Optimization of Patterned Thin Films of Photoresist for Plasma Etching Applications

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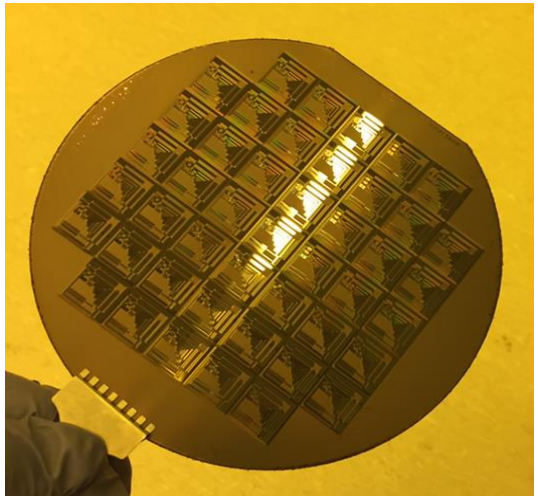
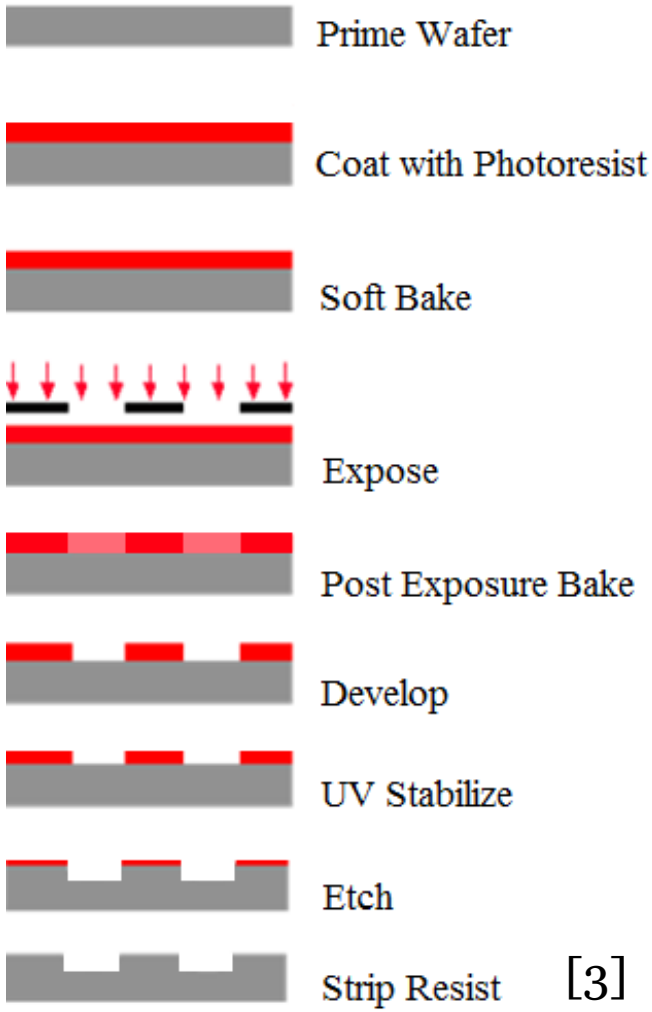
August 5, 2015



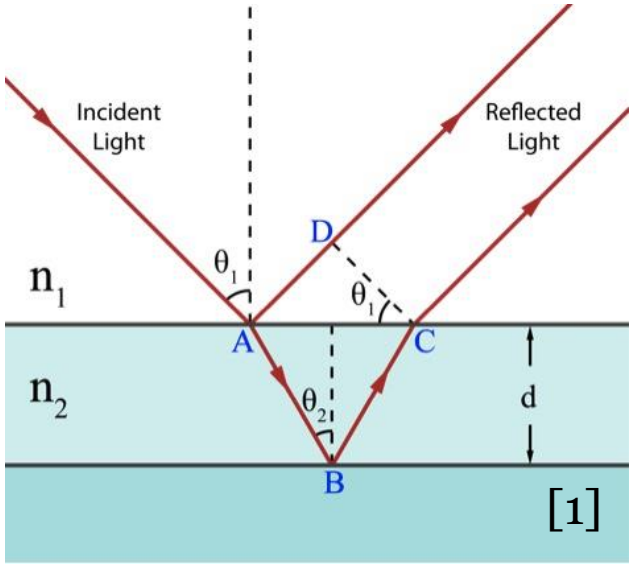
Introduction - Photolithography



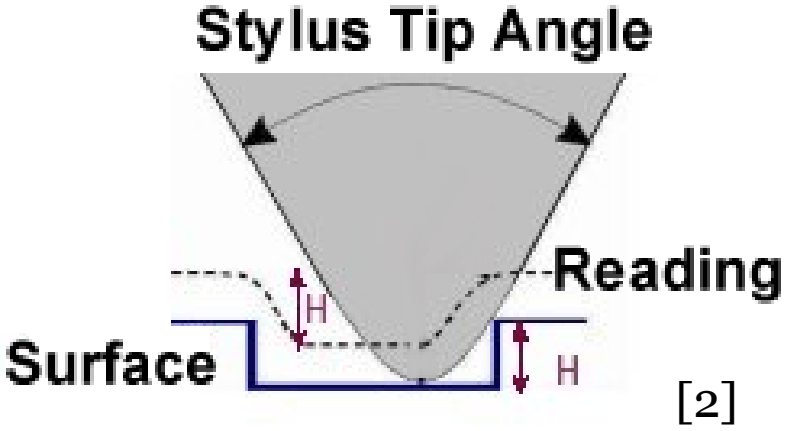
[3]

Goals

- Improve the optical models to more accurately characterize the properties of the photoresist coatings
  - Unify the metrology equipment in the Nanolab (i.e. Nanospec and AS-IQ)



Nanospec

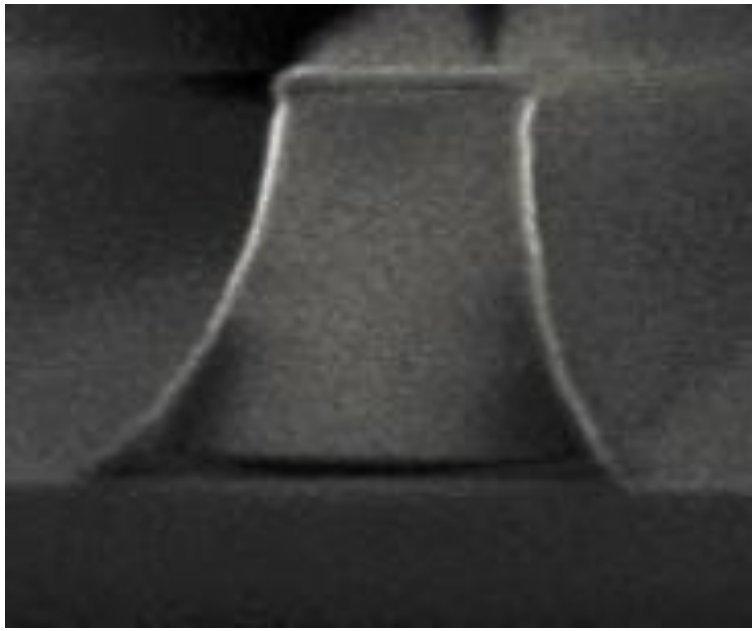


Alpha Step-IQ

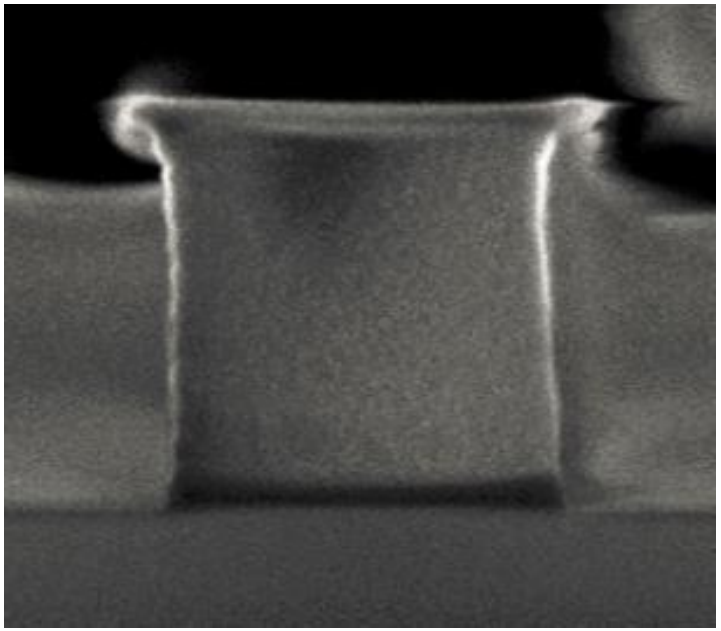
Goals

- Investigate different photoresist stabilization processes

  -Scanning electron microscope inspection of patterned thin films of photoresist



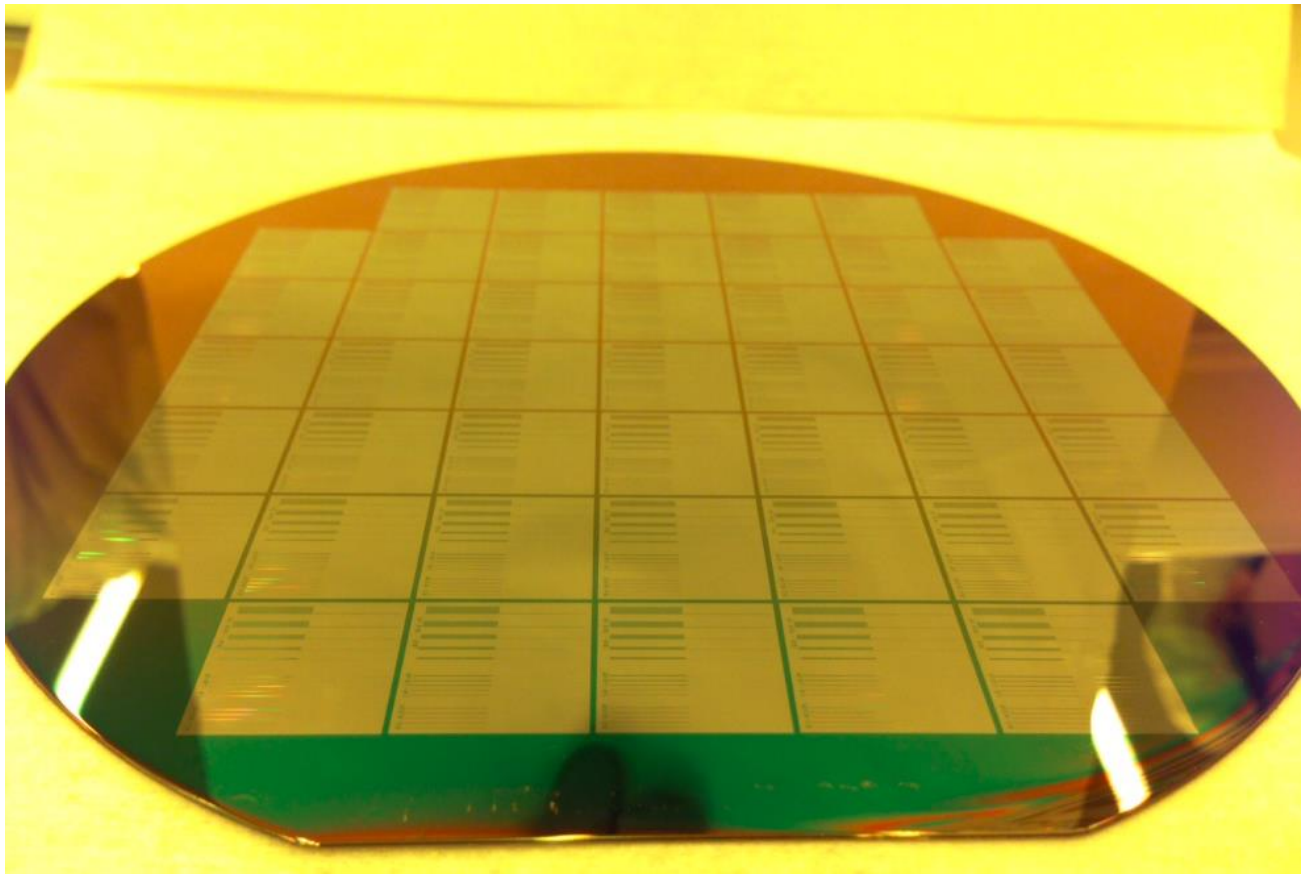
Bad



Good

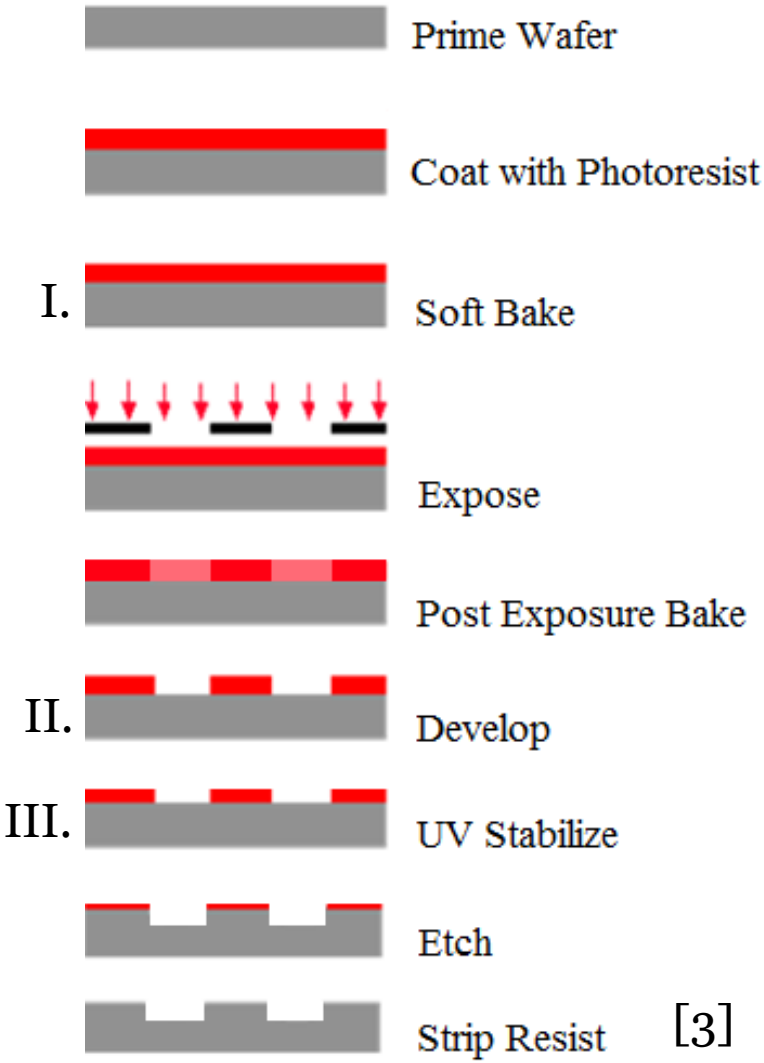
Goals

- Determination of best case SiO2 to photoresist etch selectivity



Experimental – Photoresist Film Thickness

- Replicate the lithography process on silicon wafers
- Take measurements at three distinct stages of the process:
  - -I. As Coated
  - -II. Post Development
  - -III. Post UV Stabilization



[3]

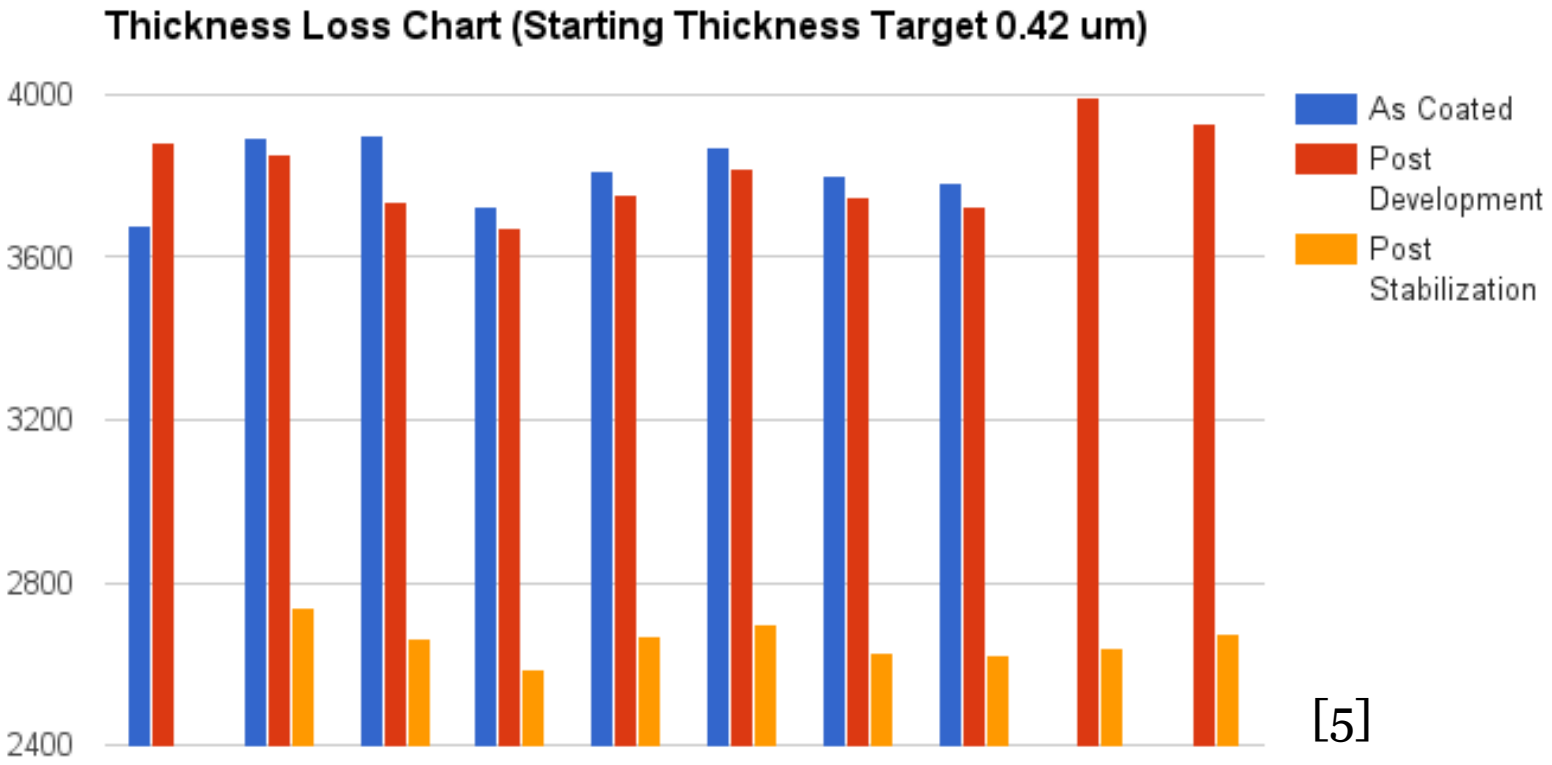
Experimental – Photoresist Film Thickness

- Data sheets provided by the photoresist manufacturers contain limited information

Technical Data	OiR 906-10	OiR 906-12	OiR 906-17
Solids (%) Min.	25.5	27.5	31
Solids (%) Max.	27.5	29.5	33
Viscosity (cst) Min.	9	14	26.7
Viscosity (cst) Max	15	20	32.7
Water Content	<0.5%		
Filtration	0.2 micron (absolute)		
Refractive Index	1.67		
Flash Point	53°C (closed cup)		
Trace Metals	None > 30 ppb		

[4]

Analysis– Photoresist Film Thickness



[5]

4.2.1 – DUV UV210-0.6 (0.42 um)

Results – Photoresist Film Thickness

Index of Refraction of Photoresist Films During Photolithography

Process Specification	Index of Refraction	Cauchy Coefficients (n1,n2,n3)	As Coated Index	Post-Development Index	Post-UV Stabilization Index
4.2.1-DUV UV-210-0.6 (0.42um)	1.532	1.532, 8.97E5, 3.00E10	n = 1.56	n = 1.56	n = 1.60
4.2.2-DUV UV-210-0.6 (0.9um)	1.532	1.532, 8.97E5, 3.00E10	n = 1.56	n = 1.56	n = 1.6C
4.3.1 i-line OiR906-12 (1.2um)	1.67	None Provided	n = 1.6C	n = 1.59	n = 1.69
4.3.2 i-line OiR906-12 (2.8 um)	1.67	None Provided	n = 1.6C	n = 1.6C	n = 1.69
4.4.1 g-line OCG 825 (1.3um)	1.64	None Provided	n = 1.6C	n = 1.62	n = 1.658

Results – Photoresist Film Thickness

As Coated

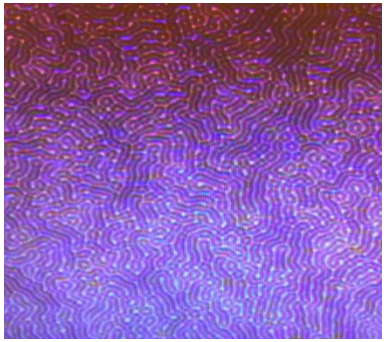
Process Specification	Nanospec Program #10 (n = 1.6C) Error	Optomized Nanospec Program Error
4.2.1 - DUV UV210-0.6 (0.42 um)	3.49%	0.96%
4.2.2 - DUV UV210-0.6 (0.9 um)	4.52%	0.07%
4.3.1 - i-line OiR906-12 (1.2 um)	0.95%	0.88%
4.3.2 - i-line OiR906-12 (2.8 um)	1.48%	1.43%
4.4.1 - g-line OCG 825 (1.3 um)	0.73%	0.73%

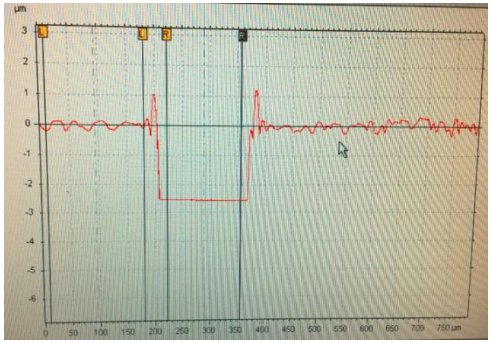
Post Stabilization

Process Specification	Nanospec Program #10 (n = 1.6C) Error	Optomized Nanospec Program Error
4.2.1 - DUV UV210-0.6 (0.42 um)	2.70%	1.57%
4.2.2 - DUV UV210-0.6 (0.9 um)	1.70%	0.43%
4.3.1 - i-line OiR906-12 (1.2 um)	2.48%	0.90%
4.3.2 - i-line OiR906-12 (2.8 um)	-	-
4.4.1 - g-line OCG 825 (1.3 um)	1.66%	0.20%

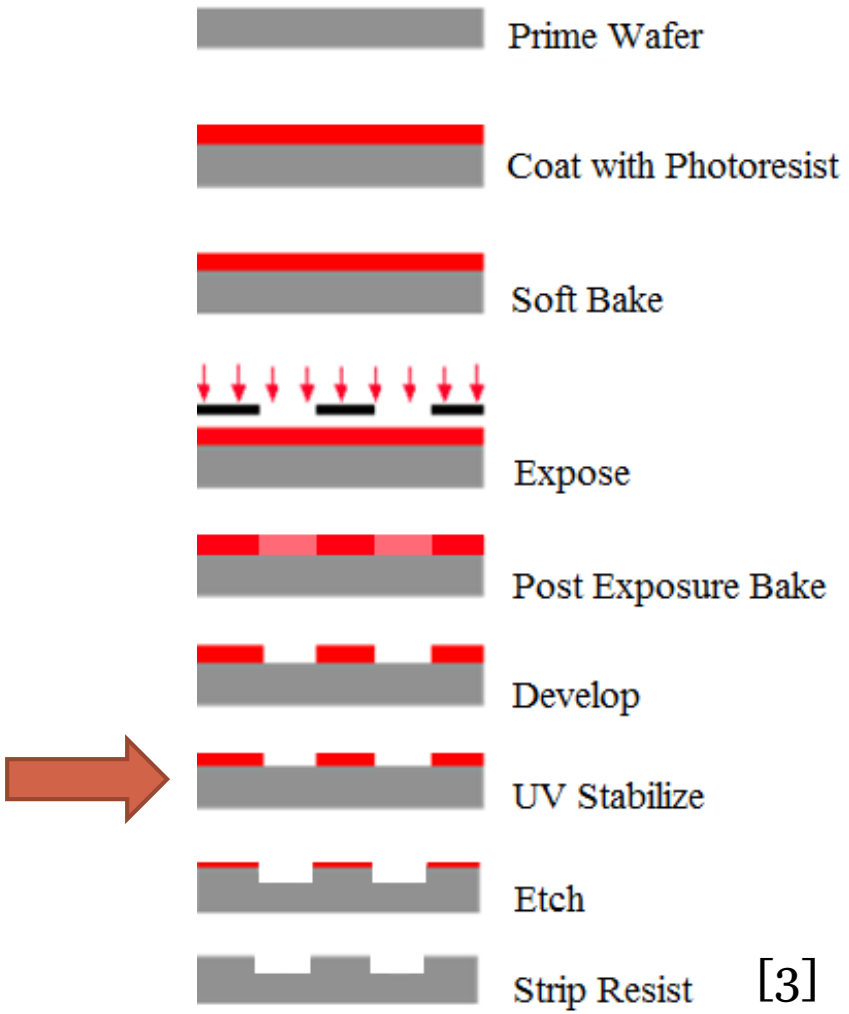
Post Development

Process Specification	Nanospec Program #10 (n = 1.6C) Error	Optomized Nanospec Program Error
4.2.1 - DUV UV210-0.6 (0.42 um)	4.02%	0.57%
4.2.2 - DUV UV210-0.6 (0.9 um)	4.25%	0.39%
4.3.1 - i-line OiR906-12 (1.2 um)	0.40%	0.27%
4.3.2 - i-line OiR906-12 (2.8 um)	0.16%	0.10%
4.4.1 - g-line OCG 825 (1.3 um)	0.73%	0.09%





Experimental – Photoresist Stabilization



[3]

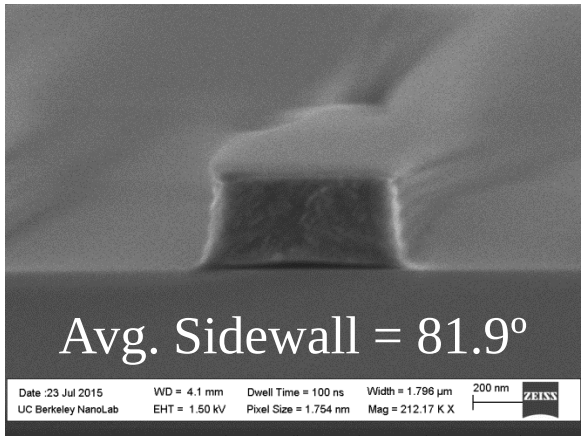
	Program U	Program J	Hard Bake
Axcelis	✓	✓	
Uvbake	✓	✓	
Oven			✓

Program U	Program J	Hard Bake
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	0-10 sec: lamp off, 110 C 10-20 sec: lamp low, 110 C 20-90 sec: lamp high, ramp 110 to 230 C 90-100 sec: lamp high, 230 C	120 C for 30 min.

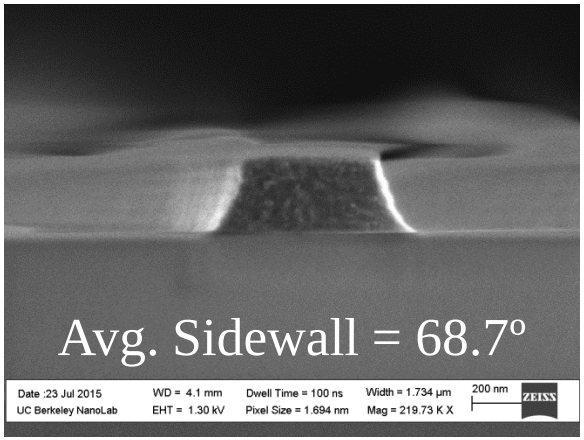
Analysis – Photoresist Stabilization

4.2.1 - DUV UV210-0.6 (0.42 um)

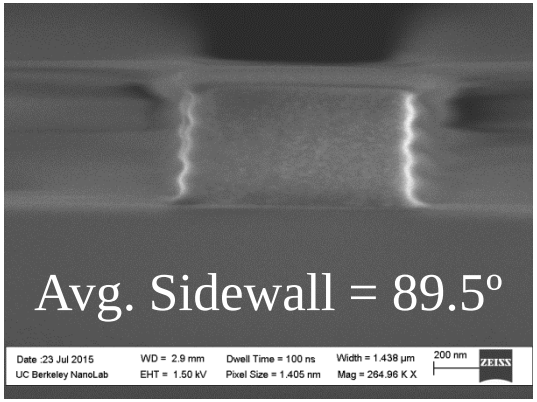
Axcelis Program U



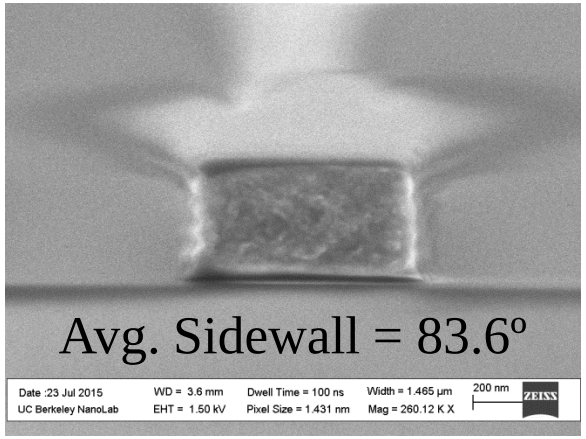
Axcelis Program J



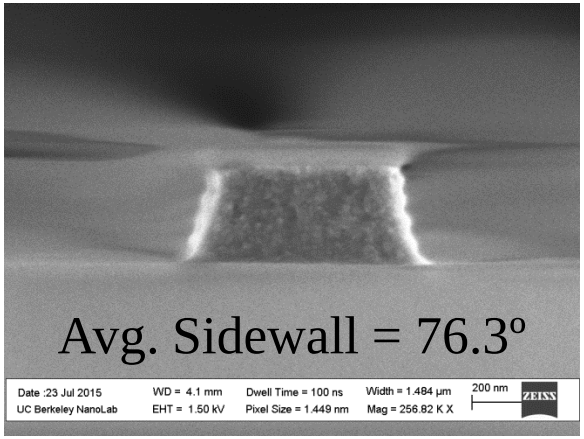
Oven Hard Bake



Uvbake Program U



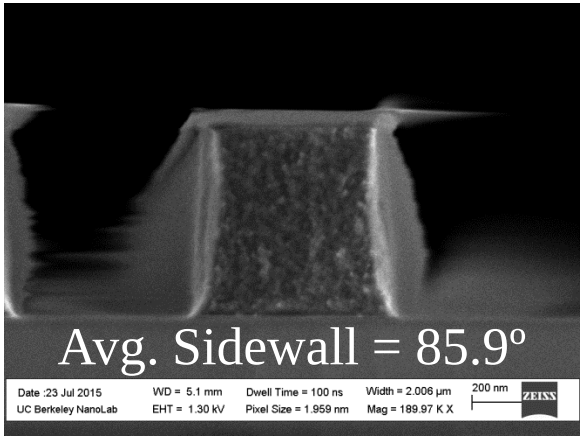
Uvbake Program J



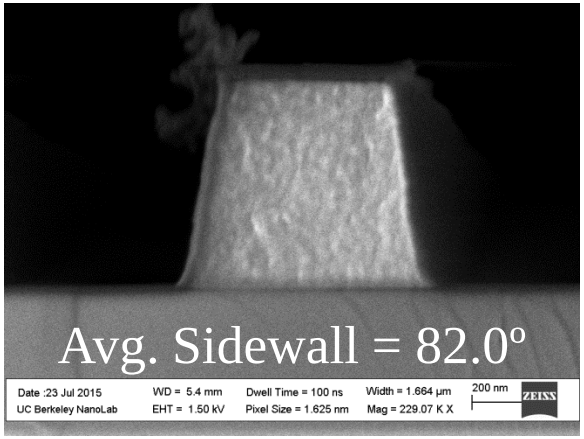
Analysis – Photoresist Stabilization

4.2.2 - DUV UV210-0.6 (0.90 um)

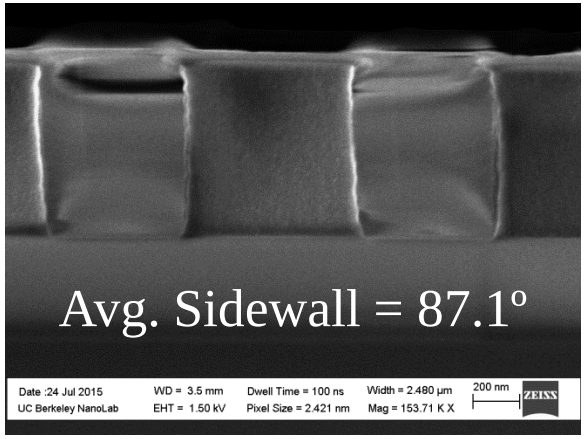
Axcelis Program U



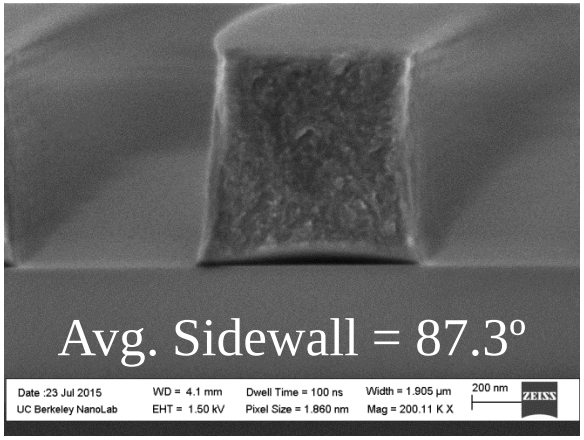
Axcelis Program J



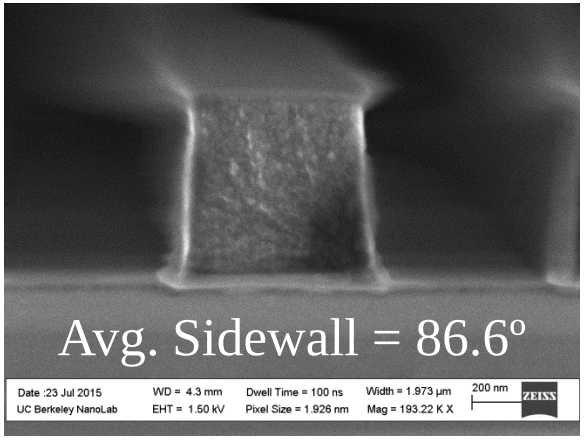
Oven Hard Bake



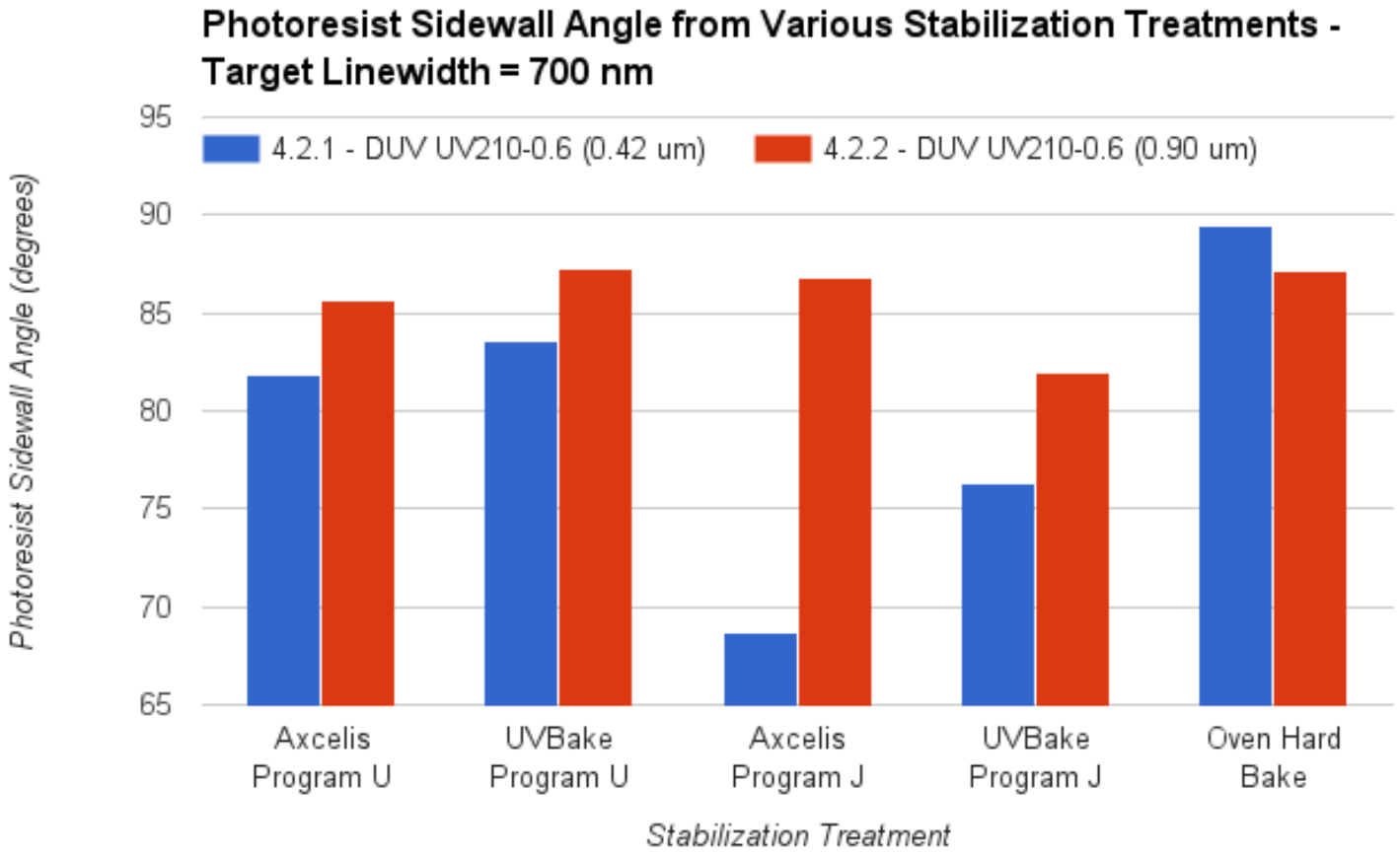
Uvbake Program U



Uvbake Program J

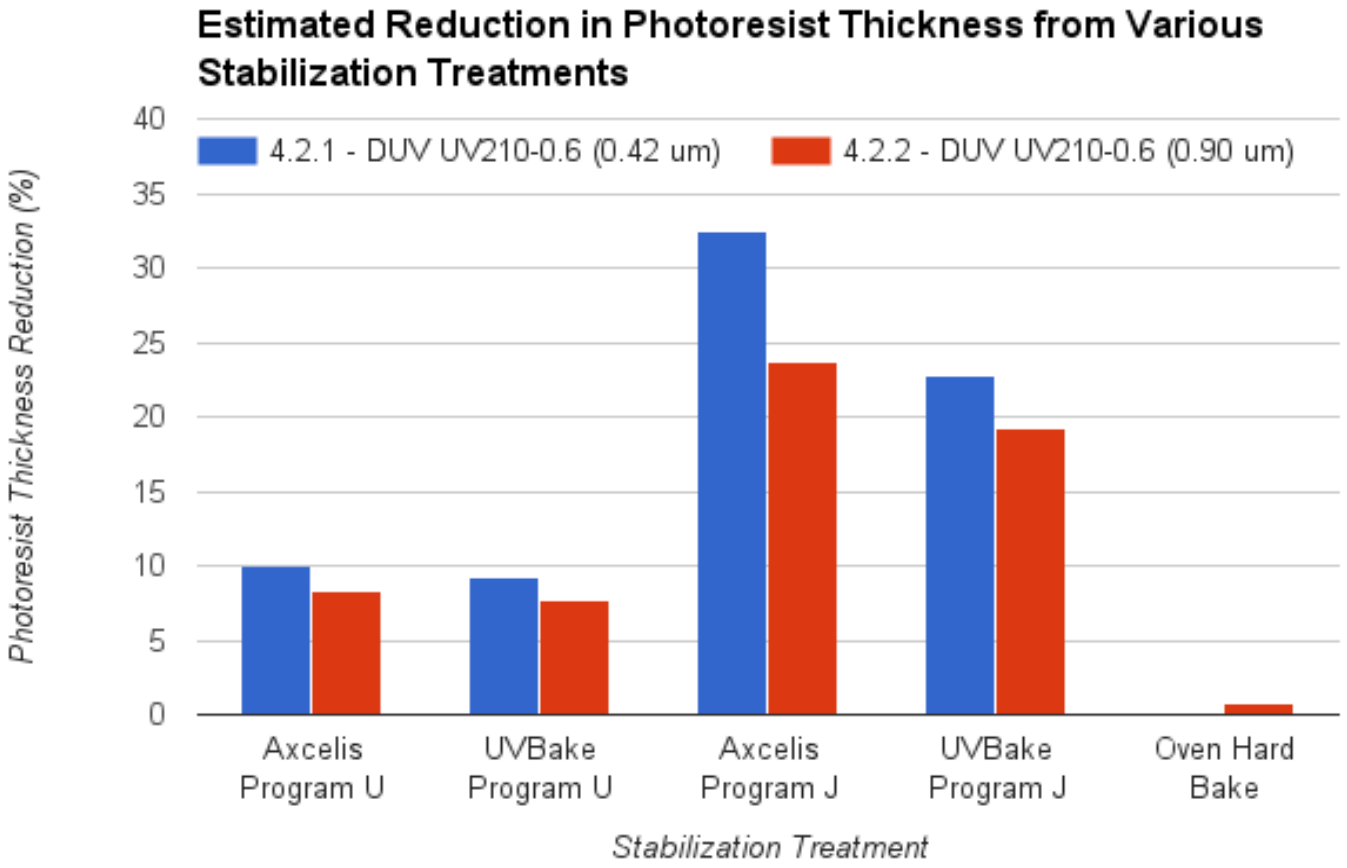


Photoresist Line Profile



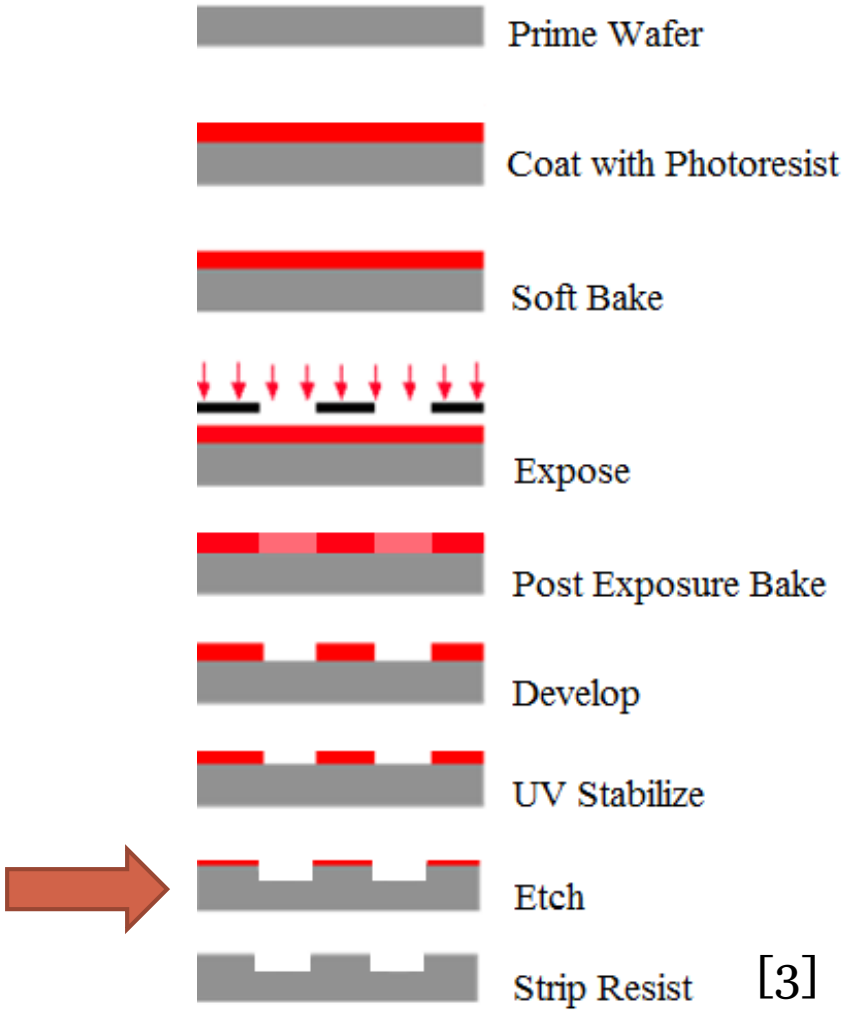
The oven hard bake resulted in the steepest sidewalls. UV stabilization program J resulted in the most tapered sidewalls. The thin DUV resist was most susceptible to tapered sidewalls.

Photoresist Line Profile



The oven hard bake resulted in the least change in film thickness. UV stabilization program J resulted in the most change in film thickness.

Experimental – Photoresist Etch



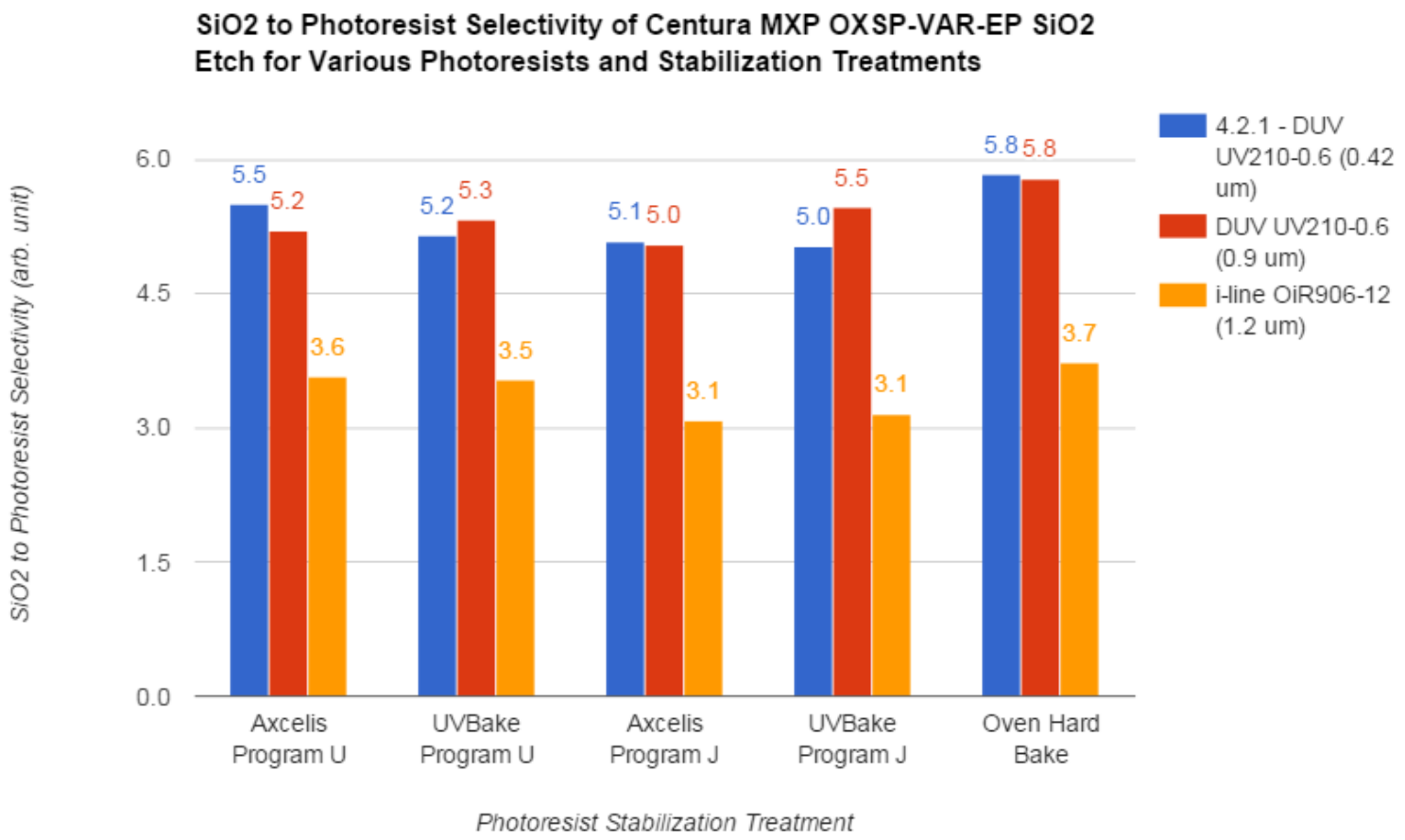
[3]

MXP-OXSP-VAR-EP

-Time = 60 sec
-Pressure = 200 mT
-Power = 500 W
-Field = 30 Gauss
-CF4 = 10 sccm
-CHF3 = 50 sccm
-AR = 120 sccm

$$\textbf{Selectivity} = \frac{\textbf{SiO2 Etch Rate}}{\textbf{PR Etch Rate}}$$

SiO2 to Photoresist Selectivity



Conclusion

- Optimized programs have been generated for the Nanospec which result in a reduction of worst case measurement error from 4.5% to 1.6%
- The oven hard bake results in the steepest photoresist sidewall angle while program J on Axcelis and Uvbake result in the least desirable sidewall profile
- The use of DUV resist with the oven hard bake gave the best etch selectivity

Acknowledgements

- Bill Flounders
- Jeffrey Clarkson
- Kim Chan
- Greg Mullins
- Francesca Calderon
- Lea Marlor
- Fanny Li
- James Hake

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UNIVERSITY OF CALIFORNIA

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NSF

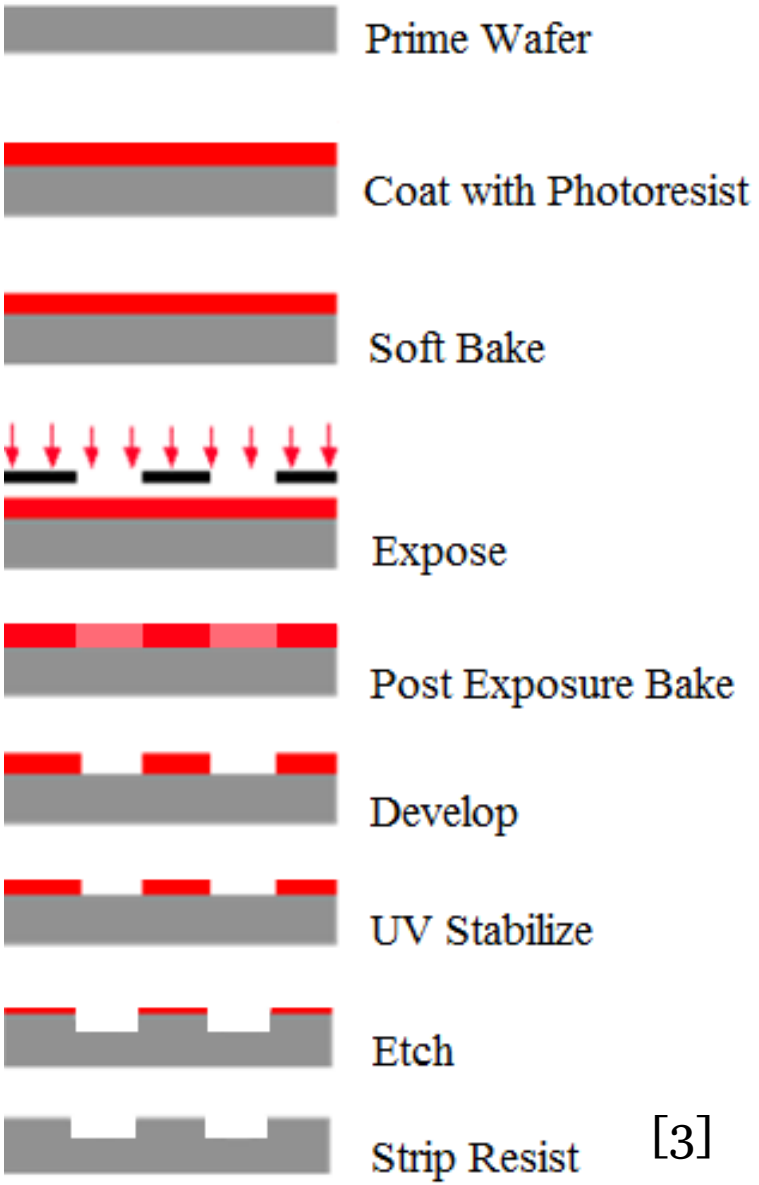
Marvell Nanofabrication Laboratory

Works Cited

- [1] "General Metrology." *Toho Technology*. N.p., 05 Sept. 2015. Web. 03 Aug. 2015.
- [2] "Profilometer Uses." *Sterling Precision Tool Works*. N.p., 01 May 2013. Web. 03 Aug. 2015.
- [3] "Semiconductor Lithography." *The Basics of Microlithography*. N.p., 23 Nov. 2006. Web. 03 Aug. 2015.
- [4] "Product Information." *Journal (American Water Works Association)*77.12, Filtration (1985): 114-16. Web. 03 Aug. 2015.
- [6] "Confused Smiley Face Gif For Webmasters." *Page 2 For Query Confused Smiley Face Gif*. N.p., n.d. Web. 03 Aug. 2015.

Comments or Questions?

[6]


Prime Wafer
Coat with Photoresist
Soft Bake
Expose
Post Exposure Bake
Develop
UV Stabilize
Etch
Strip Resist

[3]

Summary of Process Specifications

Process Specification	Prime	Coat	Exposure	Development	UV Stabilization/ Hard Bake
4.2.1 - DUV UV210-0.6 (0.42 um)	primeoven recipe #2 Pump to 1.3 torr, HMDS vapor at 90 C for 2 min	svgcoat6 (9,1,1) no prime, 7000 rpm for 30 sec., 130 C proximity softbake for 60 sec.	asml300 Job: CMOS200 19 mJ/cm2 focus offset: 0.0 um no alignment	svgdev6 (1,1,9) contact post exposure bake at 130 C for 60 sec, puddle develop in MF- 26A for 60 sec., no hard bake	Axcelis Program U and J, UVbake Program U and J, box oven harbake at 120 C for 30 min.
4.2.2 - DUV UV210-0.6 (0.90 um)	primeoven recipe #2 Pump to 1.3 torr, HMDS vapor at 90 C for 2 min	svgcoat6 (9,2,1) no prime, 1480 rpm for 30 sec., 130 C proximity softbake for 60 sec.	asml300 Job: CMOS200 18 mJ/cm2 focus offset: 0.0 um no alignment	svgdev6 (1,1,9) contact post exposure bake at 130 C for 60 sec, puddle develop in MF- 26A for 60 sec., no hard bake	Axcelis Program U and J, UVbake Program U and J, box oven harbake at 120 C for 30 min.
4.3.1 - i-line OiR906-12 (1.2 um)	primeoven recipe #2 Pump to 1.3 torr, HMDS vapor at 90 C for 2 min	svgcoat1 (1,1) 4100 rpm for 30 sec., 90 C contact softbake for 60 sec.	gcaws6 Job: 15x15MM 1.2 sec. focus offset: 0.0 um no alignment	svgdev1 (1,1) contact post exposure bake at 120 C for 60 sec, puddle develop in OPD 4262 for 60 sec.	Axcelis Program U and J, UVbake Program U and J, box oven harbake at 120 C for 30 min.
4.3.2 - i-line OiR906-12 (2.8 um)	primeoven recipe #2 Pump to 1.3 torr, HMDS vapor at 90 C for 2 min	svgcoat1 (6,4) 820 rpm for 30 sec., 90 C proximity softbake for 100 sec.	gcaws6 Job: 15x15MM 3.5 sec. focus offset: 0.0 um no alignment	svgdev1 (1,1) contact post exposure bake at 120 C for 60 sec, puddle develop in OPD 4262 for 60 sec.	Axcelis Program U and J, UVbake Program U and J, box oven harbake at 120 C for 30 min.
4.4.1 - g-line OCG 825 (1.3 um)	primeoven recipe #2 Pump to 1.3 torr, HMDS vapor at 90 C for 2 min	svgcoat1 (2,1) Coat at 5000 rpm for 30 sec., 90 C proximity softbake for 60 sec.	gcaws6 Job: 15x15MM 1.2 sec. focus offset: 0.0 um no alignment	svgdev1 (1,2) contact post exposure bake at 120 C for 60 sec, puddle develop in OCG 934 3:2 for 60 sec.	Axcelis Program U and J, UVbake Program U and J, box oven harbake at 120 C for 30 min.