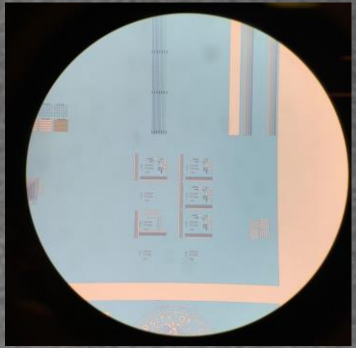
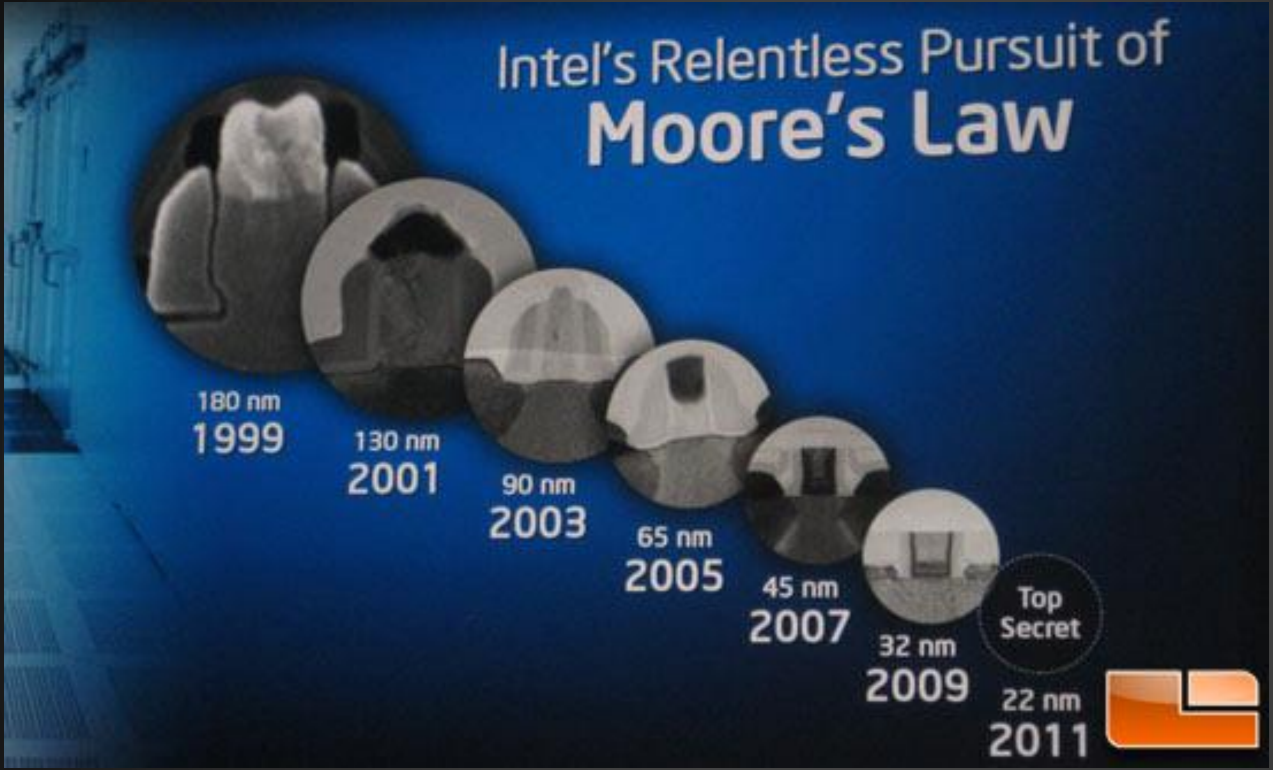
Critical Dimension Enhancement of DUV Photolithography on the ASML 5500/300



Francesca Calderon
Miramonte High School
August 13th, 2015



g-line - 436 nm

i-line - 365 nm

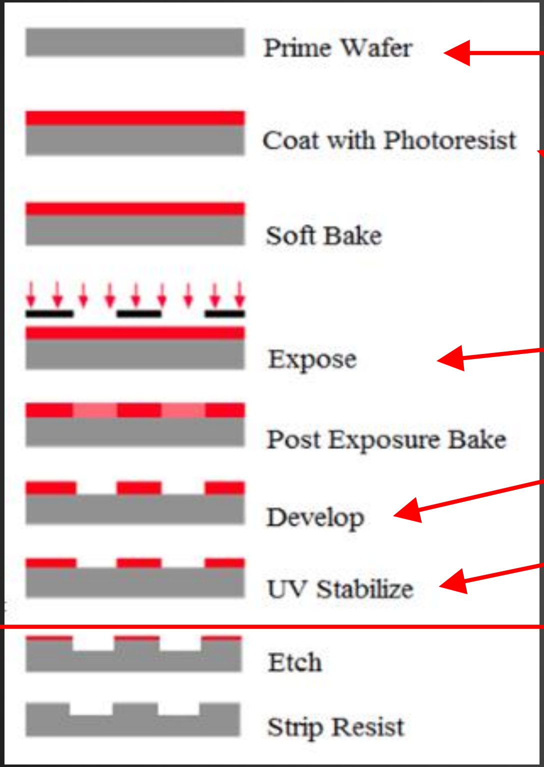
DUV - 248 nm

DUV - 193 nm

resolution ~ λ /2NA

[1] Krassenstein, Brian. "The Moore’s Law of 3D Printing… Yes It Does Exist, And Could Have Staggering Implications." *3DPrintcom*. N.p., 28 June 2014. Web. 12 Aug. 2015.

Photolithography Review



Bottom Anti Reflective Coating - svgcoat3

Photoresist Coat - svgcoat6

DUV Exposure - asml300

Develop in MF26 - svgdev6

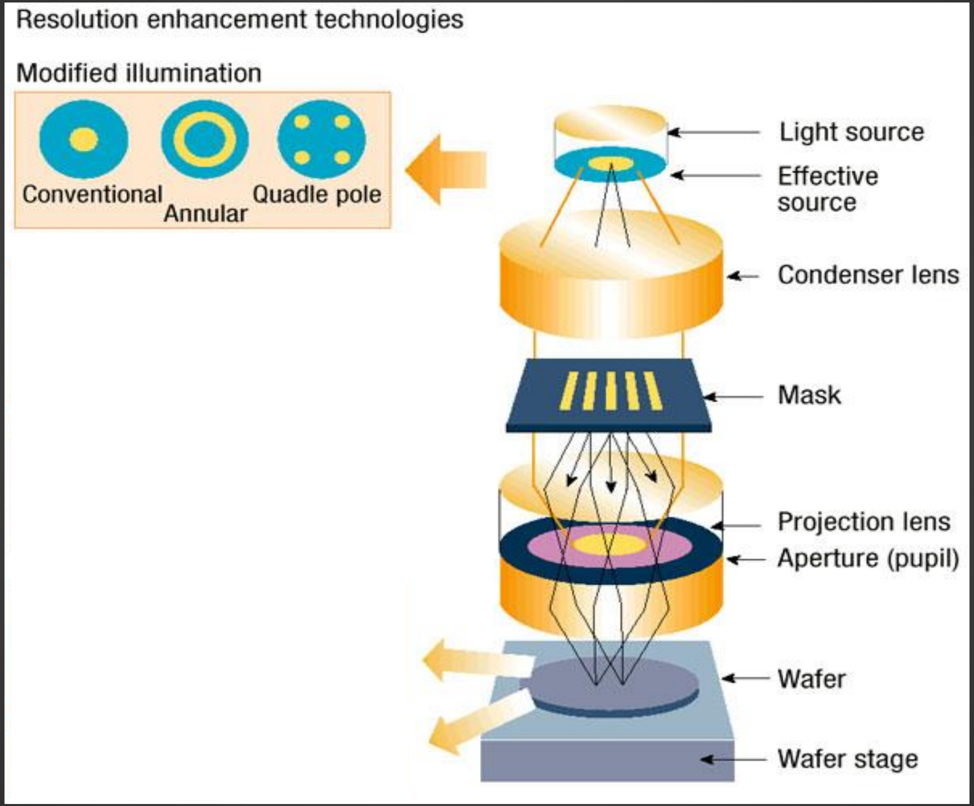
UV stabilize - axcelis/uv bake

[2] "Semiconductor Lithography." The Basics of Microlithography. N.p., 23 Nov. 2006. Web. 03 Aug. 2015.

Background and History

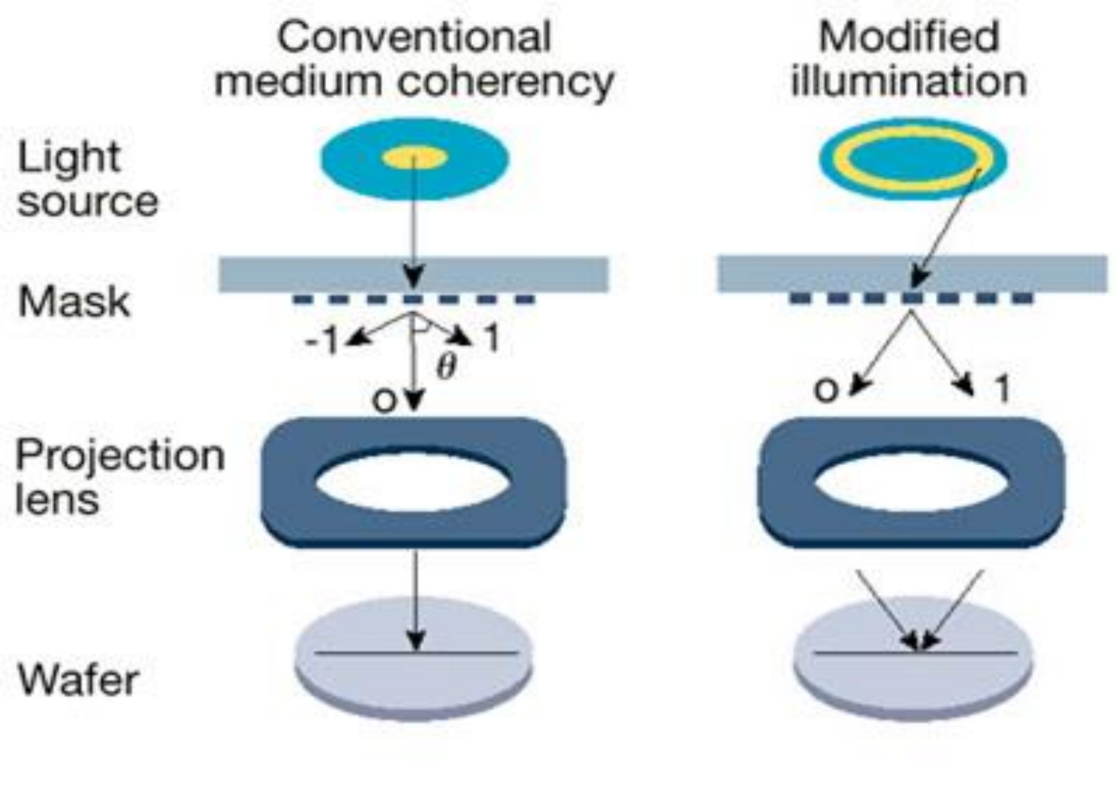
- ➢It is understood that the current resolution limit of the asml300 is 250 nm
- ➢The past baseline CMOS runs have successfully made transistors with 350 nm features
- ➢Similar systems in other labs have been shown to go down to 200 nm for an isolated line

Background: Optical Column in Stepper



[3] Ito, Takashi, and Shinji Okazaki. *Nature*. N.p., 31 Aug. 2000. Web. 12 Aug. 2015.

Theory: Annular Illumination



[3] Ito, Takashi, and Shinji Okazaki. *Nature*. N.p., 31 Aug. 2000. Web. 12 Aug. 2015.

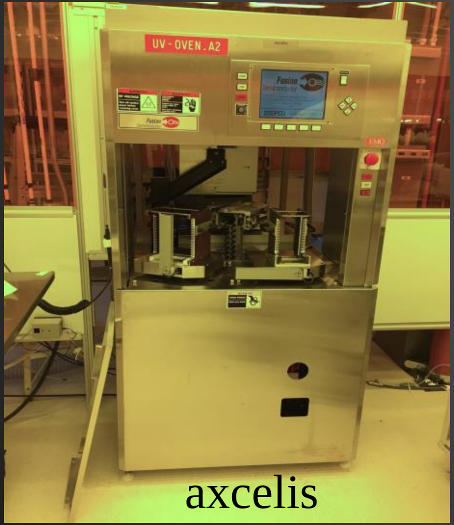
Goals

- ➢Characterize properties of UV210-0.3, a new photoresist
  - generate a process specification for lab members to reference
- ➢Determine the minimum feature size that can be produced on the asml300
  - Focus-exposure matrices and inspection with leo SEM
- ➢Characterize off-axis illumination and variable numerical aperture
  - Bossung and exposure latitude plots

Tools Qualified On :

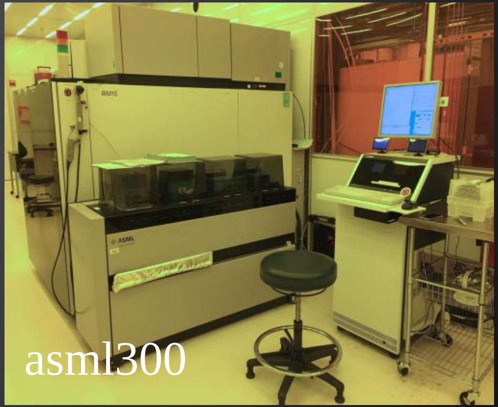
svgcoat/dev6


svgcoat3



axcelis

uvbake



asml300

Tools Qualified On :


nanospec

matrix

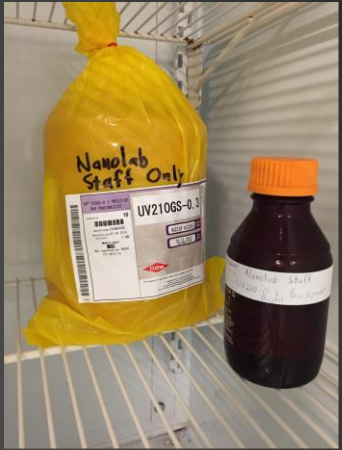

asiq

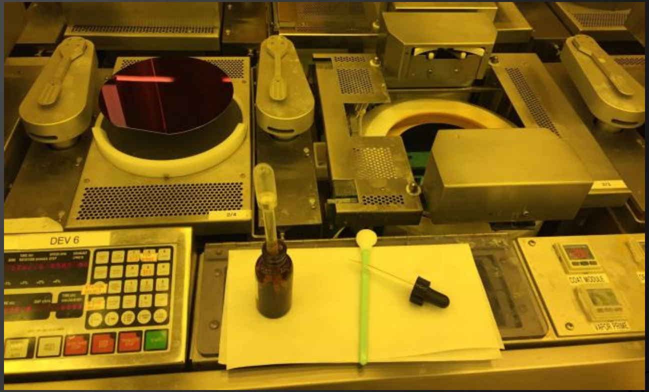
primeoven

leo

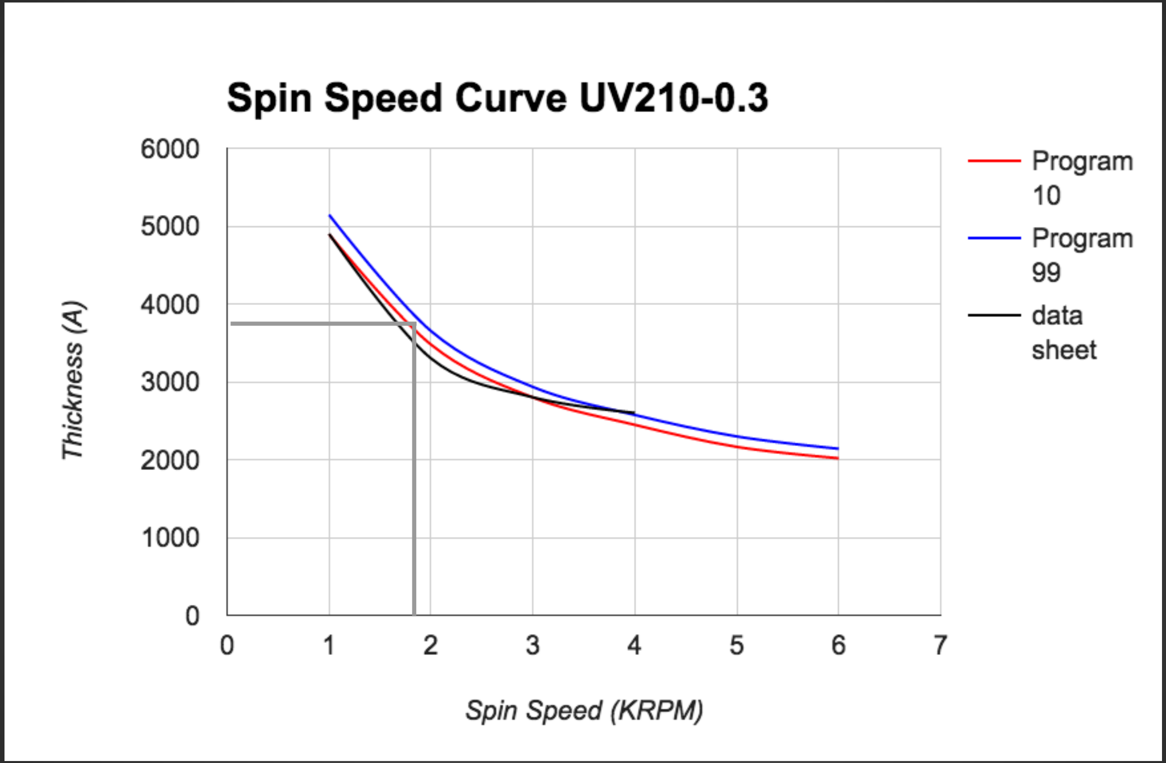
Experimental Method - Photoresist Characterization

1. Coated wafers at different spin speeds and measured film thickness
    - generate spin speed curve
2. Decided upon a spin speed to achieve a targeted film thickness
3. Created a process specification to define the final process
4. Ran process wafers to populate the process specification





Experimental Results - Photoresist Characterization



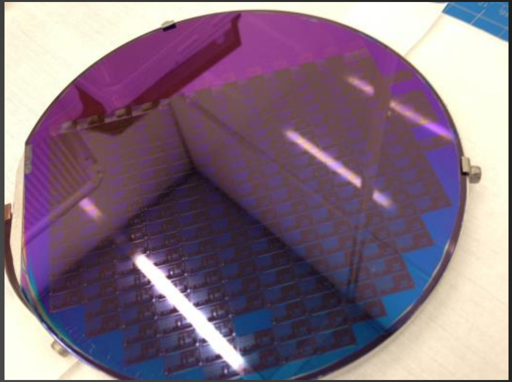
The vendor data sheet provided a spin speed curve that closely matched our experimental results on svgcoat6

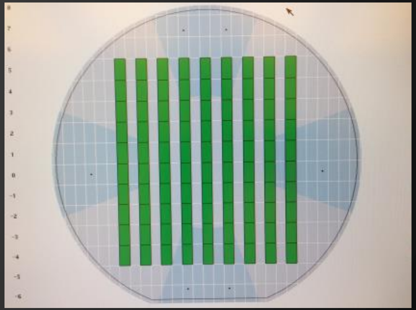
Experimental Results - Process Specification

Step	Tool	Settings
4.2.5.1 - BARC	(svgcoat3)	Program (3,3) Coat at 3,750 rpm for 30 sec., 190 C soft bake for 200 sec.
4.2.5.2 - Coat	(svgcoat6)	Programs (9,7modified,1) No prime, coat at 1,800 rpm for 30 sec., 130 C proximity softbake for 60 sec.
4.2.5.3 - Expose	(asml300)	Run stepper job CMOS200 located in Clarkson folder. Set exposure and focus offset to 14 mJ/cm2 and -0.23 microns respectively. Set alignment type to None
4.2.5.4 - Develop	(svgdev6)	Programs (1,1,9) Contact post exposure bake at 130 C for 60 sec, puddle devlop in MF-26A for 60 sec., no hard bake
4.2.5.5 - UV Stabilize	(axcelis) (uvbake)	Program U 0-10 sec: lamp off, 110 C 10-20 sec: lamp low, 110 C 20-40 sec: lamp low, ramp 110 to 140 C 40-70 sec: lamp low, 140 C

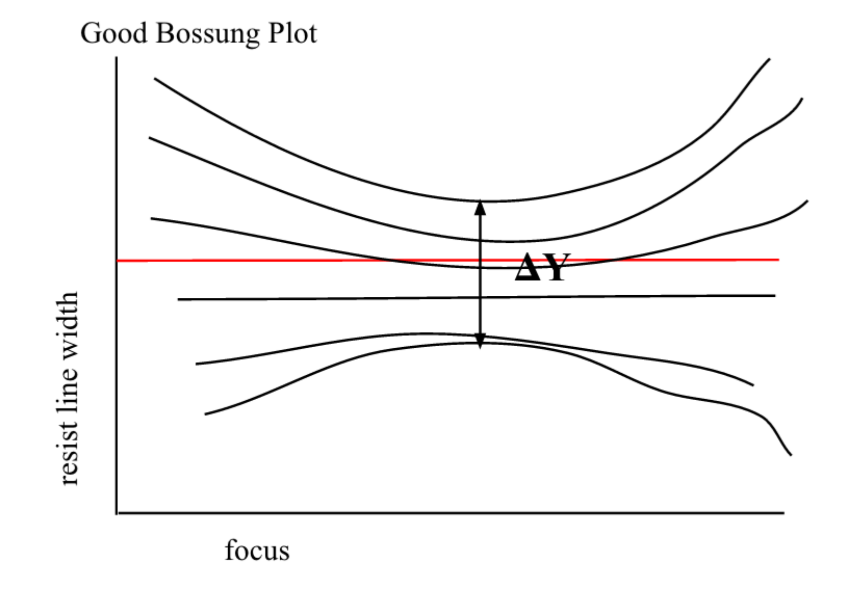
Experimental Method - Critical Dimension Enhancement

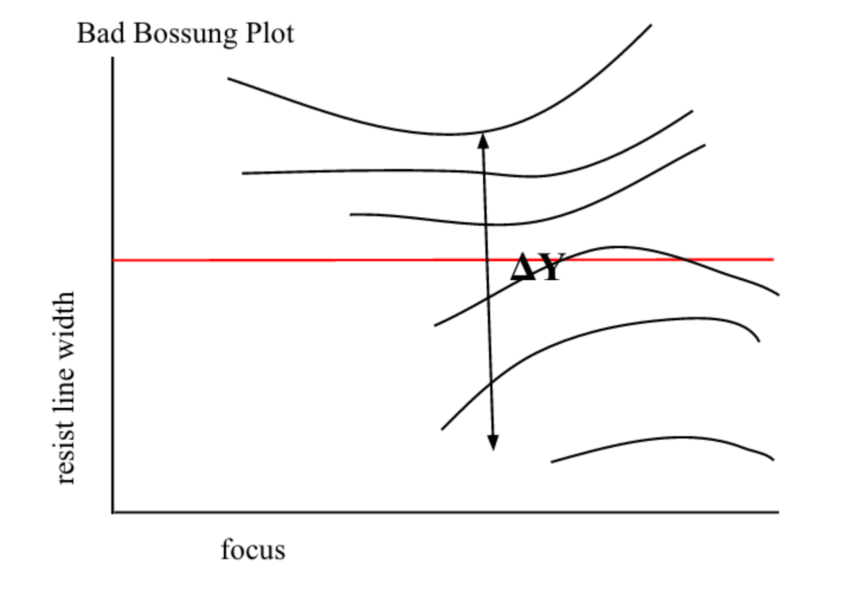
1. Ran focus-exposure matrices
2. Measured linewidth with the leo SEM
3. Created Bossung and exposure latitude plots
4. Determined ideal imaging conditions to resolve 150 nm isolated lines
5. Patterned whole wafers with ideal conditions to make sure the results were repeatable





Intro to Bossung Plots

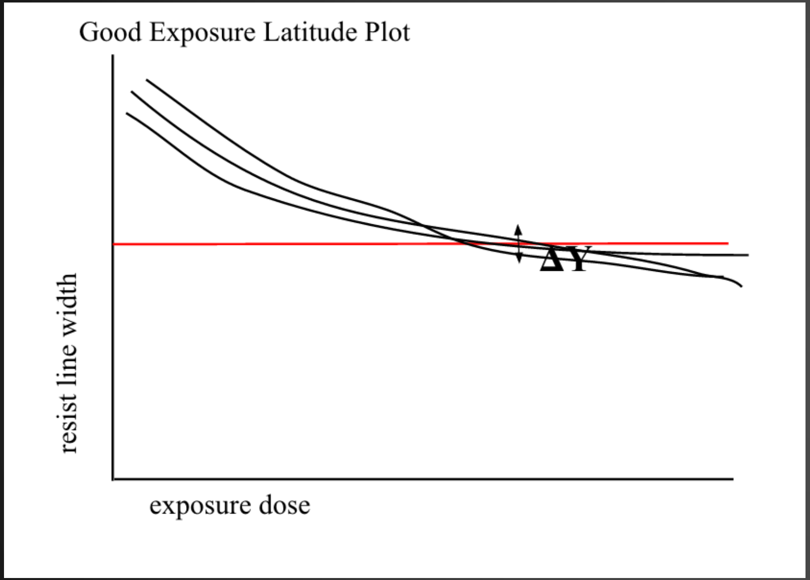


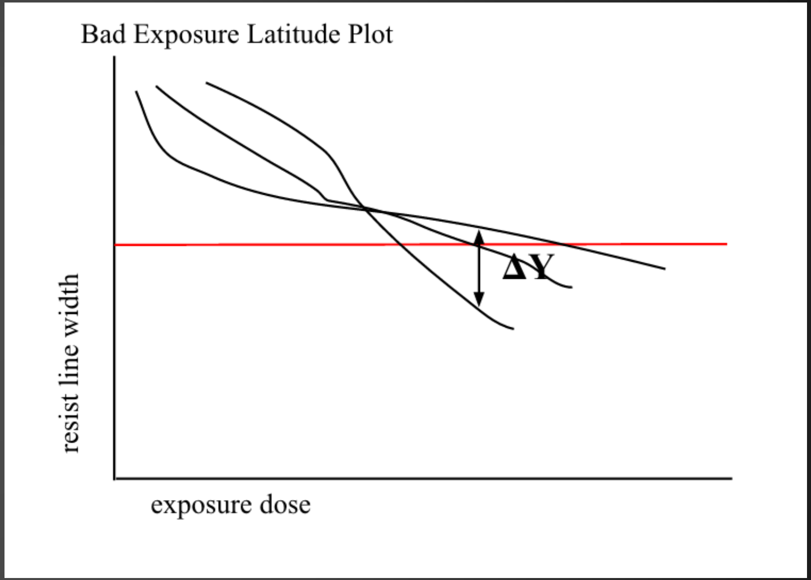


What is important:

1. A change in exposure dose results in the smallest possible change in linewidth - ΔY
2. A change in focus results in the smallest possible change in linewidth - slope

Intro to Exposure Latitude Plots

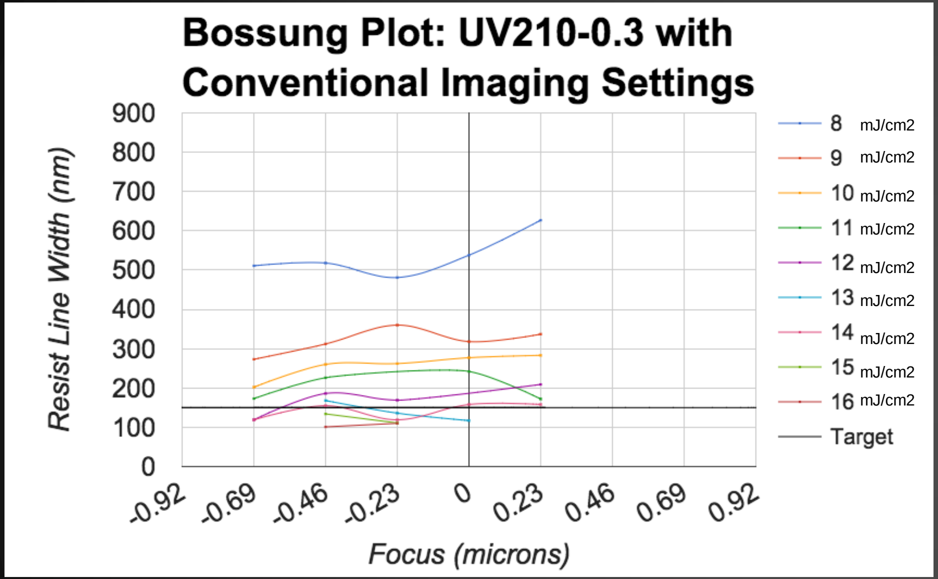


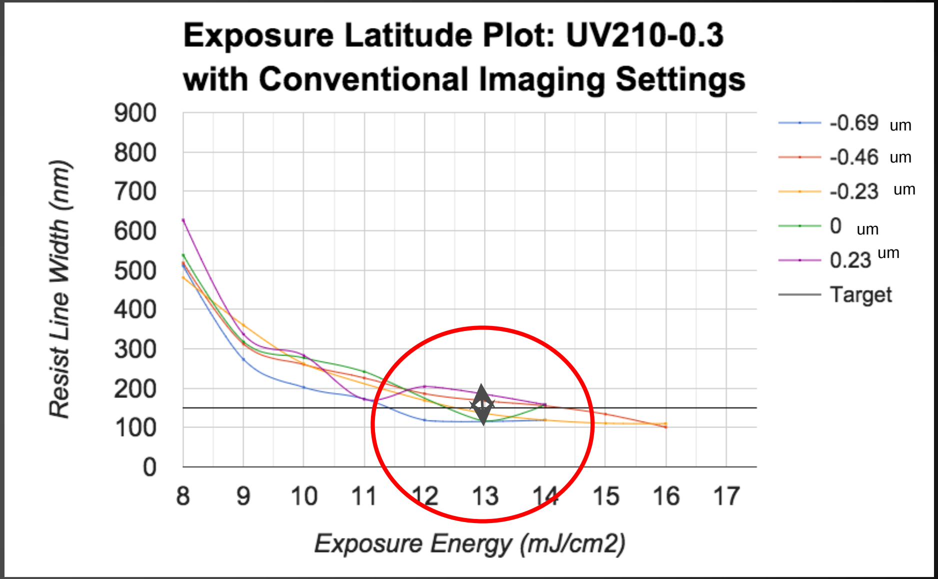


What is important:

1. A change in focus dose results in the smallest possible change in linewidth - ΔY
2. A change in exposure results in the smallest possible change in linewidth - slope

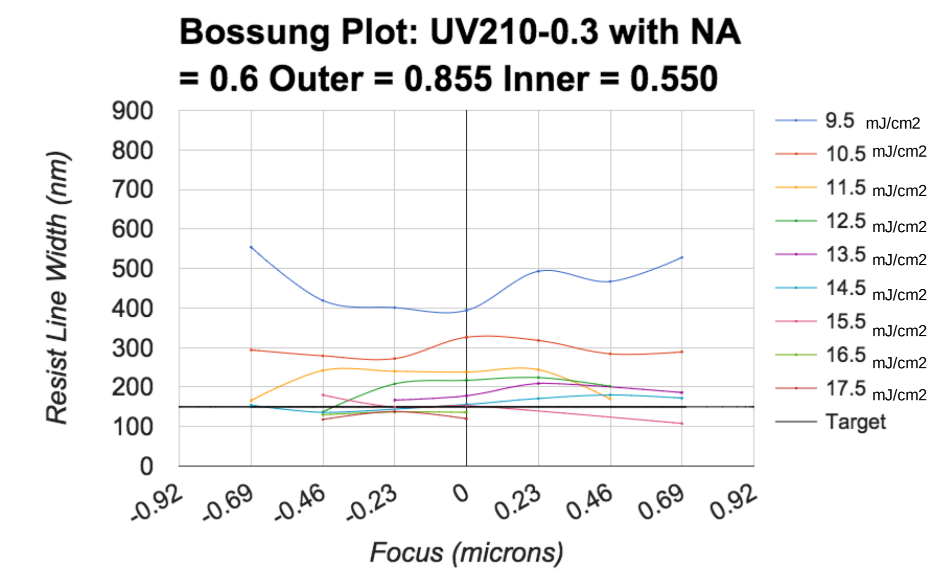
Experimental Results - Conventional Imaging

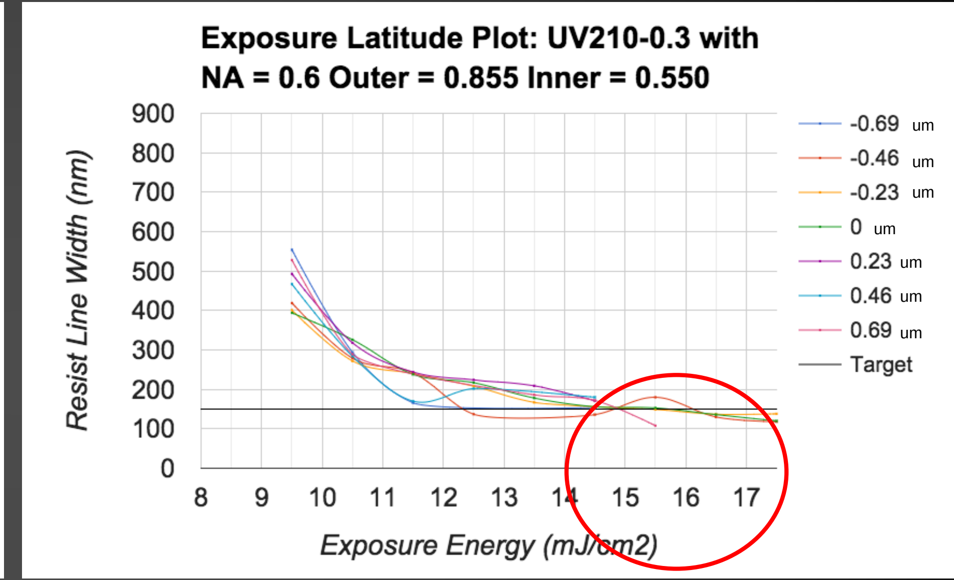




Dose: 13 mJ/cm2
Focus: -0.23 um
Enhancement: none
Exposure Latitude: 186 nm - 117 nm = 69 nm

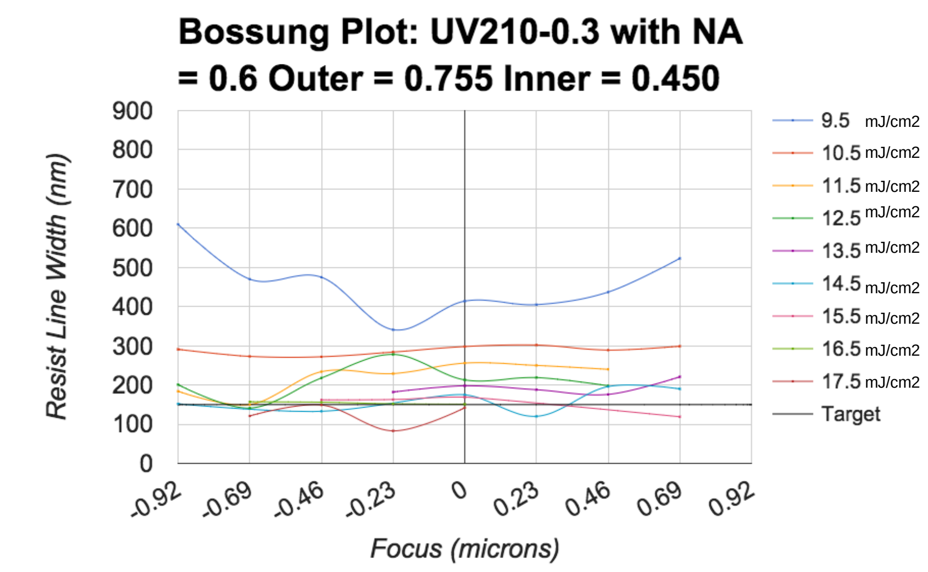
Experimental Results - Critical Dimension Enhancement

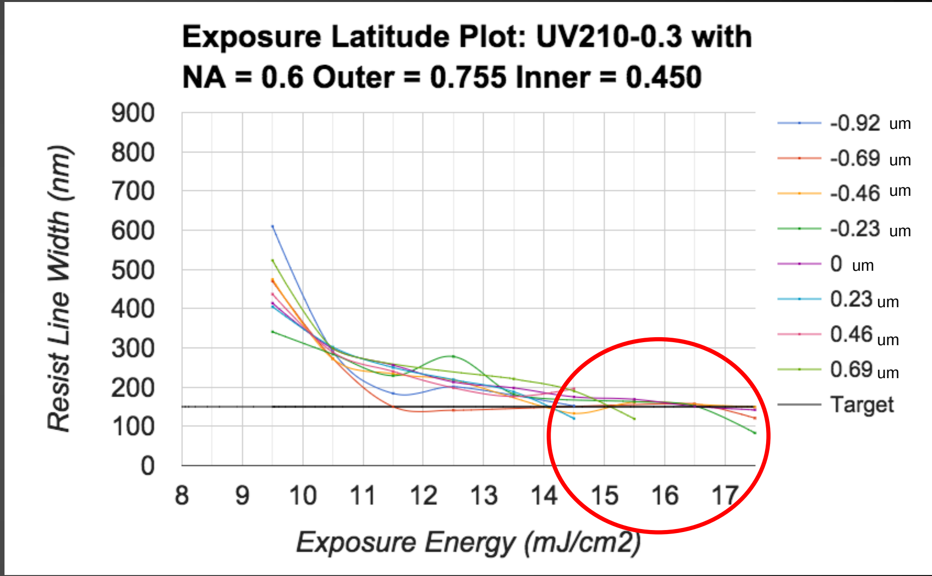




Dose: 16 mJ/cm2
Focus: -0.23 um
Enhancement: NA = 0.6 Outer = 0.855 Inner = 0.550
Exposure Latitude: 151.5 nm - 142 nm = 9.5 nm

Experimental Results - Critical Dimension Enhancement





Dose: 16 mJ/cm2
Focus: -0.23 um
Enhancement: NA = 0.6 Outer = 0.755 Inner = 0.450
Exposure Latitude: 161 nm - 157.5 nm = 3.5 nm

Chosen Image Settings

Exposure: 16 mJ/cm2

Focus: -0.23 microns

Numerical Aperture: 0.6

Annular Condition 1: Sigma Inner: 0.550
Sigma Outer: 0.855

Annular Condition 2: Sigma Inner: 0.450
Sigma Outer 0.755

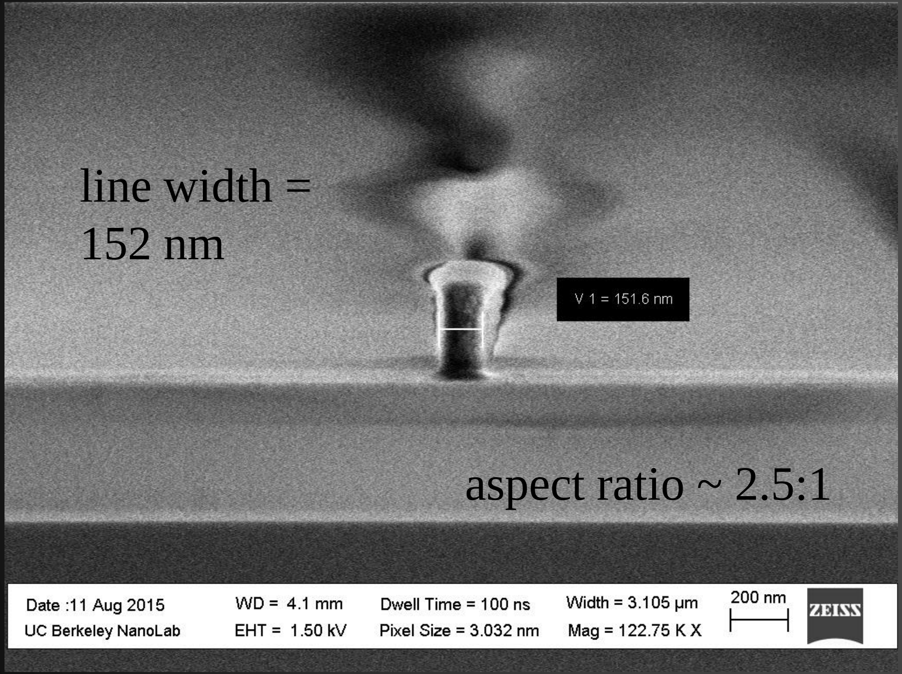
Experimental Results : Wafer Scale Performance, CD = 150 nm

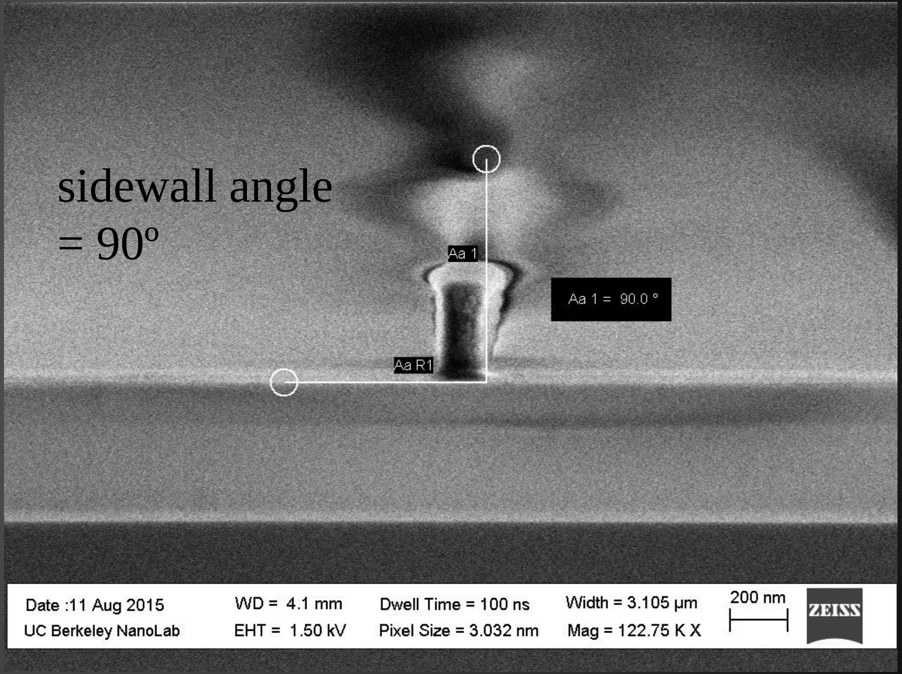
21 locations per wafer were measured

Date	8/5/2015		8/6/2015		8/11/2015	
wafer ID	IF51		IF61		IF64	
Exposure	16 mJ/cm2		16 mJ/cm2		16 mJ/cm2	
Focus	-0.23 um		-0.23 um		-0.23 um	
NA	0.6		0.6		0.6	
Sigma O	0.855		0.855		0.755	
Sigma I	0.55		0.55		0.45	
	avg:	142.4 nm	avg:	142.4 nm	avg:	150.3 nm
	Std Dev:	13.3 nm	Std Dev:	10.5 nm	Std Dev:	10.9 nm
	range:	50 nm	range:	32.0 nm	range:	39.0 nm
	yield:	90.5%	yield:	52.4%	yield:	90.5%

Best case imaging was observed with the small annular ring. It produced an average line width of 150.3 nm, with a 90.5% yield.

Experimental Results : UV210-0.3 Cross-sectional Profiles





Imaging conditions: 16 mJ/cm2, -0.23 um, NA=0.6 Sigma Outer=0.855 Sigma Inner=0.55

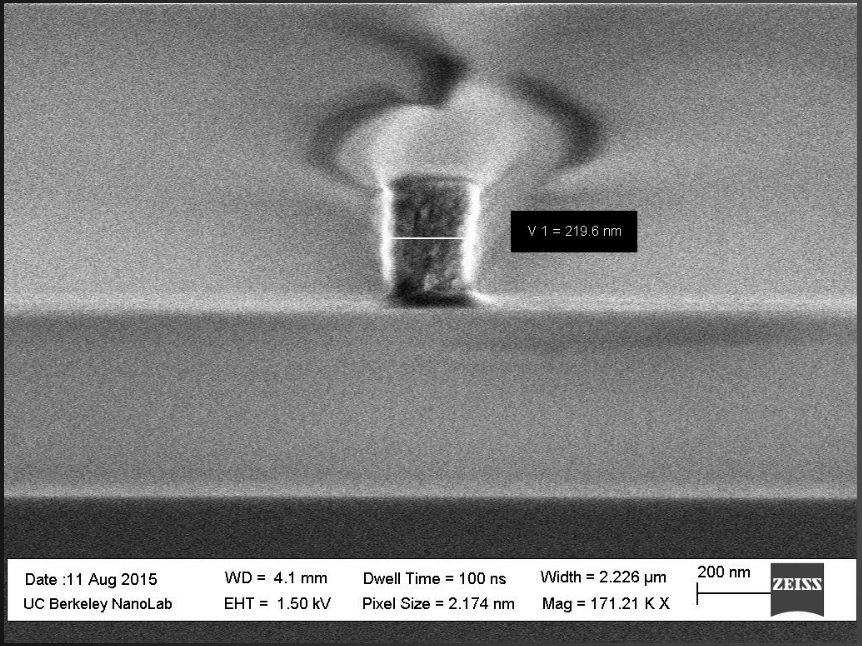
Conclusion

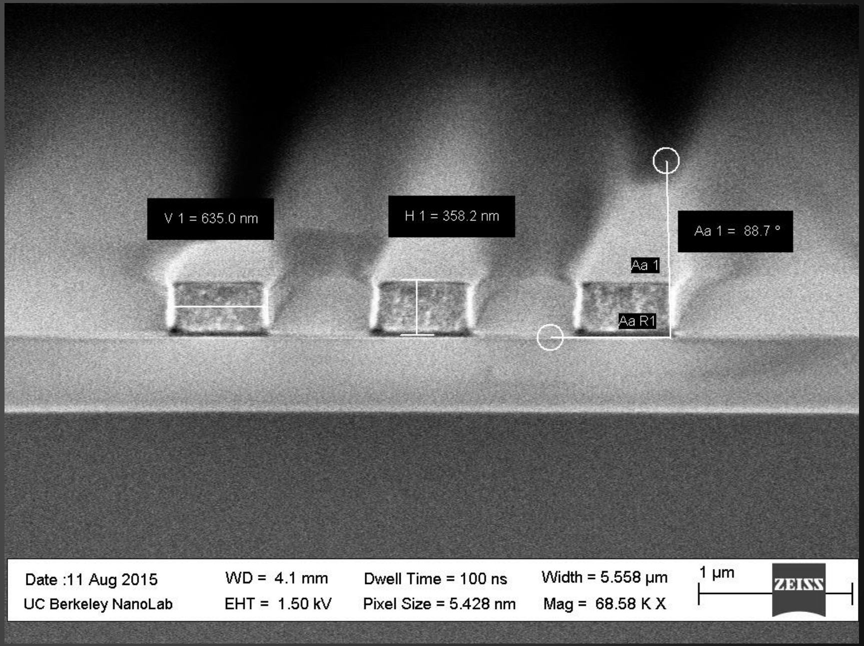
- 150 nm lines have been resolved in 3800 Å thick UV210-0.3 photoresist
- The results found are consistent from wafer-to-wafer and uniform across a wafer
- CD fidelity has good accuracy with the average line width less than 1 nm from target and a standard deviation approximately 11 nm

Acknowledgements - Thank You!

- ★Jeff Clarkson
- ★Kim Chan
- ★Irving Garduno
- ★Greg Mullins
- ★David Lo
- ★Cheryl Chang
- ★Marilyn Kushner
- ★Bill Flounders

Marvell Nanolab


V 1 = 219.6 nm
Date :11 Aug 2015
UC Berkeley NanoLab
WD = 4.1 mm
EHT = 1.50 kV
Dwell Time = 100 ns
Pixel Size = 2.174 nm
Width = 2.226 µm
Mag = 171.21 K X
200 nm


V 1 = 635.0 nm
H 1 = 358.2 nm
Aa 1 = 88.7 °
Aa 1
Aa R1
Date :11 Aug 2015
UC Berkeley NanoLab
WD = 4.1 mm
EHT = 1.50 kV
Dwell Time = 100 ns
Pixel Size = 5.428 nm
Width = 5.558 µm
Mag = 68.58 K X
1 µm