Advances in Directly Patternable Metal Oxides for EUV Resist

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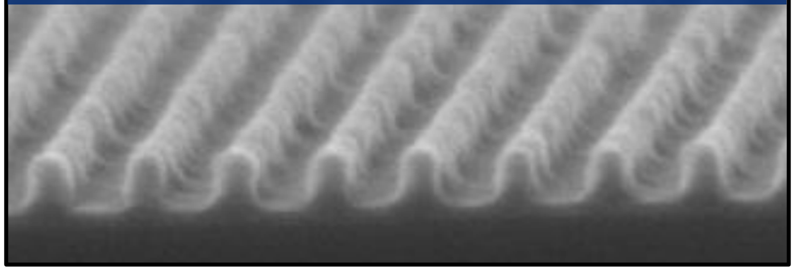
inpria

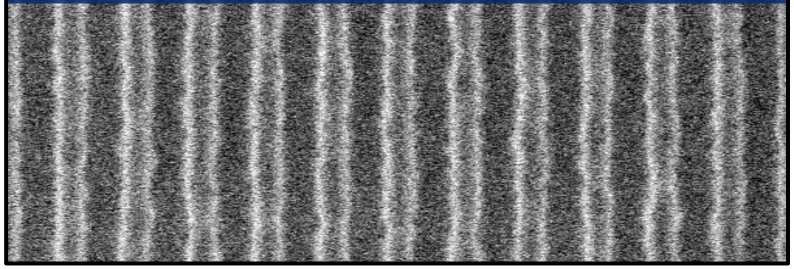
EUVL Symposium 2013

Toyama, Japan

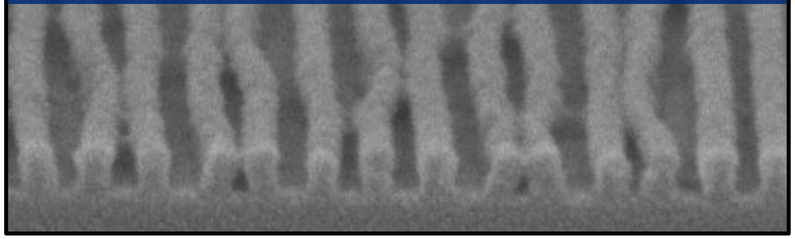
Conventional Photoresists Stretched to the Limit



Resolution



Line Width Roughness



Pattern Collapse

Patternable Metal Oxides

Resolution & LWR

Etch Selectivity

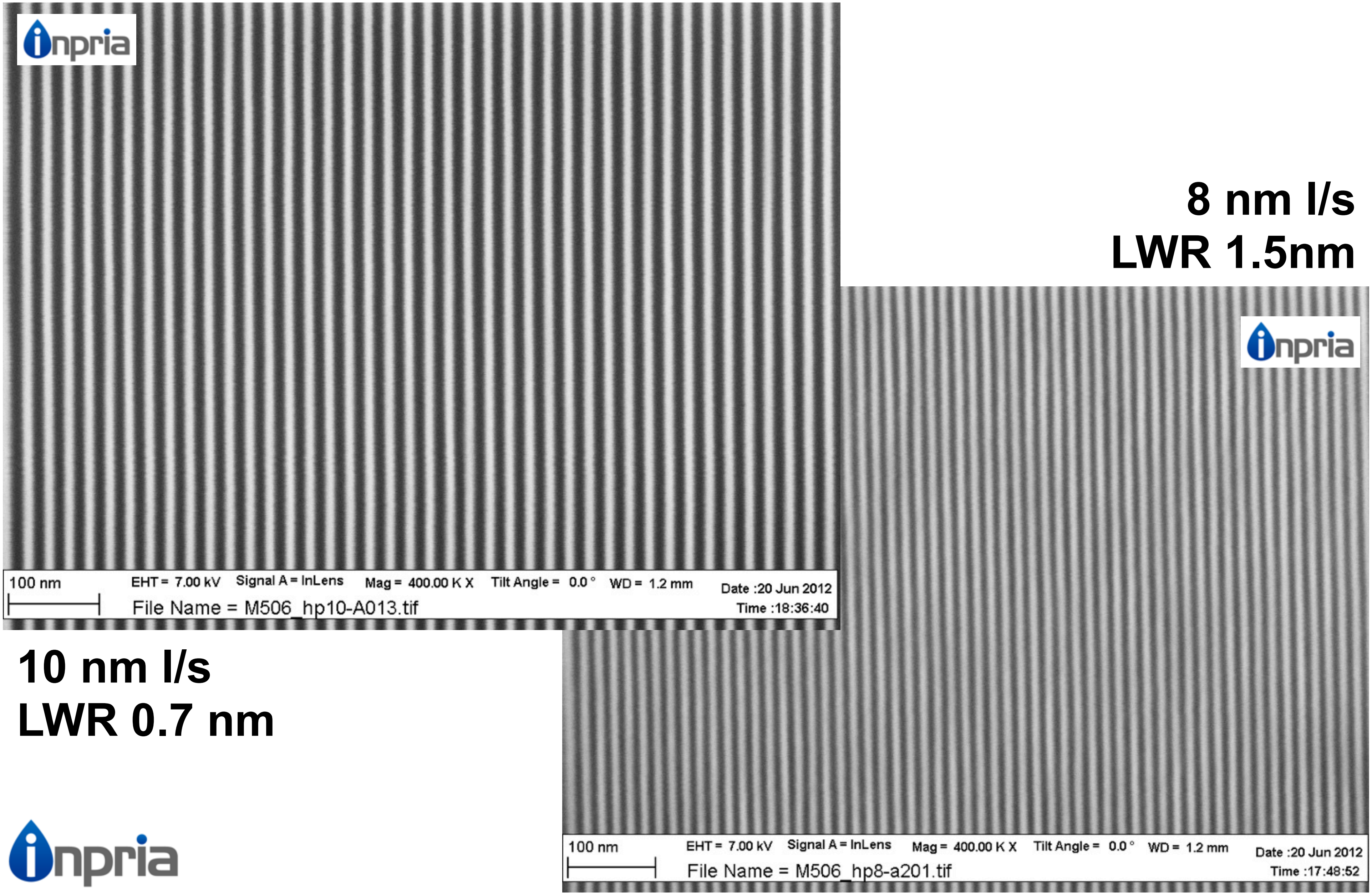
Low Blur

EUV Absorbance

Metal oxide clusters

Goal: Design photoresists with small, inorganic building blocks

Gen 1 Materials: EUV Imaging



8 nm l/s
LWR 1.5nm

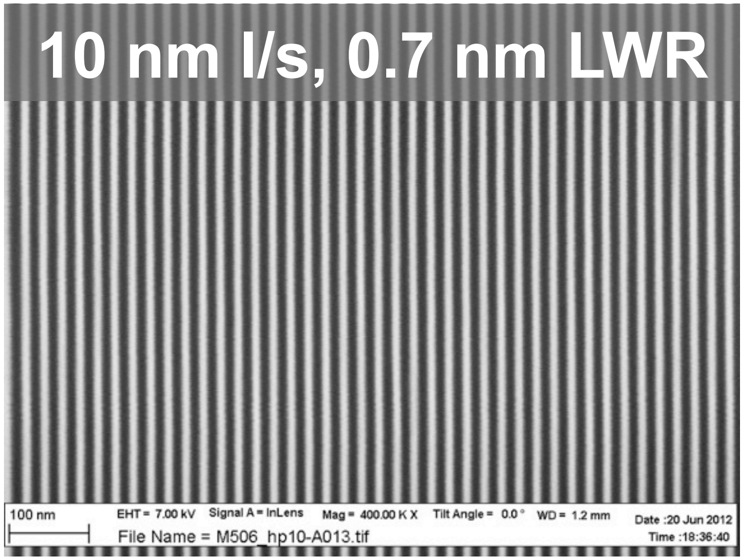
10 nm l/s
LWR 0.7 nm

Inpria Generation 1 EUV Photoresists

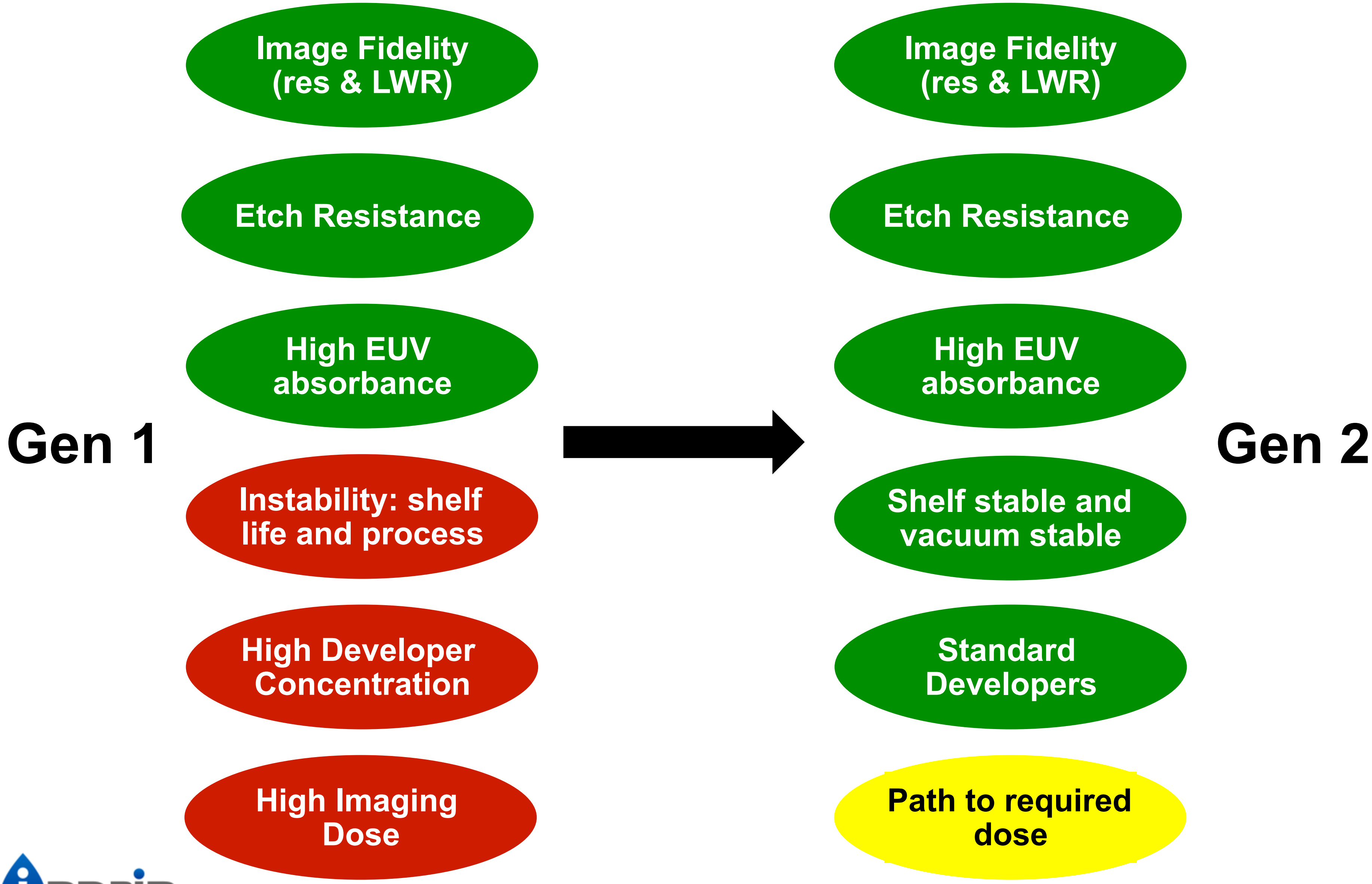
Gen 1

- Image Fidelity (res & LWR)
- Etch Resistance
- High EUV absorbance
- Instability: shelf life and process
- High Developer Concentration
- High Imaging Dose

Competing condensation and dehydration processes



New Platform Solves Key Challenges



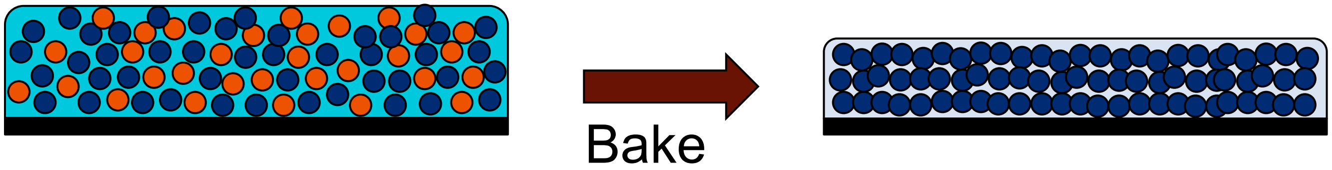
Gen 1

- Image Fidelity (res & LWR)
- Etch Resistance
- High EUV absorbance
- Instability: shelf life and process
- High Developer Concentration
- High Imaging Dose

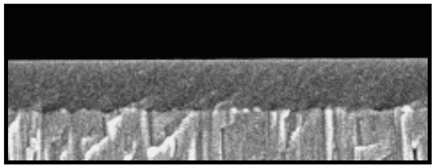
Gen 2

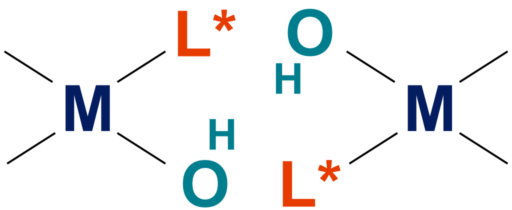
- Image Fidelity (res & LWR)
- Etch Resistance
- High EUV absorbance
- Shelf stable and vacuum stable
- Standard Developers
- Path to required dose

Inpria's Patterning Mechanism

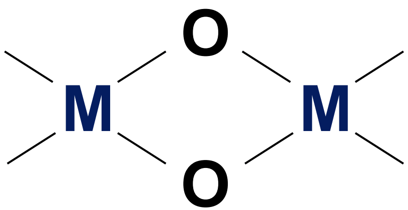


Unpatterned film



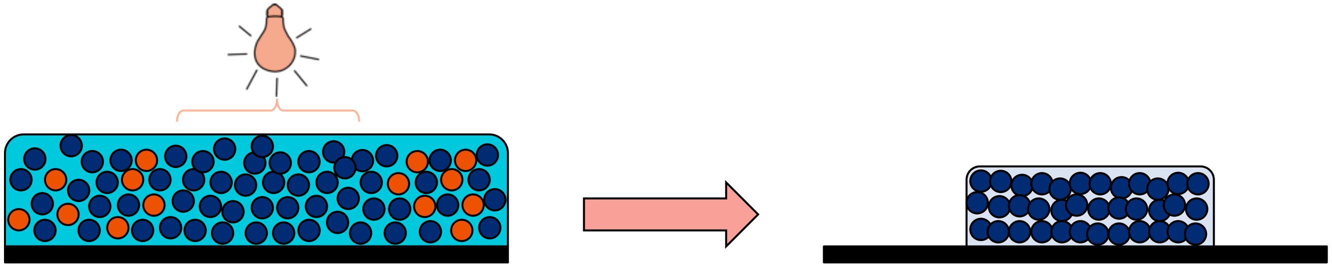


Metal hydroxo clusters



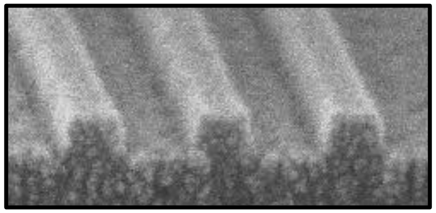
+ H_2O, L*

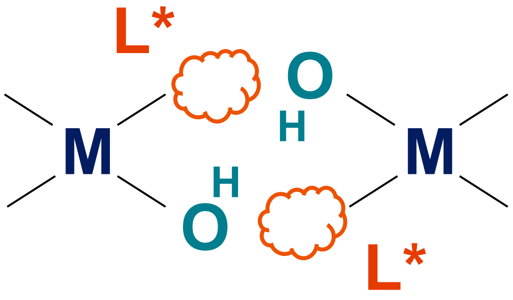
Dense metal oxide film



Develop

Patterned film



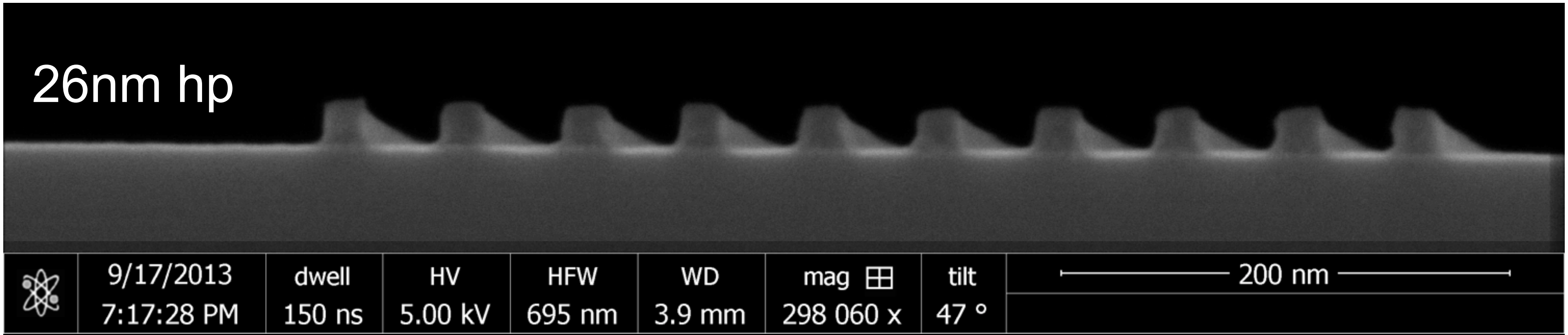


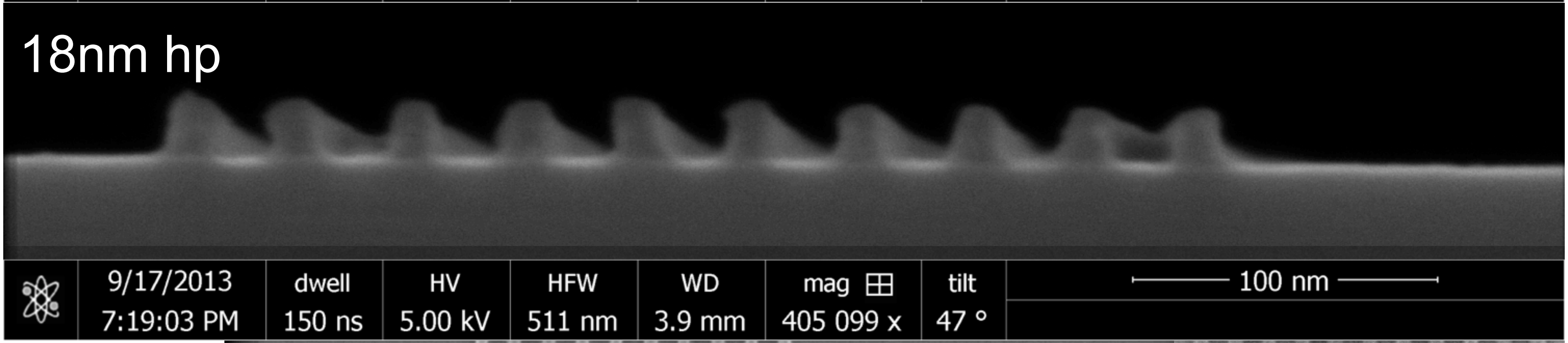
Exposure generates high solubility contrast in developer

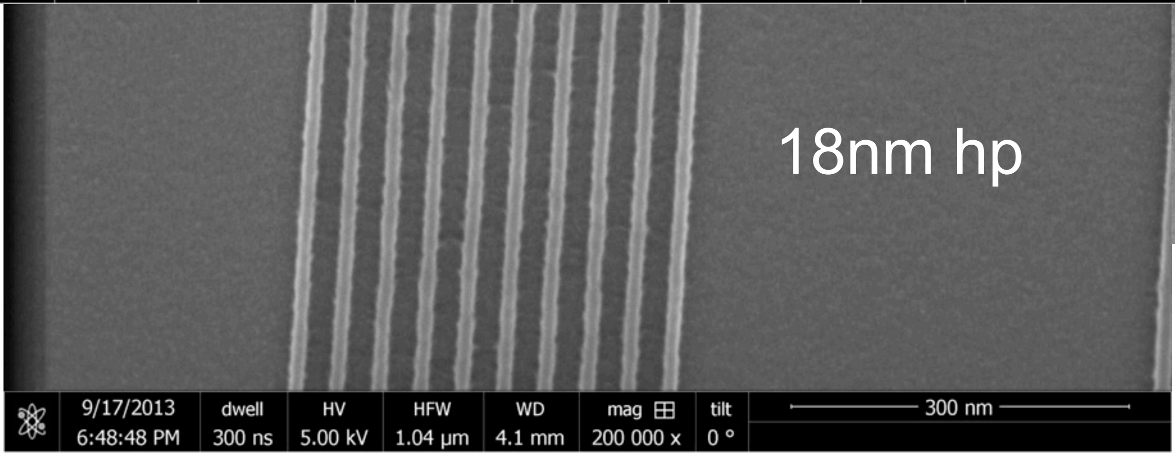
New molecular oxide clusters and ligand chemistries adopted for Gen 2 materials

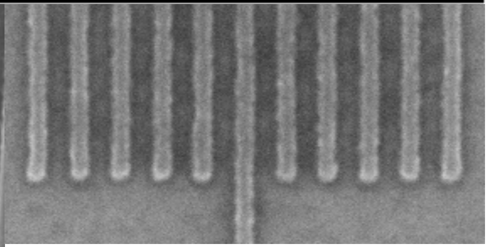
L* = radiation sensitive ligand

Gen 2 E-Beam Baseline: YA Series



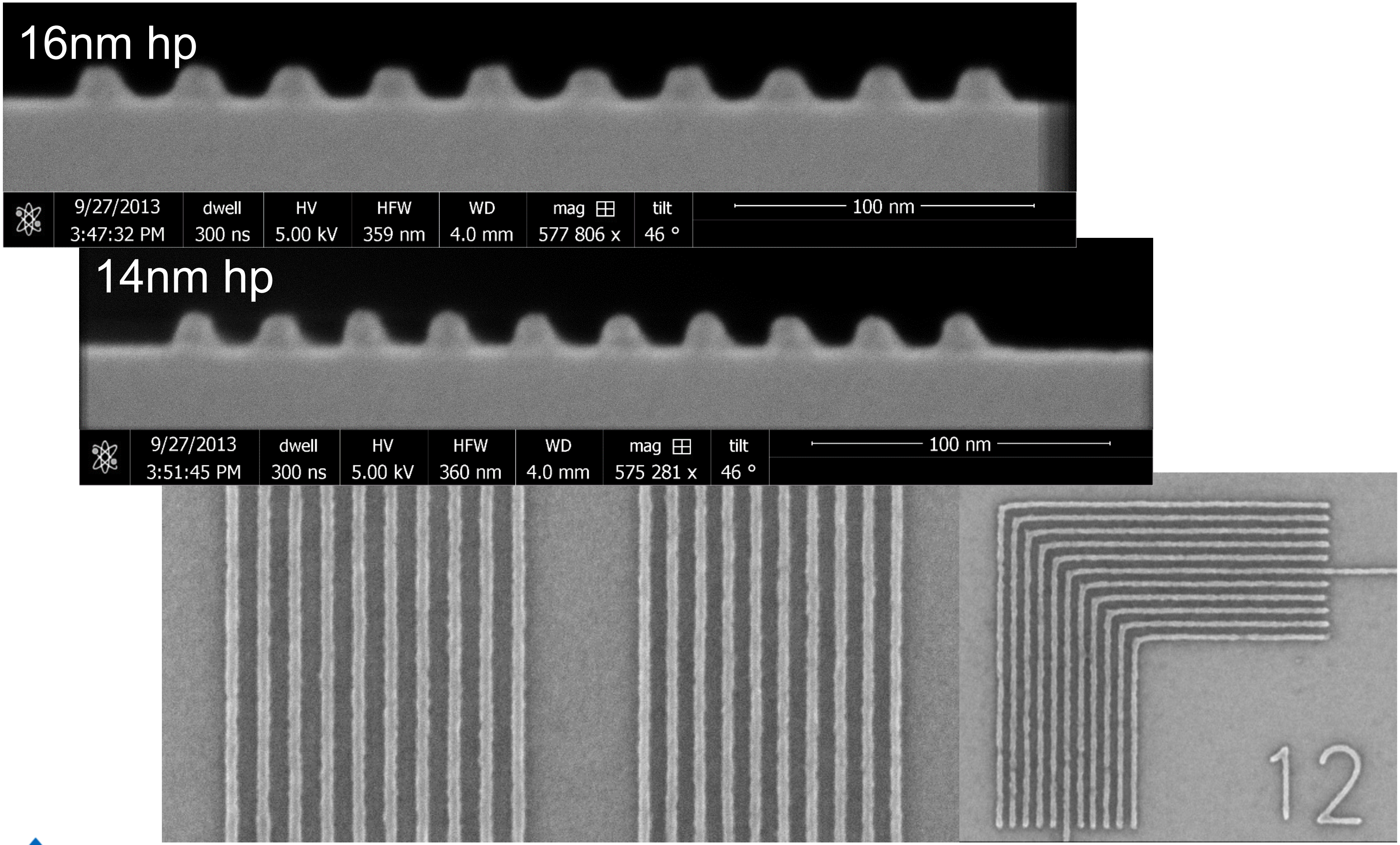






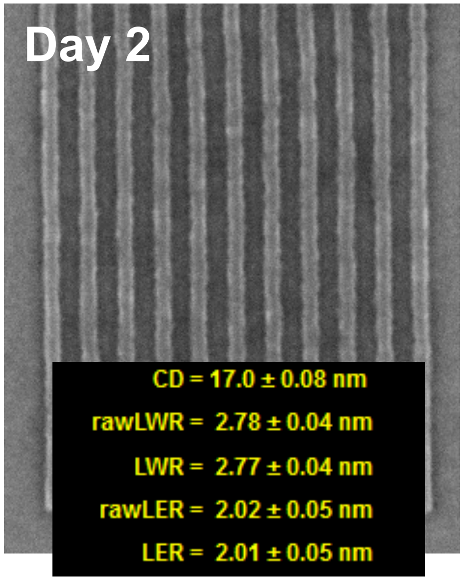
n-BA develop
20nm FT, ~1100µC/cm²

Gen 2 E-Beam Baseline: YA Series

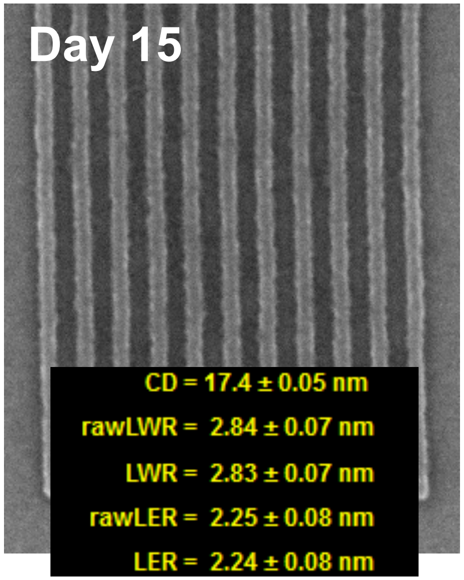


16nm hp **14nm hp** **12nm hp**

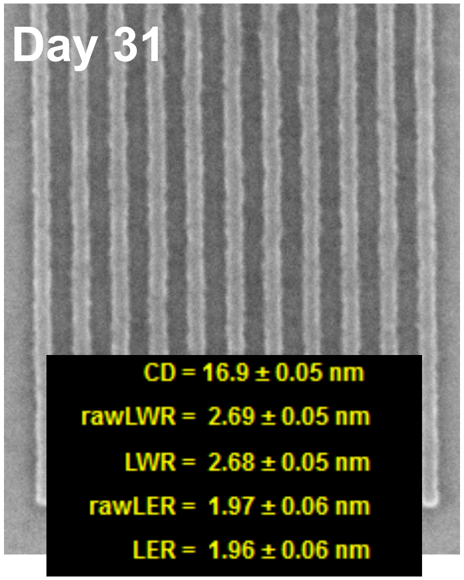
Shelf-Life >3 Months @ RT



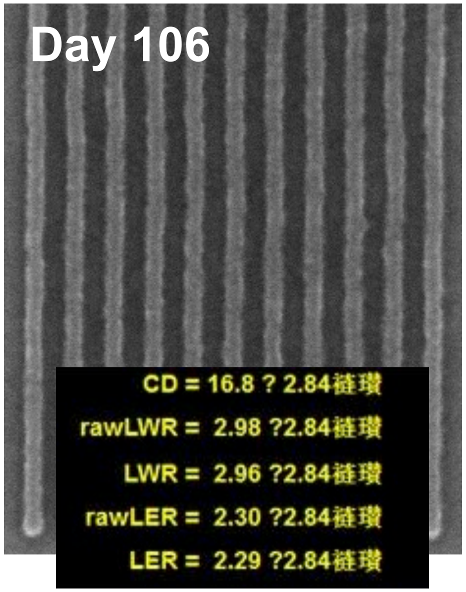
CD = 17.0 ± 0.08 nm
rawLWR = 2.78 ± 0.04 nm
LWR = 2.77 ± 0.04 nm
rawLER = 2.02 ± 0.05 nm
LER = 2.01 ± 0.05 nm



CD = 17.4 ± 0.05 nm
rawLWR = 2.84 ± 0.07 nm
LWR = 2.83 ± 0.07 nm
rawLER = 2.25 ± 0.08 nm
LER = 2.24 ± 0.08 nm



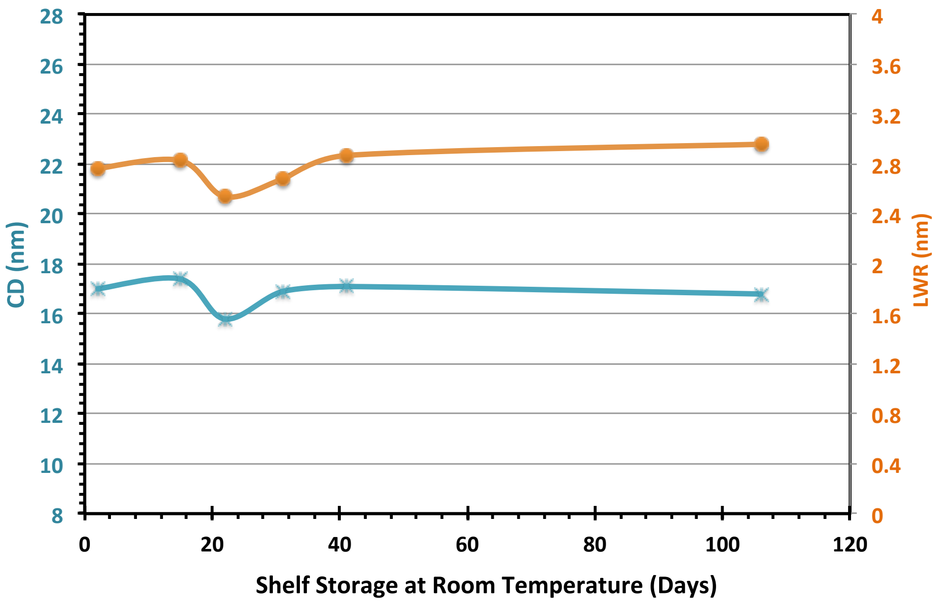
CD = 16.9 ± 0.05 nm
rawLWR = 2.69 ± 0.05 nm
LWR = 2.68 ± 0.05 nm
rawLER = 1.97 ± 0.06 nm
LER = 1.96 ± 0.06 nm



CD = 16.8 ? 2.84褳瓄
rawLWR = 2.98 ?2.84褳瓄
LWR = 2.96 ?2.84褳瓄
rawLER = 2.30 ?2.84褳瓄
LER = 2.29 ?2.84褳瓄

18nm hp by EB

Resist Shelf-life: CD stability (e-beam)



Stored at room-temperature

No systematic performance degradation observed over 15 weeks

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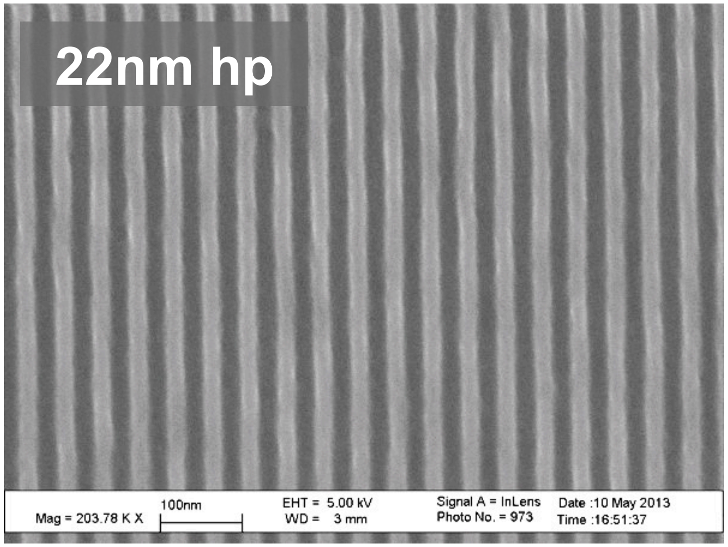
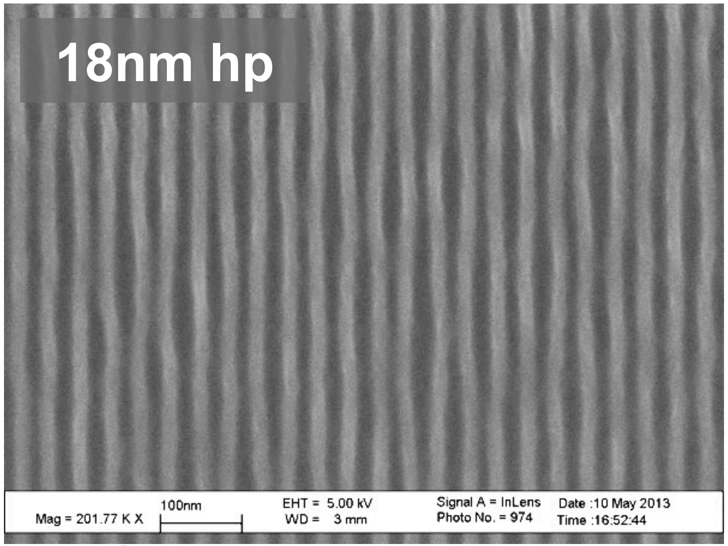
BMET EUV Imaging: YA Series

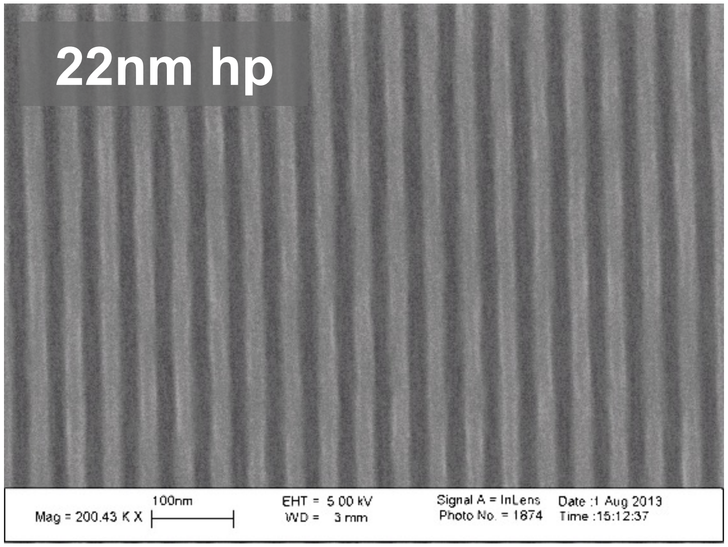
100 mJ/cm^2

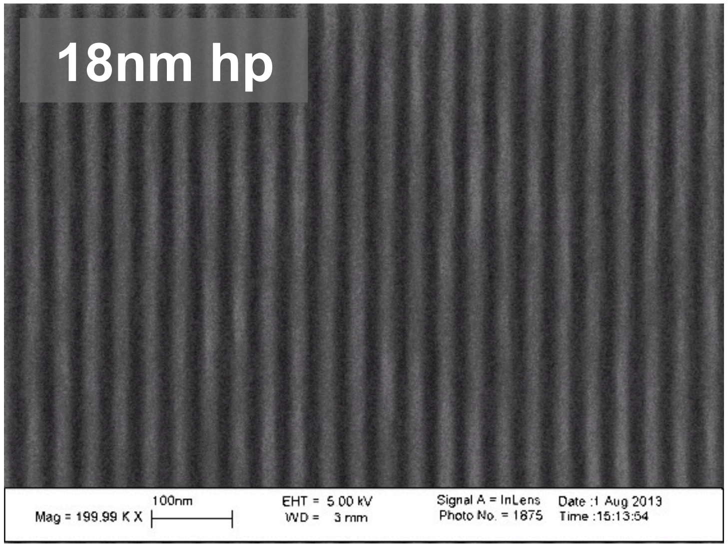




Dose reduced 40%

57 mJ/cm^2

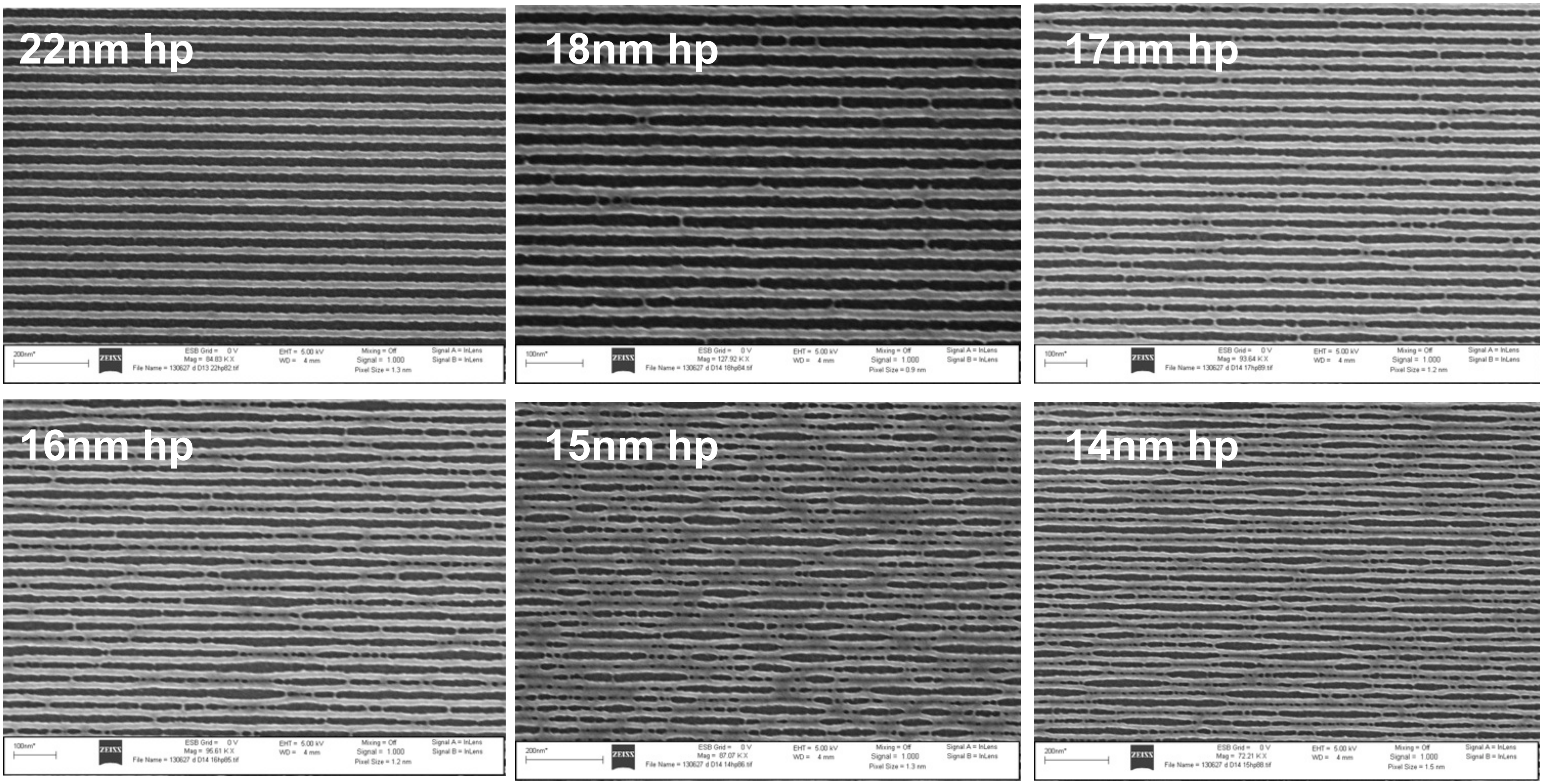




Formulation & process optimization

18nm dipole; Developer: n-BA

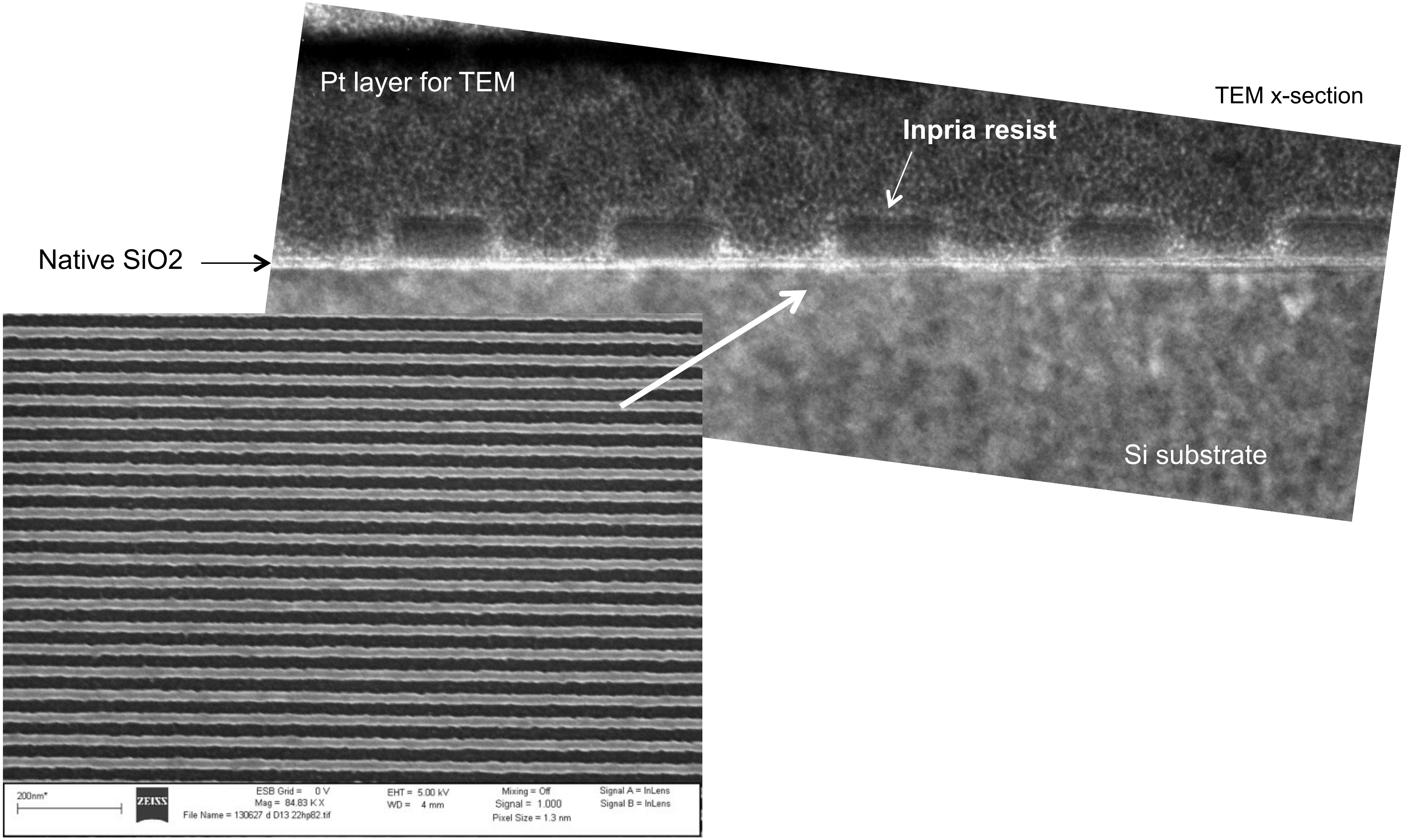
PSI EUV Imaging: YA Series



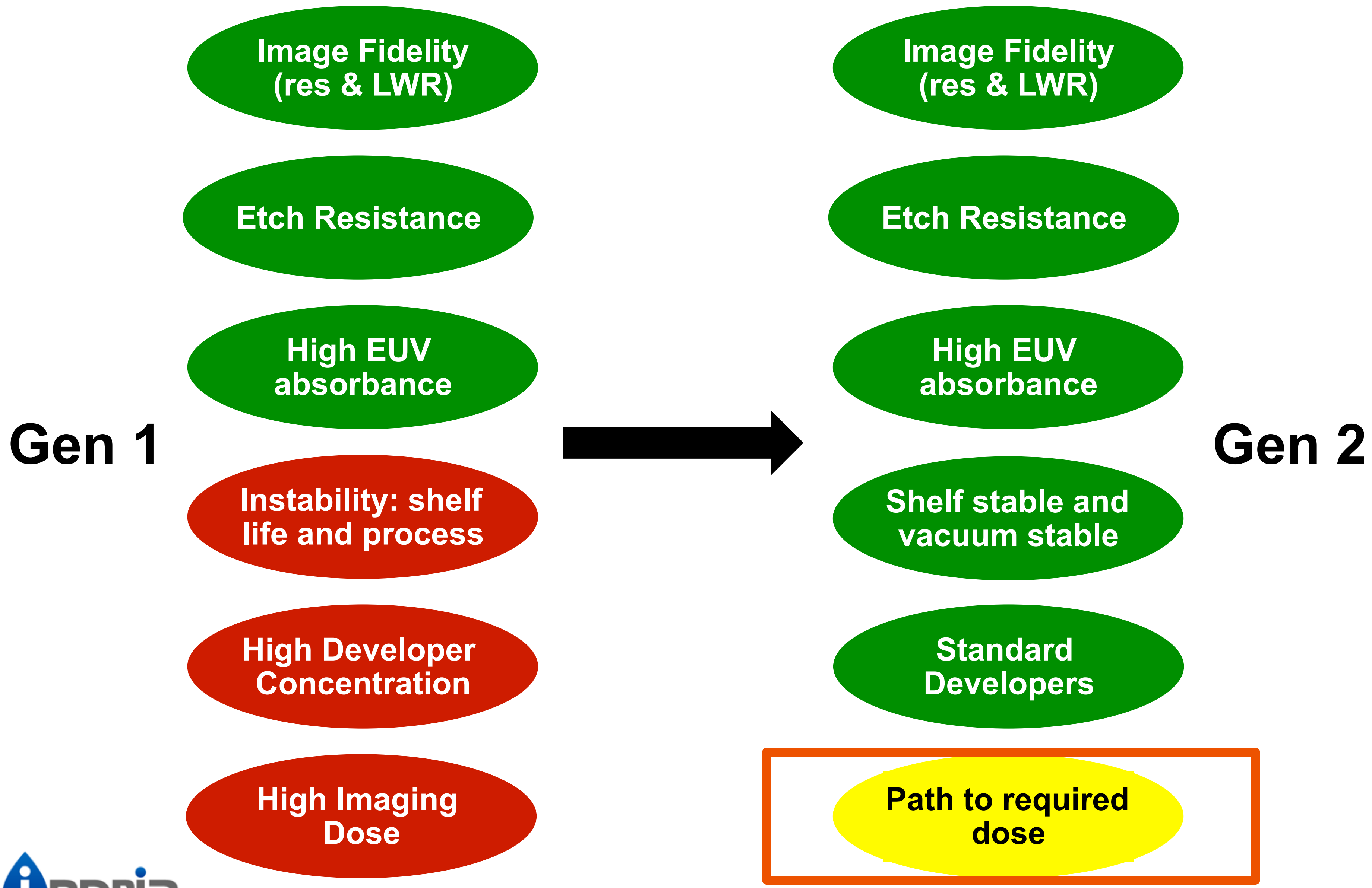
Organic developer, 20nm FT, 150C PEB, dose: ~90 mJ/cm^2

Unoptimized process

PSI EUV: TEM x-section of 22hp



New Platform Solves Key Challenges



Gen 1

Image Fidelity (res & LWR)

Etch Resistance

High EUV absorbance

Instability: shelf life and process

High Developer Concentration

High Imaging Dose

Gen 2

Image Fidelity (res & LWR)

Etch Resistance

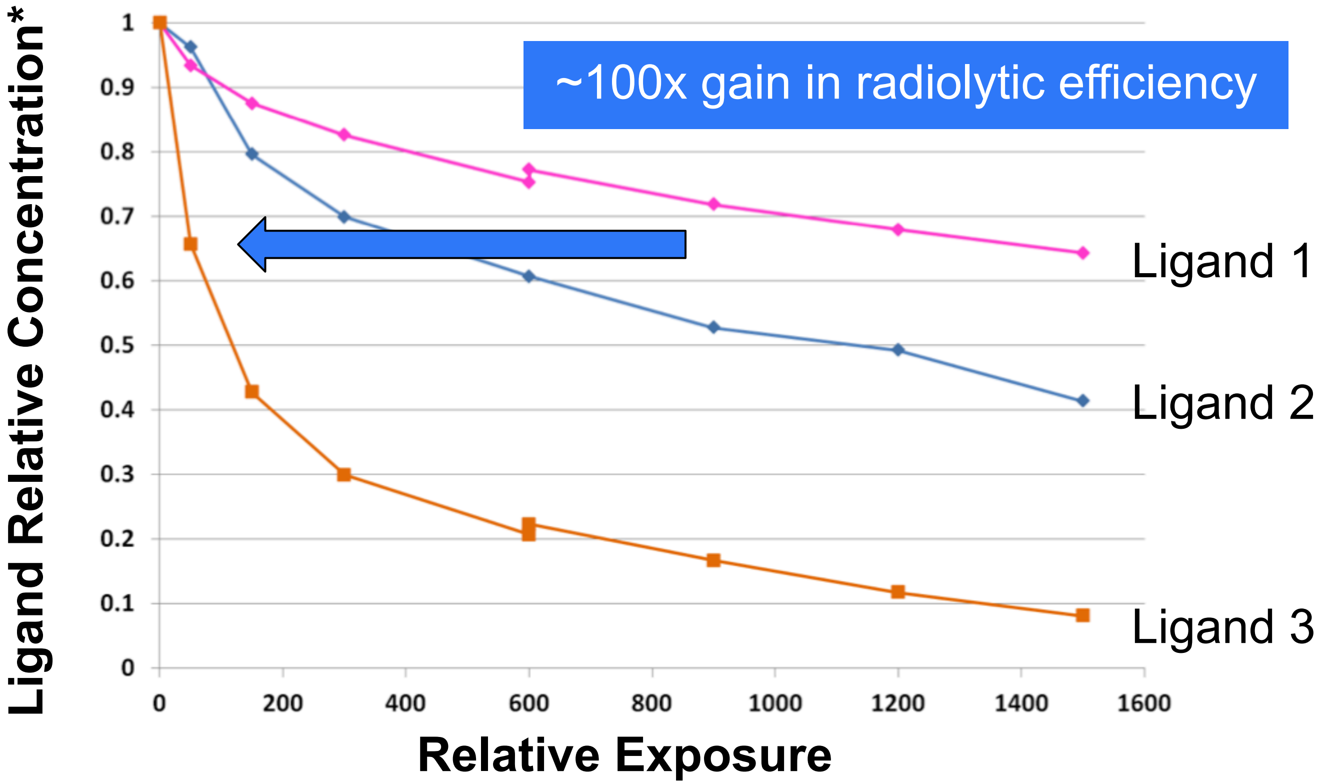
High EUV absorbance

Shelf stable and vacuum stable

Standard Developers

Path to required dose

Ligand Selection Key Lever

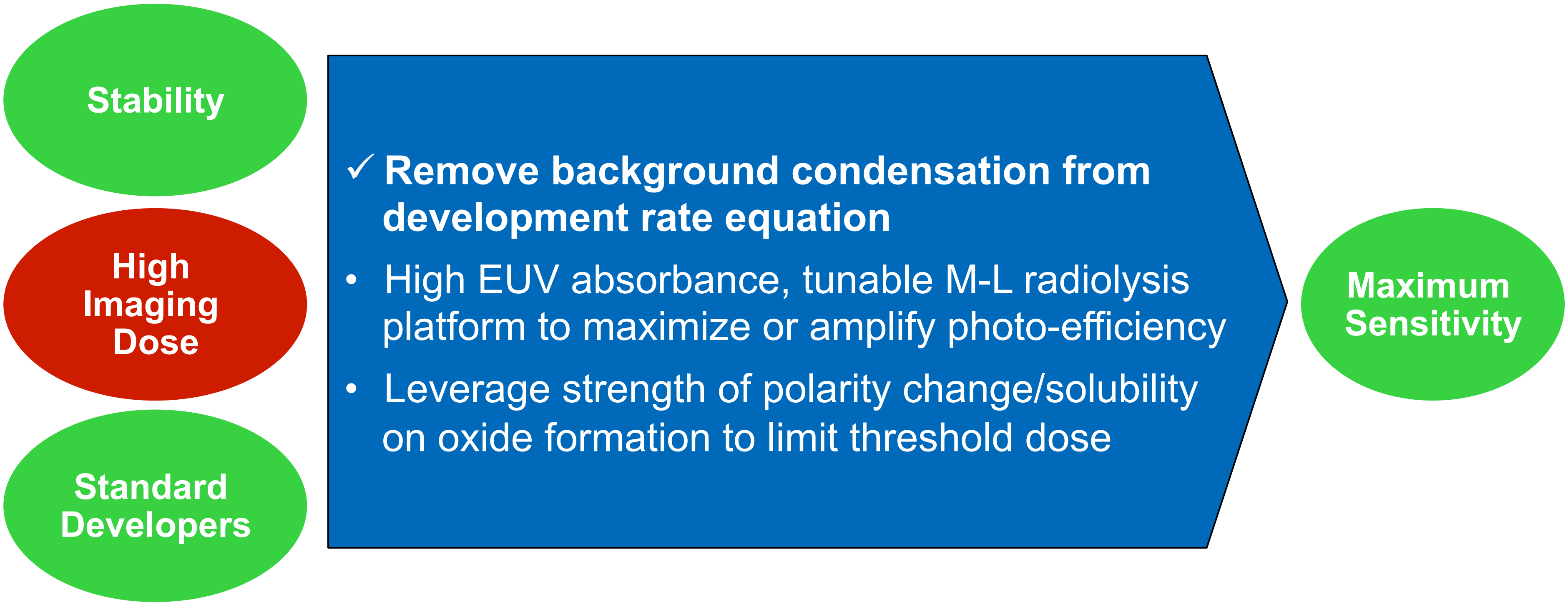


~100x gain in radiolytic efficiency

Radiolytic efficiency modulated as predicted by chemistry of ligand sequence. Demonstrates control over an important component of improving sensitivity.

* Relative FTIR absorbance

Path to Improved Sensitivity



Stability

High Imaging Dose

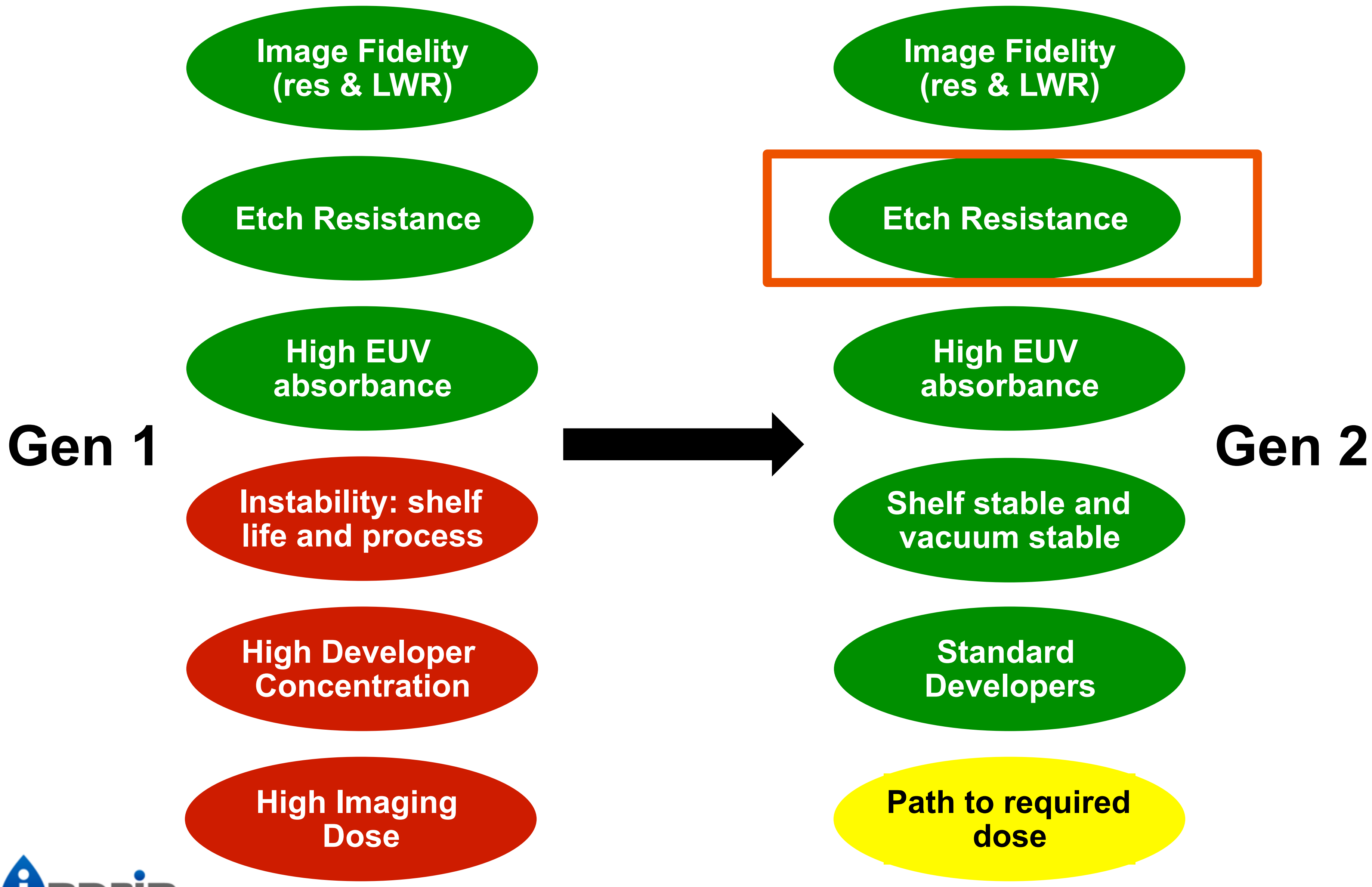
Standard Developers

- ✓ **Remove background condensation from development rate equation**
- High EUV absorbance, tunable M-L radiolysis platform to maximize or amplify photo-efficiency
- Leverage strength of polarity change/solubility on oxide formation to limit threshold dose

Maximum Sensitivity

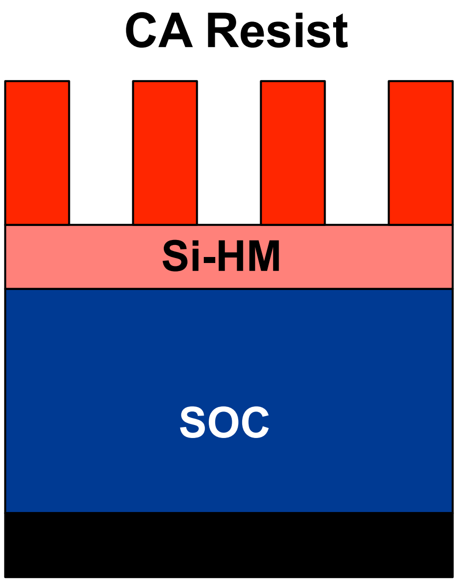
Have stable, fab compatible platform:
critical baseline for testing design modifications

New Platform Solves Key Challenges



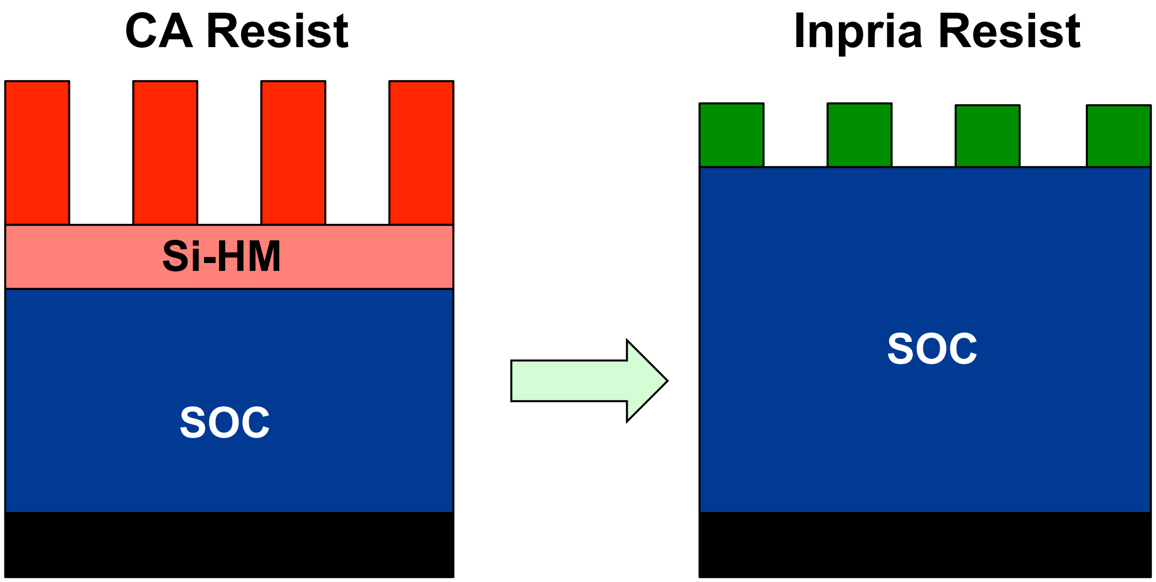
Gen 1	Gen 2
Image Fidelity (res & LWR)	Image Fidelity (res & LWR)
Etch Resistance	Etch Resistance
High EUV absorbance	High EUV absorbance
Instability: shelf life and process	Shelf stable and vacuum stable
High Developer Concentration	Standard Developers
High Imaging Dose	Path to required dose

Typical EUV Litho Module



- Thick Spin On Carbon (SOC) often required for device stack
- Opening the SOC requires use of Si-HM (thickness/selectivity)
- Drives higher aspect ratio resist: can lead to pattern collapse

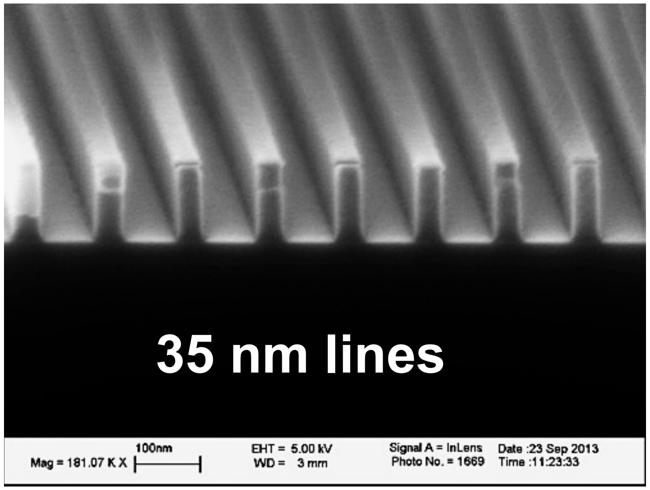
Simplified EUV Pattern Transfer



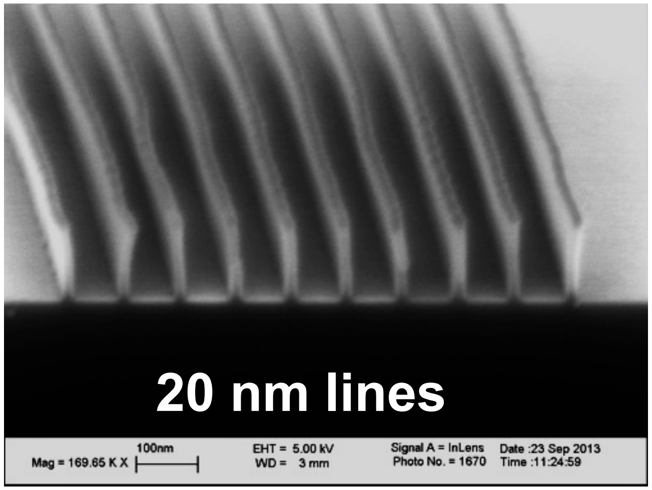
>38:1 selectivity to SOC using O_2:N_2 open

- Process simplification
  - Need <20nm of resist – mitigates pattern collapse
  - Eliminates need for Si-HM: reduces coat/etch steps
  - Allows higher SOC thickness

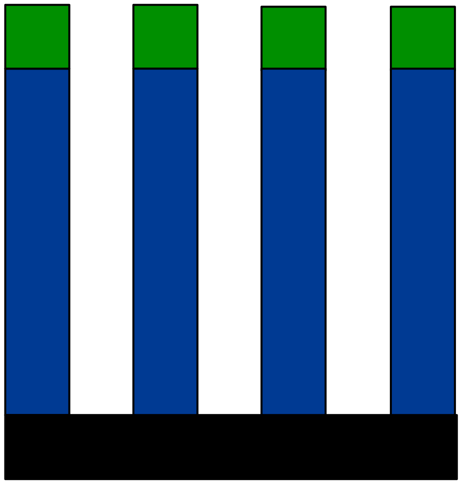
Spin-On-Carbon Open



35 nm lines



20 nm lines



20nm Inpria Resist

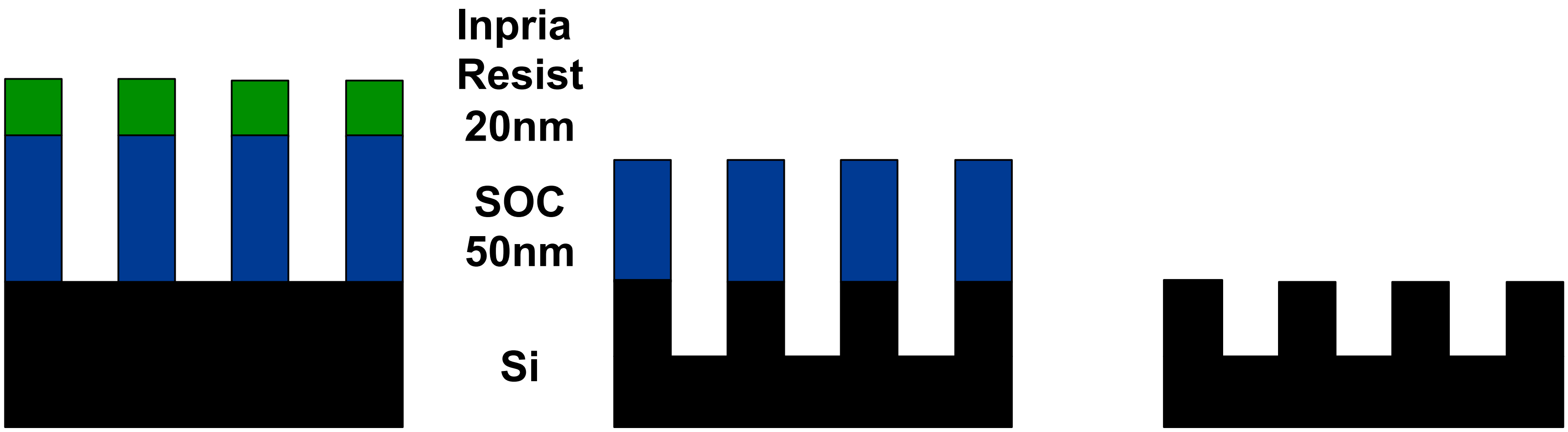
100nm SOC

EB expose, no hard bake

O_2:N_2 etch

High selectivity provides large process window for SOC open

Pattern Transfer & Resist Strip



Inpria Resist 20nm

SOC 50nm

Si

SOC open

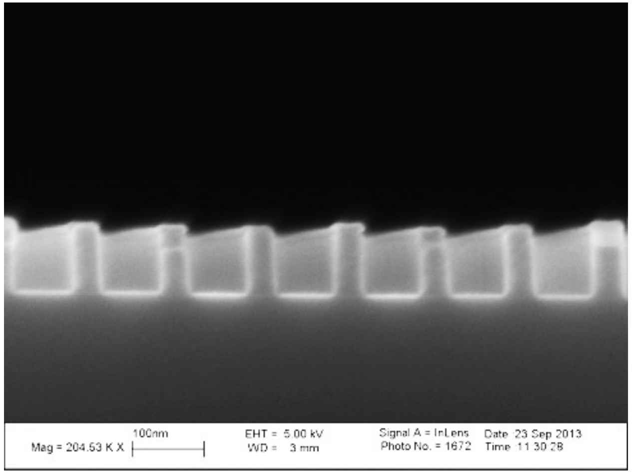
O2:N2 (300W)

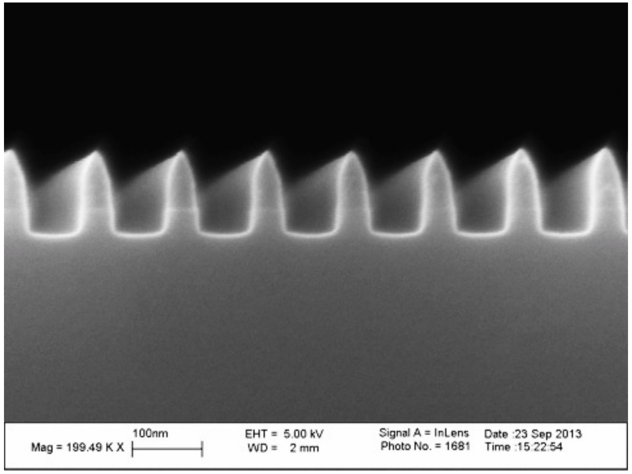
Si etch

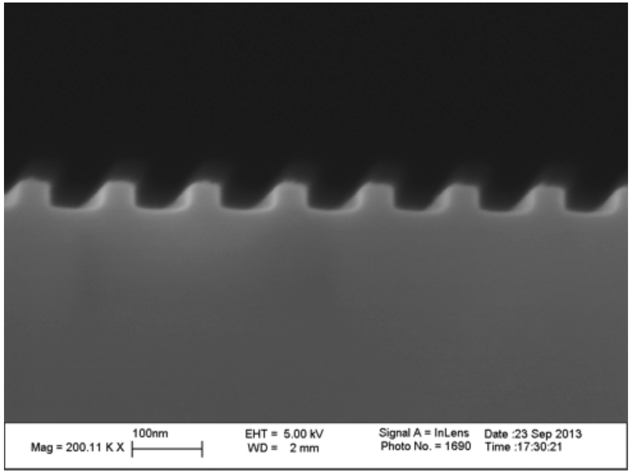
C4F8:Ar (35W)

SOC strip

After O2 (10W)







Resist consumed during etch

Summary

- New metal oxide resist platform developed
  - High resolution (12nm hp by EB)
  - Improved dose
  - Stable
  - Compatible with standard developers

- High etch selectivity and pattern transfer demonstrated

- Path identified to improved sensitivity and contrast

Acknowledgements

CXRO

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PAUL SCHERRER INSTITUT
PSI

SEMATECH

NSF

Thanks to our many partners,
and also to the Inpria team

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