Chapter 4.25

UV 210 Photoresist Process

1.0 Process Summary

1.1 This manual provides processing information for both UV210GS-0.3 and UV210GS-0.6 photoresists. These are two formulations of the same chemical, which spin out to different thicknesses. There is some overlap between the two formulations, which allows for redundancy at the half-micron thickness films.

1.2 These are deep UV photoresists and can only be exposed on asml300.

1.3 The smallest feature that can be resolved with this resist is very dependent on the film thickness. This will be discussed in more detail later in this manual.

2.0 Material Controls & Compatibility

2.1 Experiments for this resist were conducted on bare silicon and silicon oxide.

3.0 Training Procedure & Applicable Documents

3.1 This document will make use of the modeling described in more detail in the 2018 Comparison white paper.

4.0 Definitions & Process Terminology

4.1 Track - photoresist coater tool or developer tool

4.2 HMDS - Hexamethyldisilazane, a photoresist adhesion promoter

4.3 BARC - Bottom Anti-Reflection Coating, a polymeric layer that is used to better control surface reflections at the photoresist-substrate interface

4.4 Reflow - the process by which photoresist features change shape when heated

4.5 CD - critical dimension

4.6 Selectivity - the degree to which one material is preferentially etched over another. In this context, it is the comparison between how much silicon (or silicon oxide) is removed versus how much photoresist is removed during an etch. When silicon is etched more than the photoresist, it is considered more selective.

4.7 Resist - shorthand for photoresist

4.8 UV - UltraViolet light

4.9 DUV - deep ultraviolet light, in this case the 248 nm light source of our asml300 stepper

5.0 Safety

5.1 UV210 processing poses no notable risks. Please read all equipment manuals for tool-specific hazards.

6.0 ***Process Procedure***

Lithography Process Overview							
Step	Tool	Settings					
		0.28 µm	0.35 µm	0.43 µm	0.50 µm	0.86 µm	1.00 µm
BARC	svgcoat3	Recipe #3 (automatic dispense) or Recipe #4 (manual dispense)					
Coat	Picotrack1 or svgcoat6	3630 rpm n/a	2330 rpm n/a	1625 rpm 5635 rpm	1195 rpm 4645 rpm 4145 rpm	n/a 1600 rpm	n/a 1180 rpm
Softbake	picotrack1	140°C, 90 seconds, proximity bake					
Exposure	asml300	*Exposure energy depends heavily on the image you are printing. Exposure testing is required.*					
Post Exposure Bake	picotrack2 svgdev6	110°C 90 seconds, proximity bake *Minimize the time between exposure and post-exposure bake for high resolution patterns; <10 minutes between exposure & PEB recommended*					
Develop	picotrack2 svgdev6	MF-26A 45 second puddle					
Descum	Technics-c or semi	Standard descum process					
Hard Bake	oven	120°C, 30 minutes					
Photoresist Removal	msink1 or matrix	1165, 80°C, 10 minutes 2 minutes 30 seconds					

7.0 ***Process Explanation***

7.1 BARC layers before the photoresist help tremendously with backscattering. The DUV photons scatter when propagating through the resist, making the effective area exposed to light larger. When the photons encounter the substrate, they reflect; the angle of reflection depends on the angle of incidence with the substrate.

7.2 Exposure energy is not provided for these resists, as the correct exposure energy is strongly dependent on the reticle image. Images with larger open areas (more clear glass) require lower energies than images that are mostly dark.

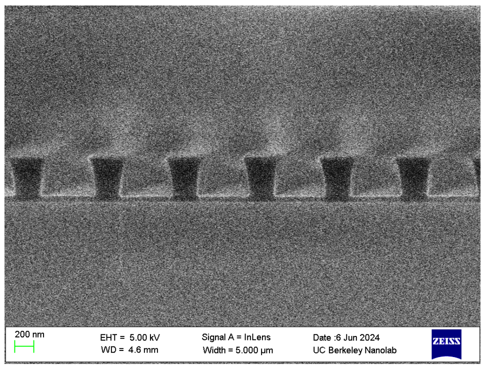
7.3 Descum - as with all resist processes, descum prior to etch or liftoff is recommended. BARC is not attacked by all etch processes, and you will need to run an oxygen descum process to remove BARC before running in some tools (sts2, lam8, etc.)

7.4 Hardbake - UV stabilization (axcelis) is not recommended for this resist. Burning at the edges of the wafer has been observed for all thicknesses of UV26 in axcelis. Tests were performed using the VWR oven in Bay 382; no change was observed for resists baked for 30 minutes, 60 minutes, or 90 minutes. The default hard bake of 30 minutes at 120 C is sufficient for most processes, but longer deviations do not appear to disrupt the process.

8.0 Process Data

8.1 Analysis of Soft Bake Conditions

8.1.1 During Spring and Summer 2024, the process for UV26 was re-examined and we determined that we had been significantly underbaking the resist. As a consequence, UV210 was also re-examined, and we found similar results as with UV26. The sidewall behavior for UV210 is shown in the images below. Baking at a temperature of 140 C instead of 130C, with the wafer in closer proximity to the hotplate produces straighter sidewalls.

<table>
<tr>
<td>
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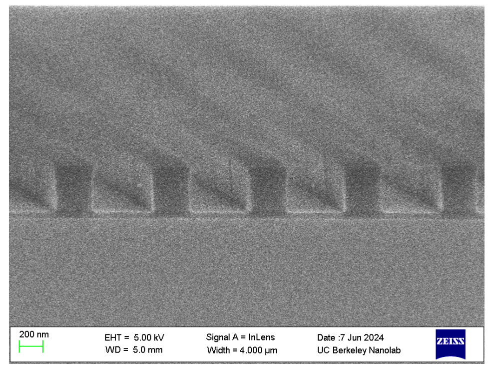
<td>
</td>
</tr>
<tr>
<td>0.43 um thick UV210. Soft bake was 130C for 60 seconds. Exposure energy on ASML was 32 mJ.</td>
<td>0.43 um thick UV10. Soft bake was 140C for 60 seconds. Exposure energy on ASML was 32 mJ. Note the straighter sidewalls when compared with the 130C bake.</td>
</tr>
</table>

8.1.2 Because the resist is being baked hotter, the thickness of the film thinned very slightly. Staff ran new spin curves and swing curves to ensure that the standard thicknesses are optimized.

8.2 Post-Exposure Delay

8.2.1 For the highest resolution features, it is important to minimize any delay between the exposure of the wafer and post-exposure bake. Process staff have observed changes in 150 nm features with as little as 15 minutes of delay between exposure and post-exposure bake. Features at this scale are at the very limit of resolvability on our ASML stepper, so it is understandable that they will be very sensitive to processing effects.

8.2.2 When running a cassette in ASML, the wafer order reverses. This means that the first wafer that is exposed is at the bottom of the send cassette but ends up at the top of the receive cassette. When developing in either track tool (picotrack2 or svgdev6) wafers are also taken from the bottom of the cassette. This means that unless the wafers are manually/individually reordered, the first wafer exposed will be the last wafer developed. The exact amount of delay will depend on how many images are in the job and the energy being requested for each given exposure.

8.2.3 The images below show SEM results for wafers made during a single run. A batch of five wafers coated with BARC and then 0.28 µm of UV210-0.3 were exposed at a single time.

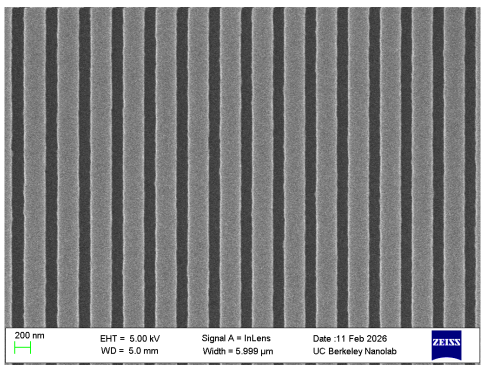
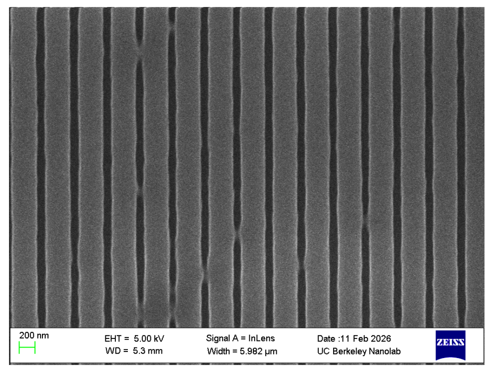
8.2.3.1 In this case, each exposure took less than 40 seconds.

8.2.3.2 Even if you run only a single wafer at a time, it takes about two minutes for the wafer to be transferred out of the stepper.

8.2.3.3 Each wafer is delayed by approximately 100 seconds going into picotrack2 (90 second post-exposure bake + some transfer time).

8.2.3.4 In this particular case, there was also a gas-mixture delay between wafers two and three on the stepper that also had to be accounted for.

8.2.3.5 The SEM images below show the difference in trench width (dark areas) for the wafer that was immediately exposed versus the wafer that waited approximately fifteen minutes. For the wafer that had to wait, the resist did not fully clear in the trenches, and the overall trench width is much narrower than designed.

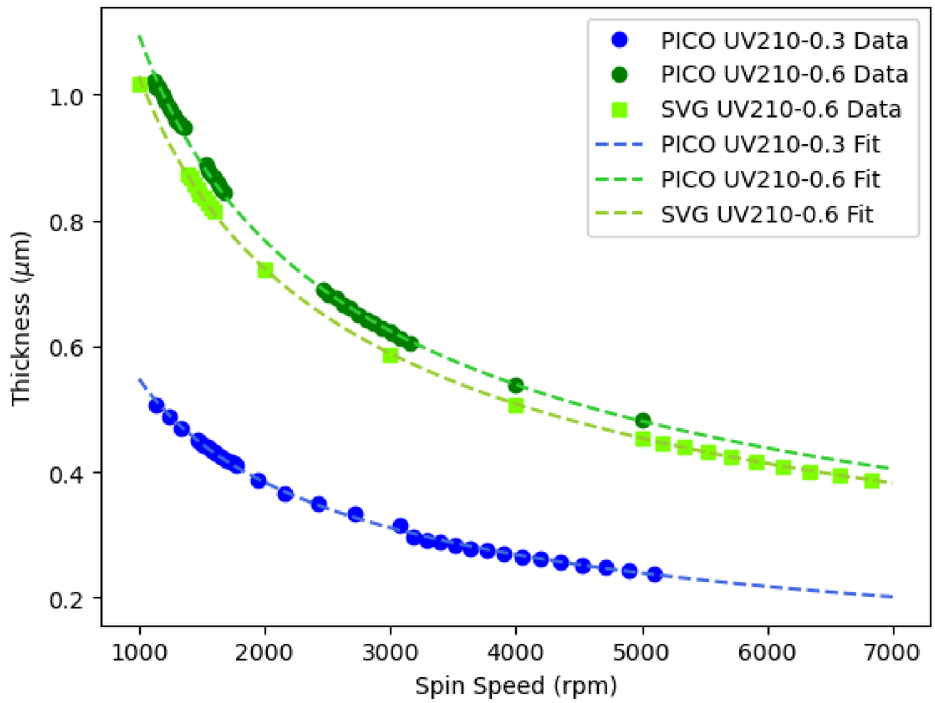
	
SEM image of 150 nm (as designed) lines exposed and developed with no delay. Measured trench width is 138 nm ± 5 nm.	SEM image of 150 nm (as designed) lines exposed and developed with ~15 minute delay. Measured trench width is 107 nm ± 8 nm.

8.2.4

8.3 Spin Curve Results

8.3.1 There are two formulations of UV210: UV210-0.3 and UV210-0.6. The 0.3 formulation is only installed on picotrack1. The 0.6 formulation is installed on both picotrack1 and svgcoat6. This requires three spin curves, since there is typically a difference between tools.

8.3.2 The spin curve can be fit to a simple exponential: $T = Ae^{-b\cdot s}$ where *s* is the spin speed, *T* is the photoresist thickness, and *A* and *b* are fit parameters. The fit parameters for the three fits are shown in the caption below.



Spin curve for UV210-0.3 on picotrack1 (blue circles). Fit parameters are A = 1.91E1, b= -5.14E-1.
Spin curve for UV210-0.6 on picotrack1 (dark green circles). Fit parameters are A = 3.65E2, b = -5.06E-1.
Spin curve for UV210-0.6 on svgcoat6 (light green squares). Fit parameters are A = 3.46E2, b = -5.09E-1.

8.4 Swing Curve Results

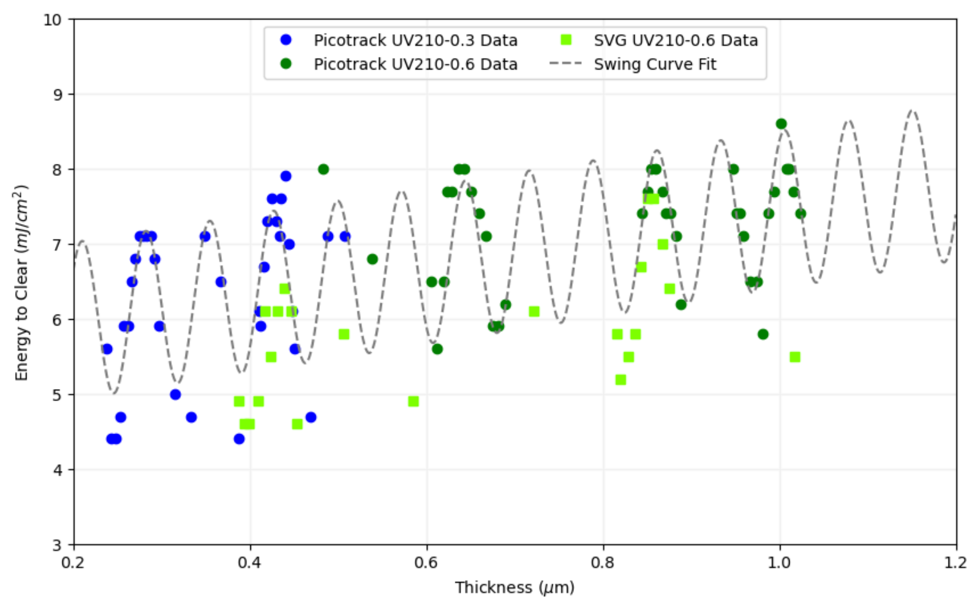
8.4.1 For a more thorough discussion of the theory of a swing curve, please refer to the 2018 Comparison paper.

8.4.2 The swing curve for UV210 is fit to the following equation:

$$f(x) = Ae^{-x/d}\cos\left(\frac{2\pi x}{\lambda} + \phi\right) + mx + b$$

8.4.3 The fit parameters are listed below:

A	$1.0476\ mJ/cm^2$	*d*	$-\ 1.554 \times 10^{13}\ \text{Å}$
λ	$723\ \text{Å}$	ϕ	$0.605\ radians$
m	$1.85\ \times 10^{-4}\ mJ/(cm^2\text{Å})$	*b*	$5.596\ mJ/cm^2$



Swing curve for UV210-0.3 on picotrack (blue circles), UV210-0.6 on picotrack (green circles), and UV210-0.6 on svgcoat6 (light green squares). The fitted line and parameters are in the text above.

8.4.4 From the fitted equation for the swing curve we can find the peak maxima, which are listed in the table below. Where it can be achieved, we have redundancies for thicknesses. The 0.43 um thickness can be achieved with either UV210-0.3 on picotrack1 or UV210-0.6 on svgcoat6. The 0.50 um thickness can be achieved with any of the formulations. Because it has the most redundancy, 0.50 um is the new thickness that is used for ASML calibrations; it is marked with stars in the table below for this reason. It is also the thickness used for the LAM8 process specification. Staff recommends using 0.50 um when defining PM marks.

	Picotrack		Svgcoat6
PR Thickness (um)	UV210-0.3 Spin Speeds (rpm)	UV210-0.6 Spin Speeds (rpm)	UV210-0.6 Spin Speeds (rpm)
0.28	3630		
0.35	2330		
0.43	1625		5635
★ 0.50 ★	1195	4645	4145
0.57		3565	3175
0.64		2825	2515
0.72		2290	2040
0.79		1900	1685

0.86		1600	1420
0.93		1365	1210
1.00		1180	1045
1.08		1030	915
1.15		905	805
1.22		805	

8.4.5 In the table, the colors denote the standard thicknesses. These have standard flows on picotrack1, and standard recipes on svgcoat6. If you want to use a non-standard thickness, please discuss your application with staff.

8.5 Comparison of BARC coatings from SVGCOAT3 versus PICOTRACK1

8.5.1 Five wafers were coated with BARC (recipe #3 coater, recipe #3 oven) on svgcoat3, and then held until the picotrack1 BARC wafers were ready. This is the "svgcoat3 BARC" batch.

8.5.2 An additional set of six wafers were coated with BARC on picotrack, (flow 02_BARC_68nm_PX200C60s_NoHMDS). This is the "picotrack1 BARC" batch.

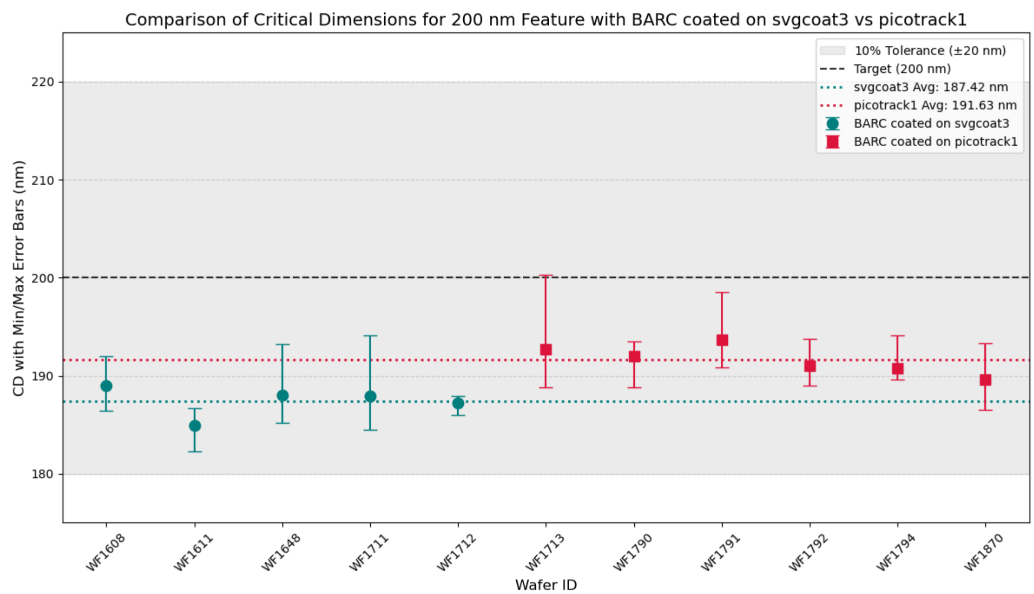
8.5.3 Two dummies were then run to prime the tool for the UV210 coating, and then all wafers were coated with 0.28 µm of UV210GS-0.3 on picotrack1 (flow 02_UV210f3_0.28um_PX140C90s). The svgcoat3 BARC wafers were coated as a batch from sender 1, and the picotrack BARC wafers were coated as a batch from sender 2.

8.5.4 IQC was run less than one hour prior to the start of the exposures.

8.5.5 Each wafer was run individually to minimize any post-exposure delay.

8.5.6 The wafers were dosed at an energy of 22.0 mJ, with a focus offset of 0, using the default (conventional) illumination settings.

8.5.7 The wafers were then run through standard developer in picotrack2, T2_PEB130C90s_MF26A45s.



8.5.8 The plot illustrates the variation in feature sizes between wafers coated with Picotrack BARC and SVGCOAT3 BARC. The svgcoat3 wafers are green, and the picotrack wafers are red. The average feature dimension is 187 nm for svgcoat3 coated wafers and is 192 nm for picotrack1 coated wafers. The difference between the batches may be due to the choice that staff made for the picotrack BARC recipe to be at 200C, whereas the svgcoat3 recipe is typically between 188 - 192C. In any case, the difference between the feature sizes is well within the tolerance of this particular feature size.

8.6 Feature Size Comparison of Old Bake and New Bake

8.6.1 It is somewhat tricky to provide a comparison of feature sizes going from the old softbake to the new softbake, since the main impact is the sidewall profile. The old softbake did not produce straight sidewalls, which had an impact on the feature size, both in the lithography and also in the subsequent processing (etch or lift-off).

8.6.2 Staff has extensive data on a particular 250 nm pillar pattern, going back to 2021. We used this pattern to compare feature sizes going from the old softbake to the new softbake. The graphs below are a variation on a Bossung plot, which typically compares Energy and Focus values. Since we want to compare feature dimensions over time, the plots below are at set energies, and the different colors represent different dates where data was collected.

8.6.3 The photoresist process was as follows:

8.6.3.1 Clean Si wafers

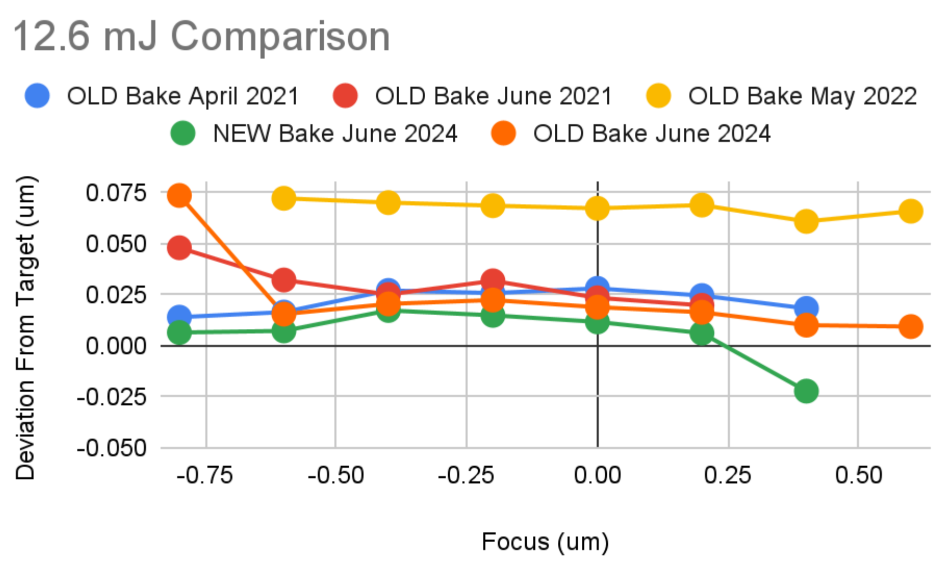
8.6.3.2 BARC coating on svgcoat3

8.6.3.3 0.36 um of UV210-0.3 on picotrack1; softbake varies with date of the experiment

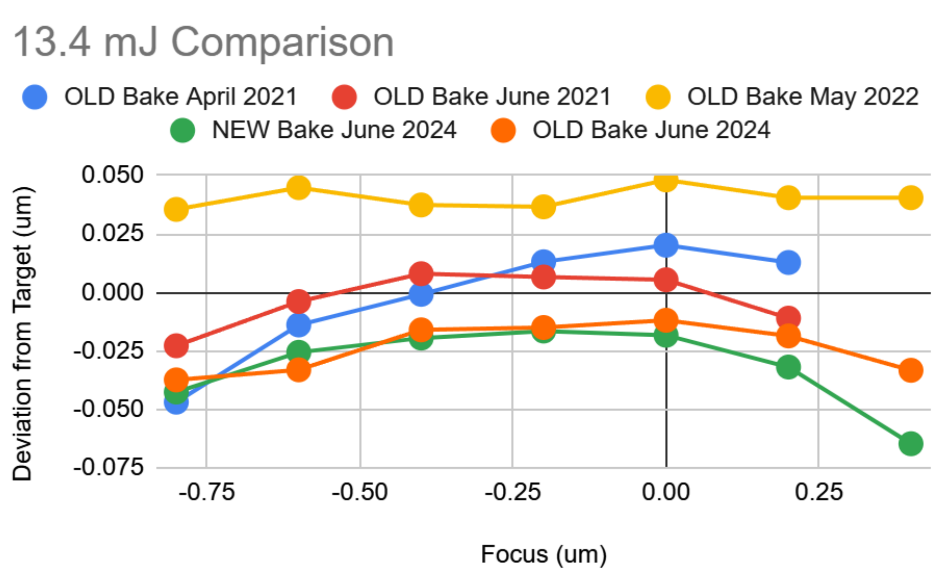
8.6.3.4 Exposure on ASML, using the MIT_FEM job, ACTIVE250 layer. The illumination settings used ANNULAR illumination, with a NA of 0.63, sigma_outer of 0.810, and sigma_inner of 0.510. The focus ranged from -0.8 µm to +0.8 µm. Energies varied from run to run, but were typically in the range of 11.8 mJ to 15.0 mJ.

8.6.3.5 Development used the standard UV210 development recipe on picotrack2.

8.6.3.6 Dies were imaged on zeiss-sem, and all measurements were done using ProSEM.

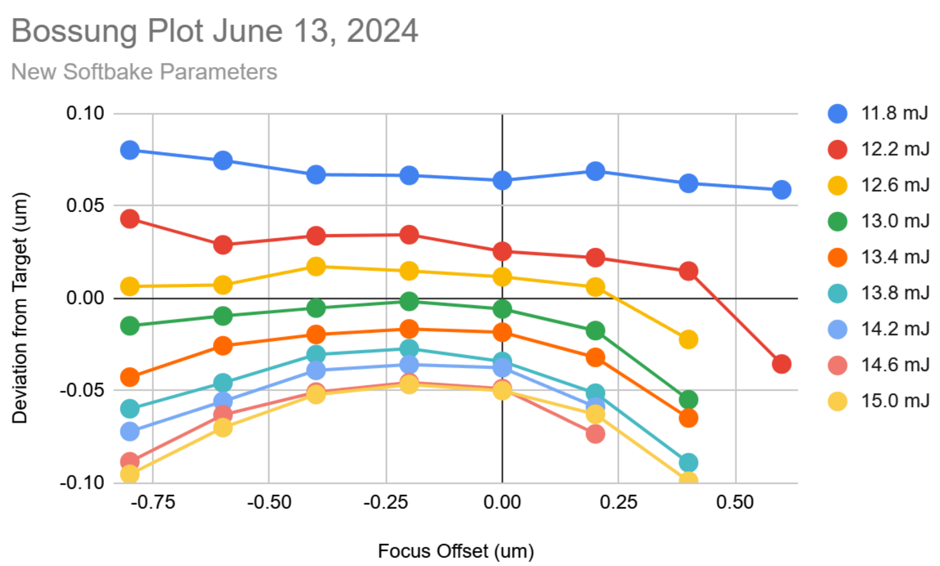


The plot above shows the deviation from target (in microns) of 250 nm circles at 12.6 mJ. The May 2022 dataset is consistently more deviant than the other datasets at all energies for unknown reasons. Excluding the May 2022 data, the feature sizes are within 25 nm of each other for focus offsets between -0.4 um and +0.2 um.



The plot above shows the deviation from target (in microns) of the same 250 nm circles, but this time at 13.4 mJ. There is only a small difference in behavior between the two June experiments, which compare the new softbake and the old softbake for most focus values.

8.6.4 There are two main benefits with the new softbake. The first and primary benefit is that the new softbake parameters produce straighter sidewalls. The second benefit is that the range of energies and focuses that will produce viable results is larger than with the old bake procedure. One way to see this is by looking at the Bossung plot for the new softbake.



Bossung plot for the new softbake parameters.

8.6.5

9.0 Troubleshooting Guidelines

10.0 Appendices