Use of Cross-Platform Metrology Techniques to Investigate the Marvell Nanofabrication Laboratory Etch Quality Monitoring Program

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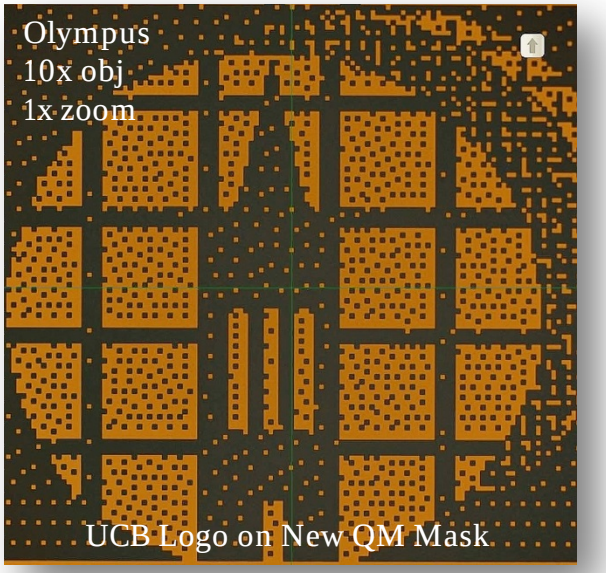
Outline



- Goals and Objectives
- Plan of Action
- Process Flow and Data
  - Quantifying Measurement Error in Metrology Tools
  - Inspect new Quality Monitoring Etch Mask
  - Implement Quality Monitoring
- Conclusions
- Acknowledgements

Goal and Objectives

- To implement the new Quality Monitor Etch Mask into the Quality Monitor Program
  1. Characterize measurement error in selected metrology tools
  2. Inspect new Etch Mask and validate subsequent photolithography processes
  3. Characterize thin film etch rates and selectivity to photoresist

Plan of Action

1. Quantify Measurement Error
   - Measure standards on selected metrology tools
2. Inspect Etch Mask
   - Characterize elbow and checkerboard features
3. Implement Quality Monitoring
   - Photolithography and etching of SiO_2, Al/SiO_2, Al/Si_3N_4, and PolySi

Selected Metrology Tools

- olympus
- keyence
- linewidth1
- nanospec
- nanoduv
- ellipsometer
- dektak

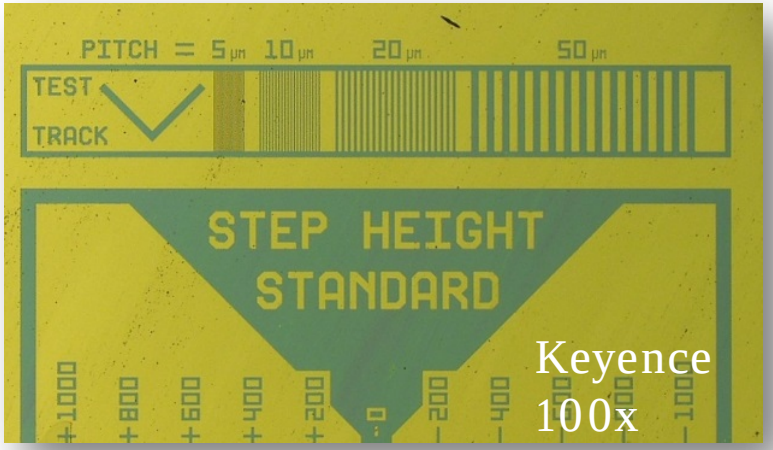
Olympus Lext OLS4000

Nanospec

1. Calibration Standards: Measurement Error in Line Width

- Measured each pitch (consisting of a space and a line) on 3 VLSI Standards at 5 different locations and found the average
  - Completed on olympus, keyence, linewidth1

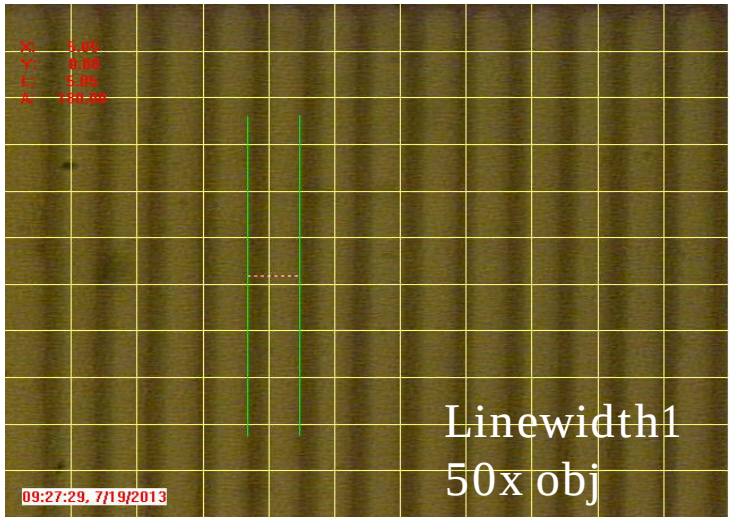
$$percent\ error = \frac{|measured - actual|}{actual} \times 100\%$$



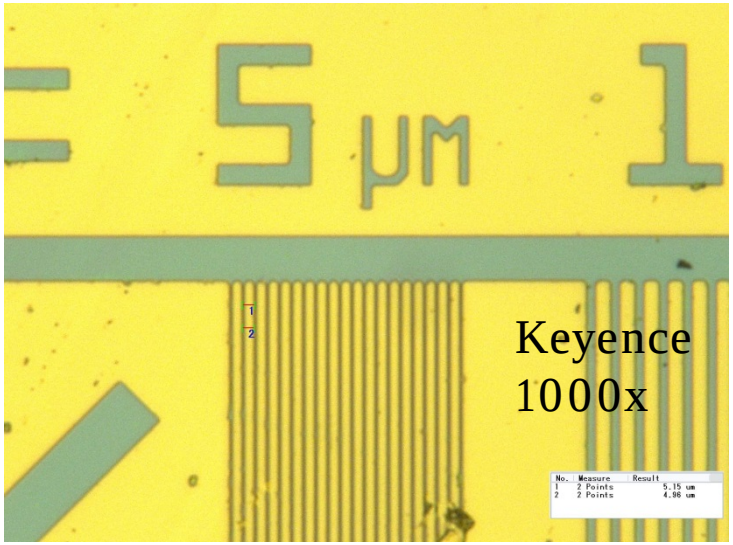
Calibration Standard Line Width Measurements - Percent Error

Standard Used	Pitch (µm)	Keyence		Olympus						Linewidth
		500x	1000x	20x obj (430x) Height	20x obj (430x) Intensity	50x obj (1073x) Height	50x obj (1073x) Intensity	100x obj (2143x) Height	100x obj (2143x) Intensity	50x
VLSI Standard 1	10	2.52%	2.12%	**0.430%**	**0.430%**	0.640%	0.640%	0.722%	0.470%	2.16%
Step Height = 9325 Å	20	1.32%	1.20%	1.341%	**0.425%**	0.624%	0.876%	0.591%	0.591%	1.94%
	50	1.92%	1.31%	0.749%	0.668%	0.523%	**0.228%**	0.516%	1.020%	1.42%
	100	1.56%	1.03%	0.624%	0.203%	0.419%	0.167%	**0.088%**	0.617%	1.40%
VLSI Standard 2	5	2.00%	2.12%	**0.420%**	**0.420%**	1.644%	1.392%	0.984%	0.984%	1.88%
Step Height = 2999 Å	10	3.26%	1.78%	**0.430%**	**0.430%**	0.640%	0.640%	0.470%	0.470%	1.72%
	20	1.43%	2.95%	0.425%	0.425%	0.632%	0.624%	0.285%	**0.165%**	2.05%
	50	0.54%	0.62%	0.830%	0.749%	**0.228%**	0.274%	0.532%	0.295%	1.42%
	100	1.72%	0.69%	0.454%	**0.203%**	0.318%	0.268%	0.481%	0.567%	1.83%
VLSI Standard 3	10	2.12%	1.74%	**0.430%**	**0.430%**	-	0.640%	-	0.790%	1.32%
Step Height = 502 Å	20	2.09%	1.78%	-	0.425%	-	0.640%	-	**0.165%**	1.83%
	50	0.70%	0.51%	-	0.426%	-	0.134%	-	**0.038%**	1.31%
	100	1.03%	0.65%	-	0.203%	-	0.135%	-	**0.038%**	1.35%

Measurement Challenges



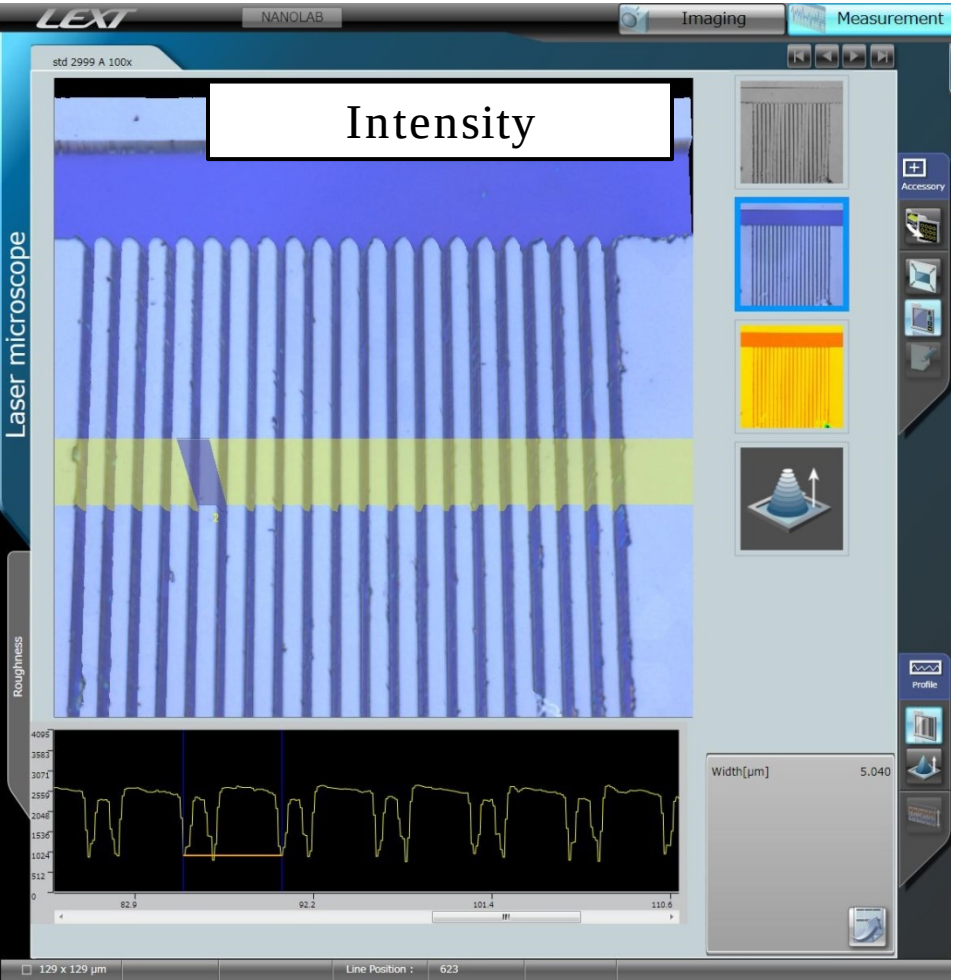
Device	Resolution
Olympus (100x obj, 1x zoom)	±0.126 µm
Keyence (1000x)	±0.19 µm
Linewidth1 (50x obj)	±0.105 µm

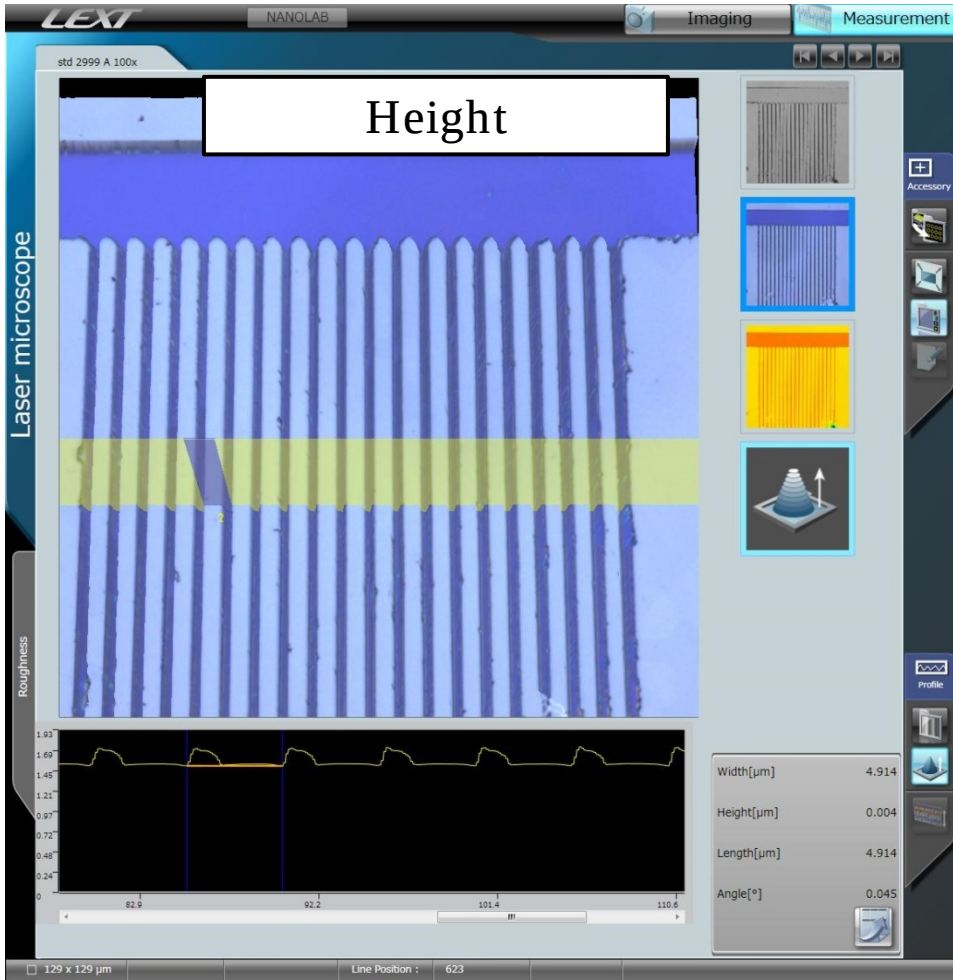


Optimizing Olympus Measurements

- Intensity or Height?

VLSI Standard – Step Height 2999 Å
5 µm Pitch
Olympus – 100x obj 1x zoom



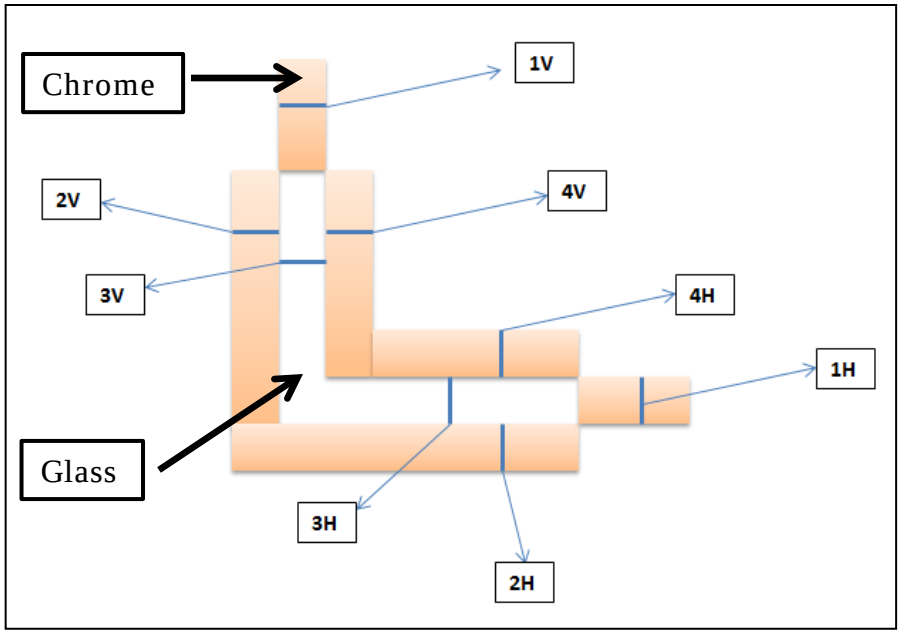


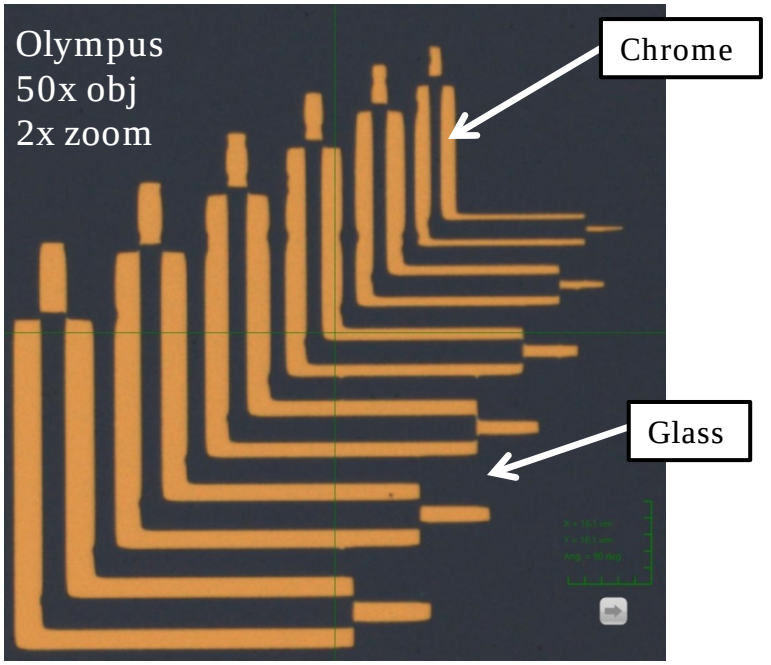
Summary: Measurement Error

- Made 2650 measurements and got qualified on 7 tools
- Best tool for line width measurements:
  olympus – measurement error < 1.6%
  - Olympus does have trouble measuring photoresist
  - Intensity is *generally* better for measurements, but in some cases, height works just as well (or better)
- **linewidth1** – measurement error < 2.2%
  - Camera resolution is poor, hard to ascertain exactly where edges of features being measured are
- **keyence** – measurement error <3.3%
  - Easy to use

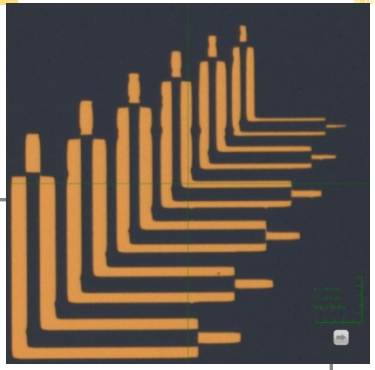
2. Inspect Quality Etch Mask

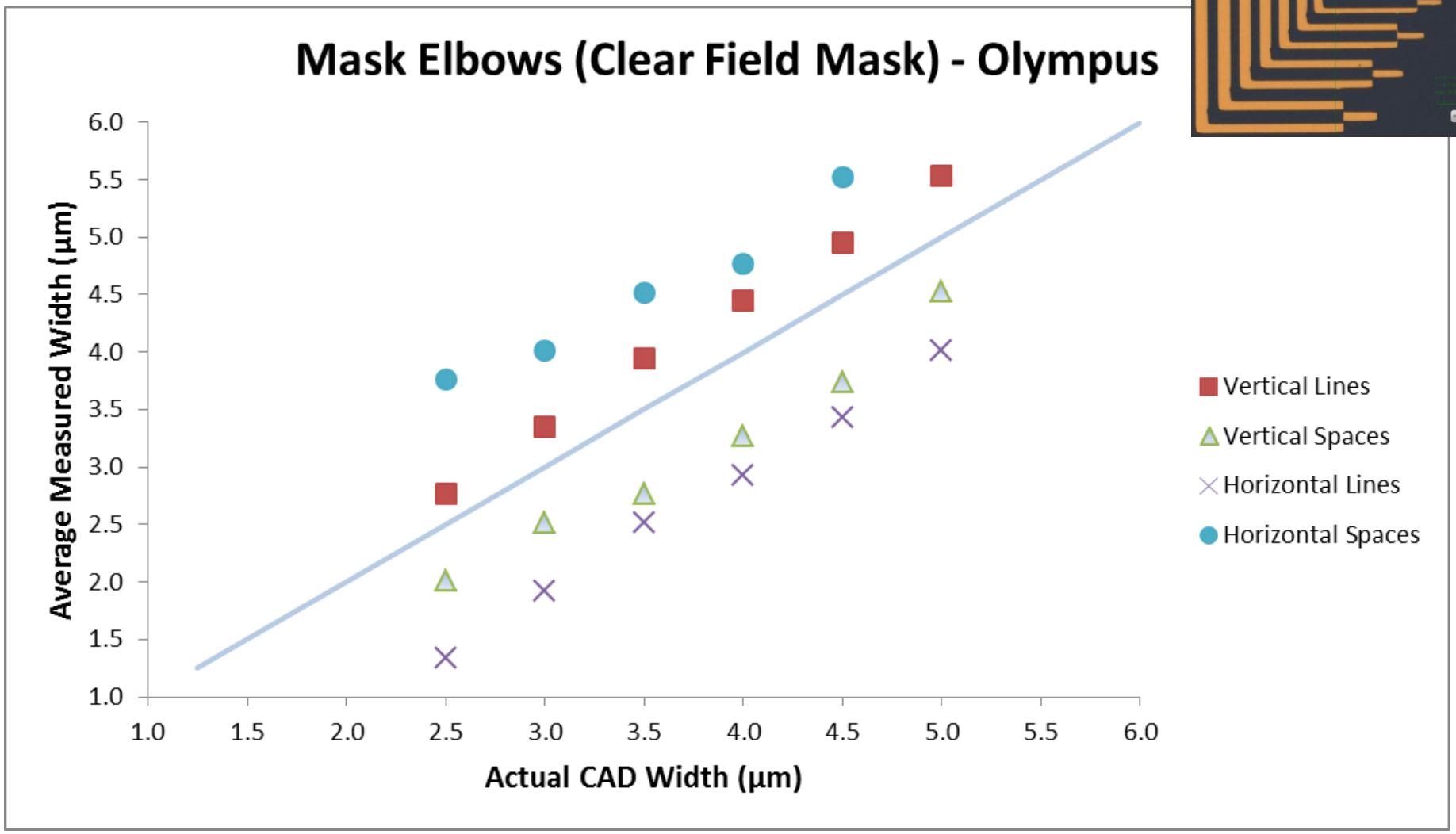
- Characterize mask by measuring elbows in 8 locations with keyence, linewidth, and olympus



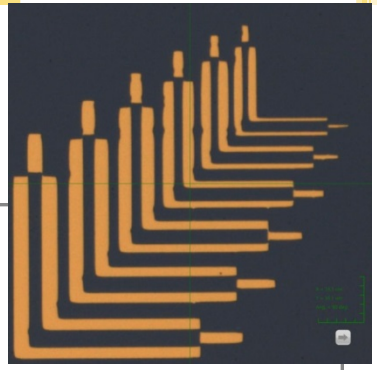


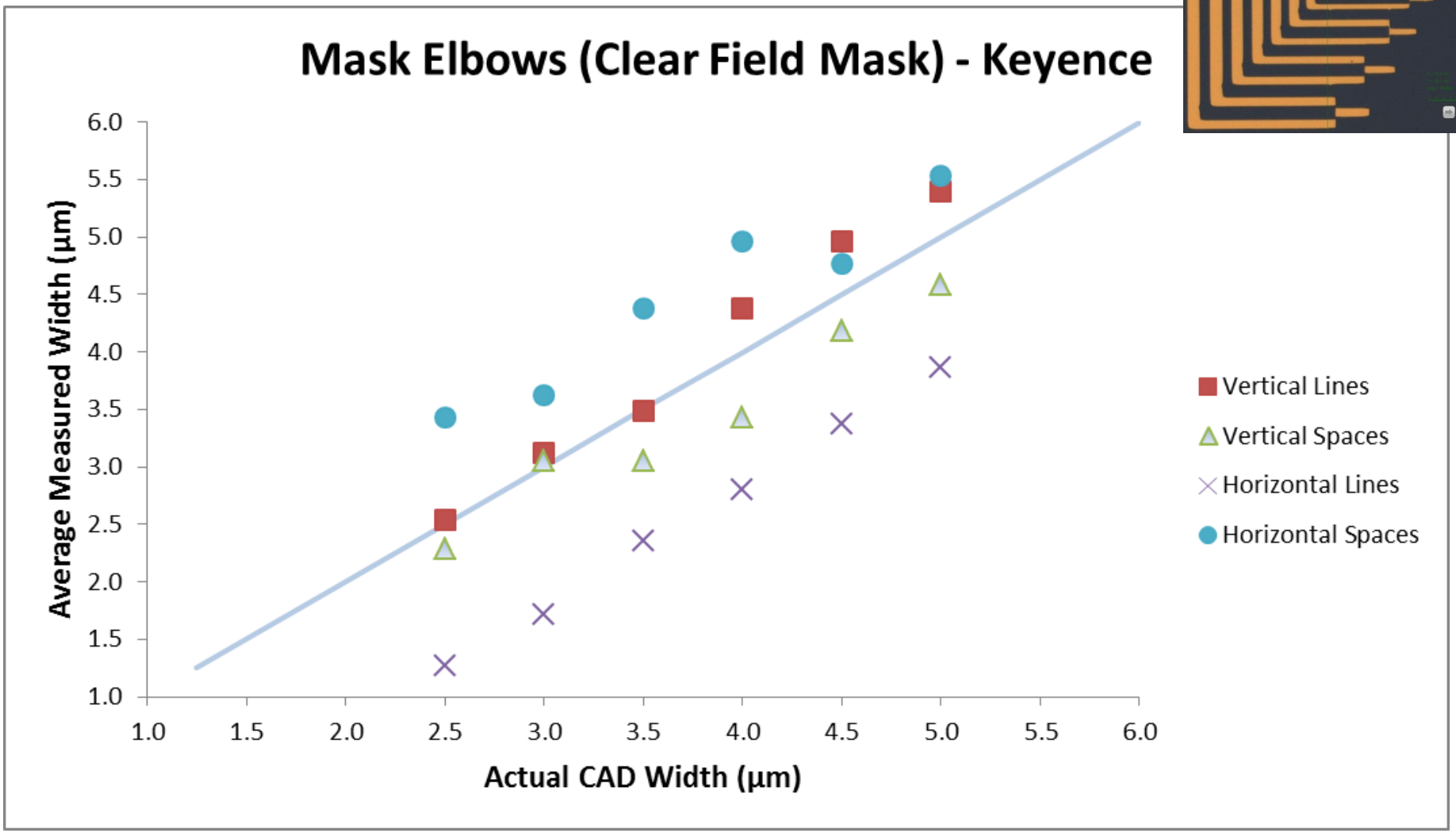
Inspect Quality Etch Mask





Inspect Quality Etch Mask





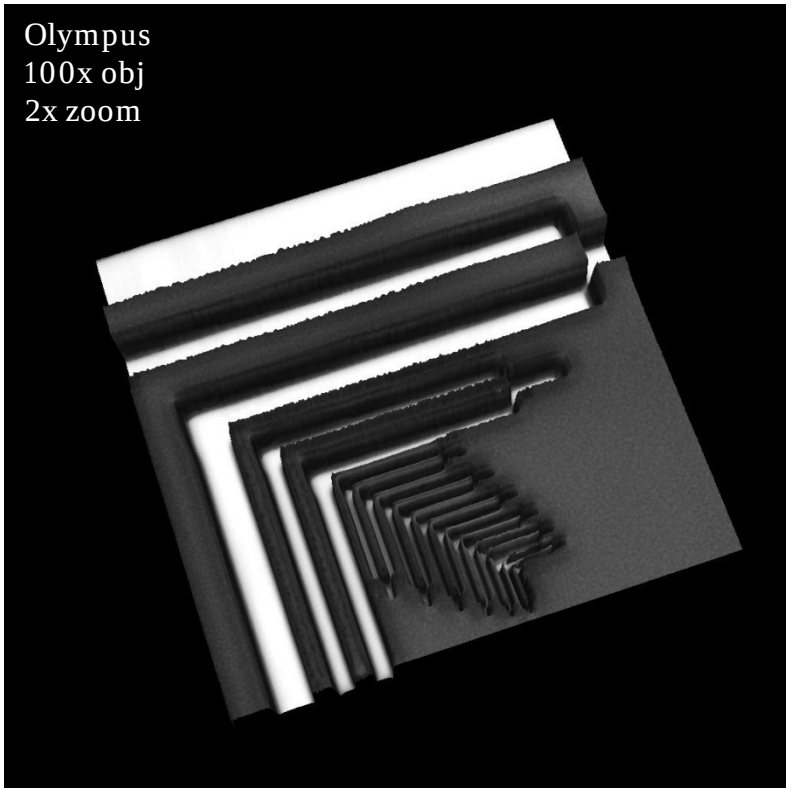
Summary: Mask Validation

- The pattern generator had difficulty rendering small features
  - Elbow features from 2.5 µm – 12.5 µm did not resolve well
    - 7 - 25% different than CAD design
    - Features can be improved with pattern generator calibration
  - Elbow features bigger than 25 µm turned out better
    - 1 – 3% different than CAD design

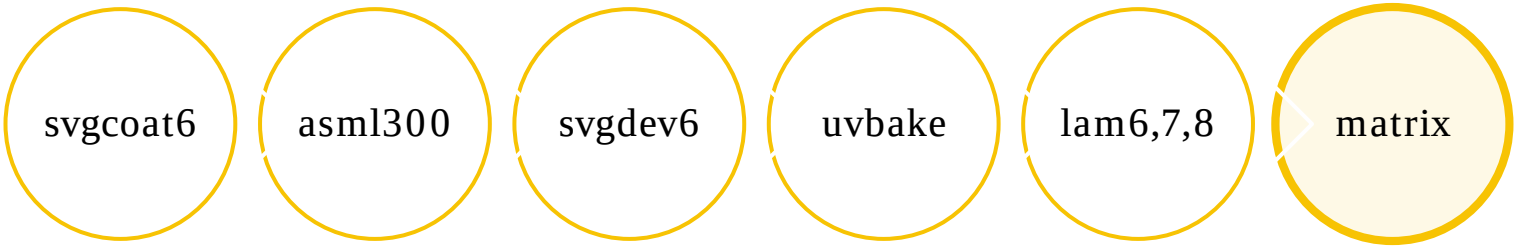
3. Implement Quality Monitoring

- Measured film of interest thickness, elbow line widths, and step height
  - Measured wafers before photolithography, post-etch with resist, and post-etch with resist stripped

Photoresist on Poly Silicon Wafer – Post-etch

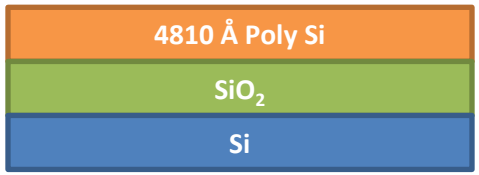


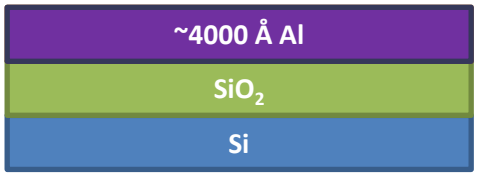
Process Flow

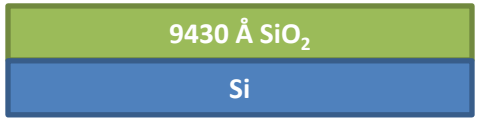


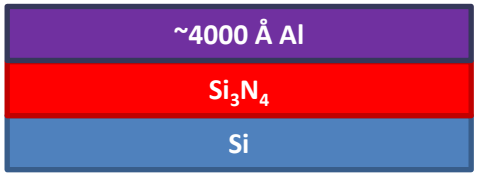
svgcoat6: Rohm Hass positive UV210-0.6 (DUV resist) - Program 2 - 9000 Å thick resist, spin speed = 1480 rpm
Soft bake: Program 1 - 130 °C, 60 sec
uvbake: Program U
lam6: 60 second etch, using program 6001_oxide_me
lam7: 25 second etch, using program staff_7001_al_me
lam8: 30 second etch, using program 8001_poly_me

Completed on four different samples:









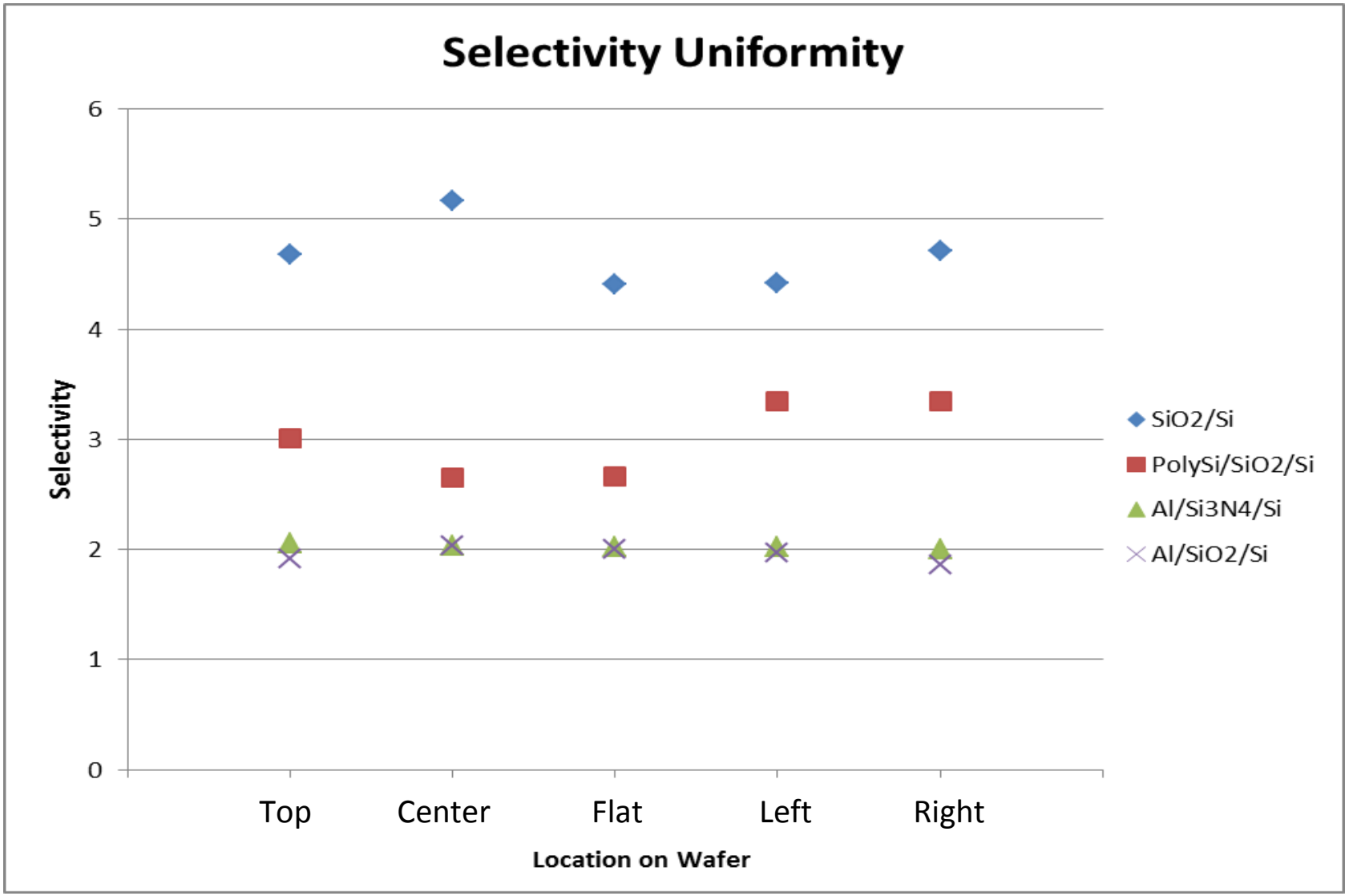
Etch Rates and Selectivity

Etch rate of photoresist (nm/sec)	Top	Center	Flat	Left	Right	Average
SiO_2/Si	1.765	1.523	1.925	1.902	1.688	1.761
$PolySi/SiO_2/Si$	1.657	1.817	1.840	1.463	1.493	1.654
$Al/Si_3N_4/Si$	6.408	6.260	6.488	6.304	6.532	6.398
Al/SiO2/Si	7.204	6.652	6.968	7.084	7.440	7.070

Etch rate of material (nm/sec)	Top	Center	Flat	Left	Right	Average
SiO_2/Si	8.260	7.867	8.490	8.400	7.958	8.195
$PolySi/SiO_2/Si$	4.983	4.823	4.897	4.890	5.000	4.919
$Al/Si_3N_4/Si$	13.164	12.752	13.148	12.736	13.112	12.982
$Al/SiO_2/Si$	13.780	13.528	13.948	13.940	13.888	13.817

Selectivity (UV 210 Resist)	Top	Center	Flat	Left	Right	Average
SiO_2/Si	4.680	5.164	4.410	4.417	4.714	4.677
$PolySi/SiO_2/Si$	3.008	2.655	2.661	3.342	3.348	3.003
$Al/Si_3N_4/Si$	2.054	2.037	2.027	2.020	2.007	2.029
$Al/SiO_2/Si$	1.913	2.034	2.002	1.968	1.867	1.957

Selectivity Uniformity Across the Wafer



Summary: Quality Monitoring Implementation

- Learned the basics of photolithography
  - Patterned 17 wafers and ran a focus exposure matrix
- Determined the etch rate of SiO_2, PolySi/SiO_2, Al/Si_3N_4, and Al/SiO_2 to be 8.195, 4.919, 12.982, 13.817
- Determined the selectively of photoresist and SiO_2, PolySi/SiO_2, Al/Si_3N_4, and Al/SiO_2 to be 4.677, 3.003, 2.029, 1.957

Conclusion

- Measurement error for olympus, linewidth, and keyence are less than 1.6%, 2.2%, and 3.3% respectively
- Inspection of the Quality Monitor Etch Mask discovered discrepancies in small features from the CAD layout
- Determined the selectivity and etch rates of SiO_2, PolySi/SiO_2, Al/Si_3N_4, and Al/SiO_2

Acknowledgements

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