EUV Resist Performance under High Stray Light Levels: an Interference Lithography Study

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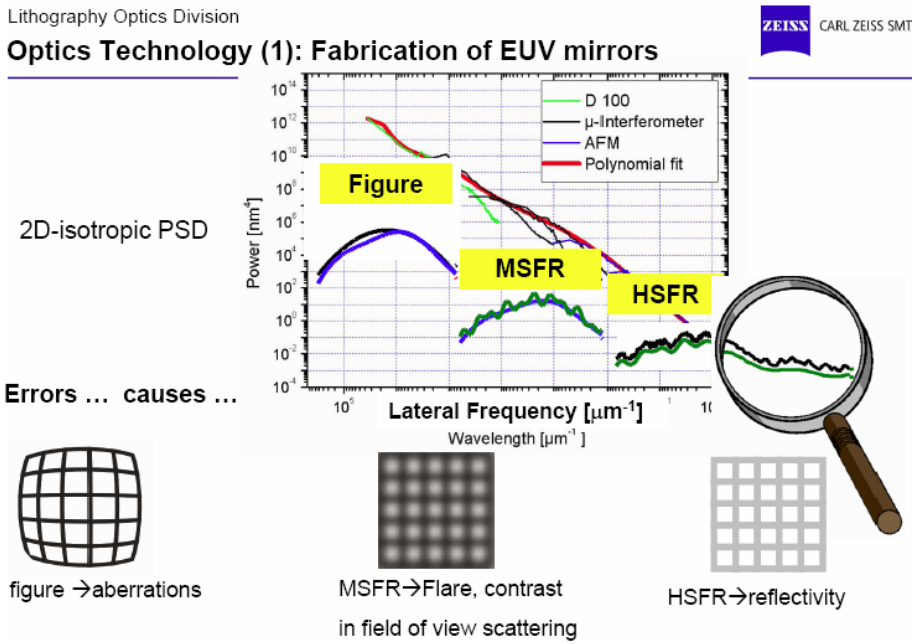
Outline

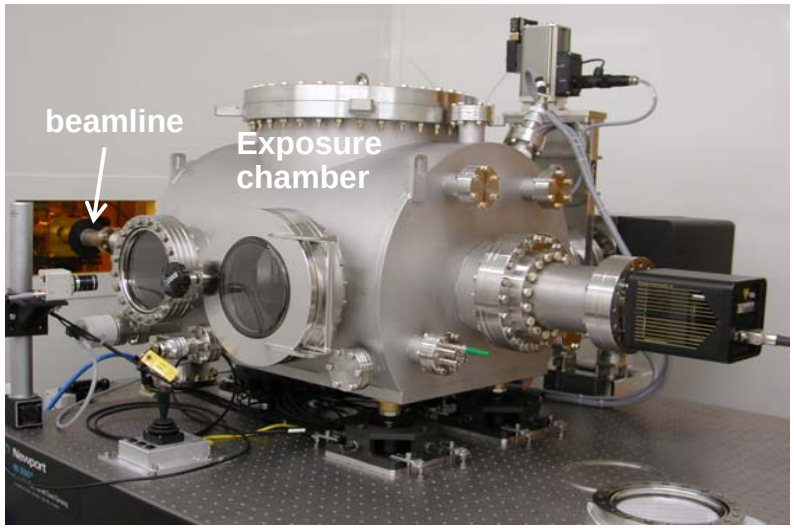
- Introduction
- Experimental Method
- State-of-the-art EUV Resist Performance
- Effect of Flare on Resist Performance
  - Exposure Latitude and Profiles
  - Line Width Roughness
- Conclusions

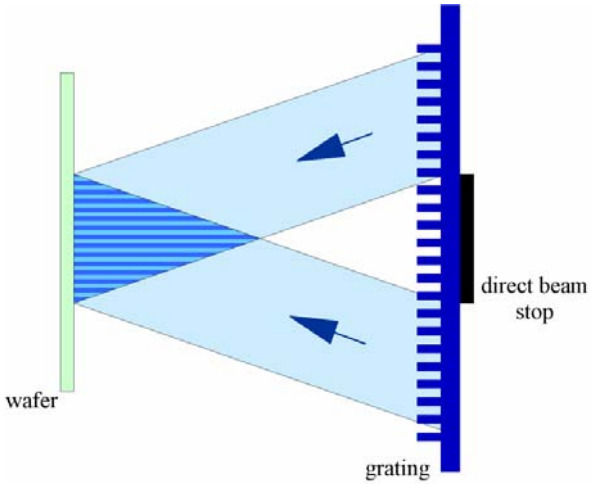
- Flare scales with $1/\lambda^2$ and is therefore a very serious issue for EUV
  - Tight roughness specifications on mirrors in MSFR are needed for flare control

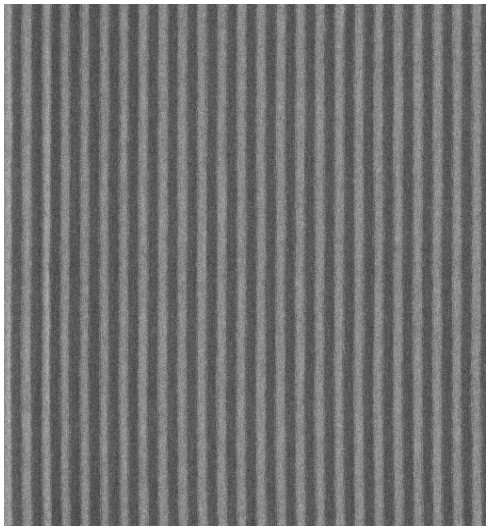


- DUV Out-of-Band radiation also results in increased effective flare

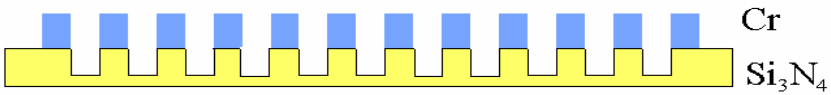
Experimental Method - The Interferometer

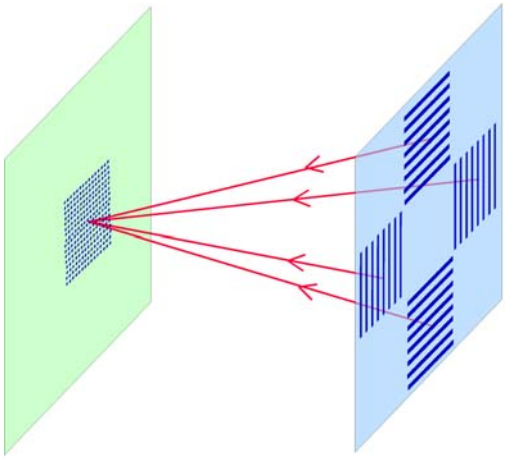


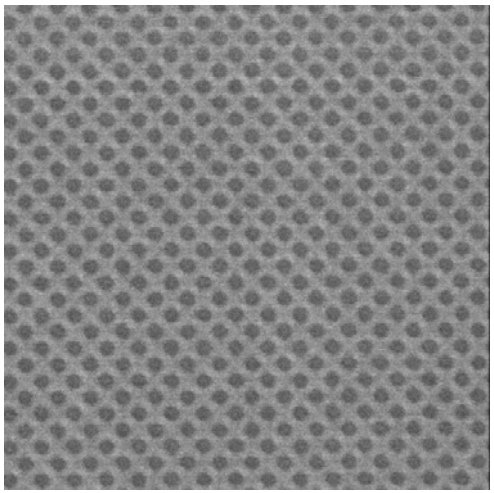




Diffraction Gratings







Thin membrane is only optical element: negligible intrinsic flare

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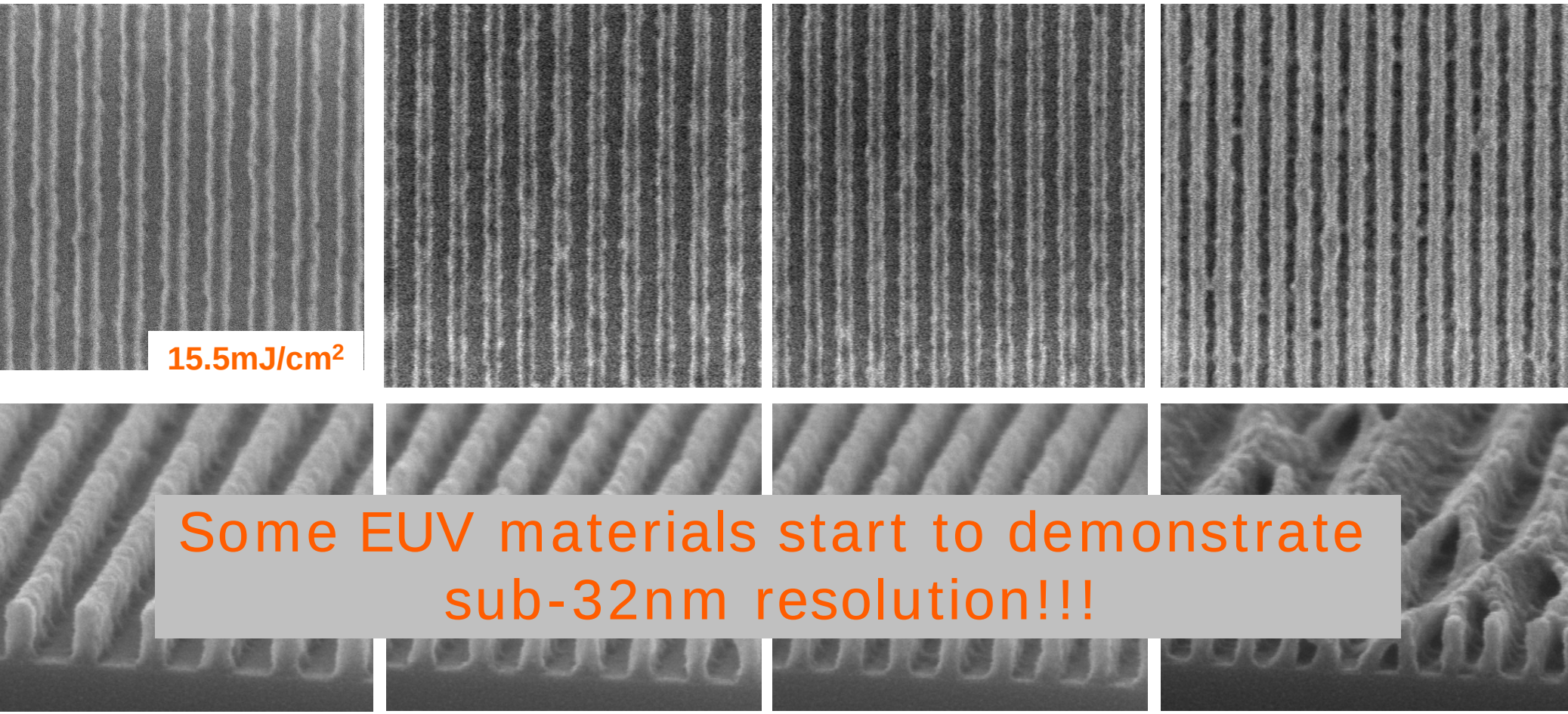
State-of-the-art EUV Resist Performance

EUV-38

40nm L/S | 32.5nm L/S | 30nm L/S | 25nm L/S



Some EUV materials start to demonstrate sub-32nm resolution!!!

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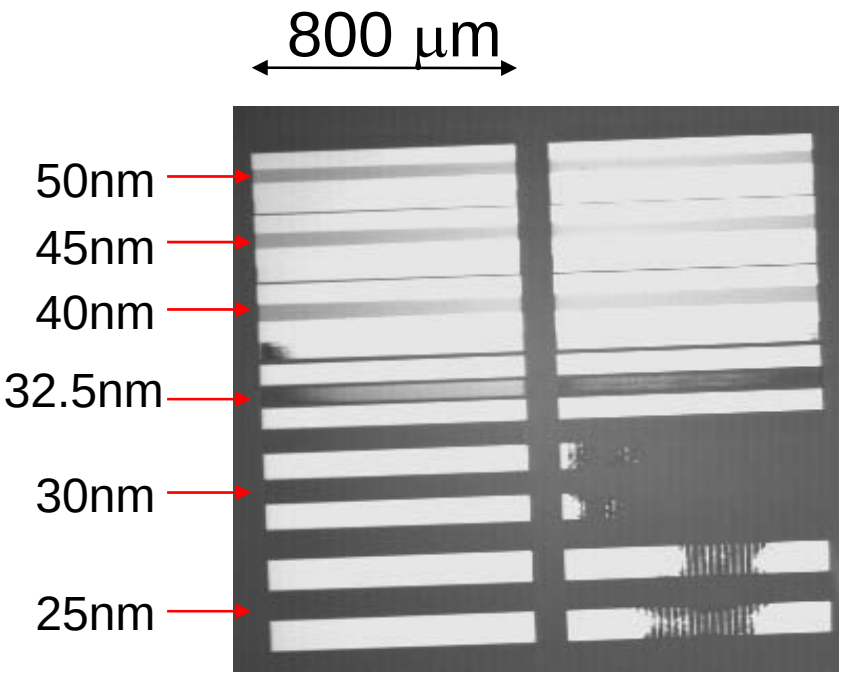
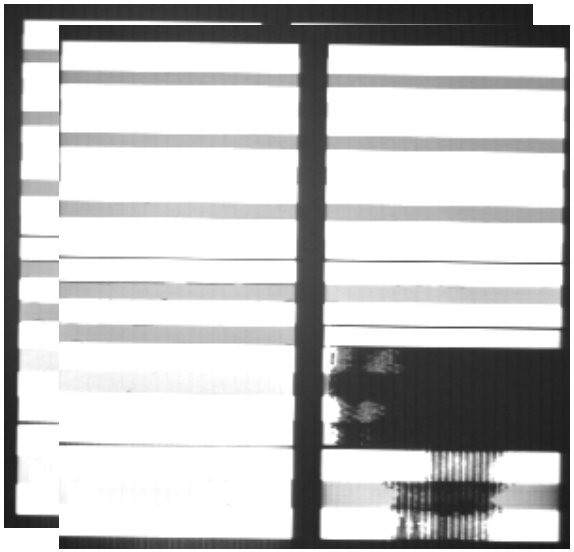
Experimental Method – Flare Exposures



Multiple pitches are simultaneously printed in a single exposure field

2nd Exposure: Flare



60 μm shift

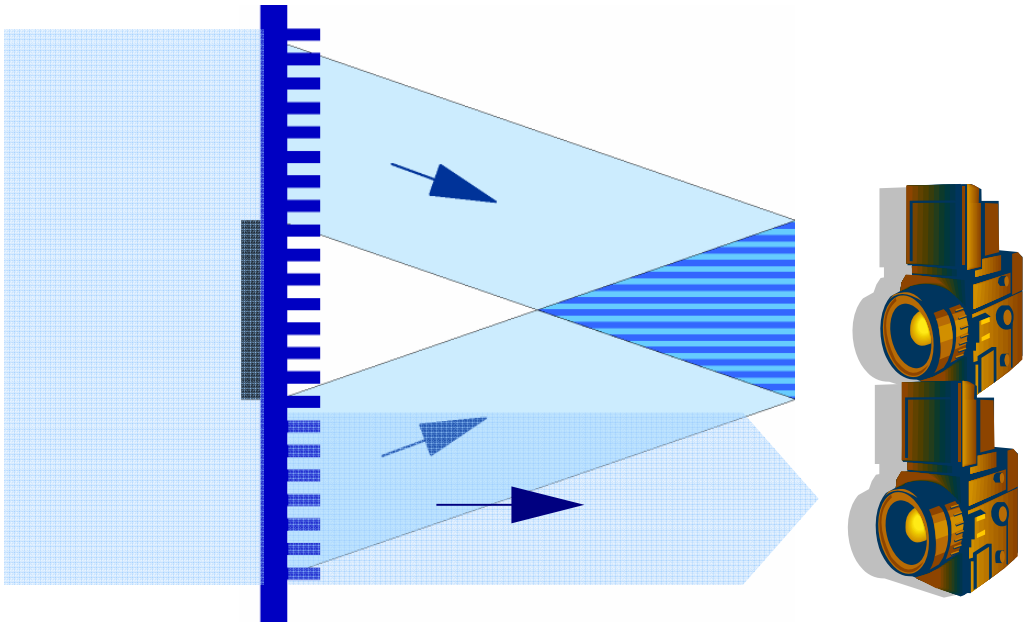
0, 10, 20, 30, 40% flare added

Note: In this presentation flare is defined as I_{min}/I_{max}*100%

Flare is treated as a DC offset to the aerial image

Calibration of mask efficiency

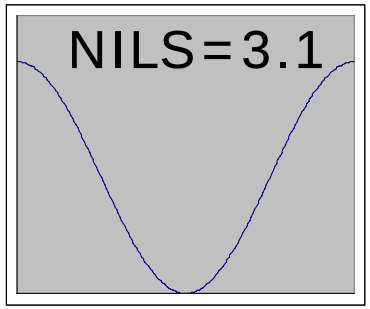
- The mask efficiency is determined by measuring the relative intensity of the 1st and 0th order diffracted light with a CCD camera.
- With this information the required relative dose to obtain a certain flare level can be determined



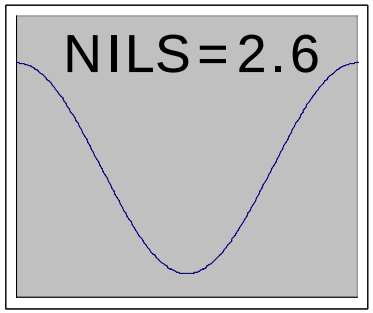
Flare Results in Reduced Aerial Image Contrast

Interference Printer: Aerial Image is pitch independent

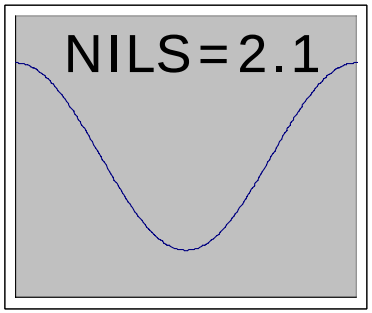
Flare = 0%



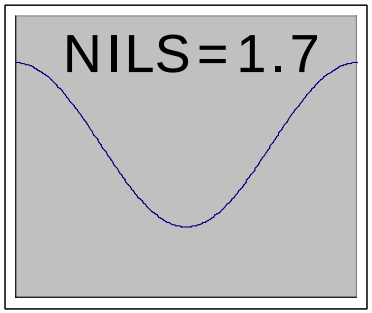
10%



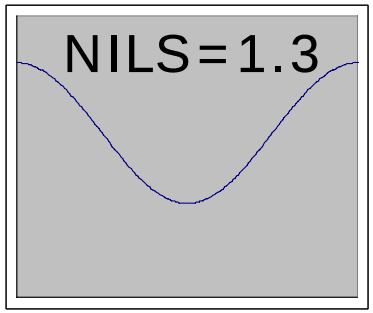
20%



30%

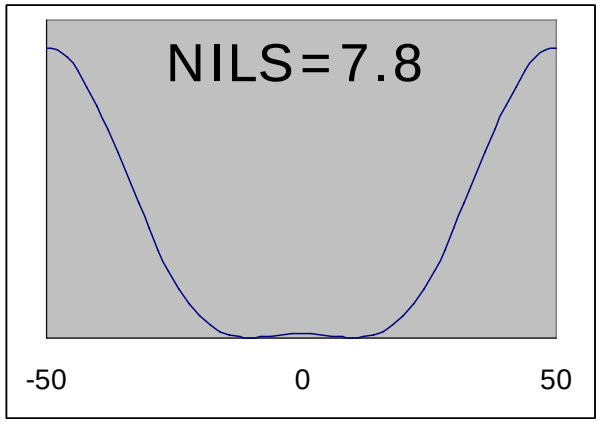


40%

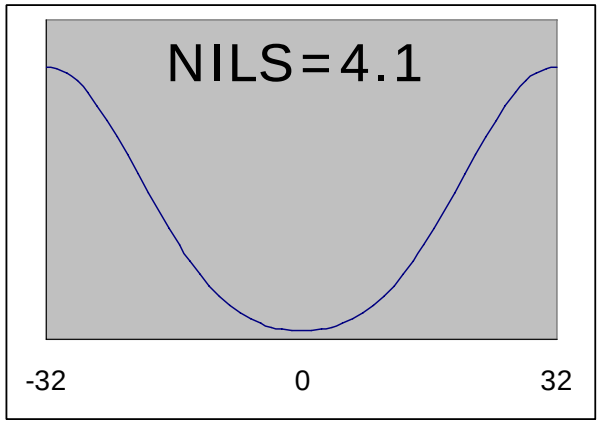


EUV Scanner (0.25NA and σ=0.5): Aerial Image depends on feature size

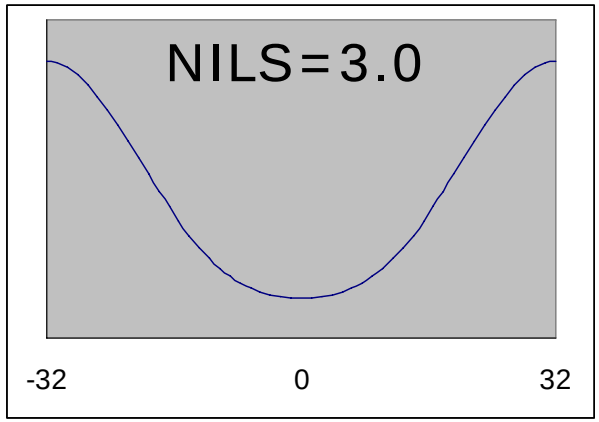
50nm L/S, 0% flare



32nm L/S, 0% flare



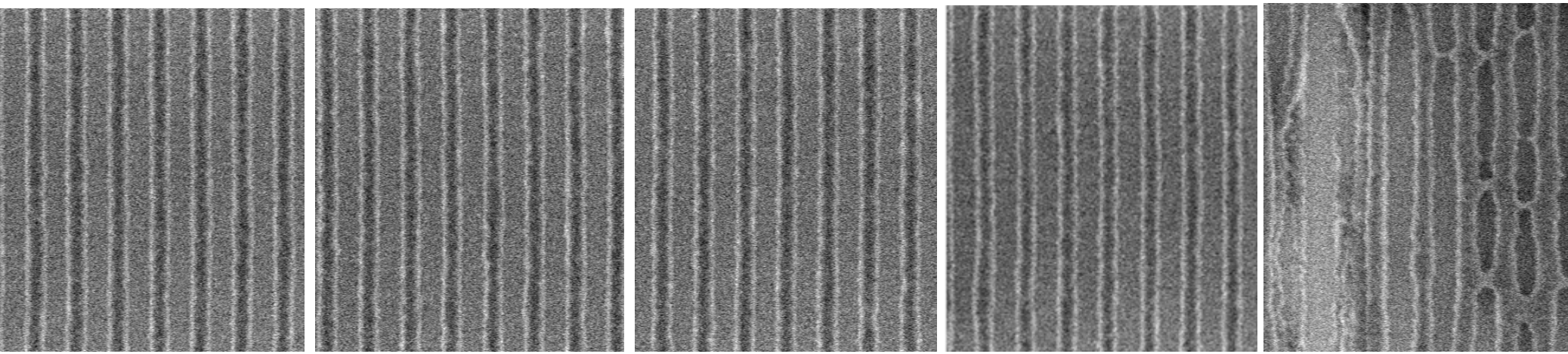
32nm L/S, 10% flare

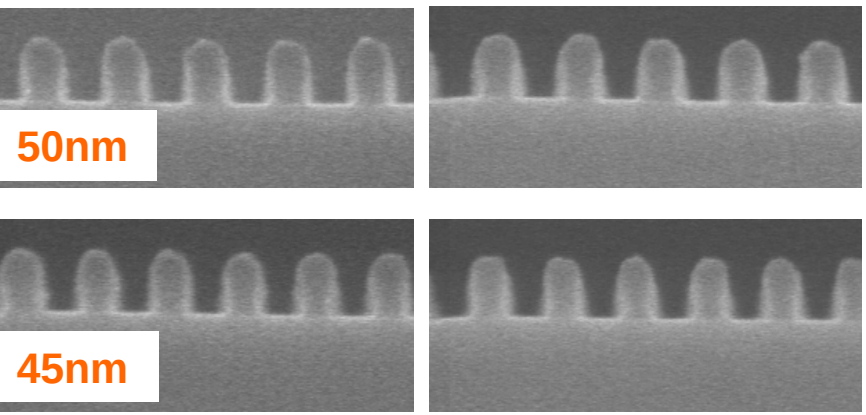


Contrast Demodulation at PSI

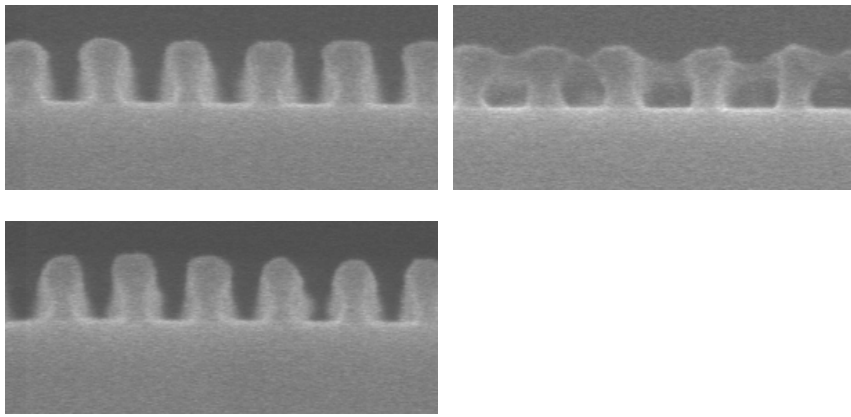
EUV-16

Flare = 0% 10% 20% 30% 40%





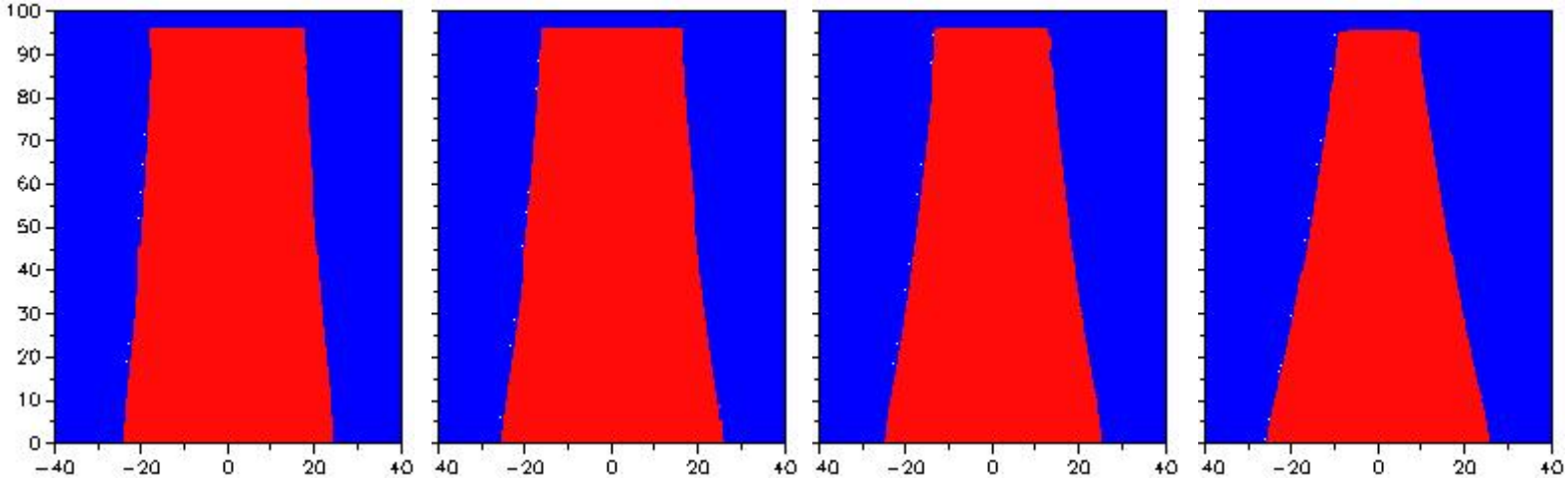
Not Available



Prolith Simulations

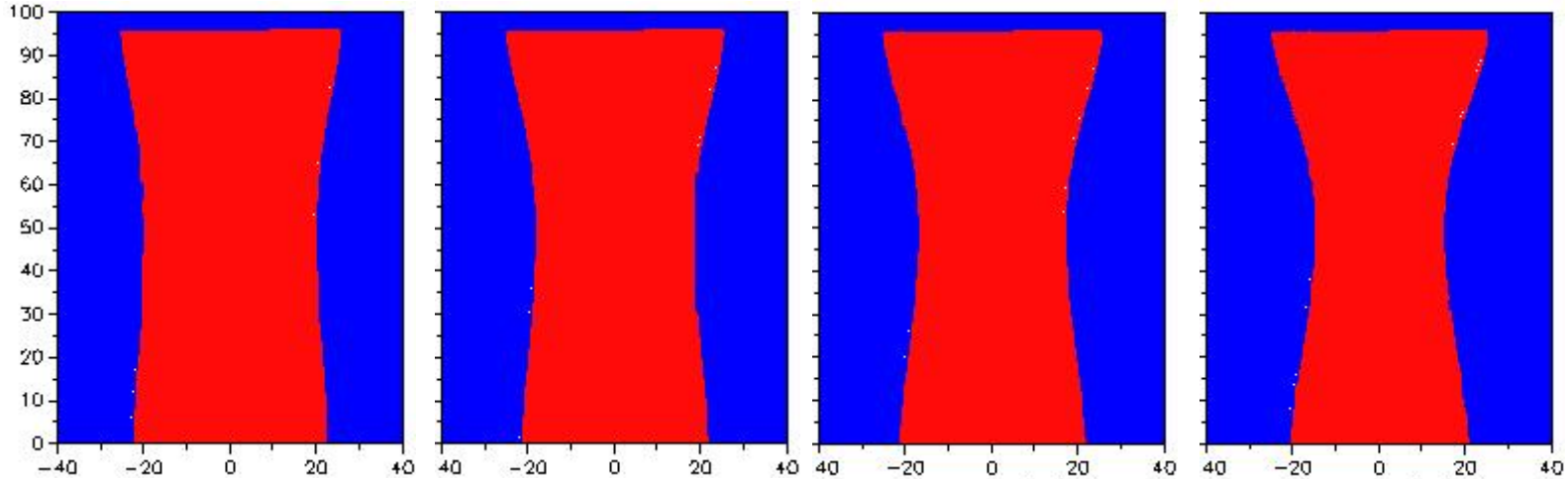
Flare level: 0% 10% 20% 30%

No chemical surface contamination



Flare level: 0% 10% 20% 30%

With chemical surface contamination



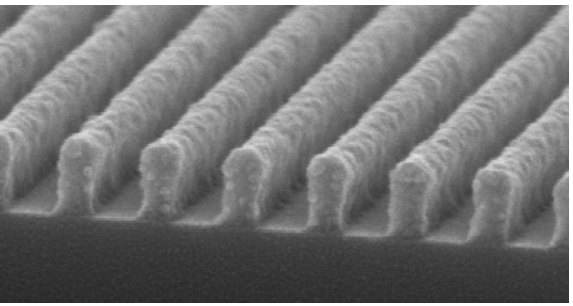
Effect of amine contamination

EUV-18

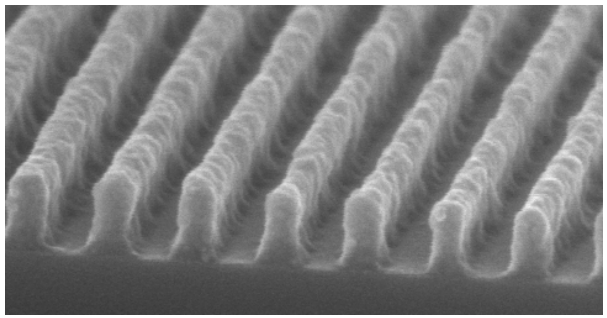
PEB under N_2 flow

50nm L/S

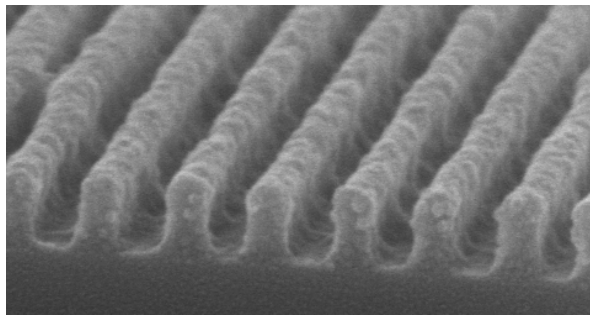
0% flare



30% flare

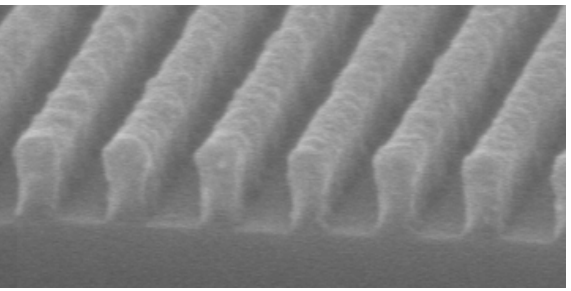


40% flare

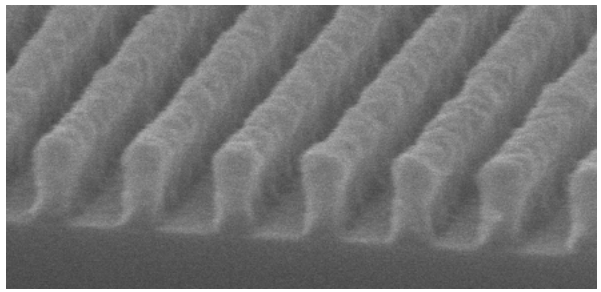


PEB under ambient conditions

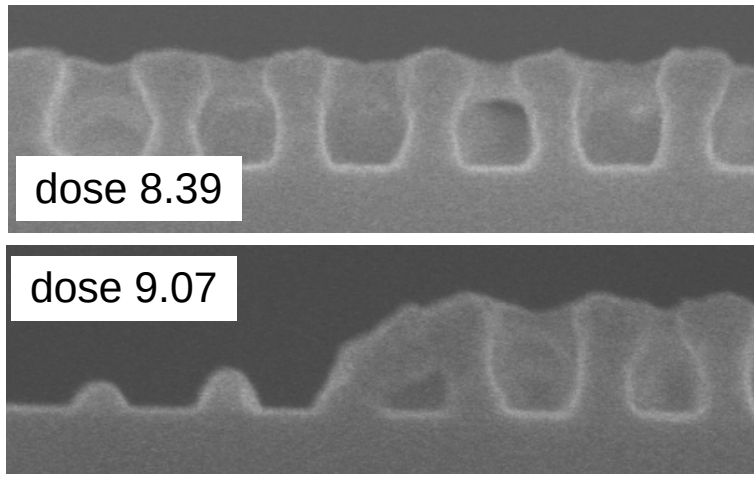
0% flare



20% flare



40% flare



Exposure Latitude

EUV-30

50nm L/S

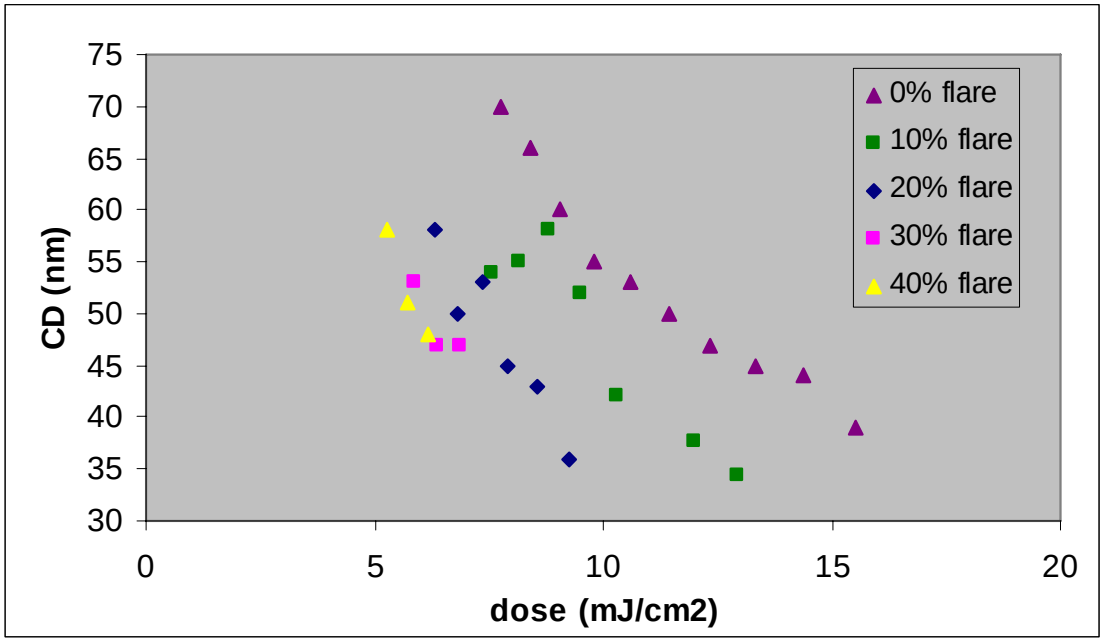


Image blurring due to acid diffusion???

	NILS	50nm	45nm	40nm
0 % Flare	3.1	34%	35%	24%
10% Flare	2.6	26%	20%	--
20% Flare	2.1	22%	--	--

~ 10xNILS

Exposure Latitude

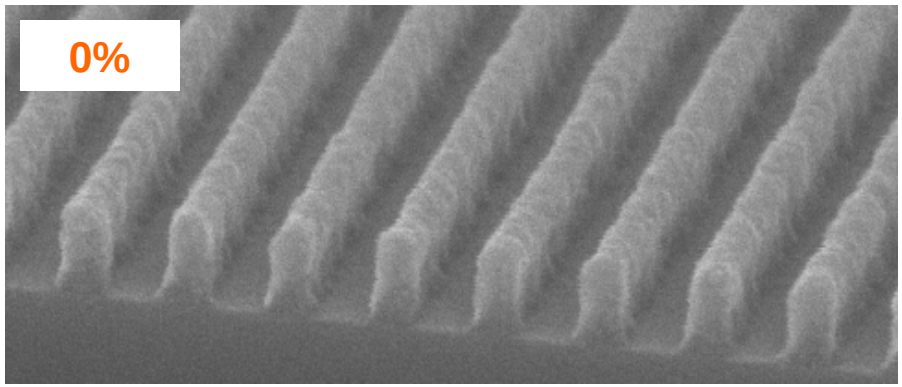
EUV-38	NILS	50nm	45nm	40nm
0 % Flare	3.1	31%	33%	--
10% Flare	2.6	21%	22%	--
20% Flare	2.1	--	17%	--

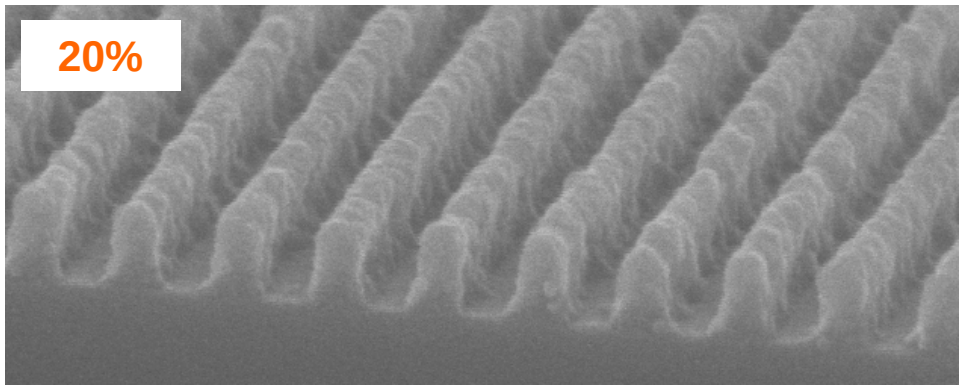
EUV-44	NILS	50nm	45nm	40nm
0 % Flare	3.1	24%	24%	23%
10% Flare	2.6	26%	19%	17%
20% Flare	2.1	15%	13%	--

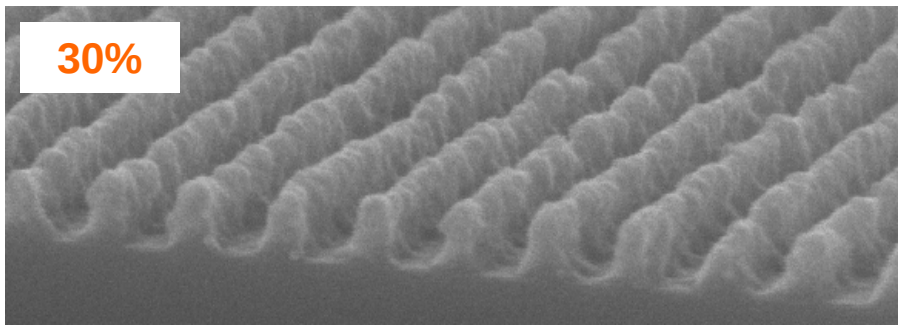
EUV-44 has less maximum contrast, but is also less affected by flare increase

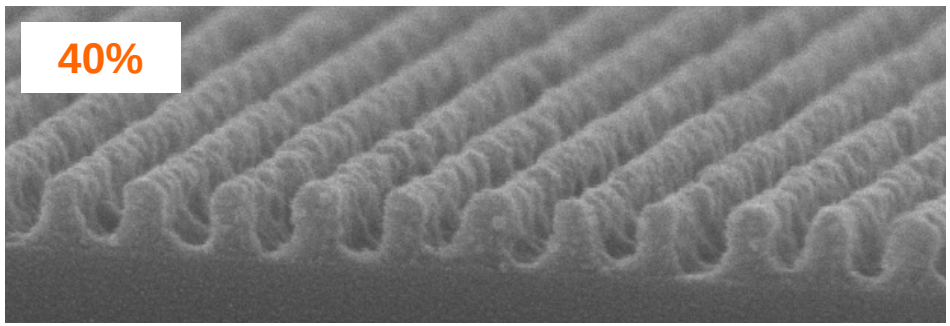
Profiles for 50nm L/S

EUV-30





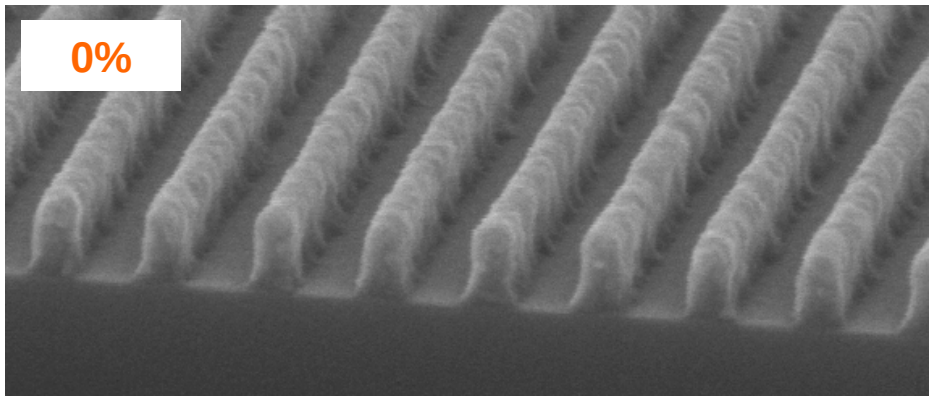


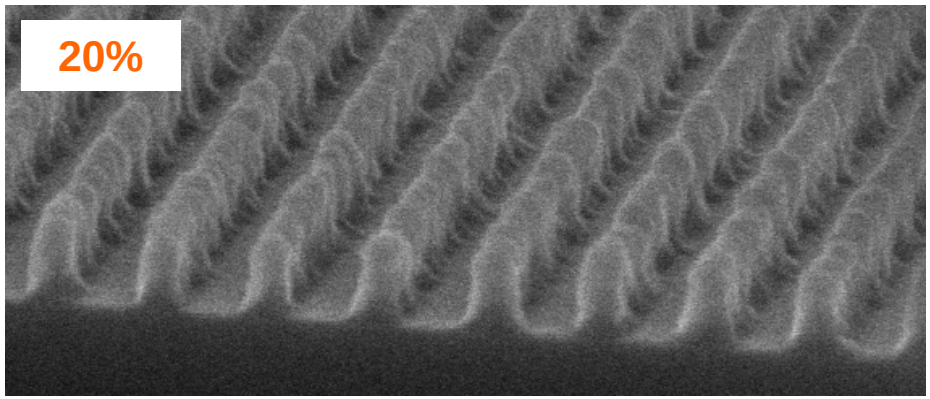


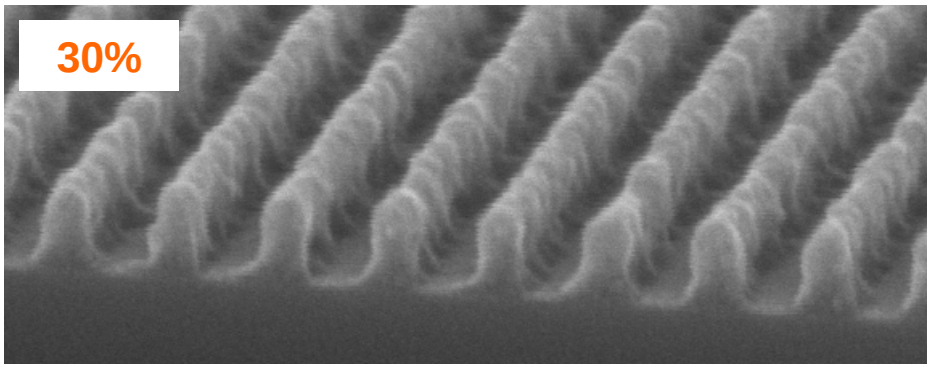
- Increased flare level results in top-loss, footing and increased LER
- The profiles of 50nm L/S patterns remains reasonable up to 20% flare

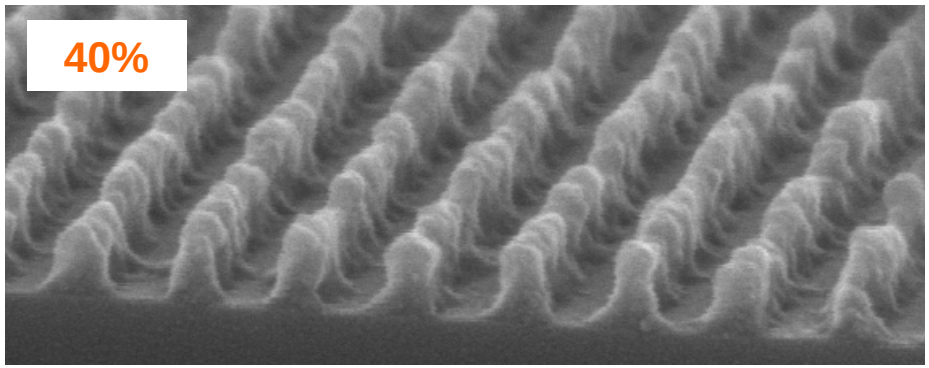
Profiles for 50nm L/S

EUV-37





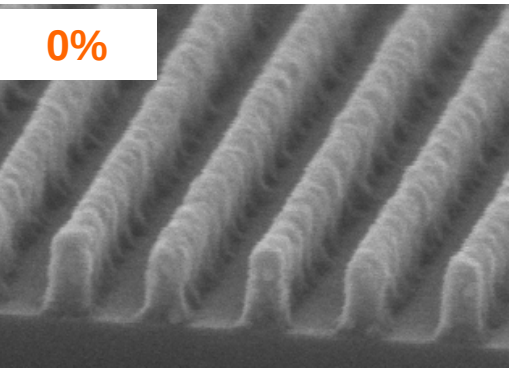


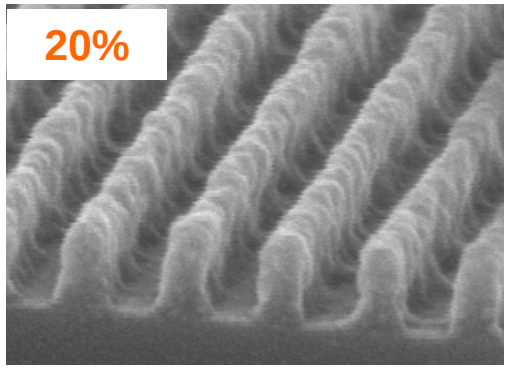


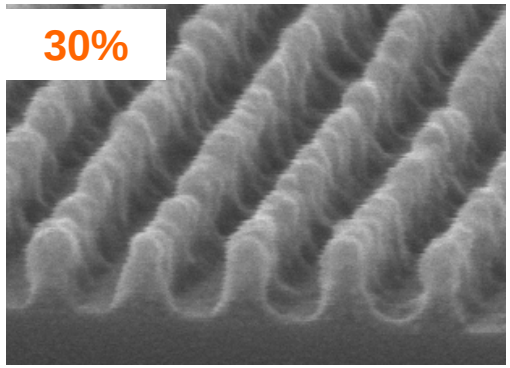
Profiles for 45nm and 40nm L/S

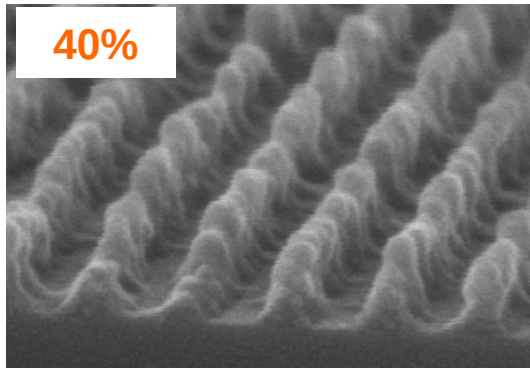
EUV-37

45nm L/S

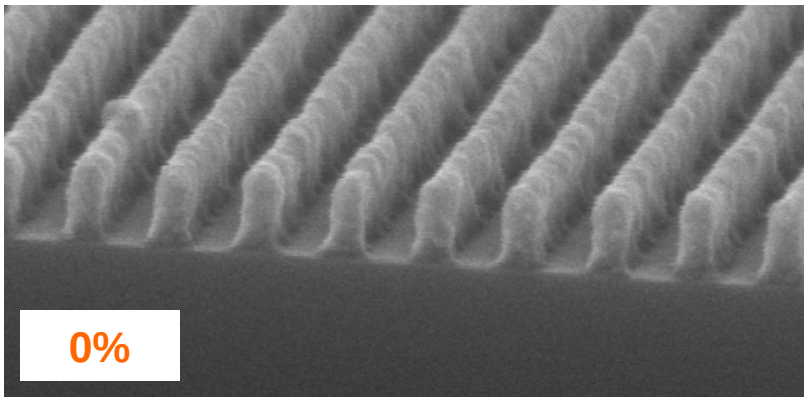


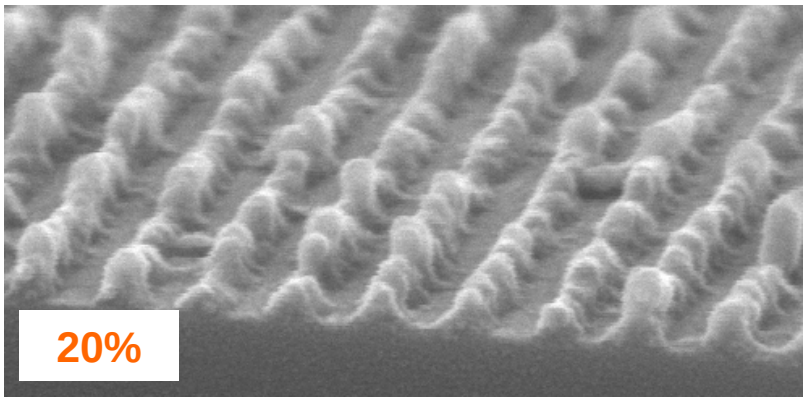






40nm L/S

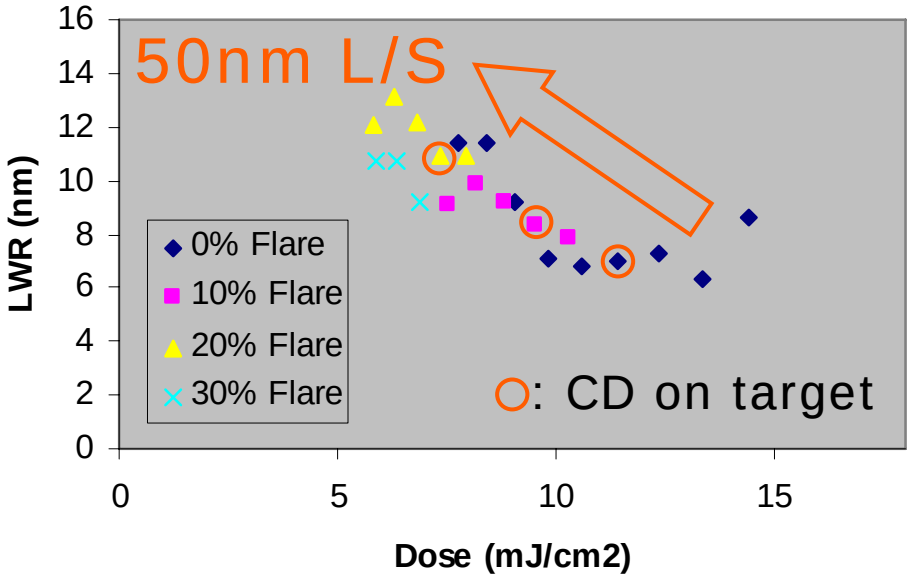


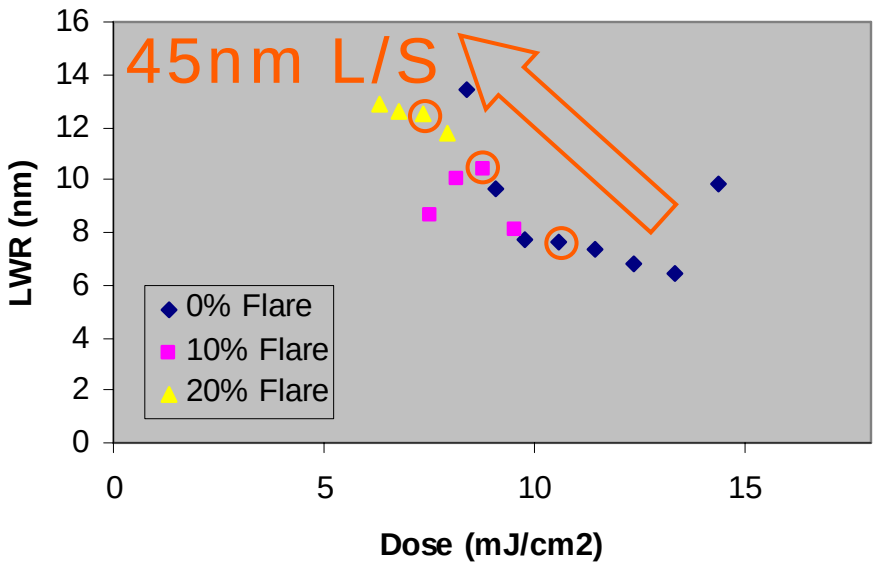


Latitude disappears rapidly for smaller dimensions

Line Width Roughness

EUV-30

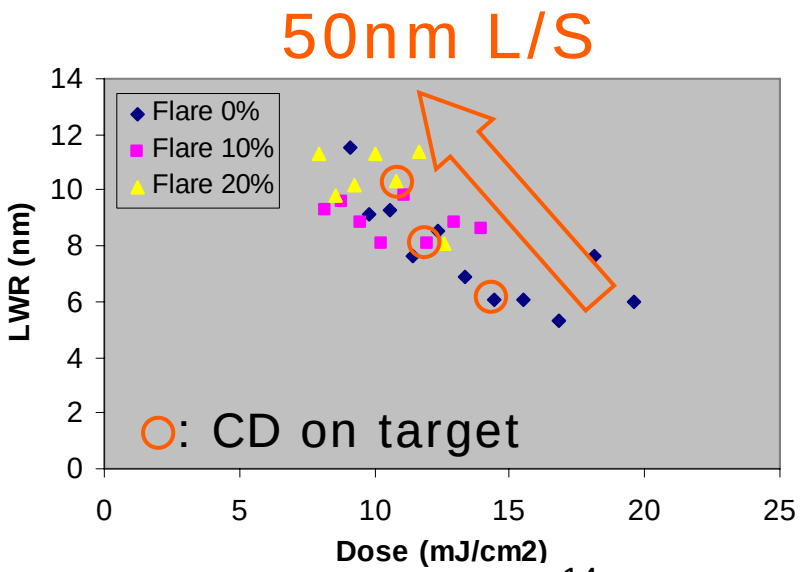


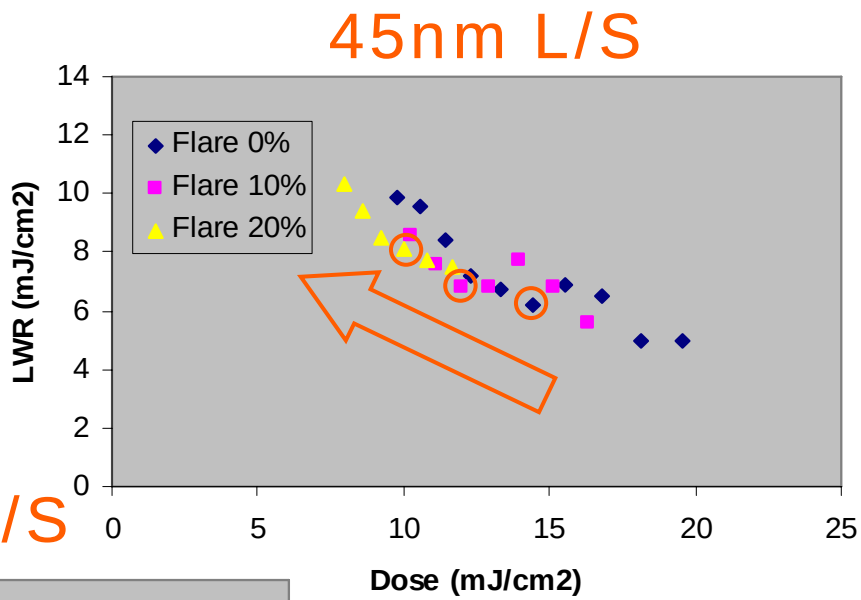


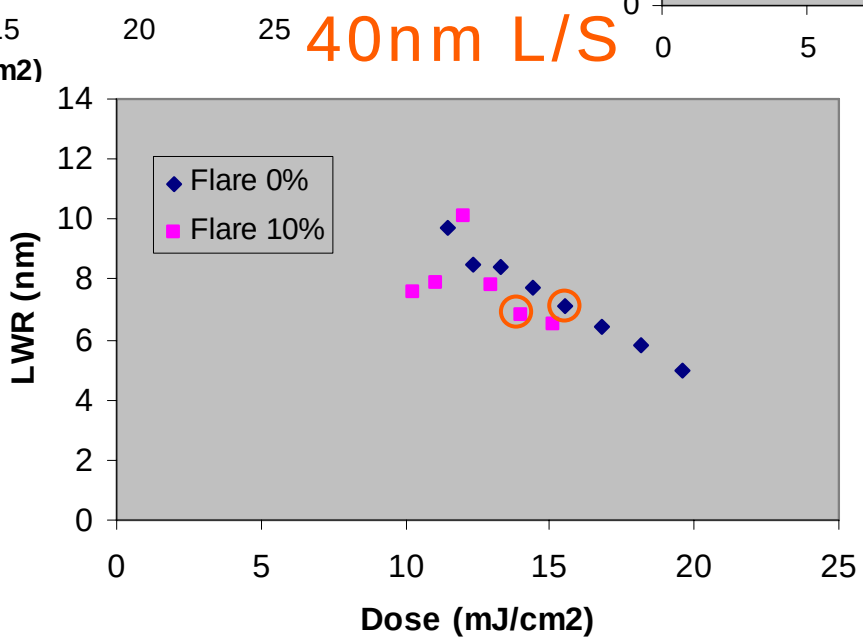
- LWR is mainly governed by shot noise statistics and image contrast
- Lowest LWR is achieved at values above the polymer grain size (2-3nm)
- No large LWR improvement should be expected from smaller grain size of molecular resists at these image contrast and dose levels
  - There may be improvement due to better material homogeneity
- Only escape possible by improving chemical contribution to shot noise: increase quantum yield and/or absorbance

Line Width Roughness

EUV-44







Conclusions

- Current EUV resists can handle very high flare levels relatively well at 50nm half pitch
- At 40nm half pitch the flare tolerance for exposure latitude and profiles is significantly reduced
  - Likely, at these dimensions acid diffusion induced image blur kicks in
- LWR increases significantly with increasing stray light for all dimensions
- These results cannot be quantitatively translated to EUV scanners
  - Flare will depend on mask layout
  - NILS depends on CD and may be higher than for interference imaging when multiple orders are captured in the pupil
  - Trends as seen in this study should be similar on a scanner
- At 32nm half pitch (NILS=4.1 for 0.25NA; σ=0.5 and 0% flare) probably little flare tolerance can be accepted to maintain imaging performance in terms of Exposure Latitude, Profiles and LWR

Acknowledgements

- Part of this work was funded by the European Commission through the More Moore project.

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