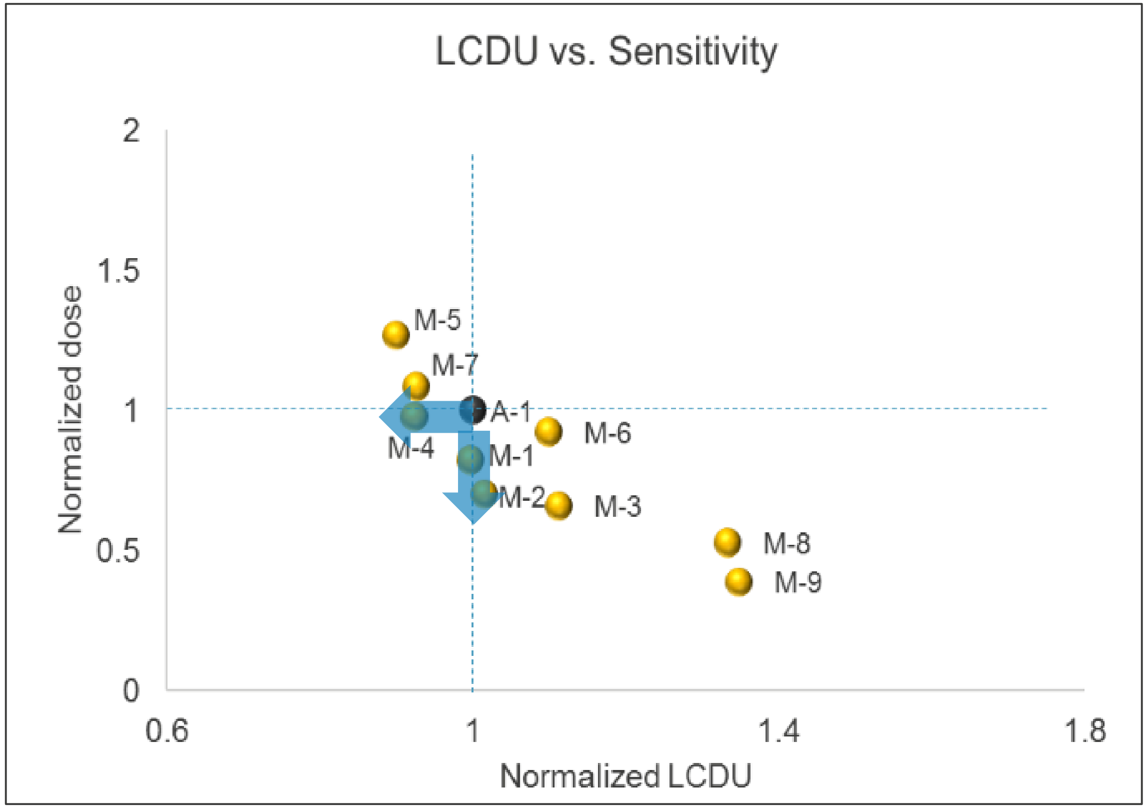
D.. De Simone et al. SPIE 2016

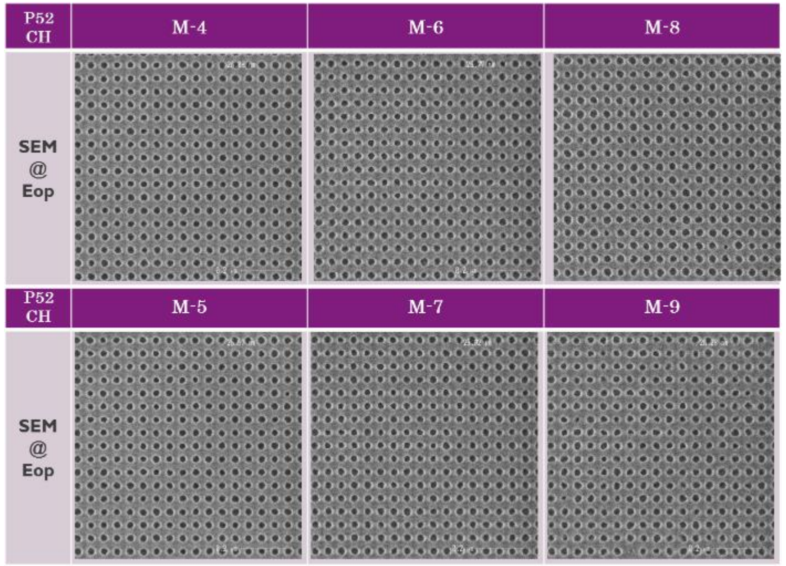
FUNDAMENTAL UNDERSTANDING

METAL SENSITIZER IN CAR

EUV absorbance → Total Electron Yield Photon emission → Secondary Electrons, Quantum Efficiency → Chemical reactions → Solubility switch

Metals can provide a knob to tune sensitivity or LCDU, but appropriate chemistry design is required





Resist Code	PAG	Quencher	ALU	Metal	Sensitivity Improve
A-1 ref CAR	x1	x1	x1	x0	0
M-1	x1	x1	x1	x1	28%
M-2	x1	x1	x1	x2	30%
M-3	x1	x1	x1	x3	34%
M-4	x1	PDQ3	x1	x2	22%
M-5	x1	PDQ4.5	x1	x2	10%
M-6	x1	x2	x1	x2	20%
M-7	x1	x3	x1	x2	28%
M-8	x1	x1	x1.3	x2	23%
M-9	x1	x1	x1.3 Less Hydrophobic	x2	19%

J. Jiang et al. Photopolymer conference 2017

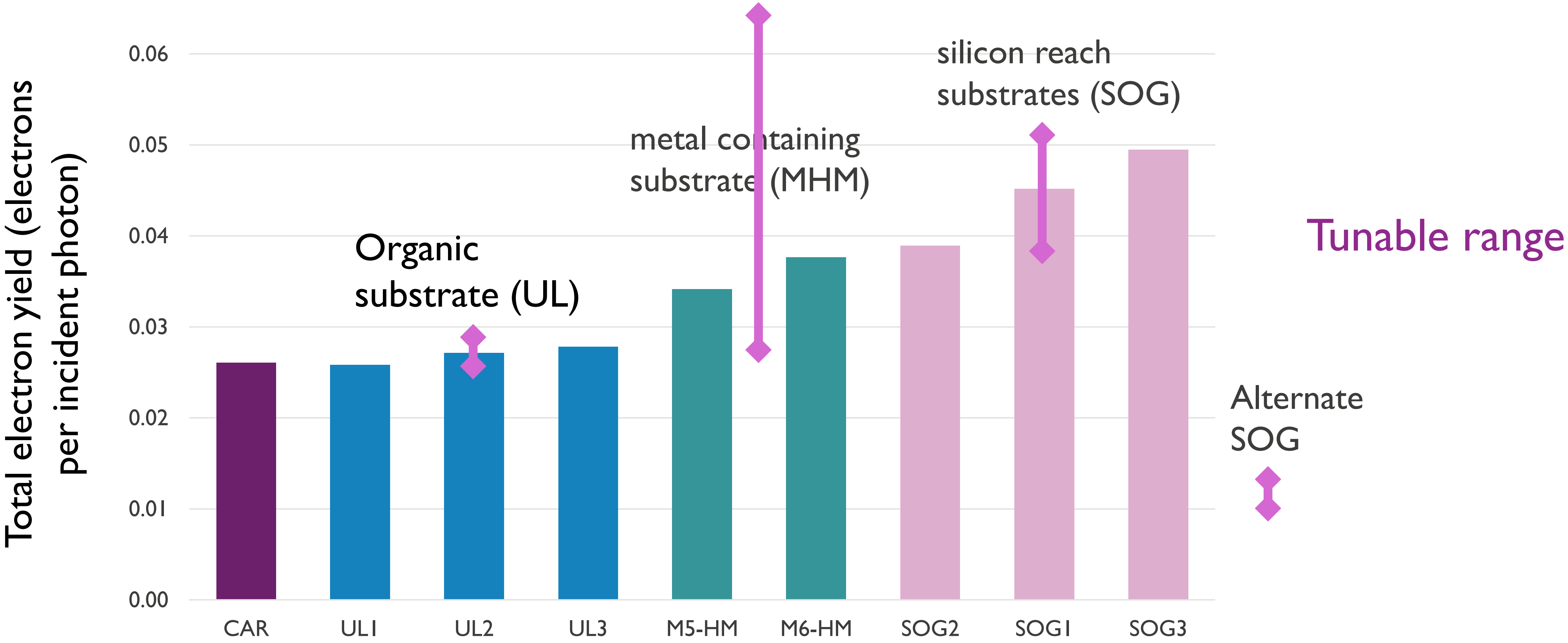
FUNDAMENTAL UNDERSTANDING

EFFECTS OF THE SUBSTRATE

EUV absorbance
Total Electron Yield
Photon emission
Secondary Electrons, Quantum Efficiency
Chemical reactions
Solubility switch

Electron yield measurements show dependence of resist substrate

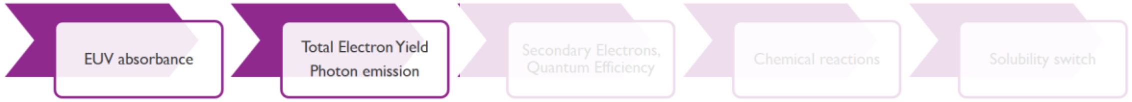
Electron yield of substrates can often be tuned



D.. De Simone et al. SPIE 2017

FUNDAMENTAL UNDERSTANDING

EFFECTS OF THE SUBSTRATE

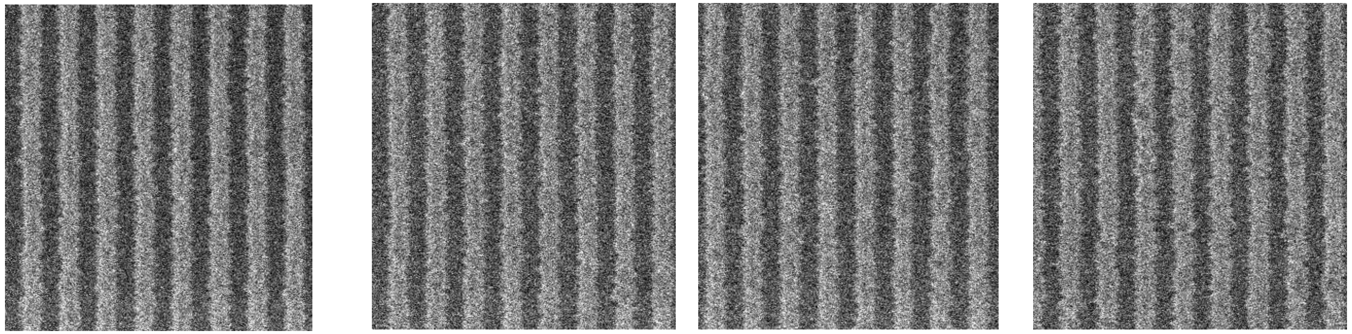


Dose to size correlates with electron yield when in presence of Metals

Substrate offers a potential improvement knob.

....but trade-offs typically exist (case I on TEY, Dose and LWR)

	Organic UL		**Metal 1 HM**	**Metal 2 HM proc.-A**	**Metal 2 HM proc.-B**	**Impact on DtS & LWR**



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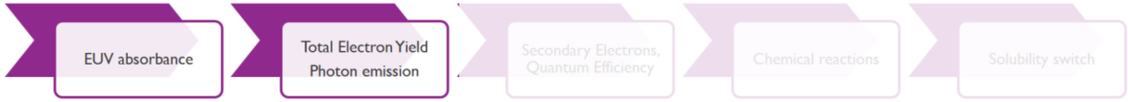
FUNDAMENTAL UNDERSTANDING

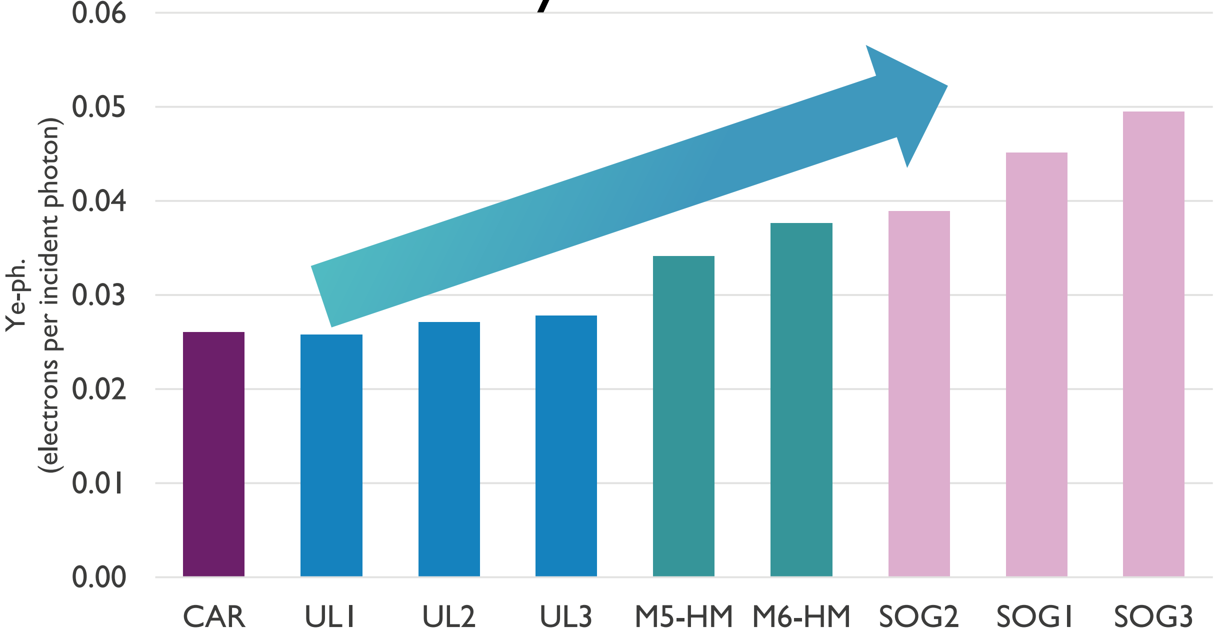
EFFECTS OF THE SUBSTRATE



Dose to size correlates with electron yield when in presence of Metals

Substrate offers a potential improvement knob.

....but trade-offs typically exist (case II on TEY and DoF)



Total electron yield vs. resist substrate

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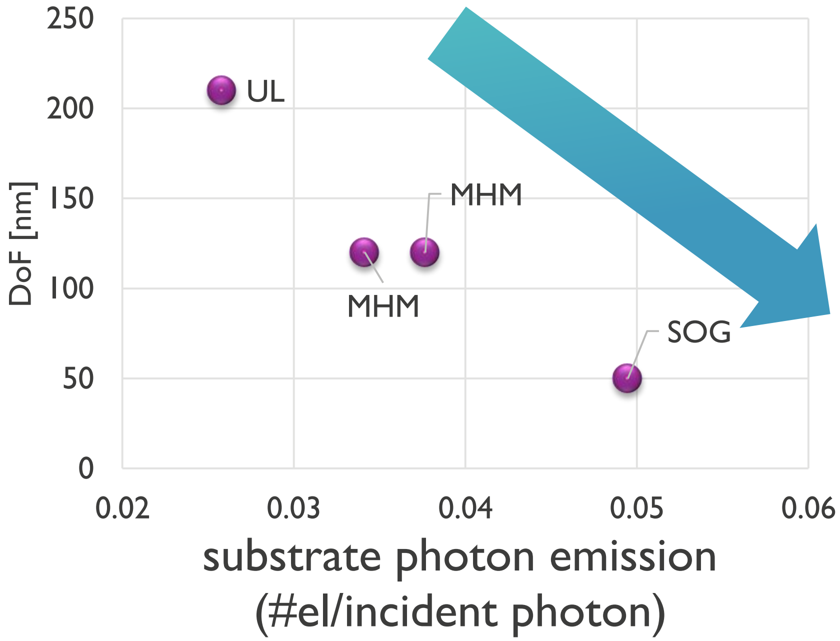
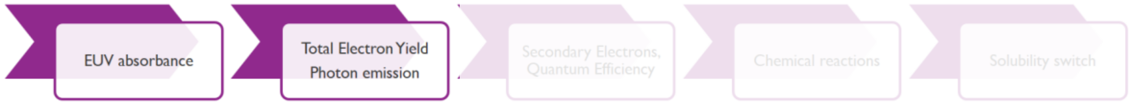


Depth of Focus vs. electron yield

FUNDAMENTAL UNDERSTANDING

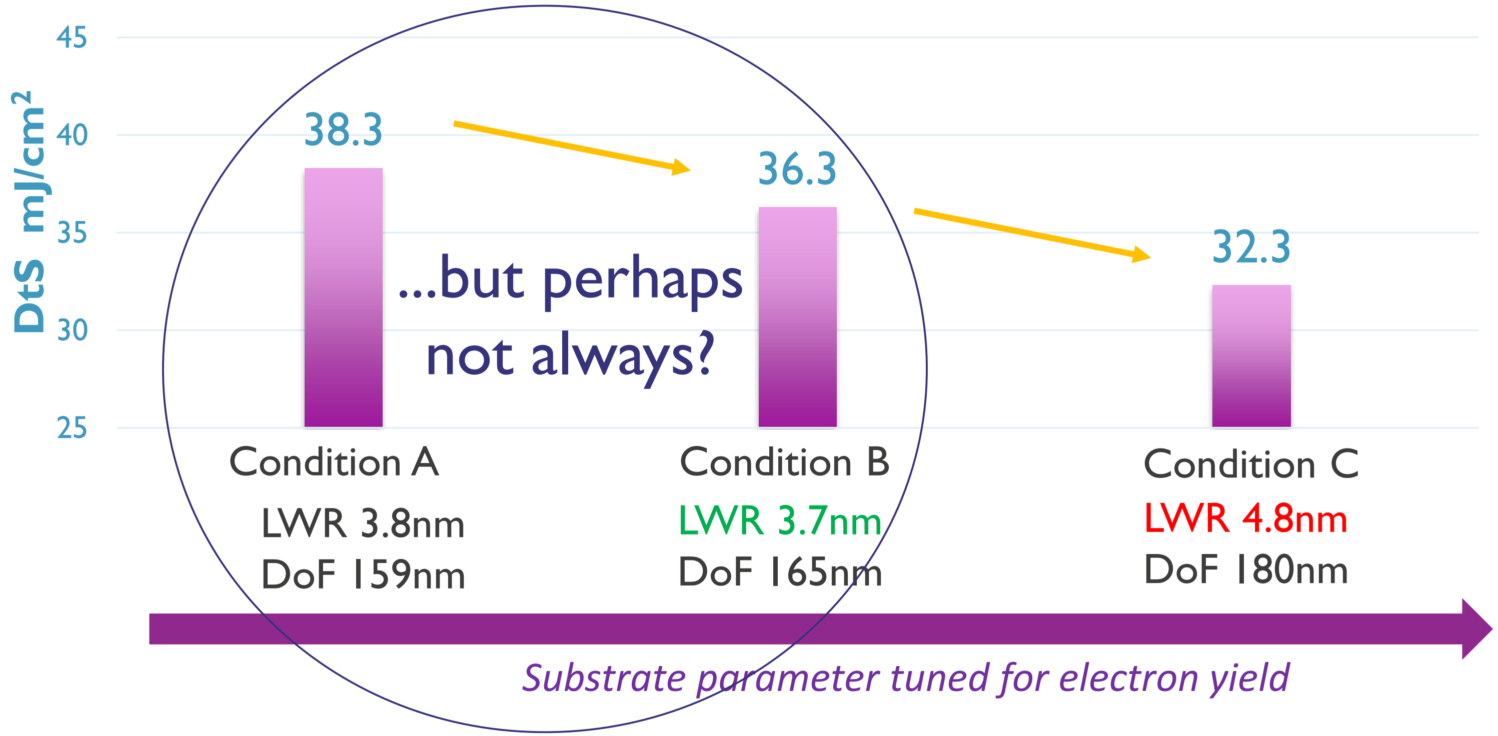
EFFECTS OF THE SUBSTRATE



Dose to size can correlate with electron yield

Substrate offers a potential improvement knob.

....but trade-offs typically exist (case III on TEY, Dose, LWR and DoF)



...but perhaps not always?

Substrate parameter tuned for electron yield

DoF @ 8%EL
CD tg 16nm +/- 5%
Pitch 32nm

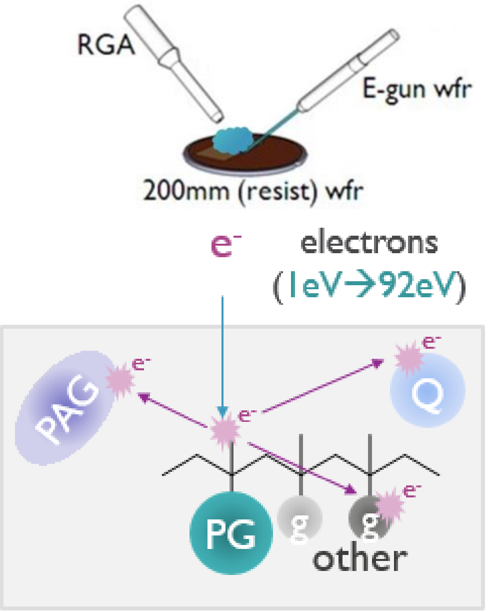
FUNDAMENTAL UNDERSTANDING

ELECTRON – RESIST INTERACTION WITH LOW ENERGY E-GUN

Chemistry happens at very low electron energies (~1eV)

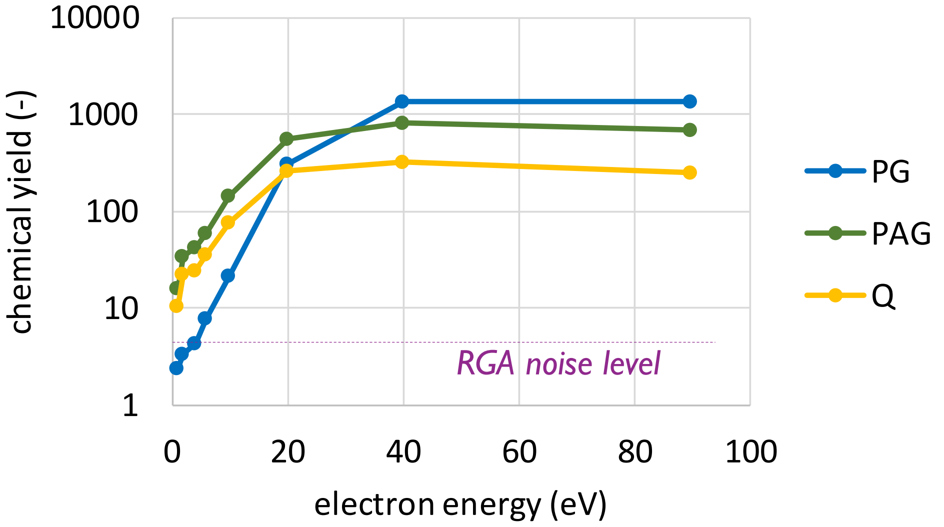
Even without a PAG, electrons can deprotect the polymer

Potential means to screen polymers and understand their role in nanobridges

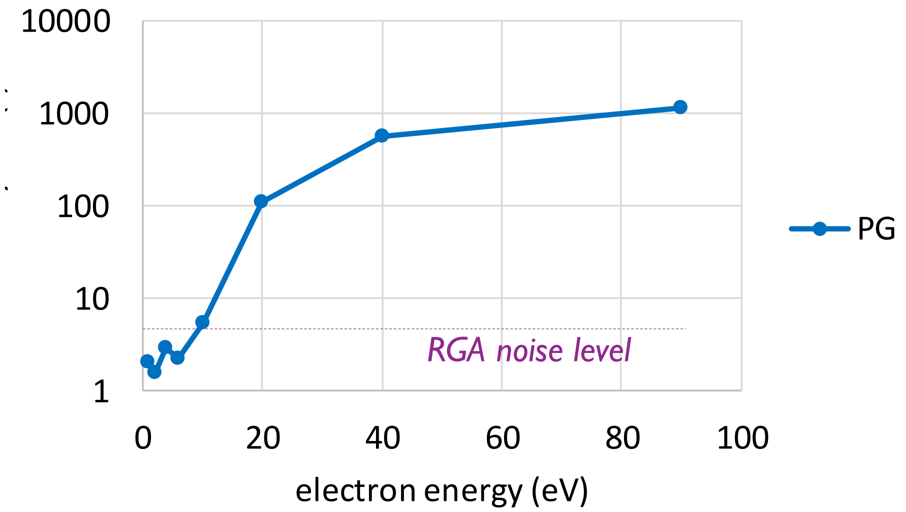


Chemical yield determined from outgassing by RGA during exposure with electrons of selected energy

Chemical Yield vs. electron energy (polymer + PAG + Quencher)



Chemical Yield vs. electron energy (polymer only)



I. Pollentier et al. upcoming EUVL symposium 2017

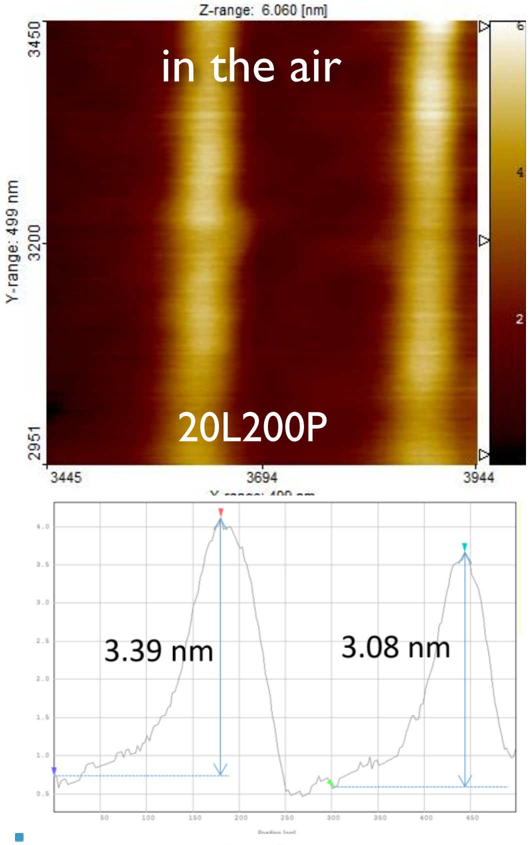
FUNDAMENTAL UNDERSTANDING

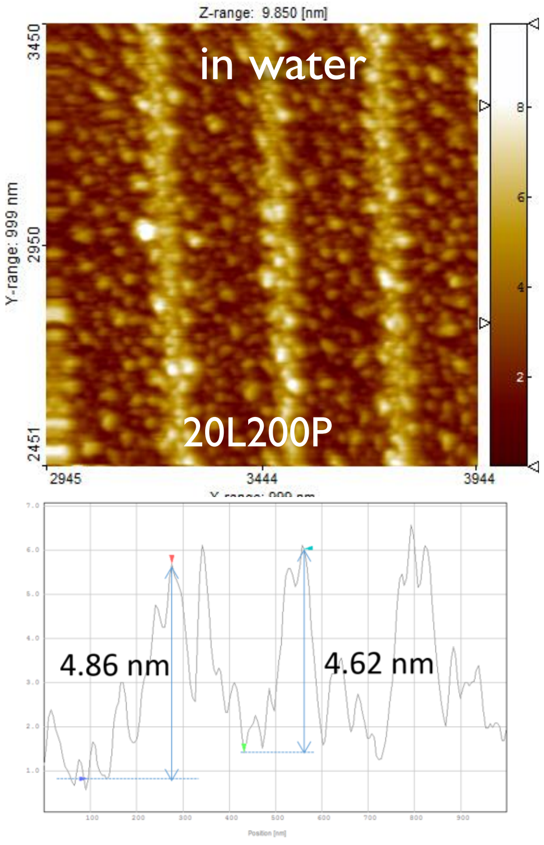
HIGH SPEED ATOMIC FORCE MICROSCOPE TO PROBE EUV RESIST DEVELOPMENT

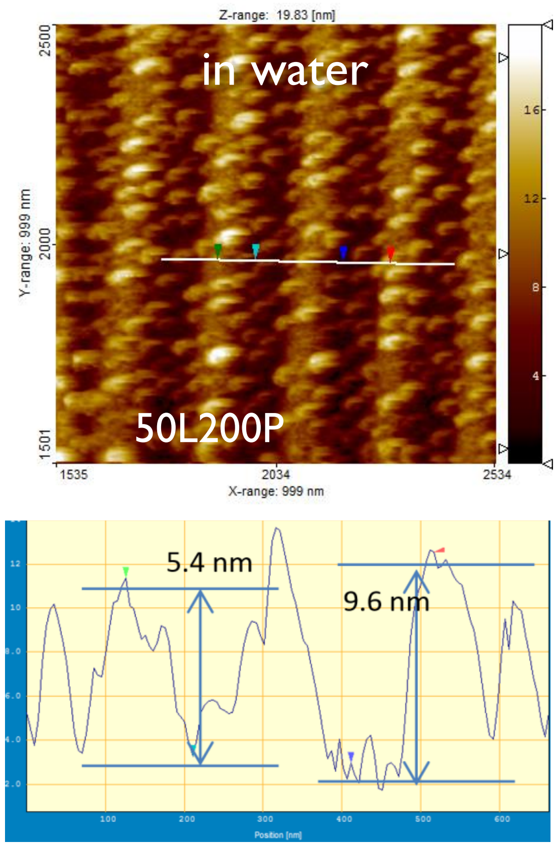
Initial wetting causes partial dissolution and swelling

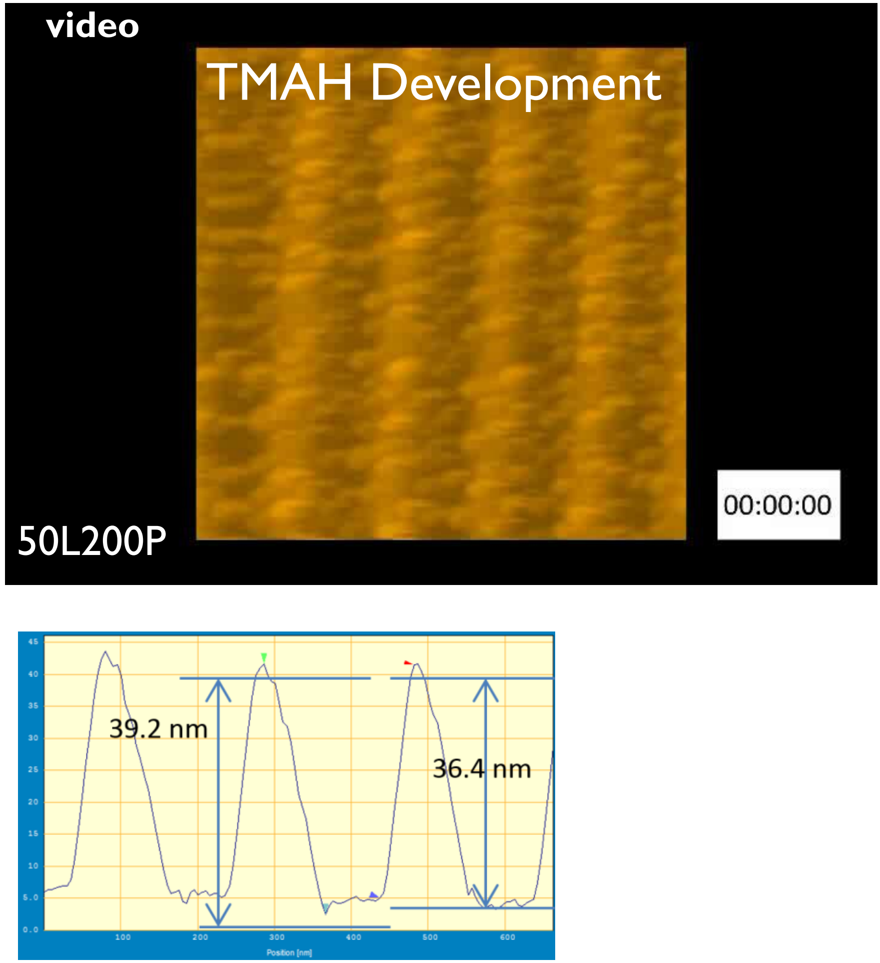
Non-homogeneity propagates throughout development

Further understanding may reveal chemical stochastics

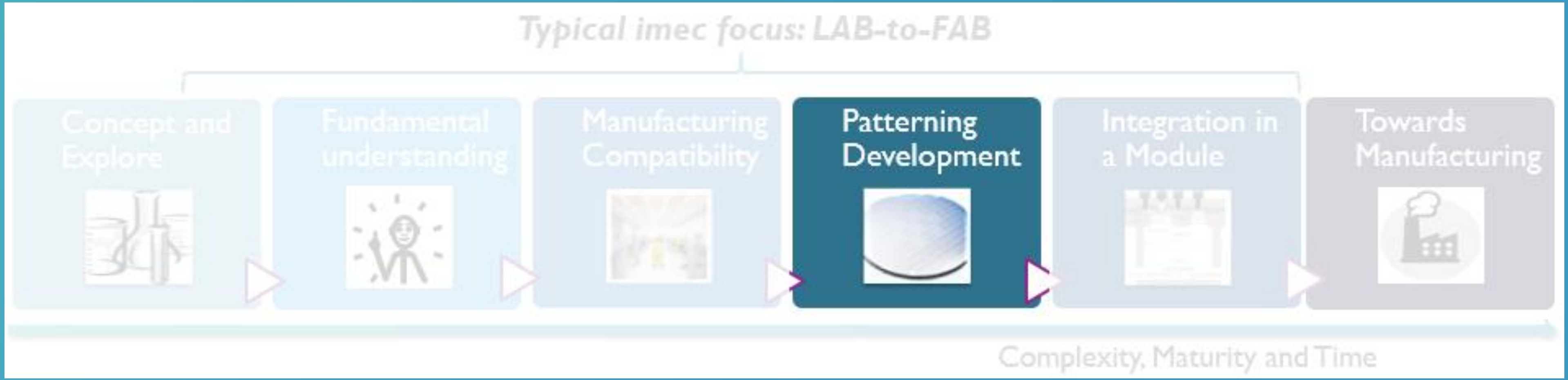








PATTERNING



Typical imec focus: LAB-to-FAB

Concept and Explore

Fundamental understanding

Manufacturing Compatibility

Patterning Development

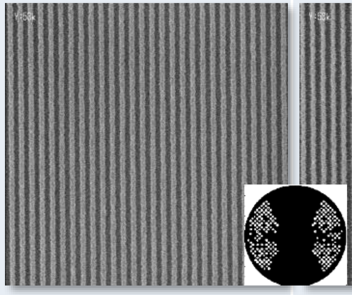
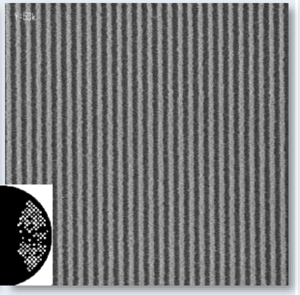
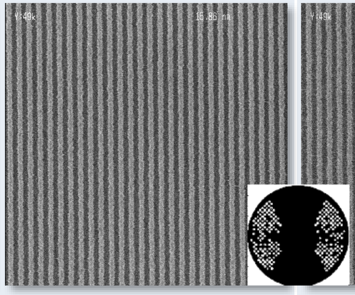
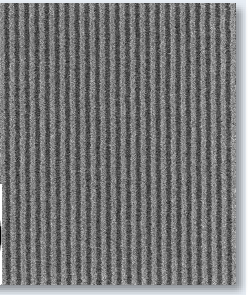
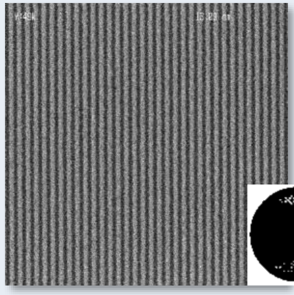
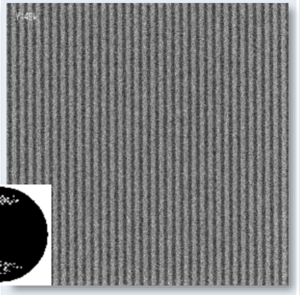
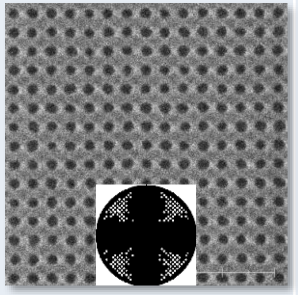
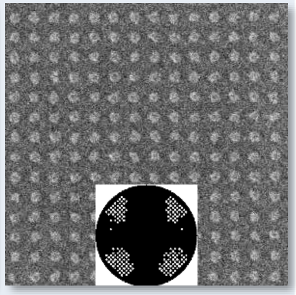
Integration in a Module

Towards Manufacturing

Complexity, Maturity and Time

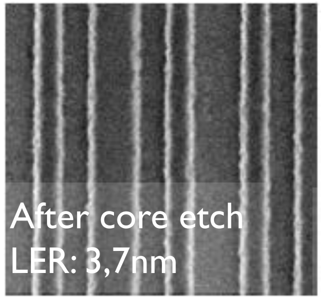
EUV RESIST PERFORMANCE

LOW DOSE IS ACHIEVED, BUT LIMITED BY STOCHASTICS

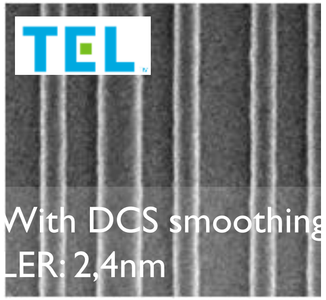
Feature	32nm pitch dense line-space / Vertical		32nm pitch dense line-space / Vertical		26nm pitch dense line-space / Horizontal		36nm pitch regular dense contacts	38nm pitch regular dense pillars
Resist type	CAR	NCAR	CAR	NCAR	CAR	NCAR	CAR	NCAR
SEM top-down image @ BE/BF								
Dose mJ/cm^2	30.5	31.4	21 🙂	20.9 🙂	39	37.3	31	30
LWR/LCDU nm	4.7	4.6	5.4 ☹	5.2 ☹	4.5	4.2	3.5	3.9

Challenge #2: LWR

SMOOTHING

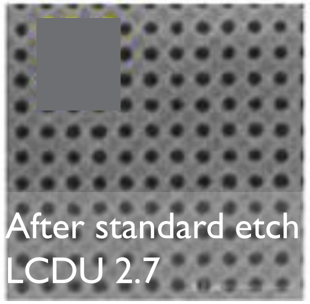


After core etch
LER: 3,7nm

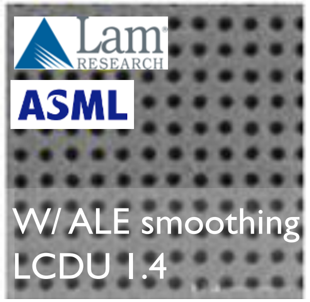


TEL

With DCS smoothing
LER: 2,4nm

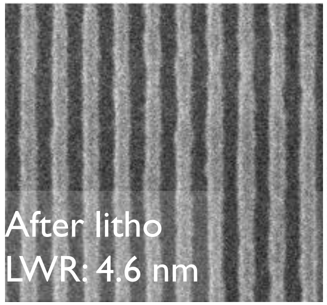


After standard etch
LCDU 2.7

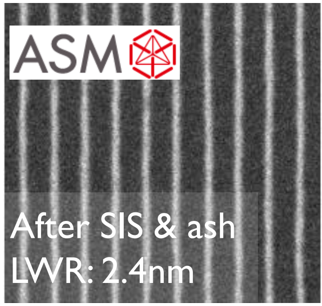


Lam RESEARCH
ASML

W/ ALE smoothing
LCDU 1.4



After litho
LWR: 4.6 nm



ASM

After SIS & ash
LWR: 2.4nm

imec

EUV RESIST PERFORMANCE

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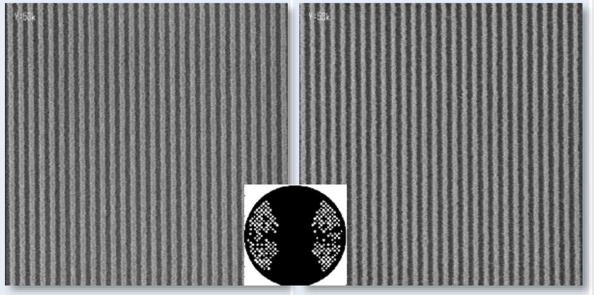
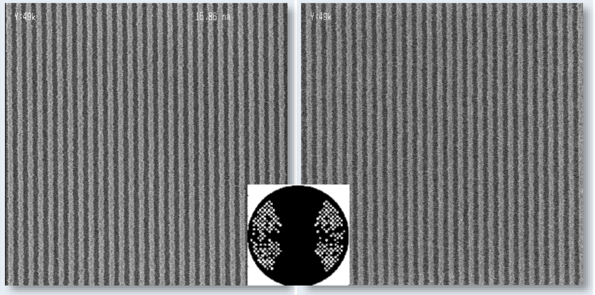
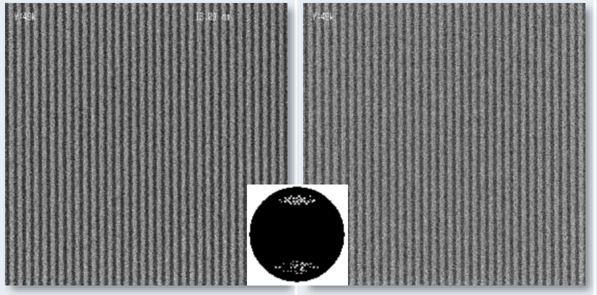
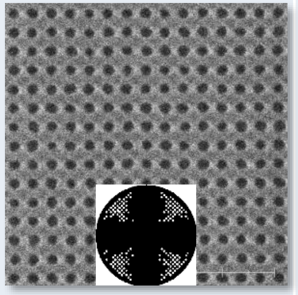
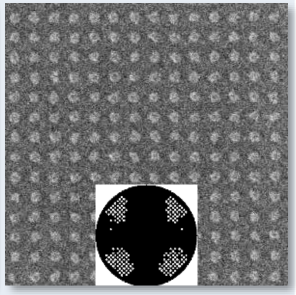
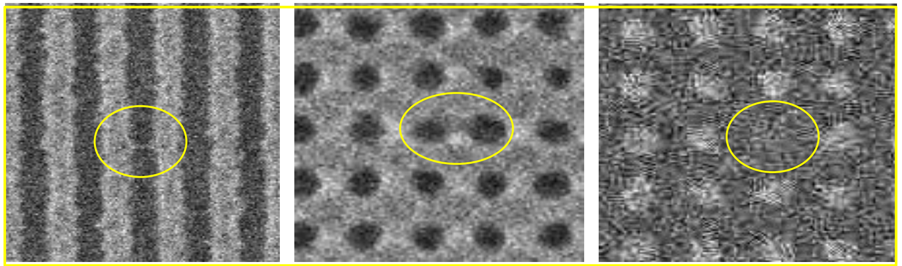
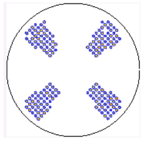
Resist type	**CAR**	**NCAR**	**CAR**	**NCAR**	**CAR**	**NCAR**	**CAR**	**NCAR**
SEM top-down image @ BE/BF								
Dose mJ/cm^2	**30.5**	**31.4**	**21**	**20.9**	**39**	**37.3**	**31**	**30**
LWR/LCDU nm	**4.7**	**4.6**	**5.4**	**5.2**	**4.5**	**4.2**	**3.5**	**3.9**

Challenge #1: Stochastic Failures



STOCHASTIC FAILURES

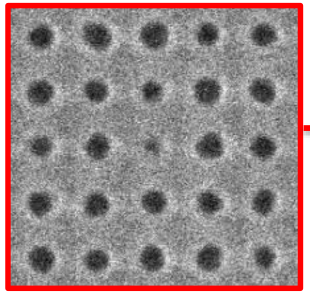
DETERMINE CD WINDOW FOR A GIVEN PITCH

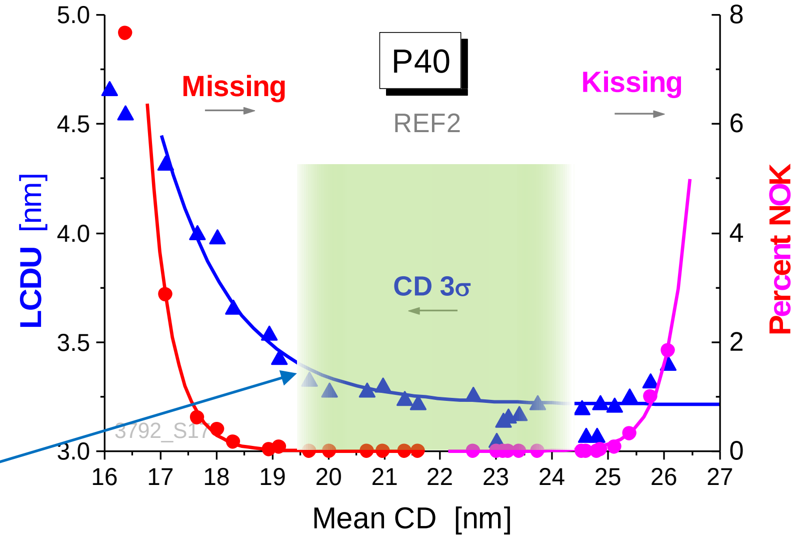


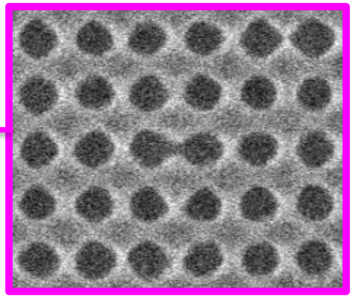
Contact Hole example

Pitch: 40×40 nm

Lower CDs: **missing contacts**







Larger CDs: **'kissing'** (i.e. merging) **contacts**

Missing-hole Patterning cliff

Kissing-hole Patterning cliff

'Failure-free' CD window

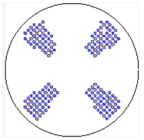
LCDU is not a good predicter of stochastic failures.

Failures must be quantified independently.

Peter De Bisschop, submitted to JM3

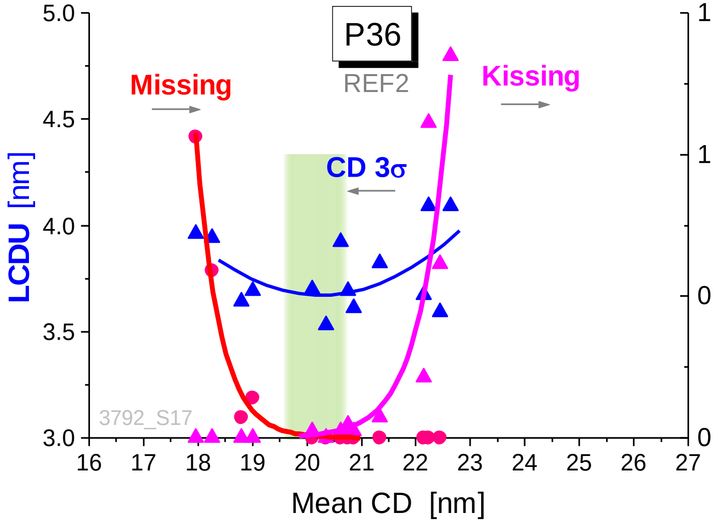
STOCHASTIC FAILURES

FAILURE FREE CD WINDOW VARIES THROUGH PITCH

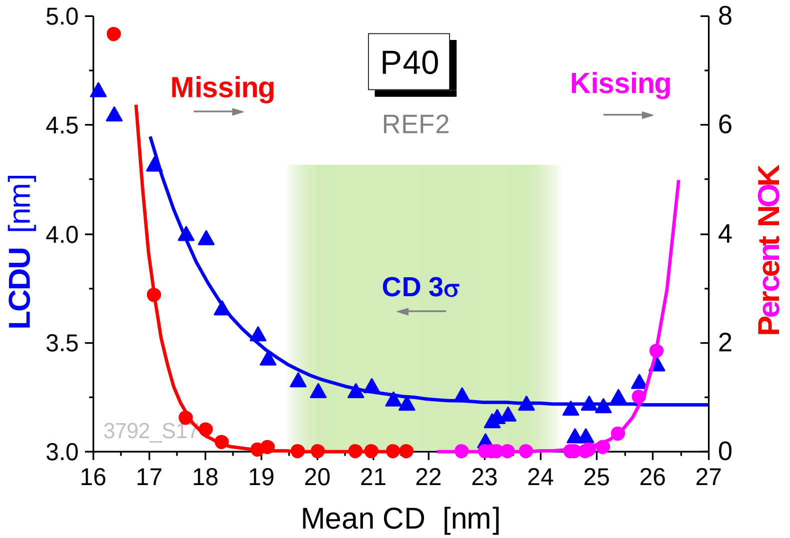


Contact Hole example

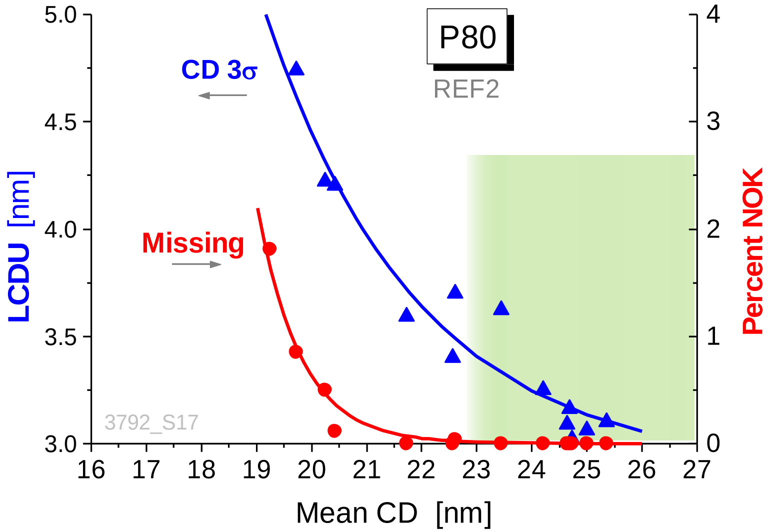
Pitch: 36×36 nm



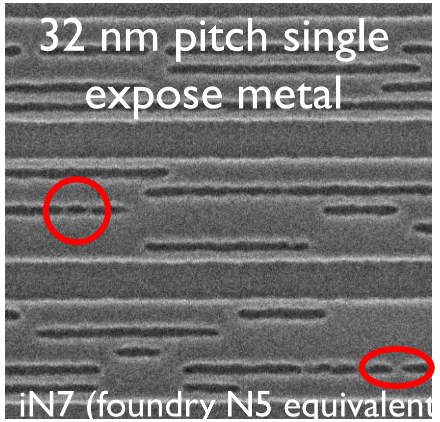
Pitch: 40×40 nm



Pitch: 80×80 nm



Stochastic failures currently limit minimum feature size with EUV single patterning

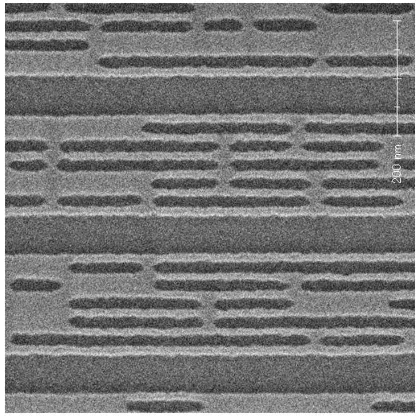


32 nm pitch single expose metal

iN7 (foundry N5 equivalent

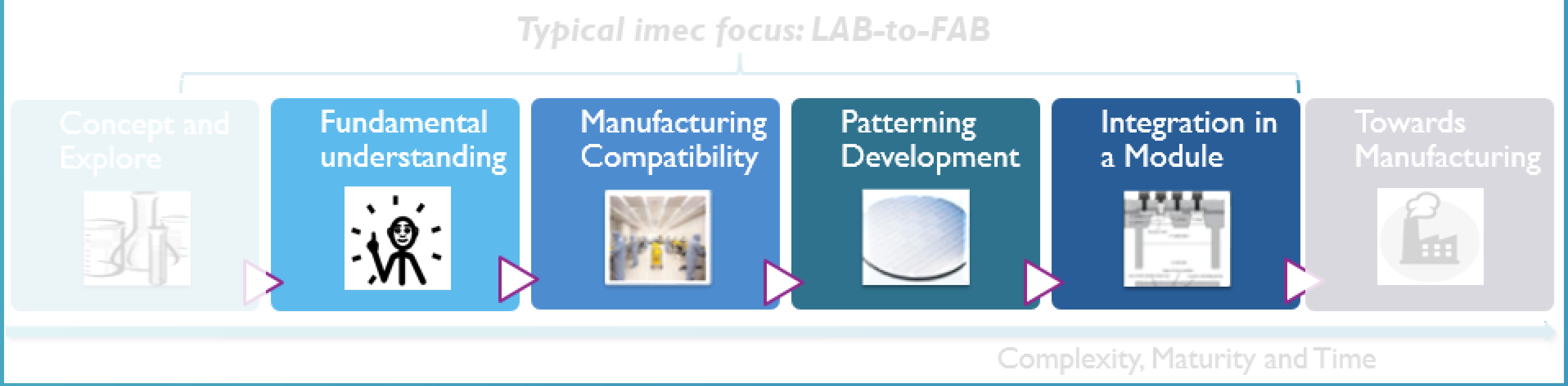
Process Co-Optimization required

- Resist material and process
- Metrology / Inspection
- Imaging optimization (Mask, source, OPC,)
- Post processing
- Alternate integration processes



Peter De Bisschop, submitted to JM3

FROM THE LAB TO THE FAB
INPRIA CASE



Typical imec focus: LAB-to-FAB

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Towards Manufacturing

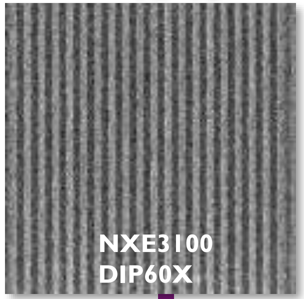
Complexity, Maturity and Time

LAB2FAB: METAL OXIDE RESIST (INPRIA CASE)

PATTERNING IMPROVEMENT →

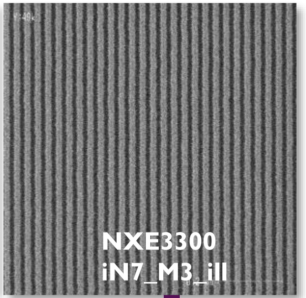
85 mJ/cm^2

HP 16



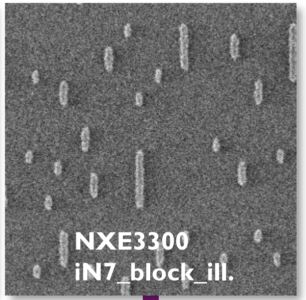
44 mJ/cm^2

HP 16



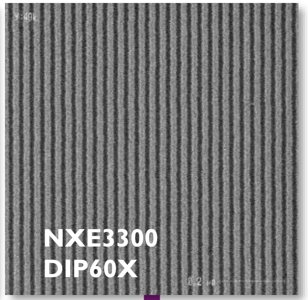
38 mJ/cm^2

CD-X 21nm



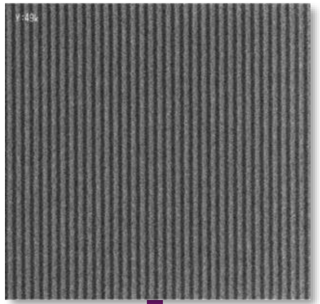
27 mJ/cm^2

HP 16



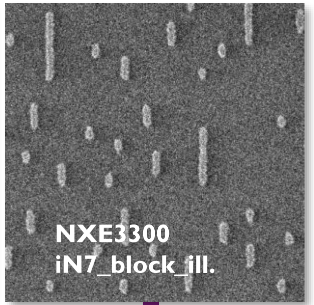
26 mJ/cm^2

HP 13

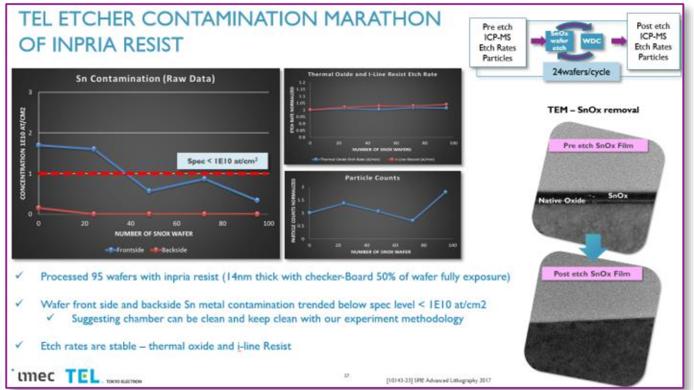


19 mJ/cm^2

CD-X 21nm



2014 **2015** **2016** **2017**



TEL ETCHER CONTAMINATION MARATHON OF INPRIA RESIST

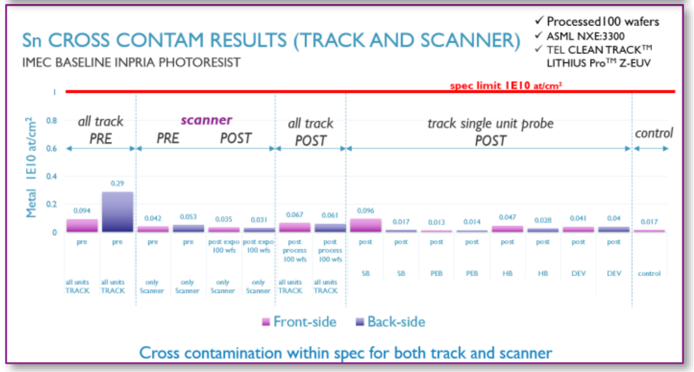
Pre etch ICP-MS Etch Rates Particles → SnOx wafer etch / WDC → Post etch ICP-MS Etch Rates Particles

24wafers/cycle

- ✓ Processed 95 wafers with inpria resist (14nm thick with checker-Board 50% of wafer fully exposure)
- ✓ Wafer front side and backside Sn metal contamination trended below spec level < 1E10 at/cm2
  - ✓ Suggesting chamber can be clean and keep clean with our experiment methodology
- ✓ Etch rates are stable – thermal oxide and i-line Resist

imec TEL

[10143-23] SPIE Advanced Lithography 2017



Sn CROSS CONTAM RESULTS (TRACK AND SCANNER)

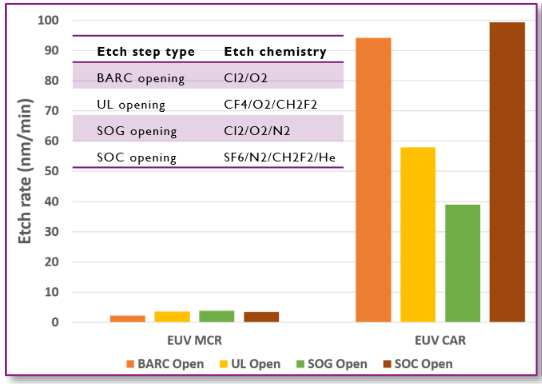
IMEC BASELINE INPRIA PHOTORESIST

- ✓ Processed100 wafers
- ✓ ASML NXE:3300
- ✓ TEL CLEAN TRACK™ LITHIUS Pro™ Z-EUV

Cross contamination within spec for both track and scanner

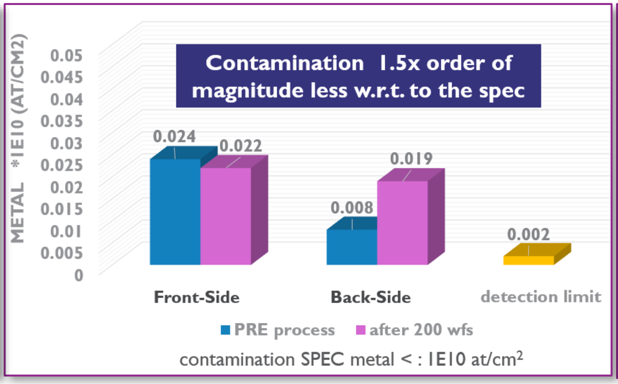
MANUFACTURABILITY ASSESSMENT →

Initial Etch exploration *ICPST32-15*



Etch step type	Etch chemistry
BARC opening	Cl2/O2
UL opening	CF4/O2/CH2F2
SOG opening	Cl2/O2/N2
SOC opening	SF6/N2/CH2F2/He

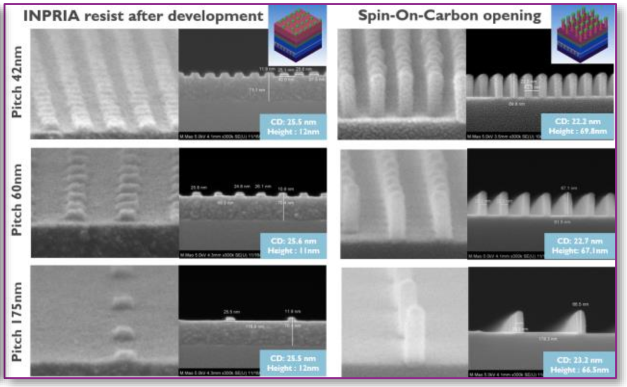
Initial Cross contamination test *ICPST33-16*



Contamination 1.5x order of magnitude less w.r.t. to the spec

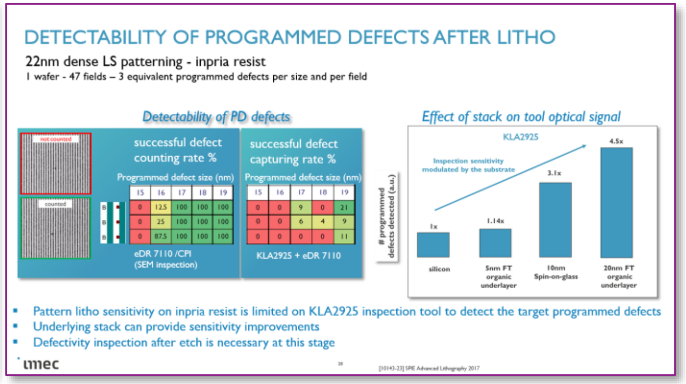
contamination SPEC metal < : 1E10 at/cm^2

iN7 block layer application *SPIE16*



Cross contamination consolidation

Defectivity *SPIE17*



DETECTABILITY OF PROGRAMMED DEFECTS AFTER LITHO

22nm dense LS patterning - inpria resist

1 wafer - 47 fields – 3 equivalent programmed defects per size and per field

Detectability of PD defects

successful defect counting rate %

Programmed defect size (nm)

15	16	17	18	19
0	12.5	100	100	100
0	25	100	100	100
0	87.5	100	100	100

eDR 7110 /CPI (SEM inspection)

successful defect capturing rate %

Programmed defect size (nm)

15	16	17	18	19
0	0	9	0	21
0	0	6	4	9
0	0	0	0	11

KLA2925 + eDR 7110

Effect of stack on tool optical signal

- Pattern litho sensitivity on inpria resist is limited on KLA2925 inspection tool to detect the target programmed defects
- Underlying stack can provide sensitivity improvements
- Defectivity inspection after etch is necessary at this stage

imec

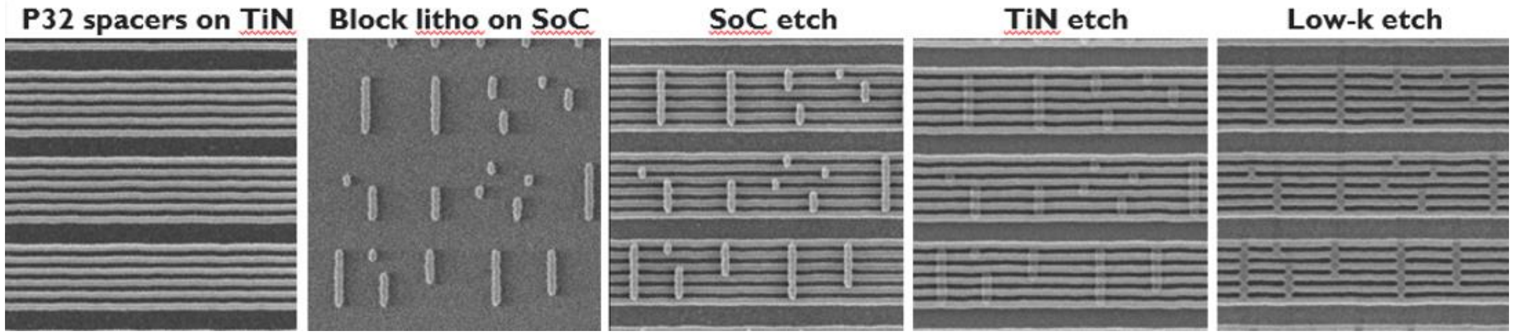
[10143-23] SPIE Advanced Lithography 2017

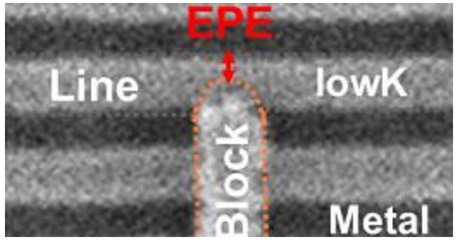
imec inpria TEL ASML KLA Tencor

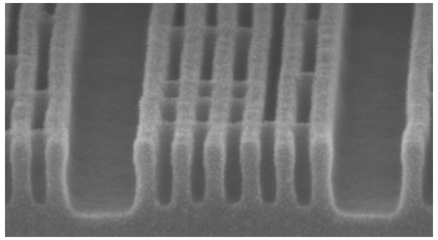
32P METAL (FOUNDRY N5) OPTION: SAQP + INPRIA EUV BLOCK

- Industry first assessment of SAQP + EUV single expose block with metal containing (Inpria) resist
- Integration into BEOL electrical test vehicle
- Assessing edge placement error (EPE) and viability for manufacturing

Joost Bekaert, SPIE 2017
Mark Mason, SPIE 2017



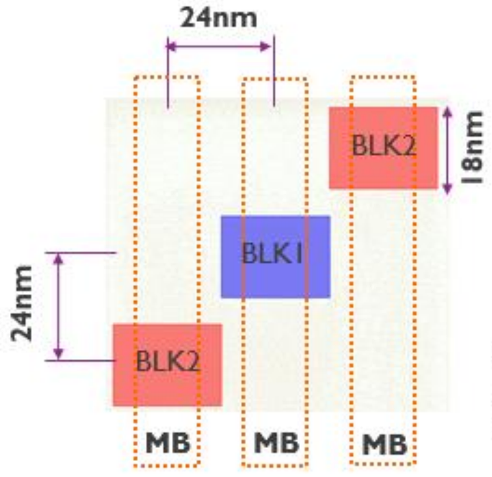




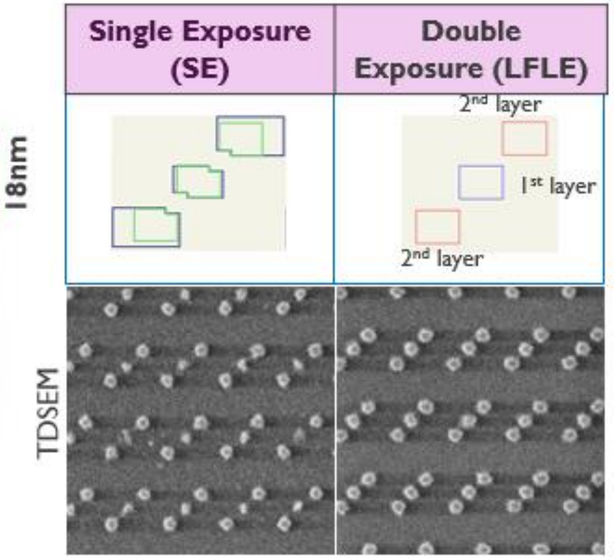
EXTENSION TO IN5 (FOUNDRY N3)

- Development of options for ~20-24 nm pitch metal blocks using Inpria NCAR:
  - i.e.: Litho-develop-litho-etch process (LDLE)

Waikin Li, to be published, 2017 EUVL Symposium

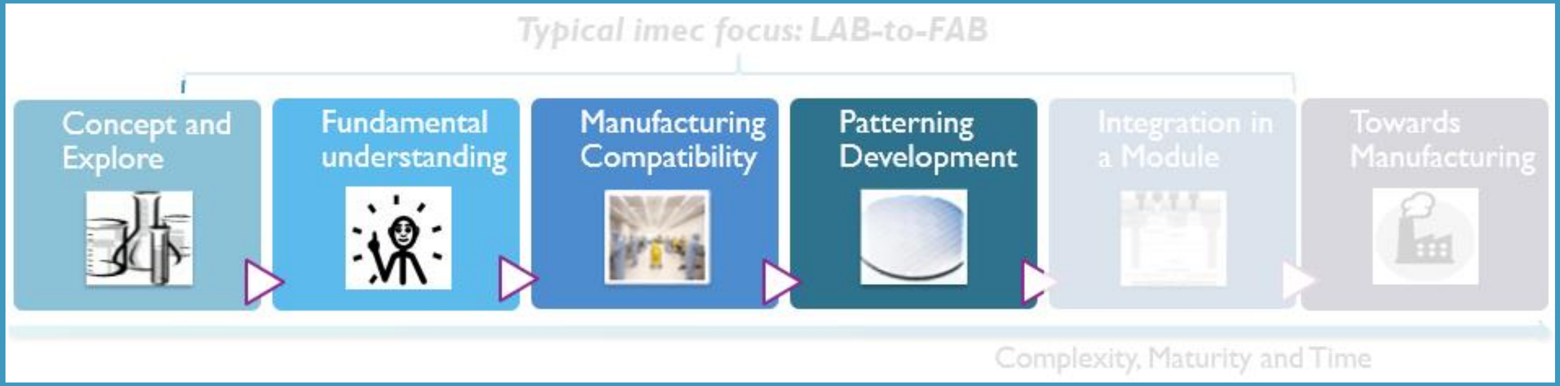


BLK size : 24x18nm
C2C: 34nm



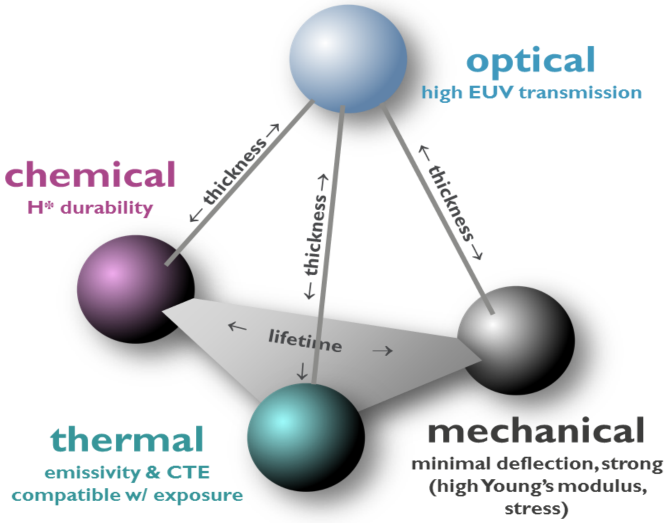
EUV MASKS

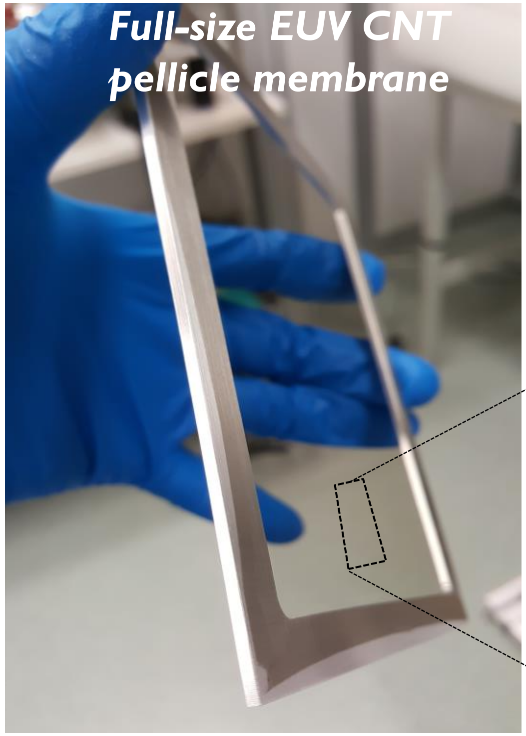
PELLICLE
ALTERNATE ABSORBERS
HIGH-NA 3D MASK EFFECTS



CARBON NANOTUBE PELLICLE

Coated CNT mesh for Gen2 250+W HVM Pellicle



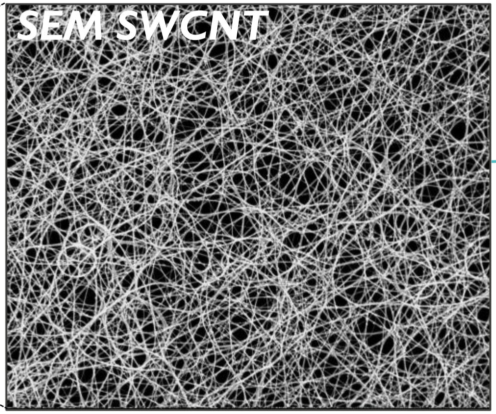


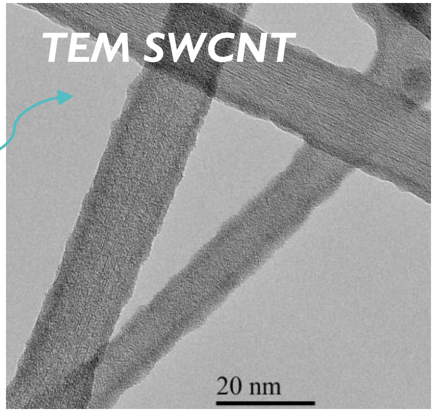
Carbon nanotube (CNT); uncoated

- Base layer for pellicle
- > 97% EUV Trans (tgt >90%)
- Full-size with high yield
- Mechanically robust
- DUV transmits, not reflects

CNT fibers can be varied

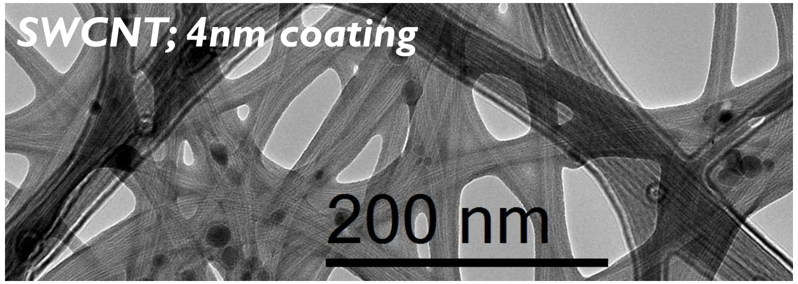
- Single or multi-walled
- Diameter, bundling





COATING required for use in scanner

- Multiple films in development
- Scattering with coating must be limited

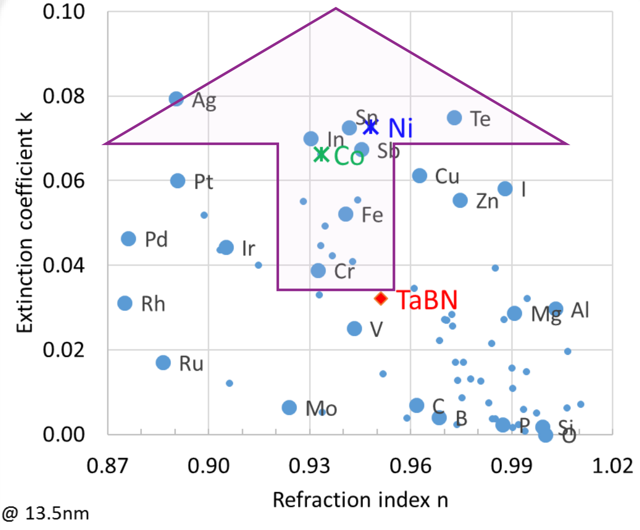


uncoated meets optical requirements → coating for 250W/H* being assessed

ALTERNATE MASK ABSORBER (NICKEL, COBALT)

PATTERNING BY PHYSICAL ETCHING

Higher absorption material desired to reduce 3D mask effects

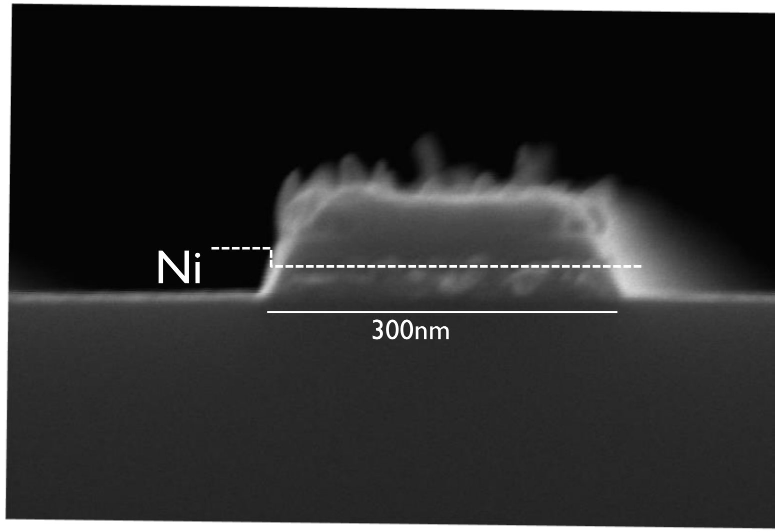


Ni and Co as first experimental learning

Ni and Co etching is demonstrated.

- Tests on wafer substrate
- Patterning in resist (ArF)
- Transfer into hard mask to avoid resist contamination by metal
- Ion Beam Etch (IBE)
  - Good CD control
  - No micro-trenching
  - No footing

Improvement of etch selectivity and patterning smaller pitches ongoing

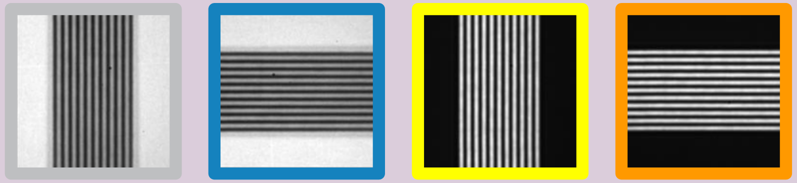


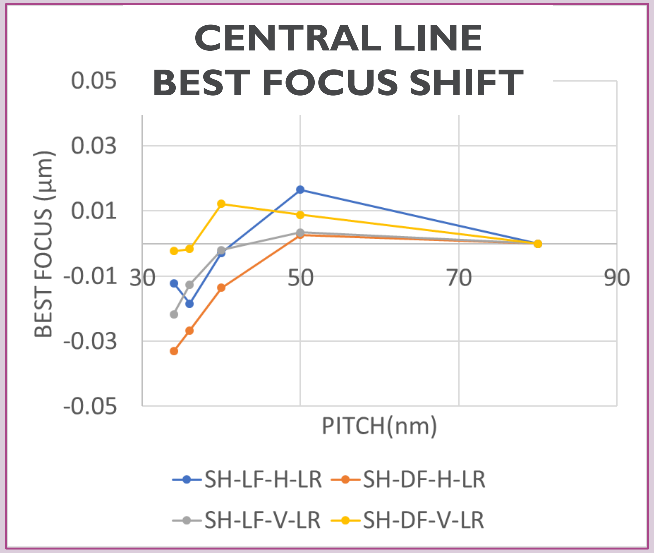
Philipsen et al., to be pub. JM3(2017)

EUV HIGH NA ANAMORPHIC IMAGING

QUANTIFY EXPERIMENTALLY M3D EFFECTS AT HIGH NA
USING ANAMORPHIC IMAGING AND COMPARING TO SIMULATION

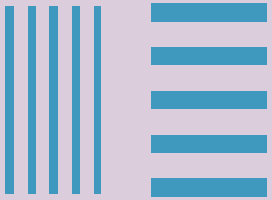
SHARP
0.33 NA isomorphic / 6° CRA - 4x4
where possible comparison to /3300 resist data



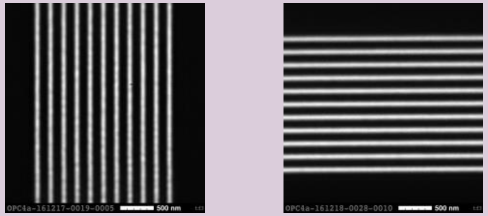


SHARP demonstrates sensitivity to 3D mask effects, although not yet in quantitative agreement with simulations or 3300 data. Improvements in focus measurement in progress.

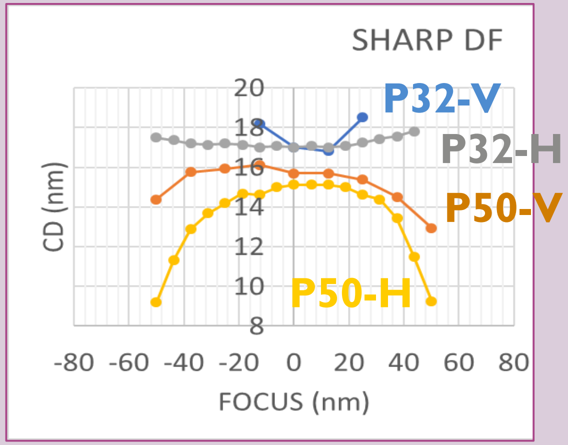
SHARP
0.55 NA anamorphic / 6° CRA - 4x8
unique experimental aerial imaging at NA0.55



MASK (4X8)
VERT. P200 / HORIZ. P400

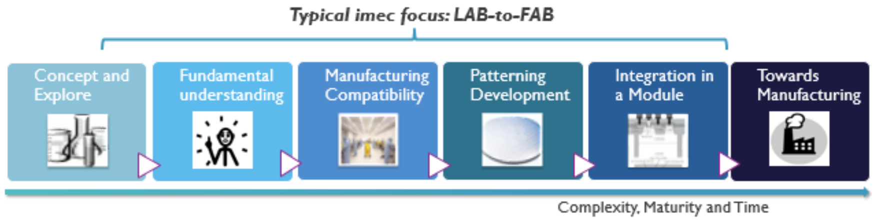


SHARP (1X1)
VERT. P50 / HORIZ. P50



Enabling a study of resolution, mask effects and anamorphic imaging

SUMMARY
EUV DEVELOPMENTS AT IMEC


Typical imec focus: LAB-to-FAB

Concept and Explore

Fundamental understanding

Manufacturing Compatibility

Patterning Development

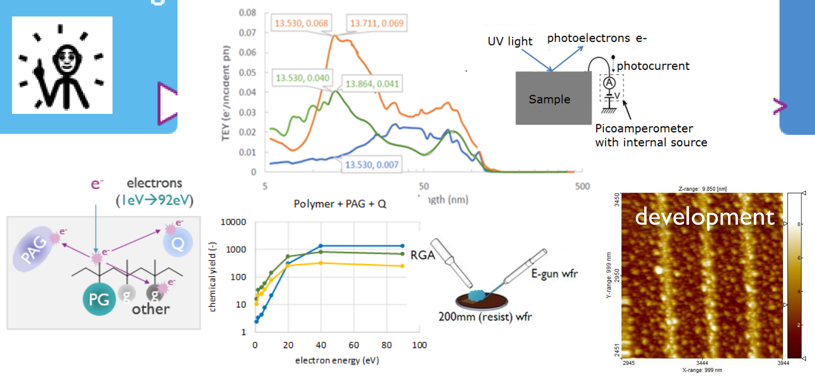
Integration in a Module

Towards Manufacturing

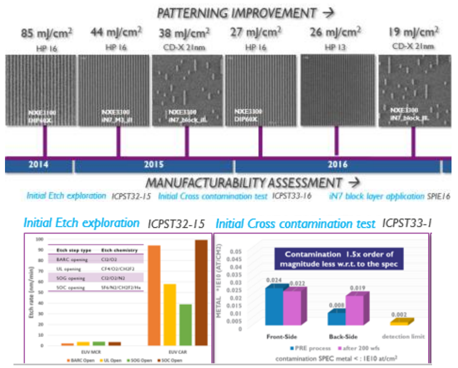
Complexity, Maturity and Time

EUV materials and patterning

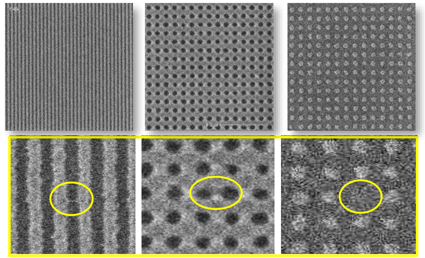
Fundamental understanding

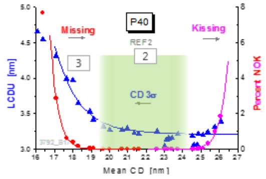


Manufacturing Compatibility

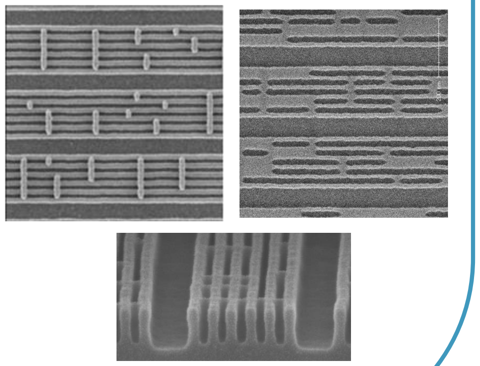


Patterning Development



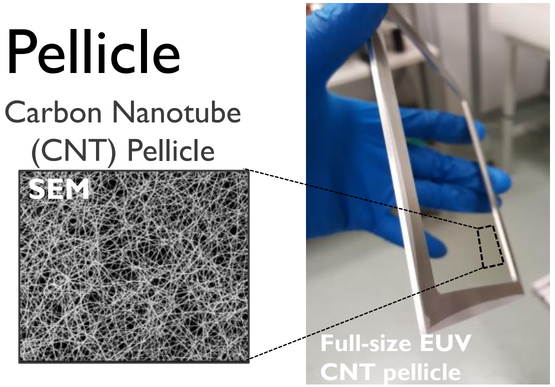


Integration in a Module

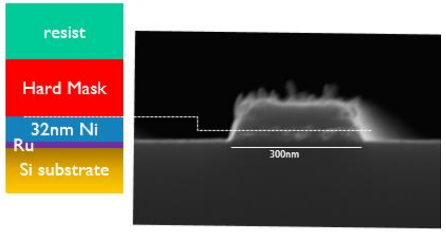


CNT Pellicle

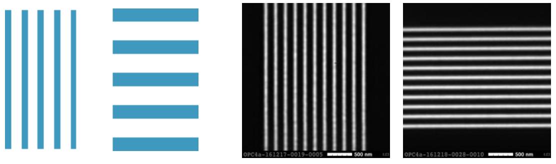
Carbon Nanotube (CNT) Pellicle



Alternate mask absorber



High-NA 3D-mask effects



MASK (4X8) **SHARP (1X1)**

ACKNOWLEDGEMENTS

EUV DEVELOPMENTS AT IMEC

EUV materials and patterning

Dr. Norito Kotani (RIBM)

Dr. Ramanujam Kumaresan (RIBM)

Prof. Nannarone (IOM-CNR)

Alessandro Vaglio (KLA)

Michael Carcasi (TEL)

All material suppliers at imec

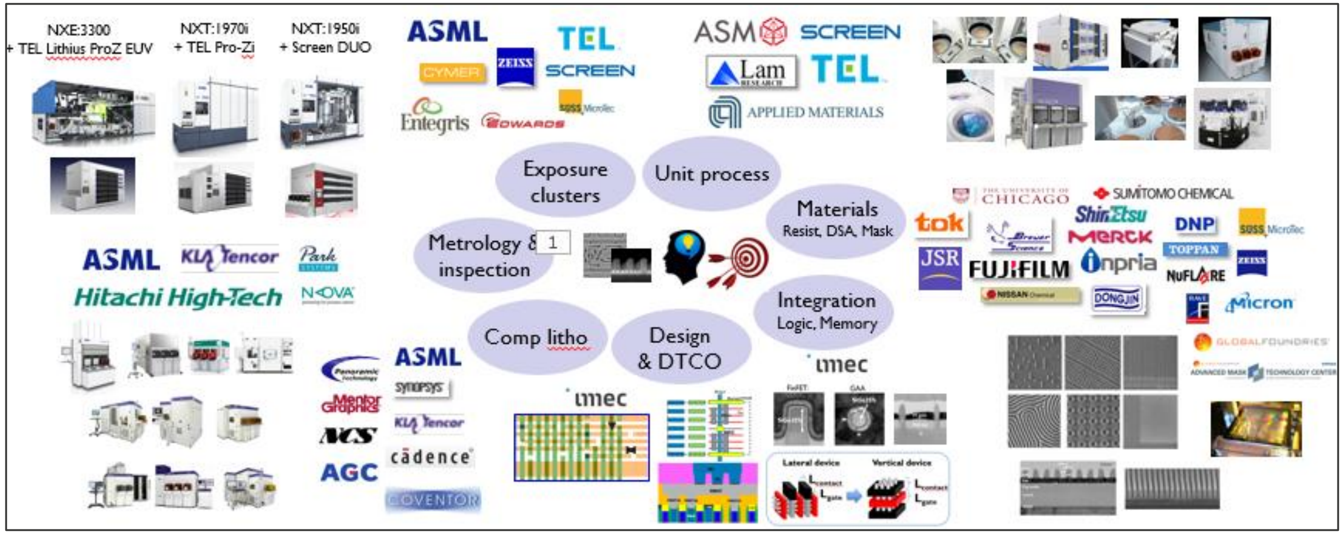
Alternate mask absorber

Support from the European Union's Horizon 2020

High-NA 3D-mask effects

Jack Liddle (Zeiss)

Markus Benk and Kenneth Goldberg (LBLN)

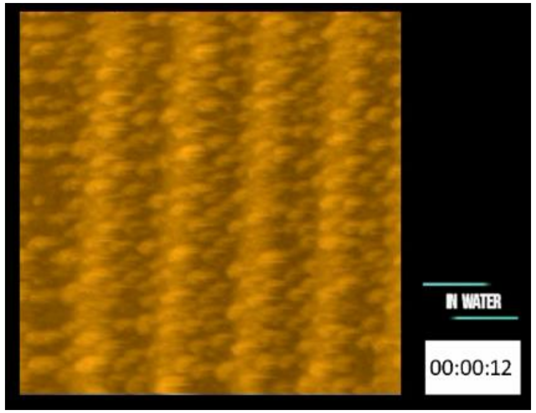


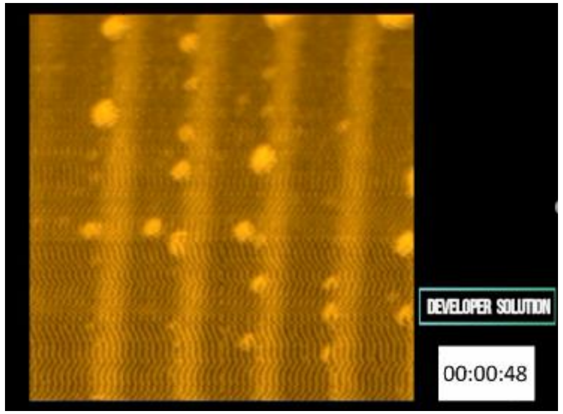
imec

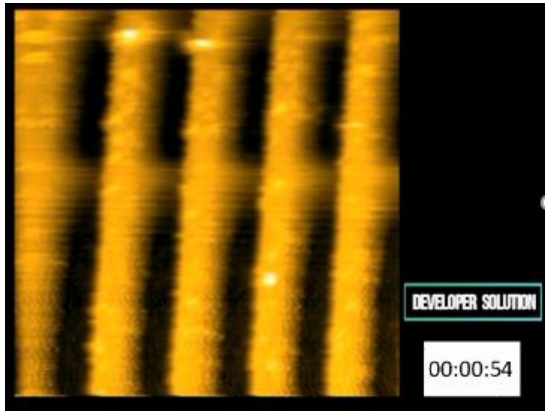
embracing a better life

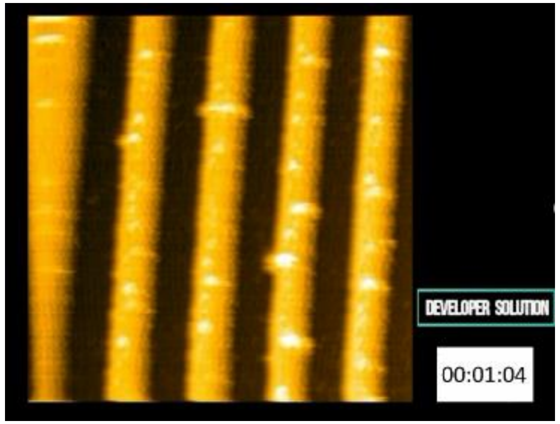
FUNDAMENTALS UNDERSTANDING

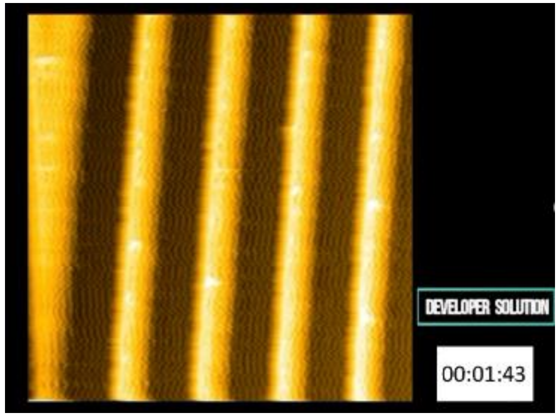
HIGH SPEED ATOMIC FORCE MICROSCOPE TO PROBE EUV RESIST DEVELOPMENT

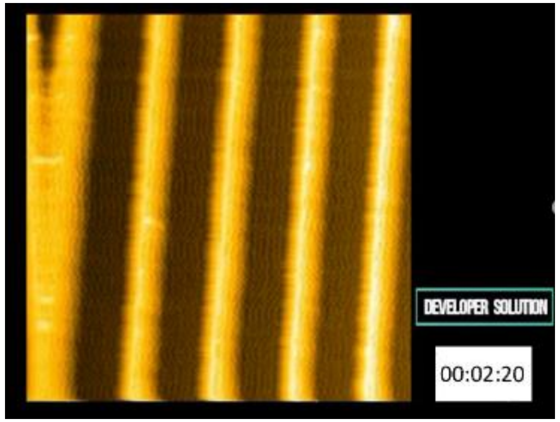


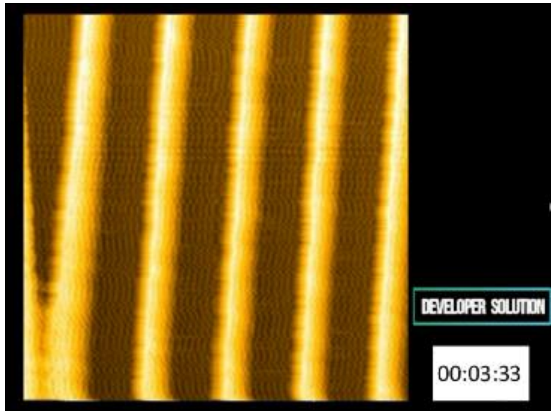












EUV INSERTION

IMEC NODE PROCESS ASSUMPTIONS: EUV RAMP

Layer	Shape	N7 (40p metal)	N7+ (36-40p metal)	N5 (28-32p metal)	N3 (21-24p metal)
HVM Ramp		**2017/18**	**2018/19**	**2020/21**	**~2023**
Fin	L/S (H)				
Fin_Keep	Fin Keep (H)				
Fin_Cut	Fin Cut (V)				
Gate	L/S (V)				
Gate Vt	2D rectangle				
Gate_Cut	Slotted trench (H)				
M0A	Slotted trench (V)				
Mint	L/S (H)				
Mint_TRIM/BLK	Trench / Pillars (2D)				
Vint-A	Contact holes				
Vint-G	Contact holes				
M1	L/S (V)				
M1 TRIM/BLK	Trench / Pillars (2D)				
V0	Contact holes				
Mx	L/S				
M1 TRIM/BLK	Trench / Pillars (2D)				
Vx	Contact holes				
Total EUV masks (0.33NA)					

193i

EUV