Patterning Capabilities of EUV Resists

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Resist Suppliers

Outline

- Requirements for EUV resists
- Intel EUV resist development program
- Resolution results
- Line width roughness (LWR) results
- Sources of LWR

Challenges for EUV Resists

Patterning Requirements for 32 nm node:

Resolution	15 nm (iso) and 45 nm (1/2 pitch)
LWR (3σ)	≤ 1.5 nm for device performance
DOF	≥ 0.2 μm
Photoresist Collapse	No collapse acceptable for 100 nm pitch

Resist Requirements Specific to EUV:

Sensitivity	2 - 5 mJ/cm2 for high throughput
Absorption	Low absorbance in EUV for good side wall profiles
Outgassing	Very low under vacuum for EUV and out of band radiation

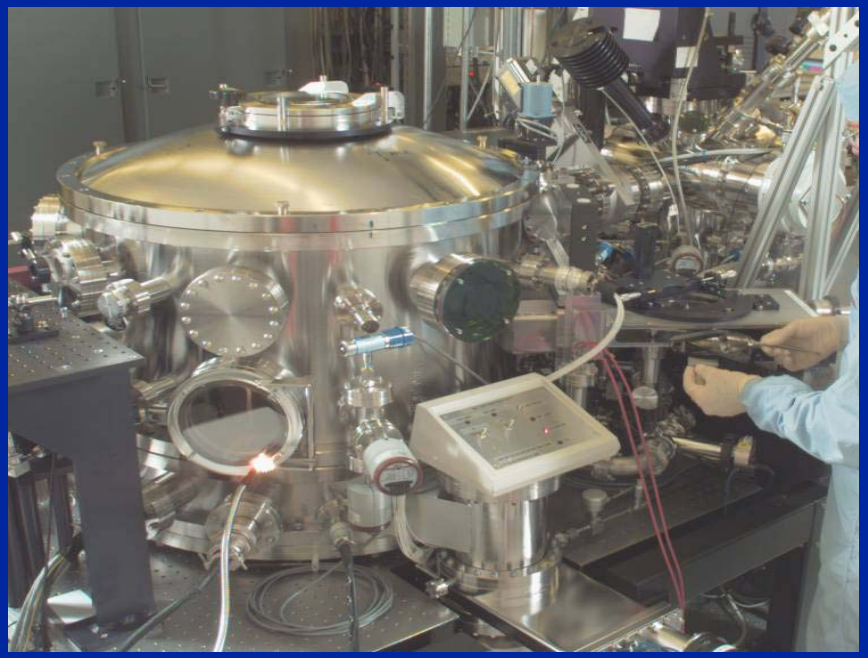
Intel EUV Resist Program

- Resist Supplier Engagement
  - Joint development programs established with several photoresist suppliers
- Resist Evaluation Capability
  - Sandia 10X, Sandia ETS, LBNL F2X
- Resist Absorbance Testing at LBNL
- Resist Outgassing Testing at University of Wisconsin
- University Projects to accelerate research in areas of high risk
  - Projects to reduce LWR, absorbance, collapse, and environmental issues
  - Include polymer design, PAG design, process development, and modeling

Resolution Testing Facilities

Sandia 10X

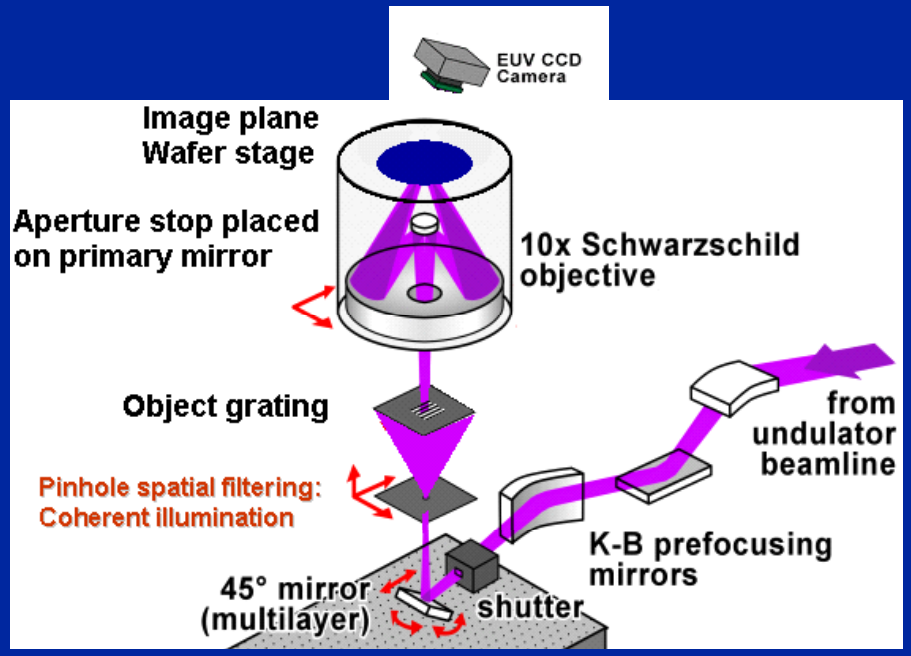
Resolution = 80 nm
NA = 0.088



The 10X tool is an EUV tool with a laser produced plasma source, 10X reduction optics, and a simple wafer handling system.

LBNL F2X

Resolution = < 50 nm
NA = Variable

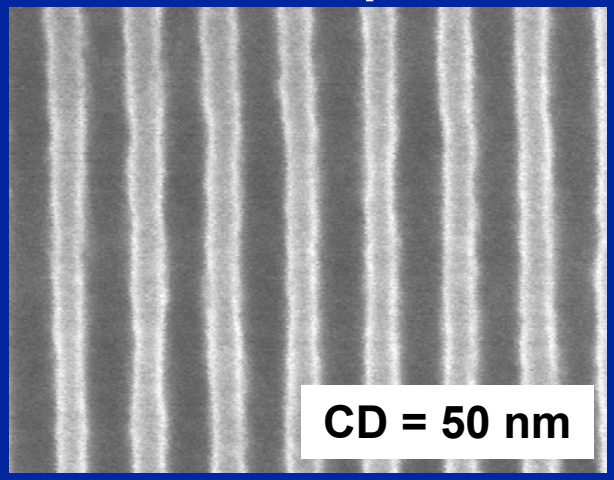


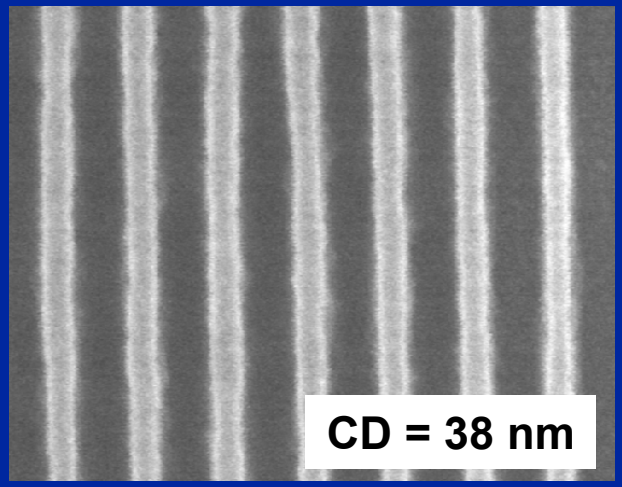
The F2X uses a frequency doubling technique to print smaller features using a grating structure as a mask. EUV radiation comes from a synchrotron ring.

Resolution Results from F2X Dense Lines/Spaces

Resist from supplier B

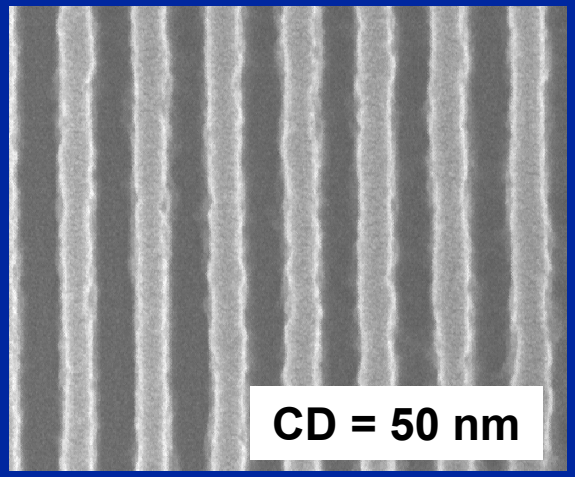
100 nm pitch

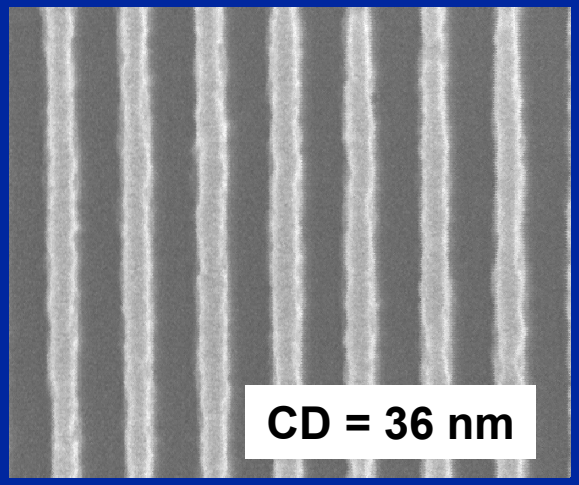




Resist from supplier A

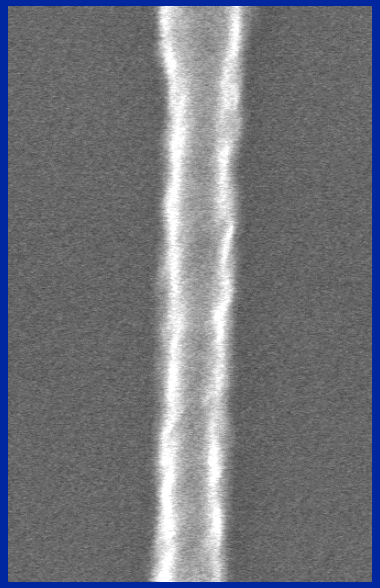
100 nm pitch





Resolution Results Isolated Lines

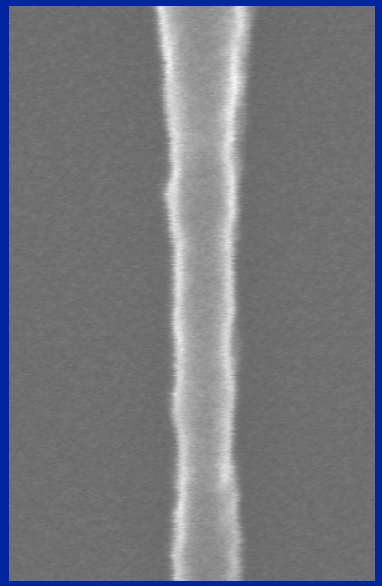
Current EUV isolated line results are limited by the resolution of EUV lithography tools. With better tools, resolution for isolated line may improve.



Resist from Supplier A

Printed on Sandia 10X

CD = 55 nm

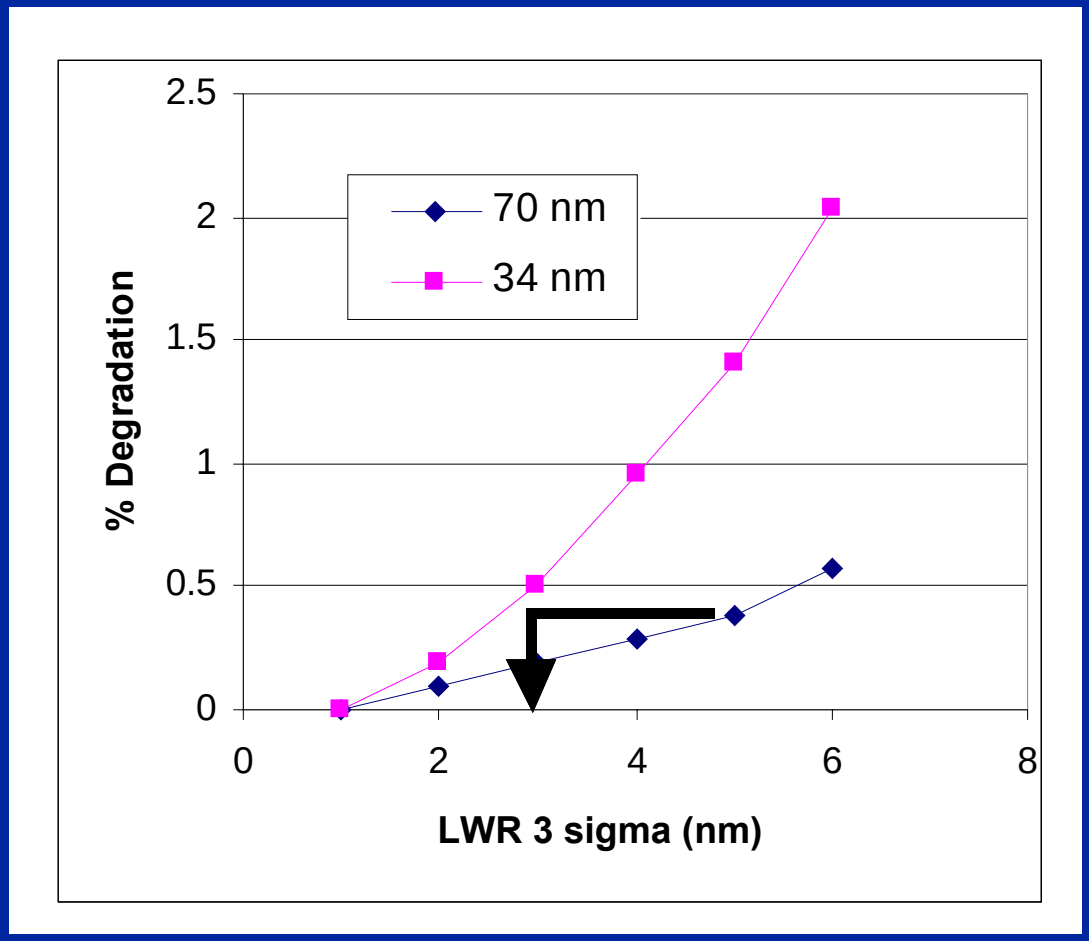


Resist from Supplier D

Printed on Sandia 10X

CD = 45 nm

LWR Impact on Device Performance

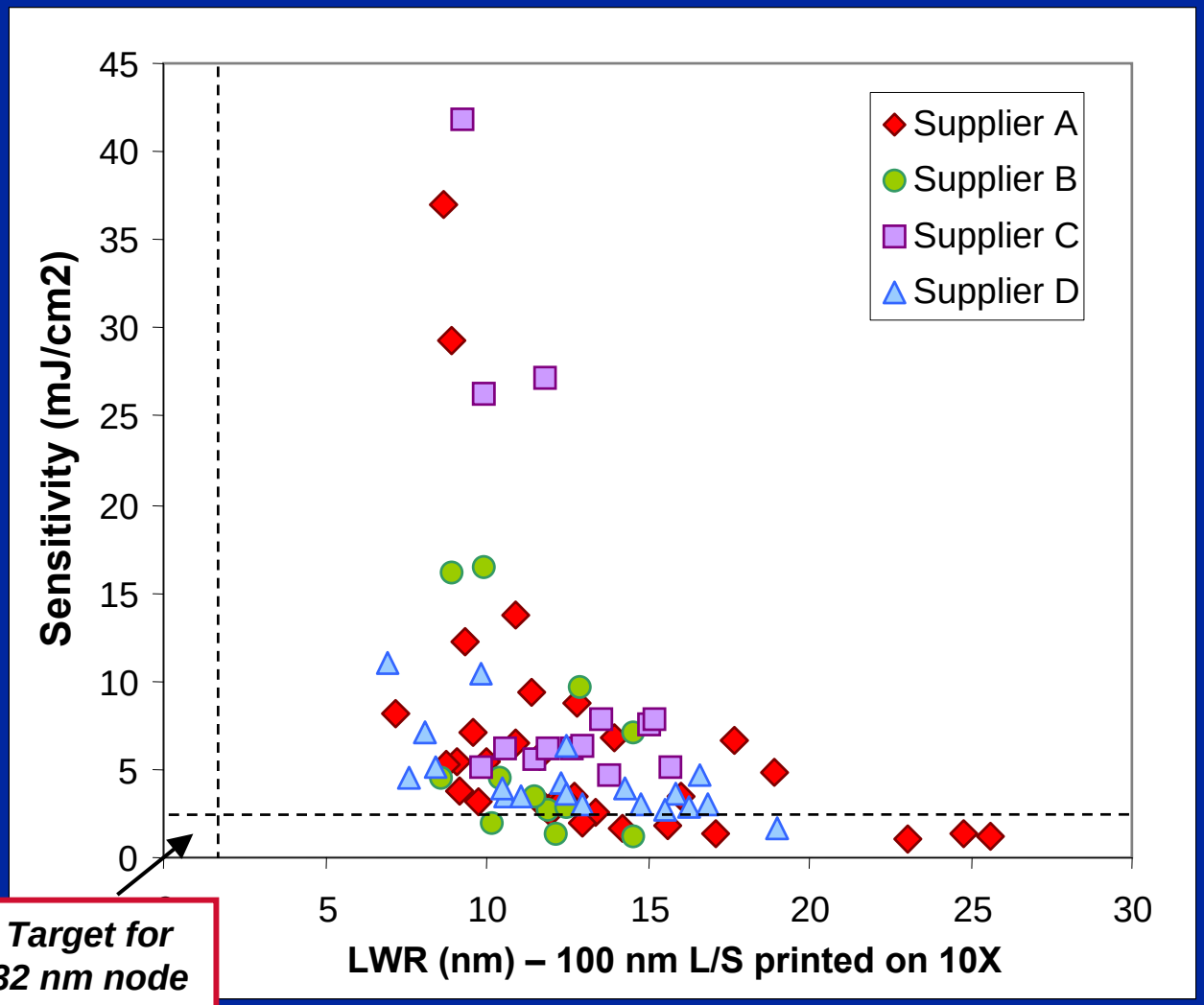


IDSAT degradation for 70 nm devices (130 nm technology) and 34 nm devices (65 nm technology).

Arrow shows LWR required for 34 nm device to prevent increased degradation relative to 70 nm device.

1 Determination of the Line Edge Roughness Specification for 34 nm Devices, IEDM 2002 Tech Digest

LWR vs. Sensitivity

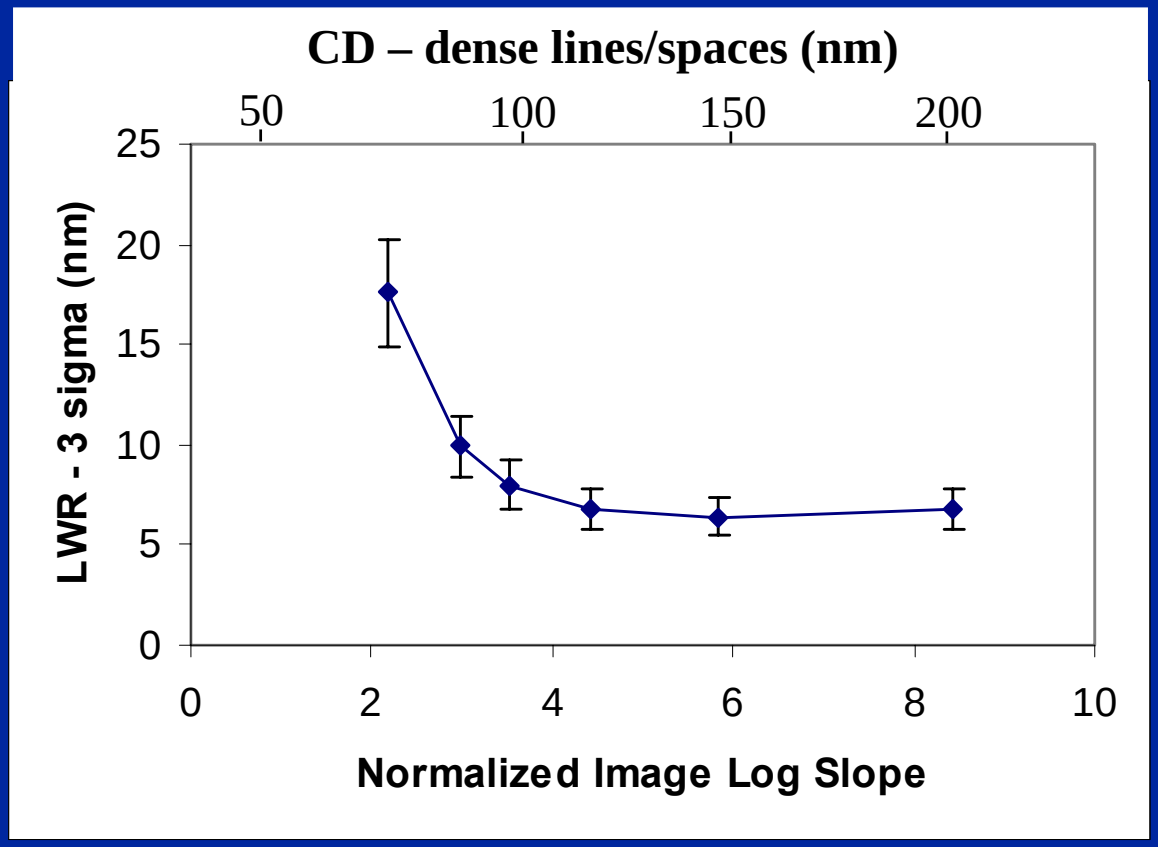


In the last year, improvement in LWR has been minimal.

MUCH IMPROVEMENT IS NEEDED IN LWR

Impact of Aerial Image on LWR

Effect of NILS on LWR for an EUV resist



Improvement in LWR is not a linear function of normalized image log slope (NILS).

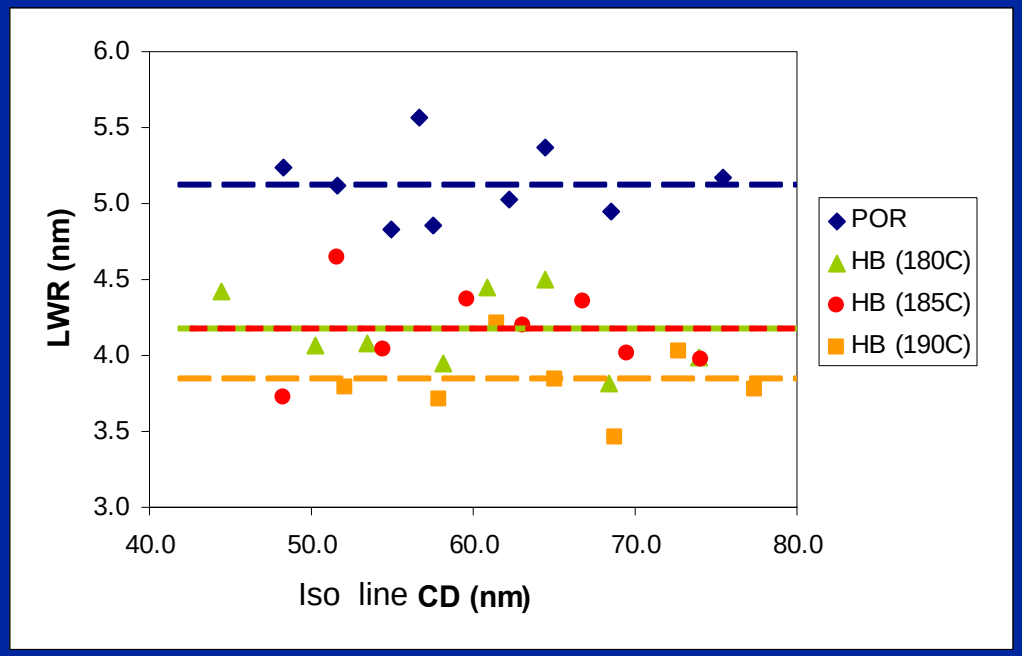
Aerial image improvement will help LWR to a limited extent.

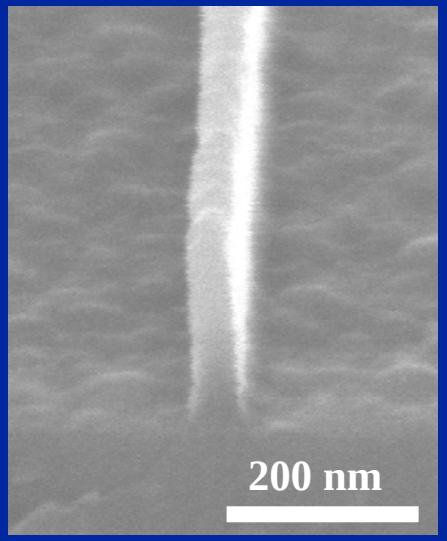
Impact of Process Conditions on LWR

Improvement in LWR due to process improvements may be limited.

A study of the effects of processing conditions using 193 nm resists showed that, at POR processing conditions, LWR is near its minimum value.

LWR may be reduced by adding additional processing steps, specifically to reduce LWR. For example, a hard bake step reduces LWR.

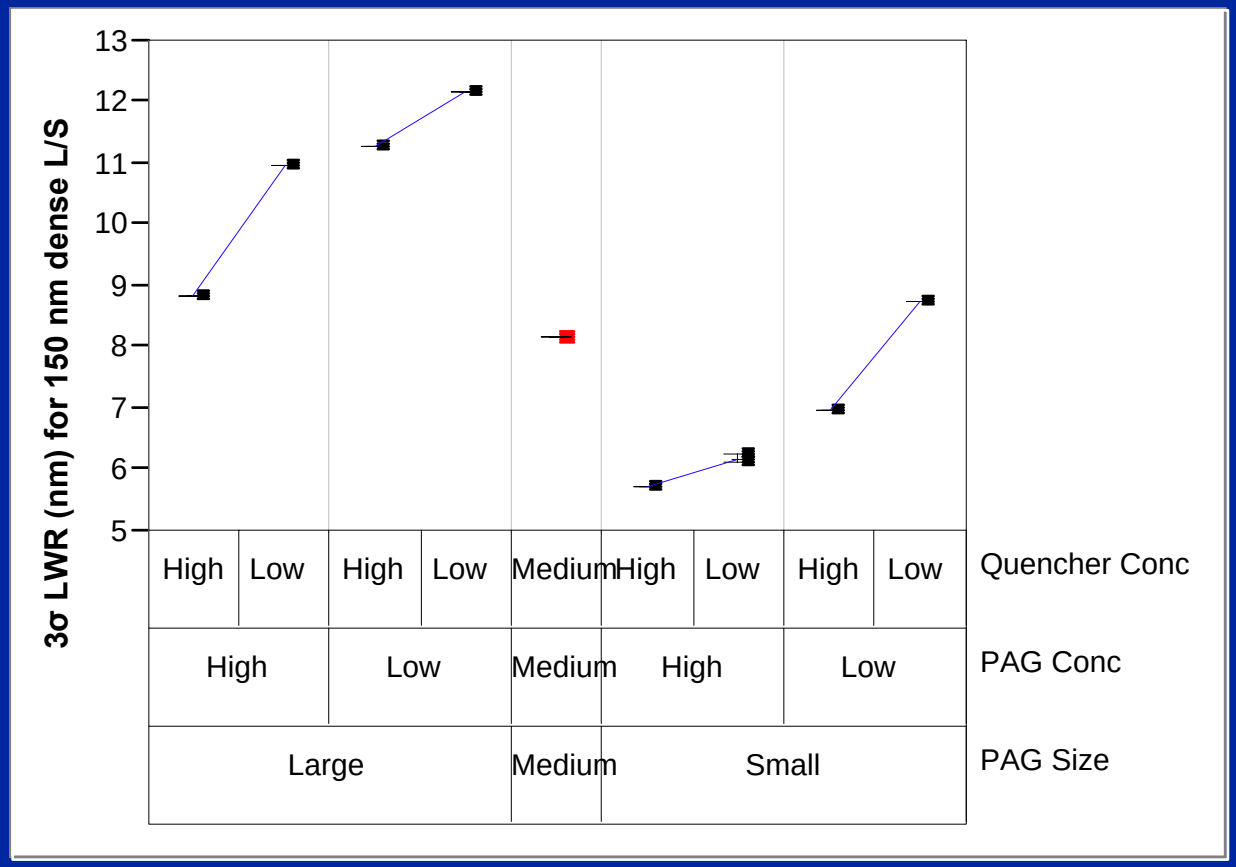




Profile of resist after HB

Photoresist Material Improvements Needed for Reduced LWR.

EUV resist DOE with PAG and quencher varied and all other material and processing variables held constant.



Small PAGs/acids have lower LWR.

Longer acid diffusion length may smooth roughness due to:

-PAG clustering?

- Shot noise?

Summary

- Some EUV resists have met resolution targets for dense lines/spaces at the 32 nm node.

- With better tools, EUV resists are expected to meet resolution targets for isolated lines at the 32 nm node.

- Meeting LWR targets is highest risk for photoresists at the 32 nm technology node – regardless of the lithography platform that is used (EUV, 157 nm, etc).

- To meet LWR targets, changes in the resist platform are necessary.

Acknowledgements

- Resist Suppliers
- Sandia National Labs

  John Goldsmith, Dan Folk, Jerry Selfridge
- Berkeley National Lab

  Erik Anderson