Neg + dark, neg + bright, pos + dark, pos + bright

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This memo provides through dose imaging data for all four resist tone / mask tone combinations: neg + dark, neg + bright, pos + dark, pos + bright.

Contents

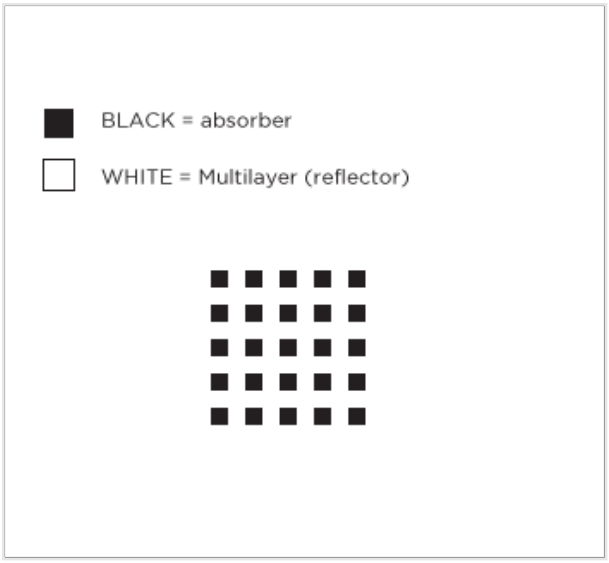
Change log

1.0.0

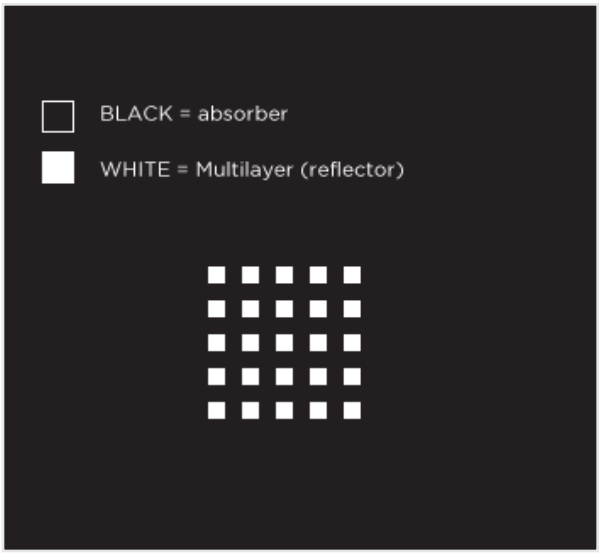
Initial release

Reticle: bright field vs. dark field

The next figure depicts a bright field contact mask (left) and dark field contact mask (right). Black is absorber. White is multilayer.



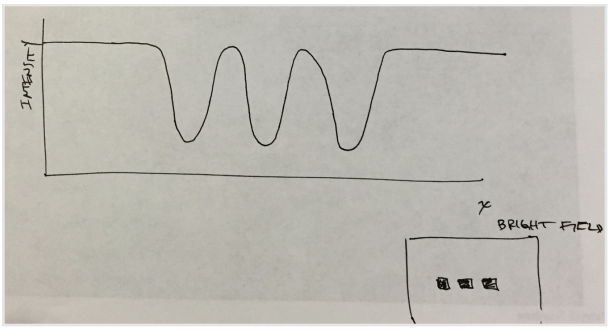
Bright field 1:1 contacts

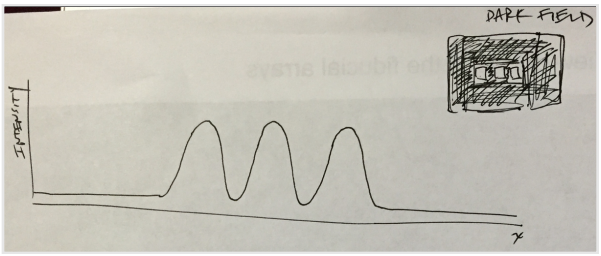


Dark field 1:1 contacts

Aerial image: bright field vs. dark field

The next figure depicts the aerial image cross-section from a bright field mask (left) and a dark field mask (right).





Aerial image from a bright field mask. Baseline is “light everywhere” and light intensity drops in areas where absorber was on the mask.	Aerial image from a dark field mask. Baseline is “no light everhwyere” and bright areas of light only exist in places where the reflector was on the mask.

Negative resist

Negative resist is rendered un-dissolvable anywhere the deposited energy is > Eo.

Negative resist + bright field

The following diagram depicts a developed wafer (bright field contacts + negative resist) through the entire range of doses.

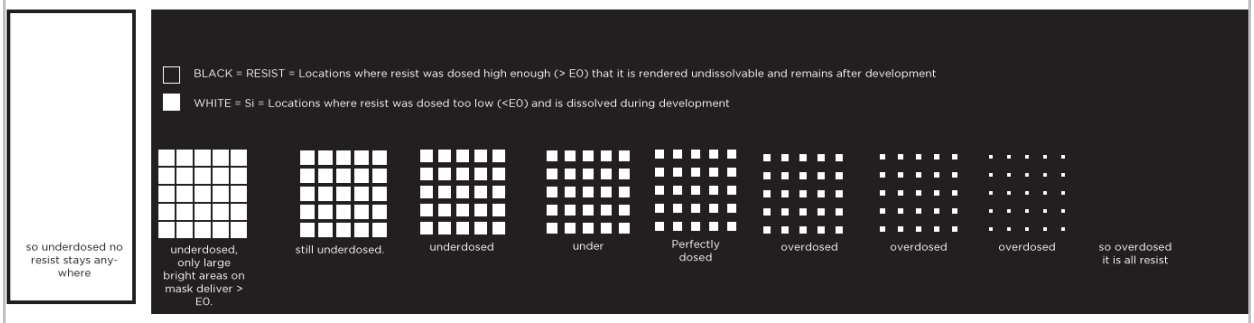
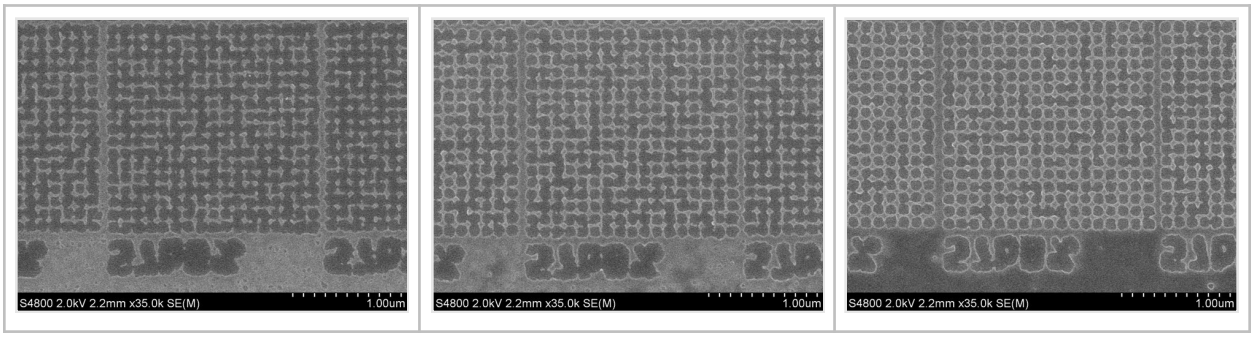
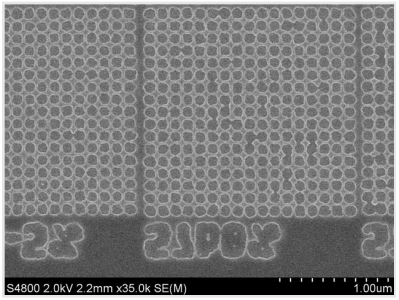
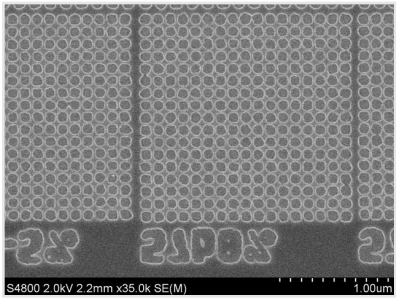
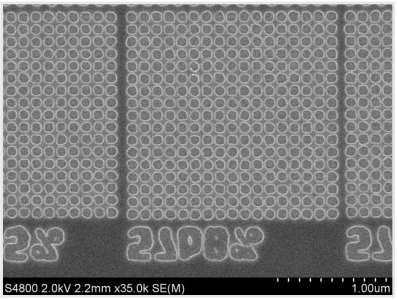
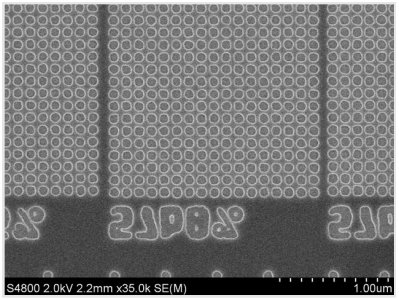
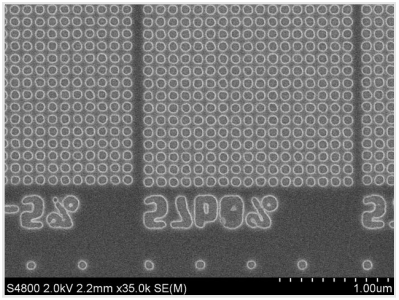
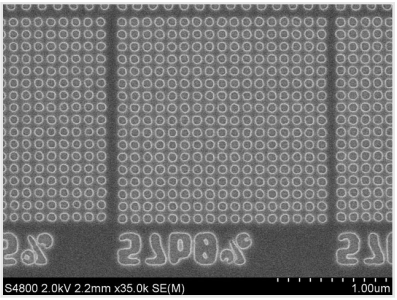
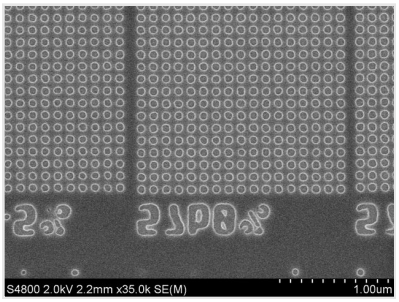
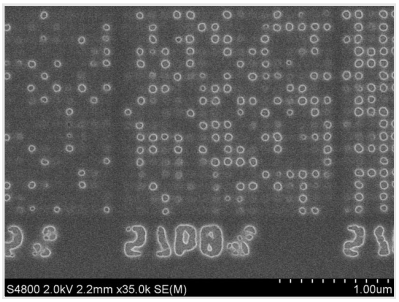
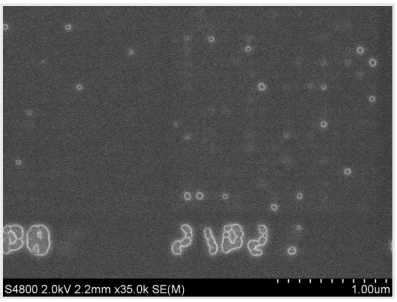


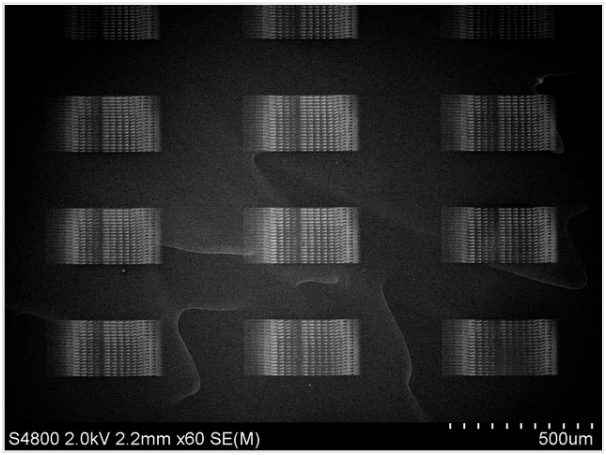
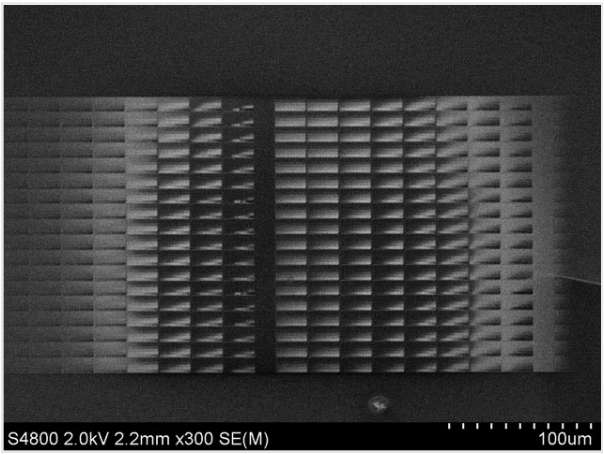
Figure 1. Bright field mask with negative resist. Negative resist is rendered un-dissolvable anywhere the deposited energy is > E0.

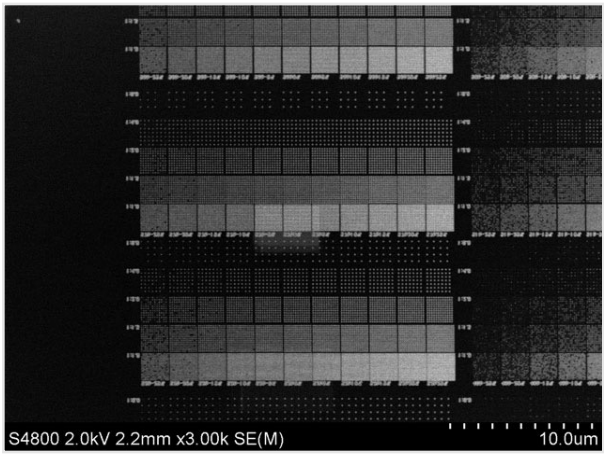
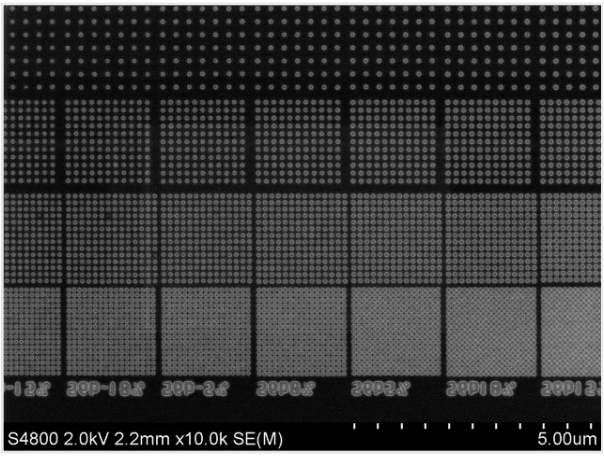
The following image series shows printing results through dose for bright field contacts with a negative resist.



D1. In this image the light color is negative resist rendered un-dissolvable during exposure	D2.	D3 As dose increases, negative resist around the edges of the contacts is rendered un-dissolvable and the hole pattern starts to emerge
		
D4 Hole pattern evident.	D5	D6. More and more resist starts to fill in the holes, decreasing their diameter.
		
D7	D8. e-size (approx.)	D9
		
D10	D11. Here dose is so high that some of the holes fully close	D12. Dose so high most of the holes are fully closed. Nearly one solid mass of resist.

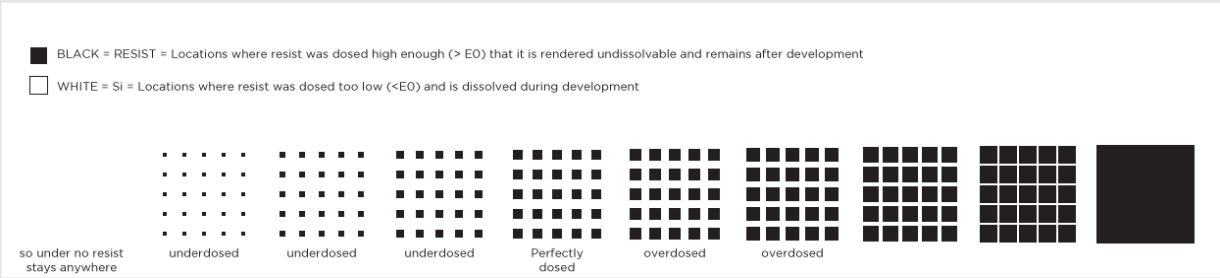
The following image sequence starts at the FEM level and zooms into the "bias / duty cell" level within a single exposure. Still bright field negative resist.

	
FEM zoom out, showing each exposure is easy to see.	Zooming in on a single exposure in the FEM

	
Zooming on a few of the bias / duty cells within an exposure	Even higher zoom

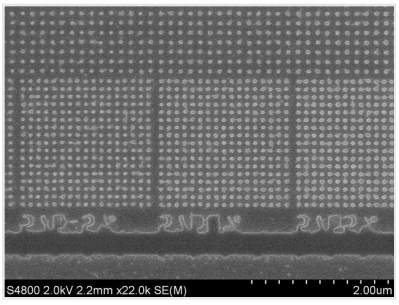
Negative resist + dark field

The following diagram depicts a developed wafer (dark field contacts + negative resist) through the entire range of doses.

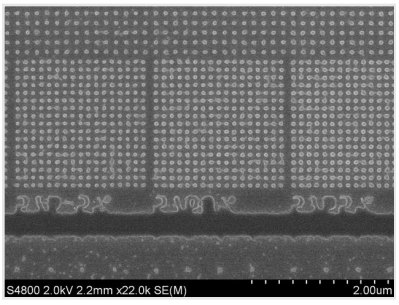


Dark field mask with negative resist. Negative resist is rendered un-dissolvable anywhere the deposited energy is > E0.

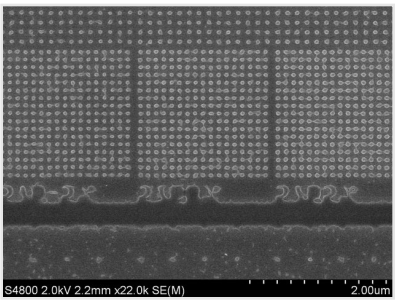
The following image series shows printing results through dose for dark field contacts with a negative resist.



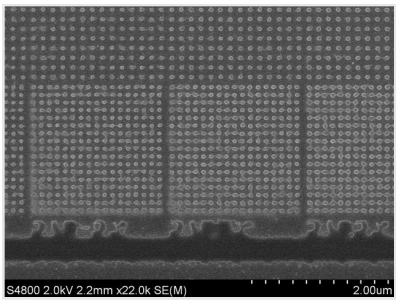
D1. Here only the center of the contact delivers enough energy to render resist un-dissolvable. We have “small pillars of resist”



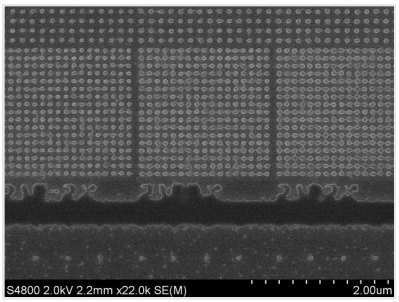
D2 As dose increases, resist pillars get larger indiameter.



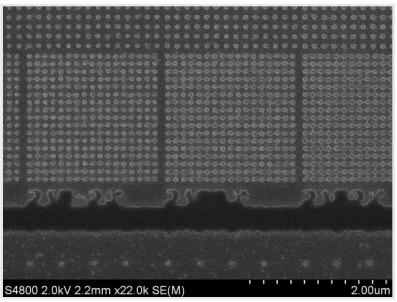
Dose3



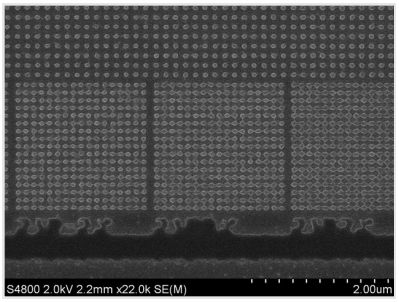
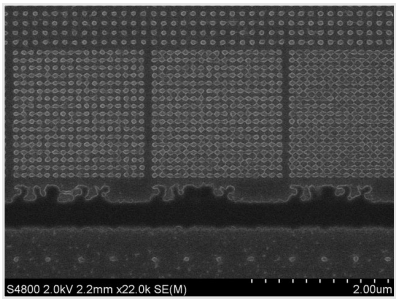
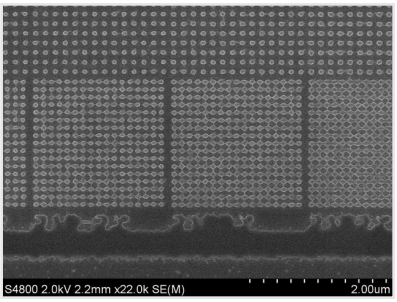
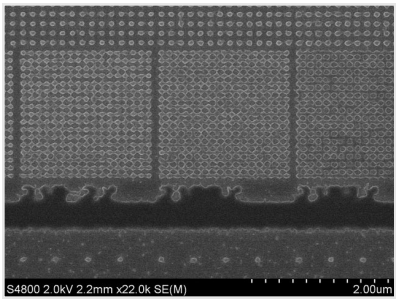
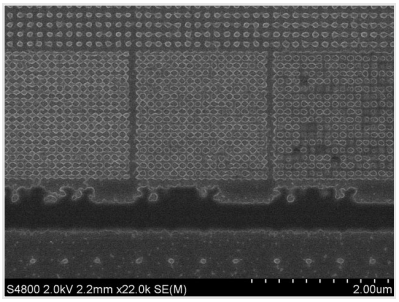
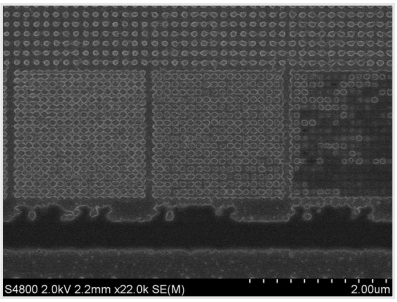
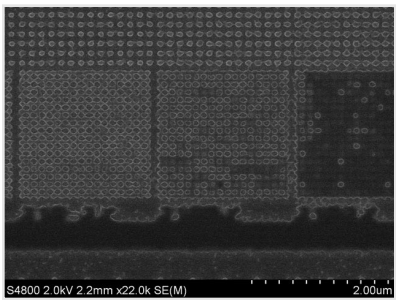
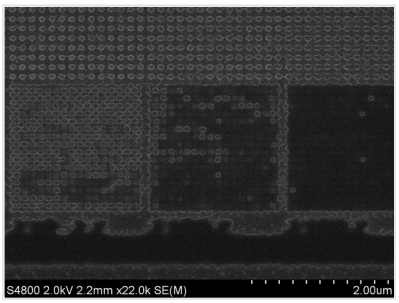
Dose4



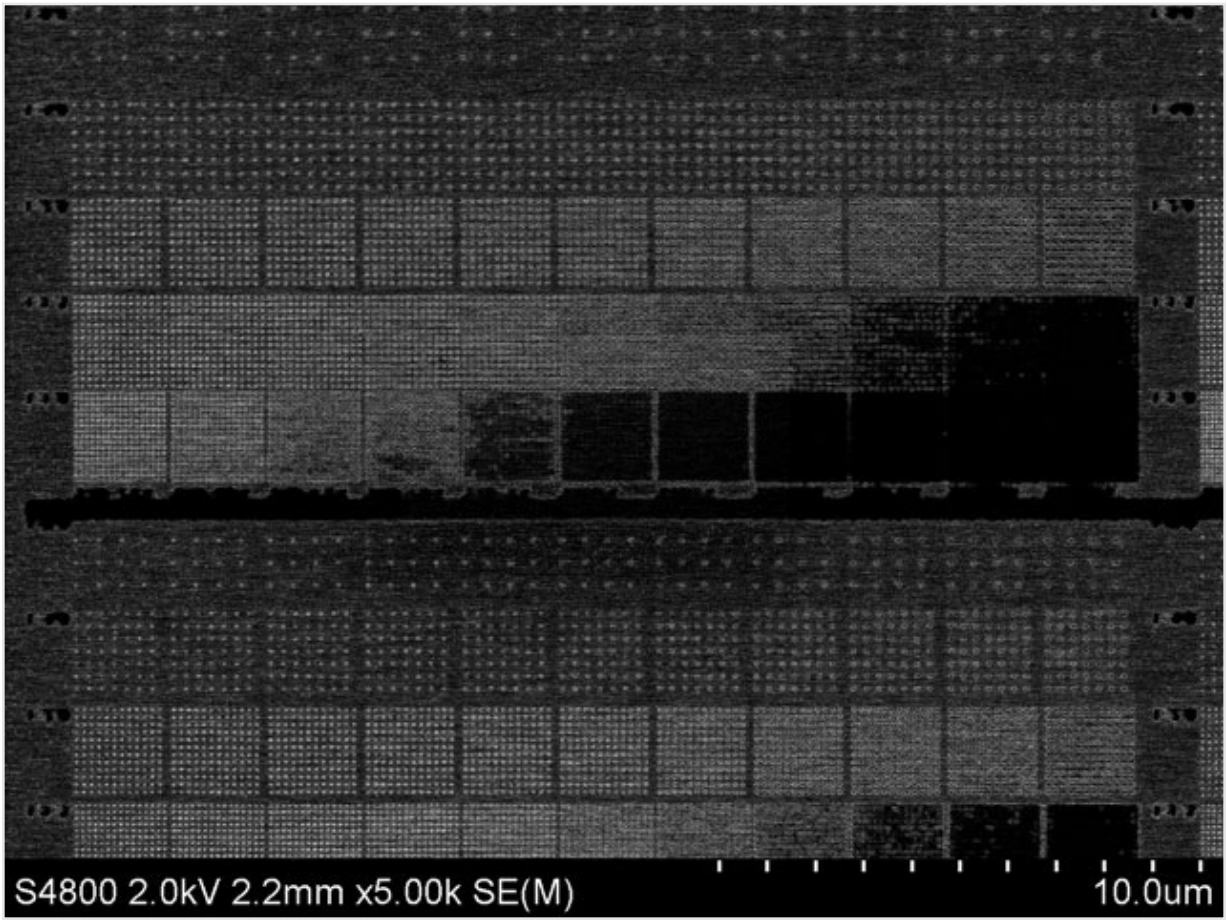
Dose 5 Pillars continue to get larger in diameter as dose increases. Some begin to short to their neighbor in the vertical or horridontal direction due to aberrations (this FEM only had one focus value in it)



Dose 6

		
Dose 7	Dose 8	Dose 9 Nearly all of the 1:1 bias 0% are shorted to their neighbor in the horizontal direction.
		
Dose 10	Dose 11 Here, the “pillars” are so big, they have merged into one big mass of resist that now has diamond-shaped holes.	Dose 12
		

Dose 13	Dose 14 Here dose is so high that the pillars have more-or less merged into a single solid block of resist throughout the entire area of the contact 1:1 bias 0% contact features.	



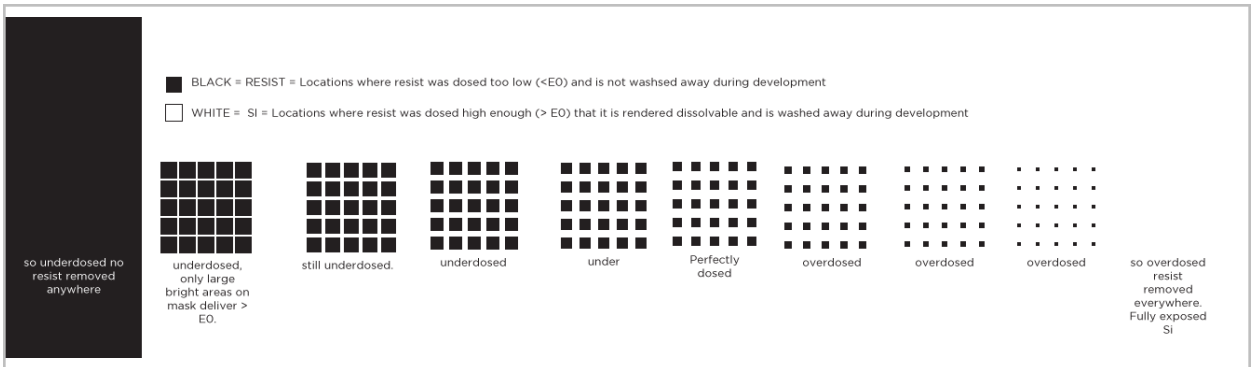
Zoom out showing overdosed cells (the ones that look black are pillars that are so large, they are merged into a single block of resist). Since these cells are one single chunk of resist, no edges for e-beam to scatter off of, and the signal is low in the SEM image.

Positive resist

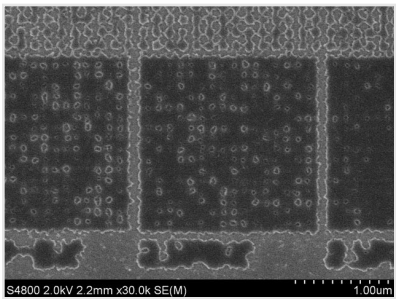
Positive resist is rendered dissolvable to developer anywhere the deposited energy is > Eo.

Positive resist + bright field

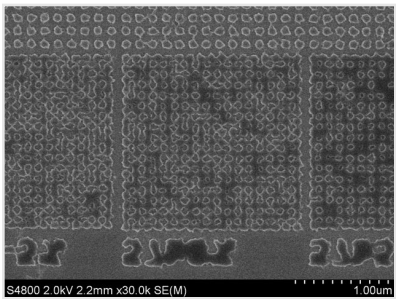
The following diagram depicts a developed wafer (bright field contacts + positive resist) through the entire range of doses.



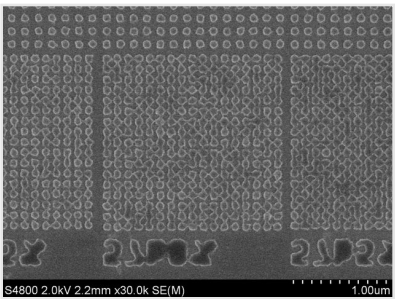
Positive resist + bright field through dose. Positive resist is rendered dissolvable to developer anywhere the deposited energy is > E0.



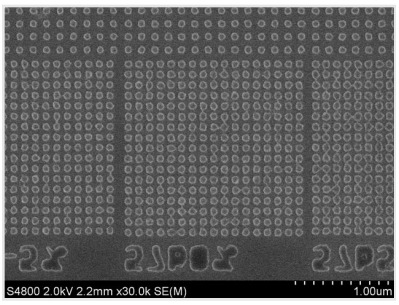
Dose 1. Only large bright areas surrounding contact area deliver > E0 and render resist dissolvable. Large dark square is resist dosed too low to be dissolved.

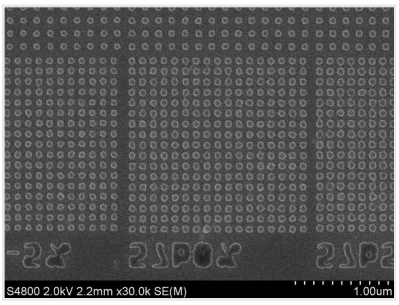


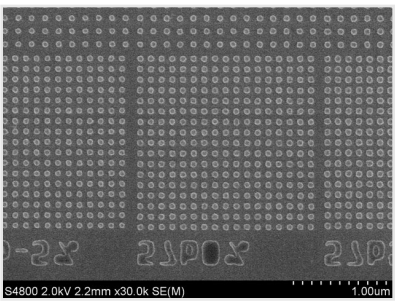
Dose 2. More areas within the contact area deliver > E0 and are removed in development.

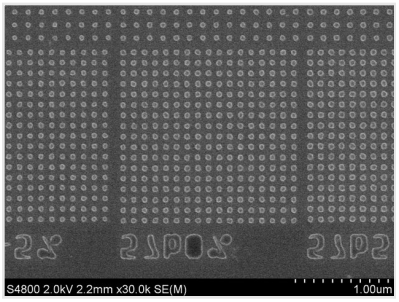
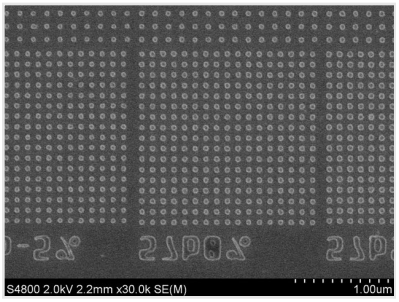
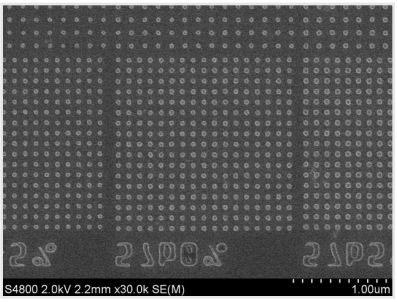
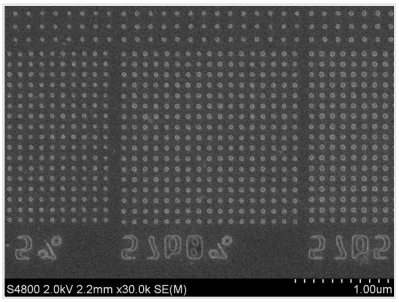
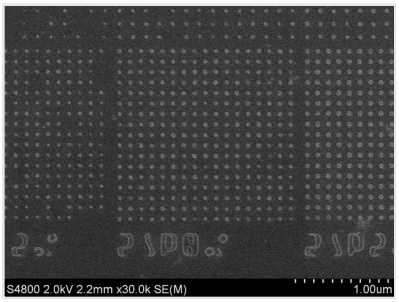
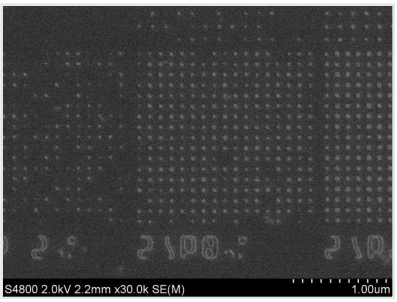
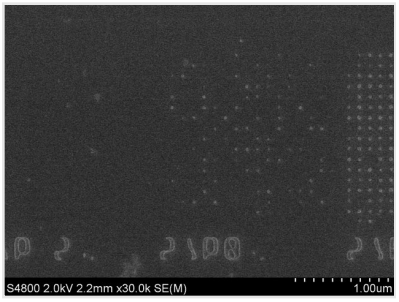


Dose 3 Grid of “Pillars of resist” now taking shape.





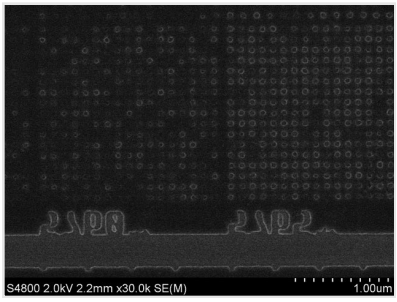


Dose 4. Distinguished pillars of resist have now formed	Dose 5.	Dose 6. E-size. Pillars of resist are 1:1 and sized correctly.
		
Dose 7	Dose 8.	Dose 9. As dose increases, the diameter of the resist pillars decreases.
		
Dose 10	Dose 11. Remaining pillars of resist have small diameters now.	Dose 12.
		
Dose 13. Diameters of resist pillars reduced to zero. Almost all resist removed. Fully exposed Si.	Dose 14.	Dose 15

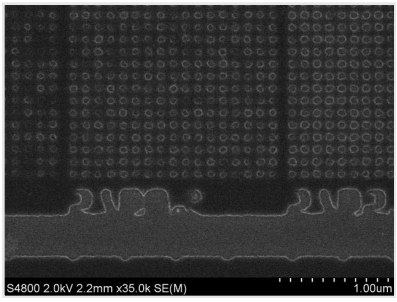
Positive resist + dark field

The following diagram depicts a developed wafer (dark field contacts + positive resist) through the entire range of doses.

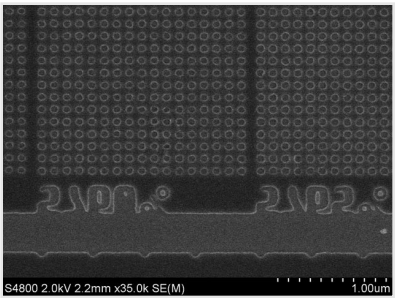
Dark field mask in positive resist. Positive resist is rendered dissolvable to developer anywhere the deposited energy is > E0.



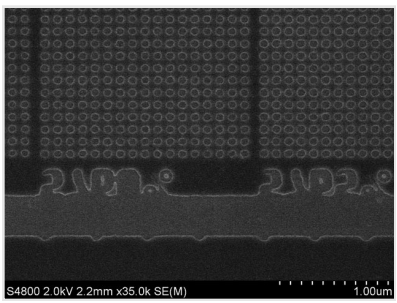
Dose 1. Dose is so low that only the center of some of the contacts are rendered dissolvable. Small holes are intermittent.

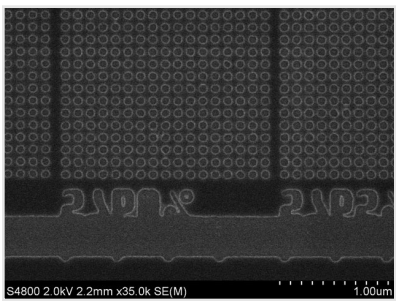


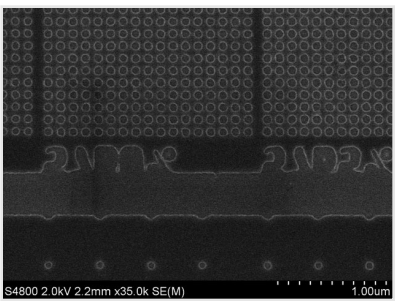
Dose 2. As dose increases, small holes in resist become more uniform.

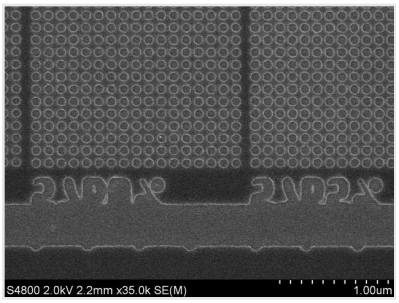
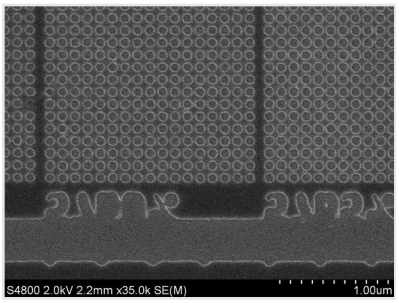
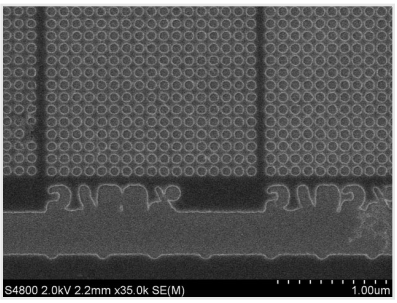
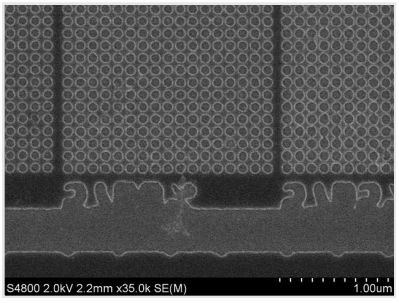
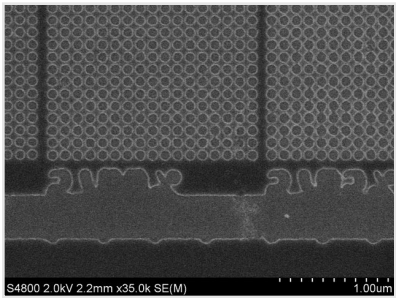
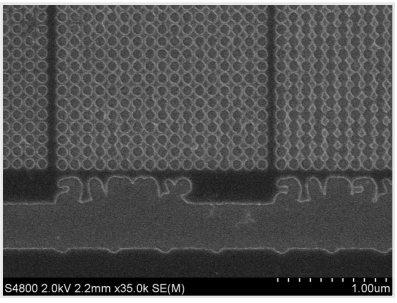
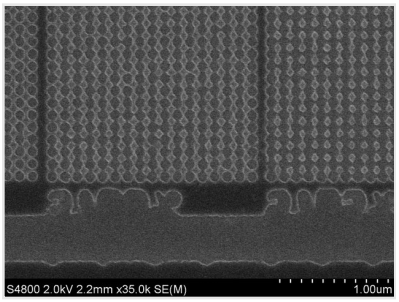
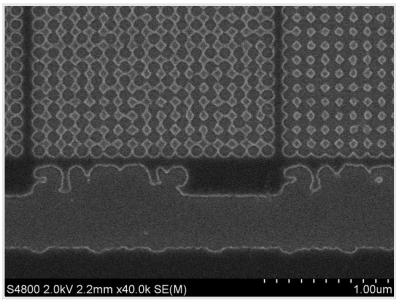


Dose 3

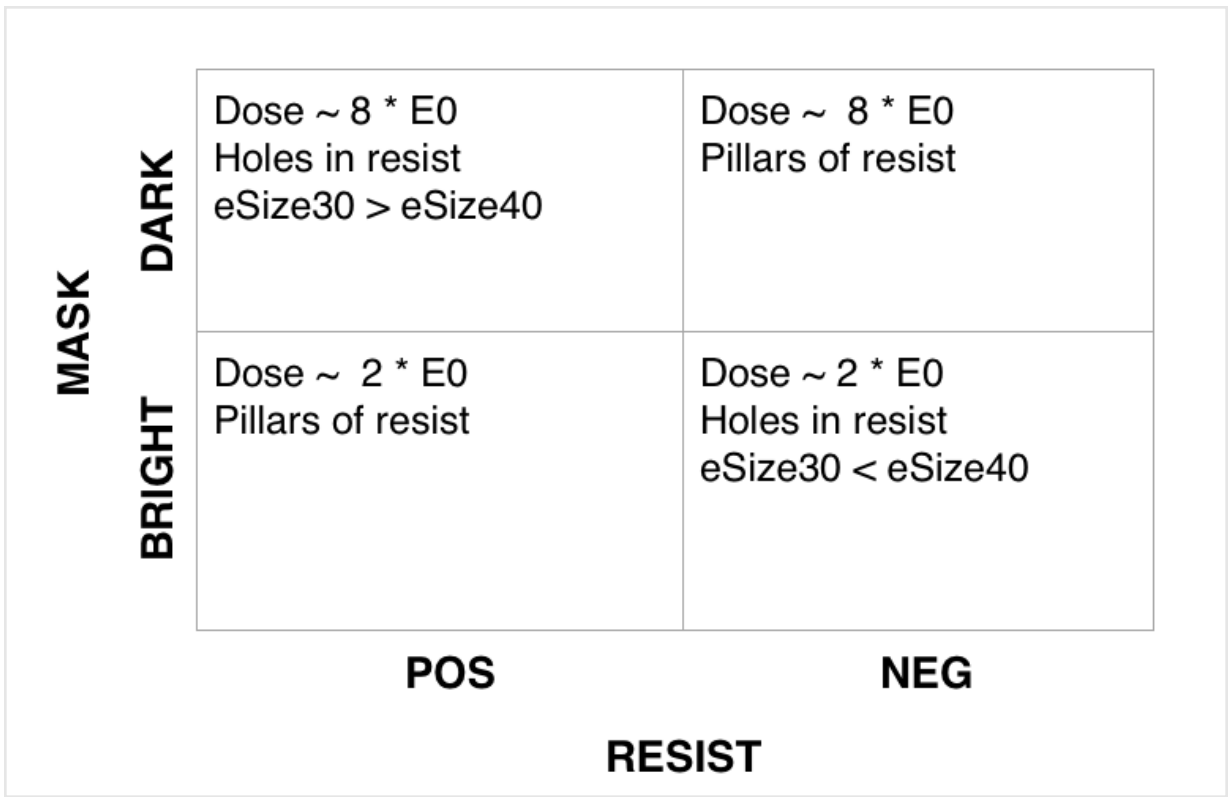






Dose 4. Holes in resist continue to increase in diameter as dose increases.	Dose 5. Close to E-size	Dose 6
		
Dose 7	Dose 8. As dose increases, the diameter of the holes in resist continues to increase. Soon holes will be touching their neighbors.	Dose 9
		
Dose 10	Dose 11	Dose 12. Some holes begin to short / touch neighbors.
		
Dose 13	Dose 14. Dose so high that most holes are now so big they have shorted / touched with neighboring holes.	Dose 15

Dose matrix



Dark field mask in positive resist. Positive resist is rendered dissolvable to developer anywhere the deposited energy is > E0.