Resist Evaluation using EUV Interference Lithography

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SEEDS FOR TOMORROW'S WORLD

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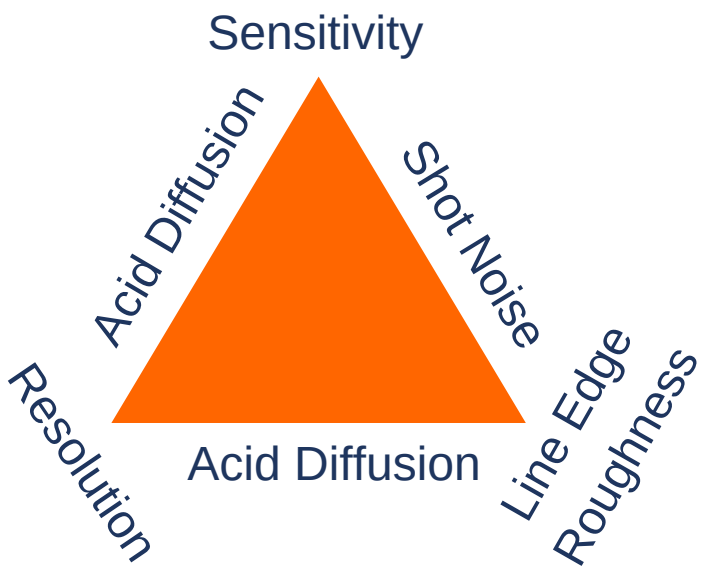
Outline

- Introduction
  - Motivation for EUV resist screening using interference lithography
- Method
  - Operating principle of achromatic EUV interference printer at PSI
  - Demonstration of lithographic capabilities using PMMA
- Results on Chemically Amplified Resists
  - Lines/Spaces
    - -Resolution, LER, Sensitivity and Acid Diffusion
  - Contact Holes
    - -Resolution
- Summary

Motivation

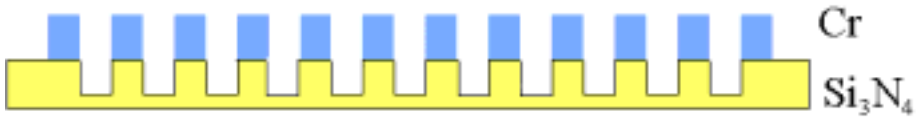
- Lithographic Uncertainty Principle for Chemically Amplified Resists: Fundamental interplay between sensitivity, resolution and line edge roughness.
- Meeting the goals for sensitivity, resolution and LER for the 45nm node and below is a challenge.
- Shot Noise effects and Sensitivity can only be characterized by at wavelength exposures.
- IMEC needs to select a resist for ASML's EUV α-tool by Q4 2005.

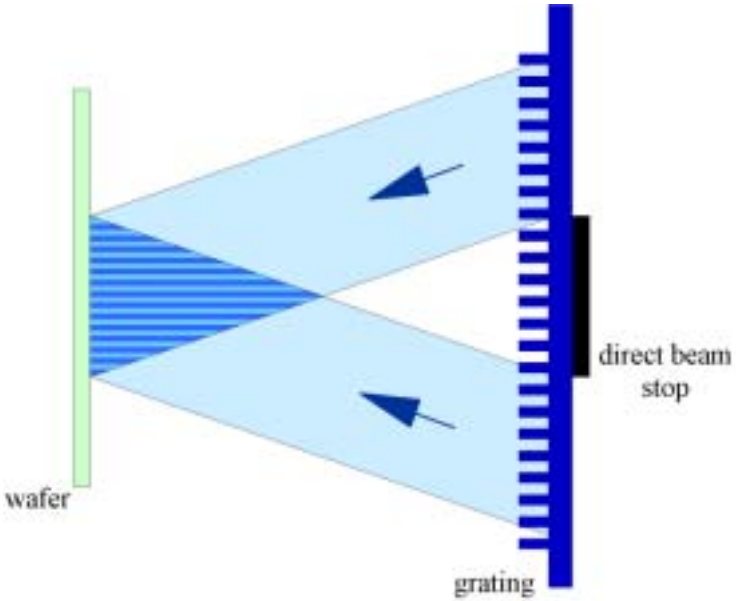


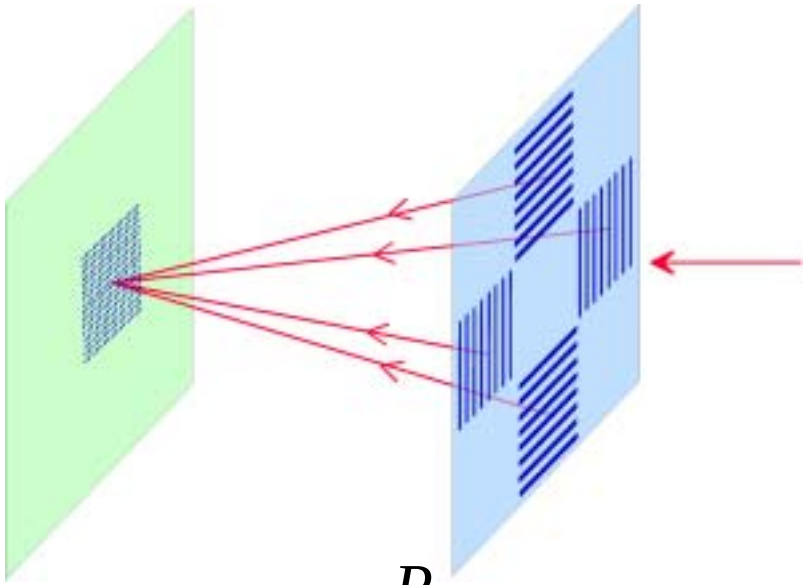
courtesy J. Lammers
Philips Research Leuven

Achromatic Interference Lithography

Mask:







$$P_{wafer} = \frac{P_{mask}}{2}$$

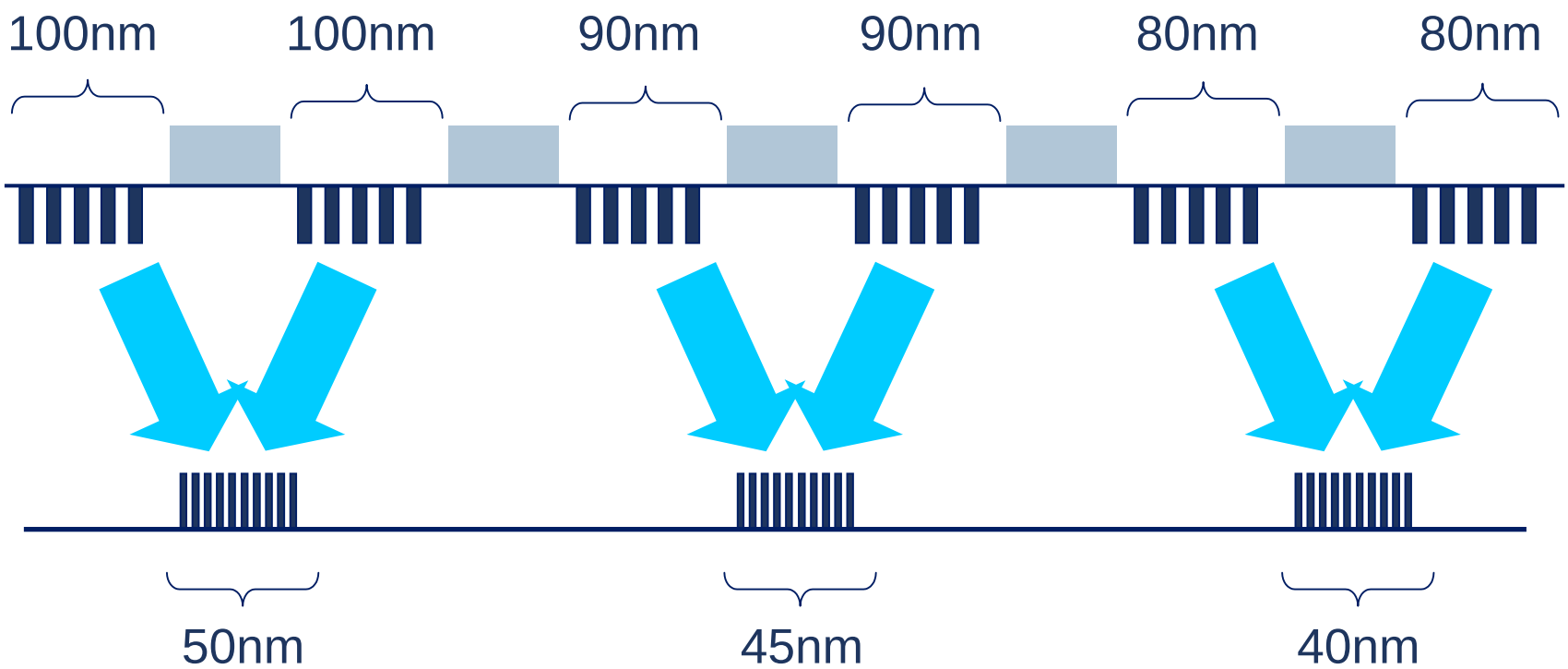
Line/Space Pattern

$$P_{wafer} = \frac{P_{mask}}{\sqrt{2}}$$

Contact Hole Pattern

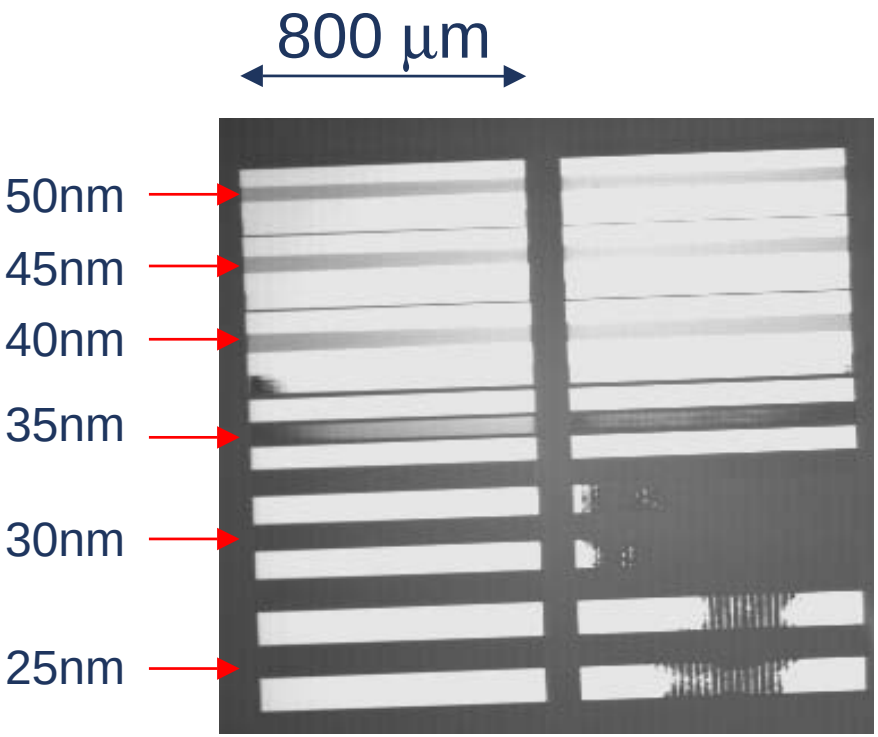
Achromatic Interference Lithography

- Printed pitch is wavelength independent. Therefore no monochromator needs to be used, resulting in short exposure times. ($\lambda/\Delta\lambda$=25-50)
- Using a suitable mask layout, various patterns and/or pitches can be written in a single exposure

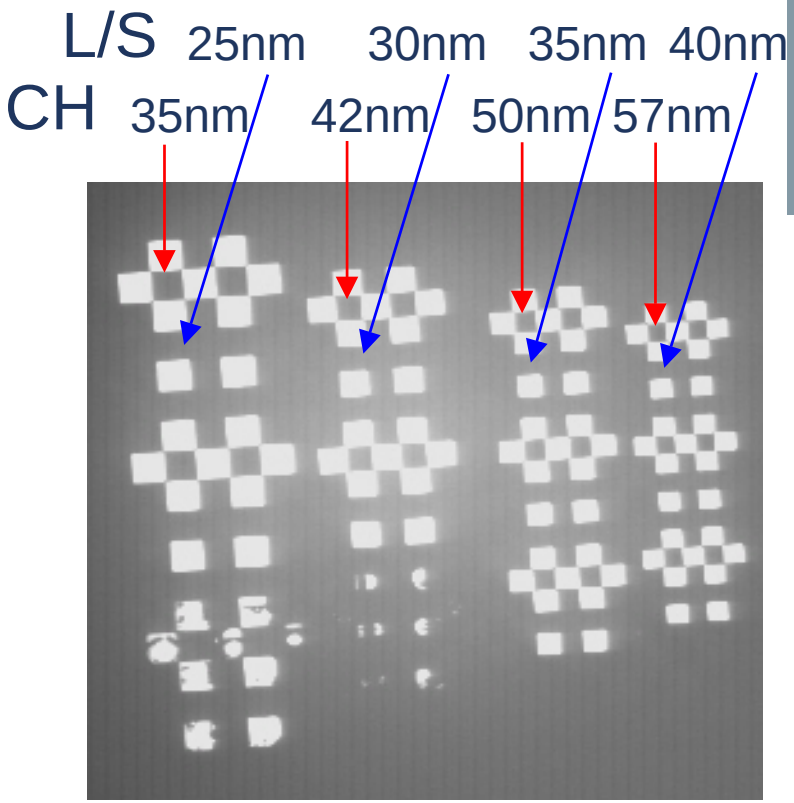


Achromatic Interference Lithography

- All CDs in this presentation refer to half pitch values at wafer level.



Cleavable line/space patterns



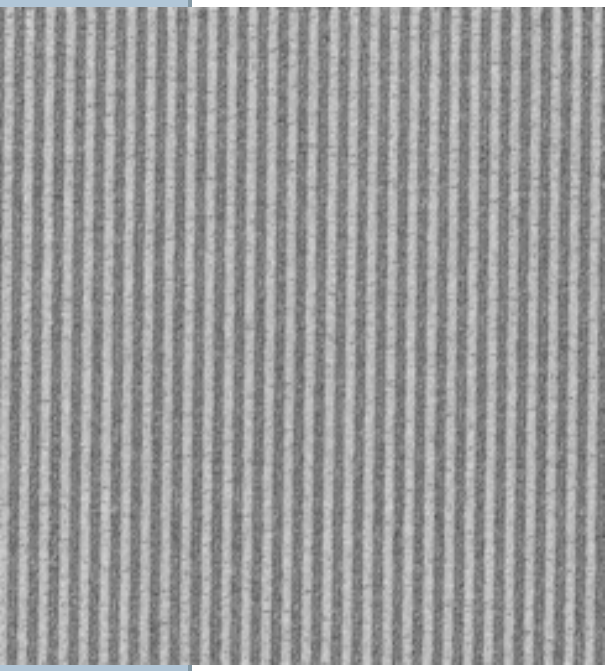
Line/space and contact hole patterns

Achromatic Interference Lithography

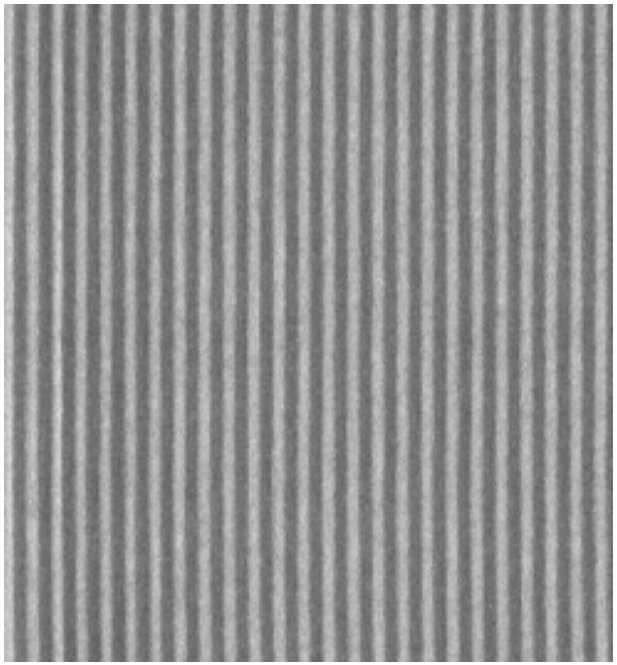
- Operational since Q3 2003
- Vacuum during exposure ~10^{-6} mbar
- Photon flux ~35mW/cm^2 on mask
- Sample stage for 4, 5 & 6” wafers
- Sample stage for 8’’ under construction
- Software for automatic exposure control
- Hotplate available next to exposure tool for minimum post-exposure delay

Results in PMMA

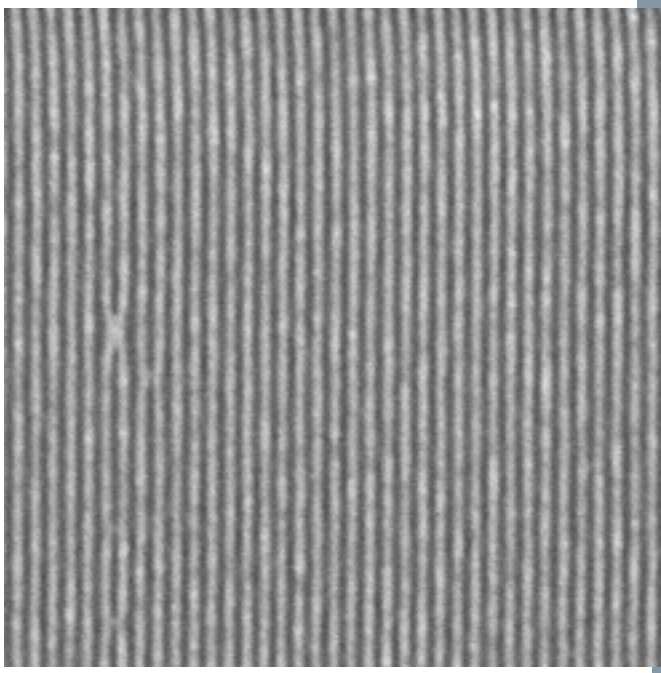
50nm L/S



30nm L/S

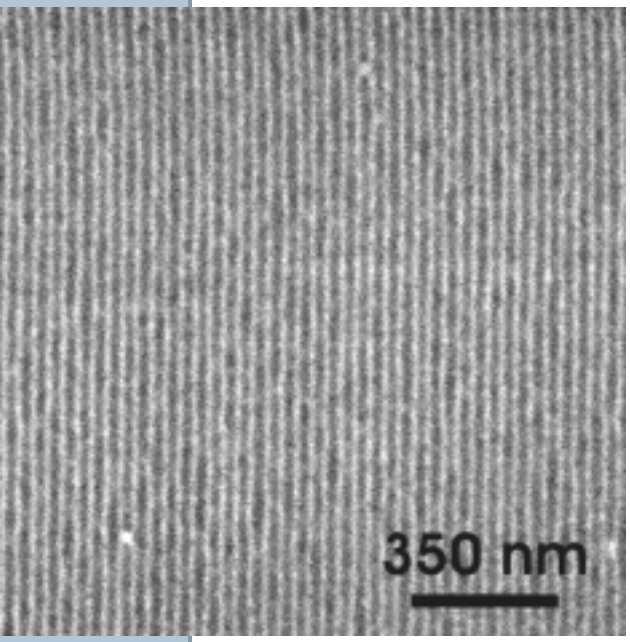


20nm L/S

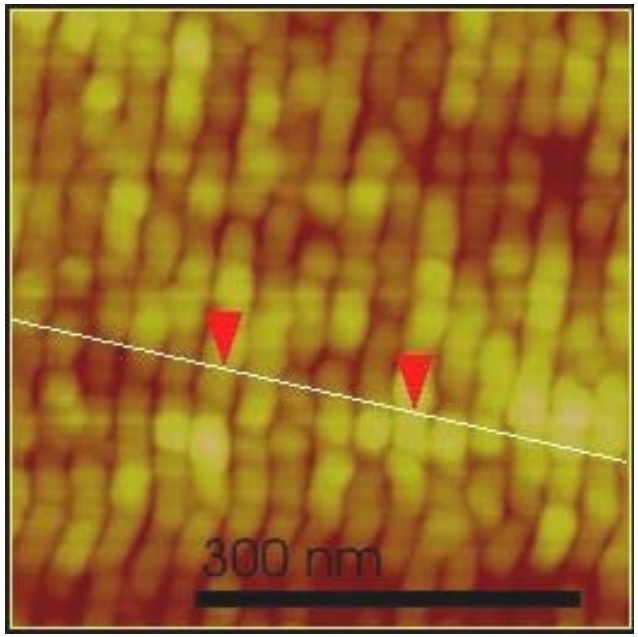


Results in PMMA

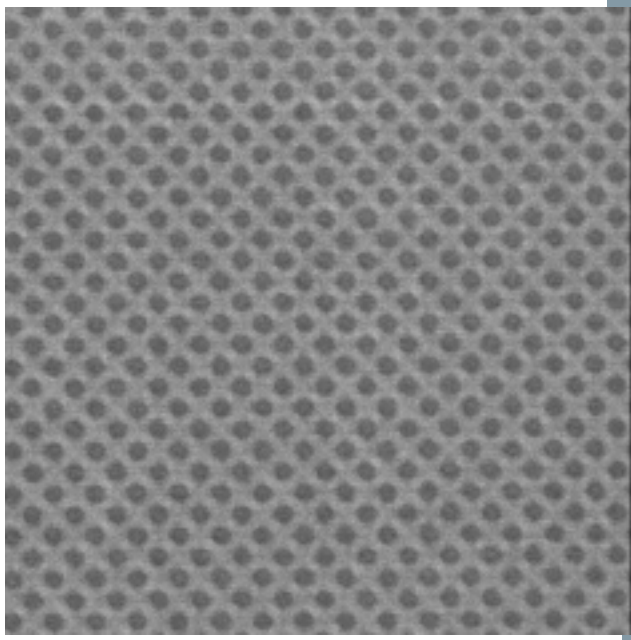
17.5nm L/S



15nm L/S



35nm CH



Best resolution obtained with optical lithography so far!

Chemically Amplified Resists

- 13 resists from 4 different vendors have been screened with interference lithography.

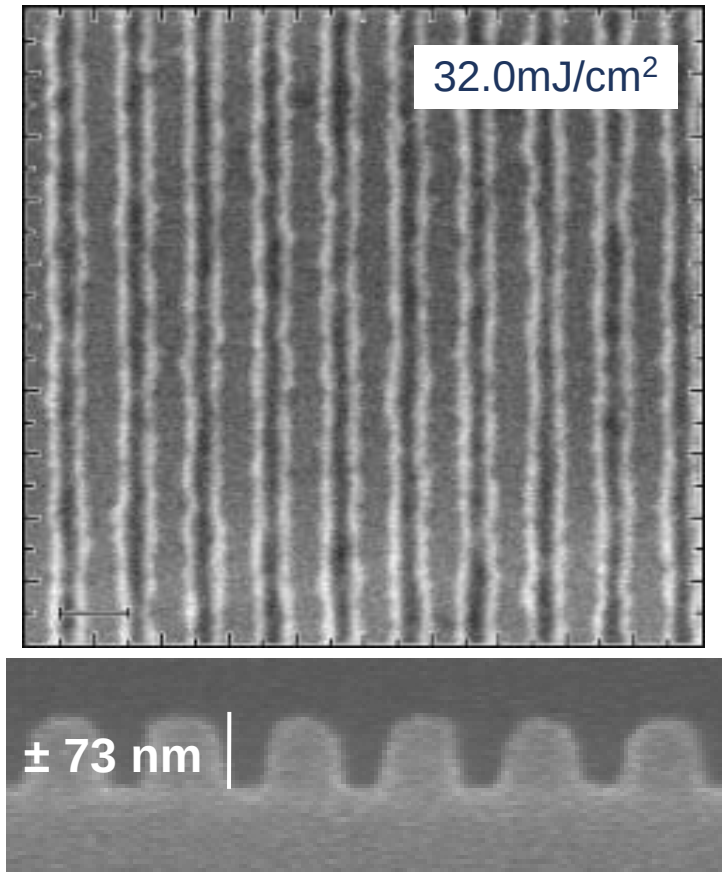
- Three of these materials have been investigated in more detail.
  - Main focus on line/space performance.
  - Ultimate resolution has been determined.
  - Line edge roughness was measured by off-line analysis of top-down SEM pictures (V. Constantoudis et al. SPIE 2004, Vol. 5375, 967-977).
  - Relative sensitivity (mask dependent!) has been determined.
  - Vendor recommended processing conditions were used (unless noted otherwise).

- Best resist has also been tested for contact hole patterns.

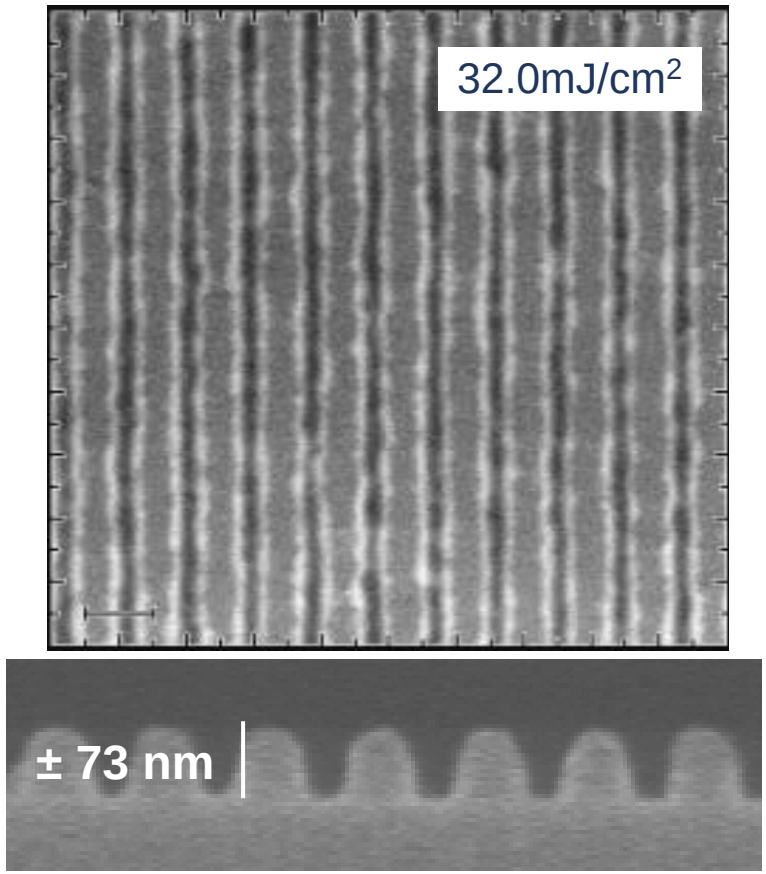
ESCAP platform

Lines/Spaces Performance
Resist A

50nm L/S



45nm L/S



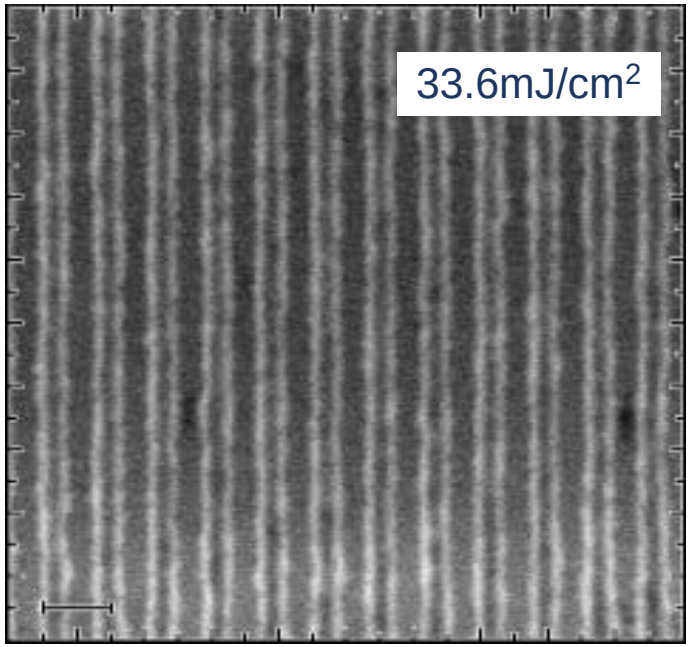
E_{size} for 50nm 1:1 is ~11mJ/cm2 on ALS/MET

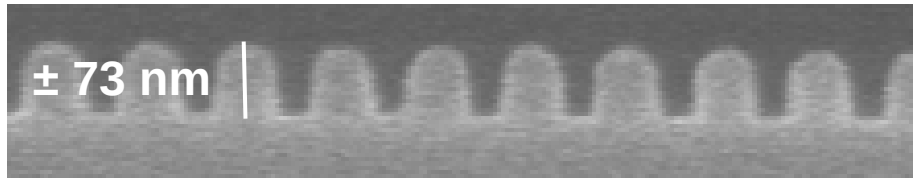
Film Thickness: 80nm

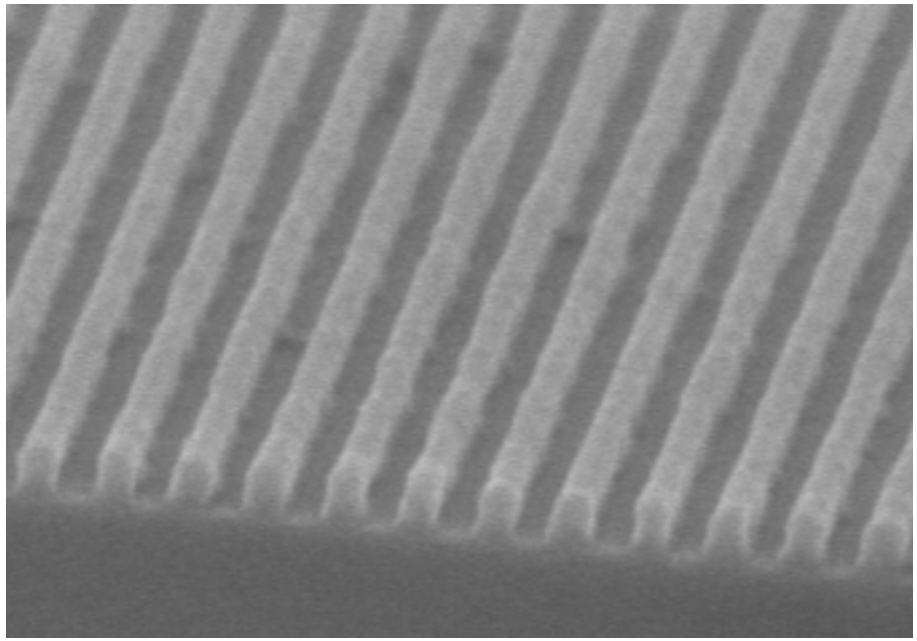
ESCAP platform

Lines/Spaces Performance
Resist A

40nm L/S





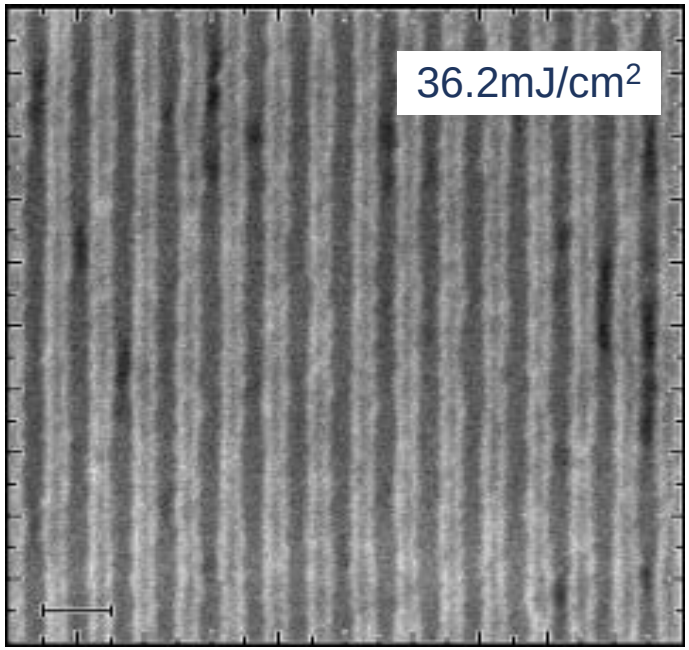


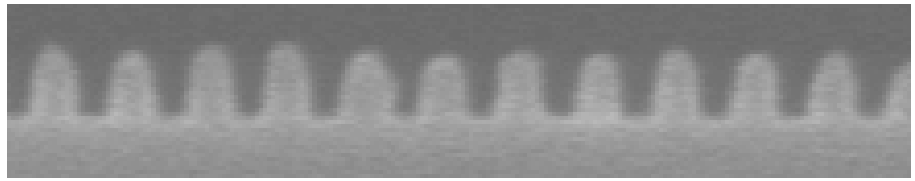
Film Thickness: 80nm

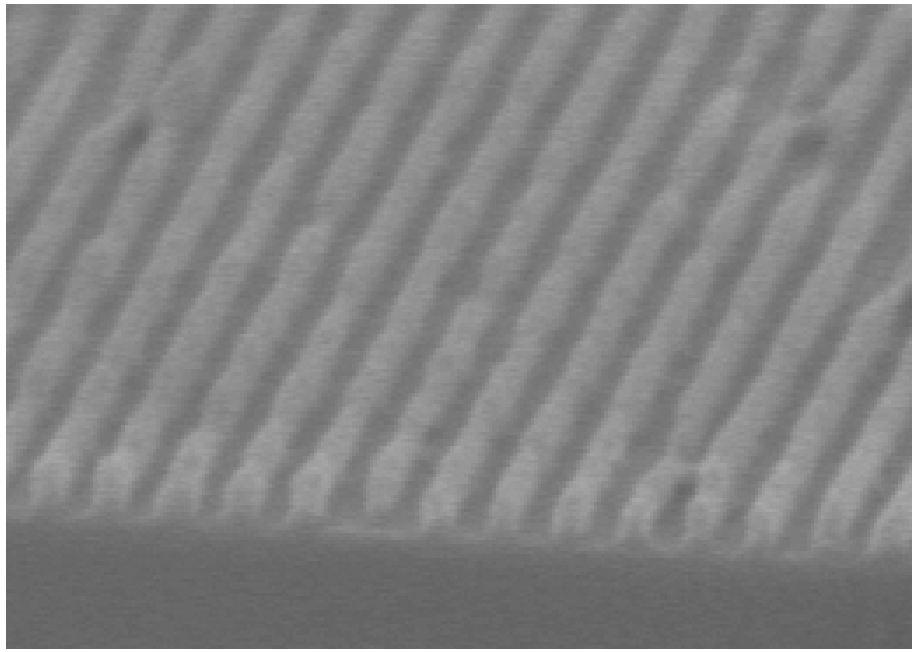
ESCAP platform

Lines/Spaces Performance
Resist A

35nm L/S





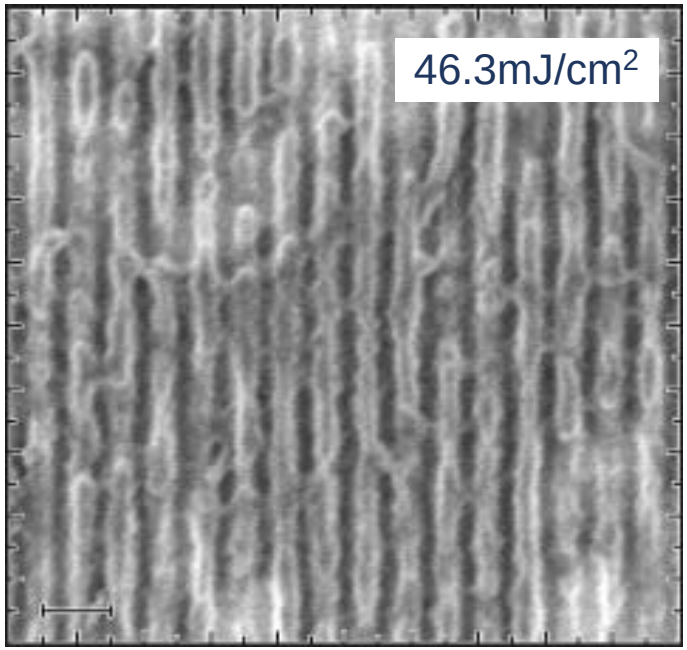


Film Thickness: 80nm

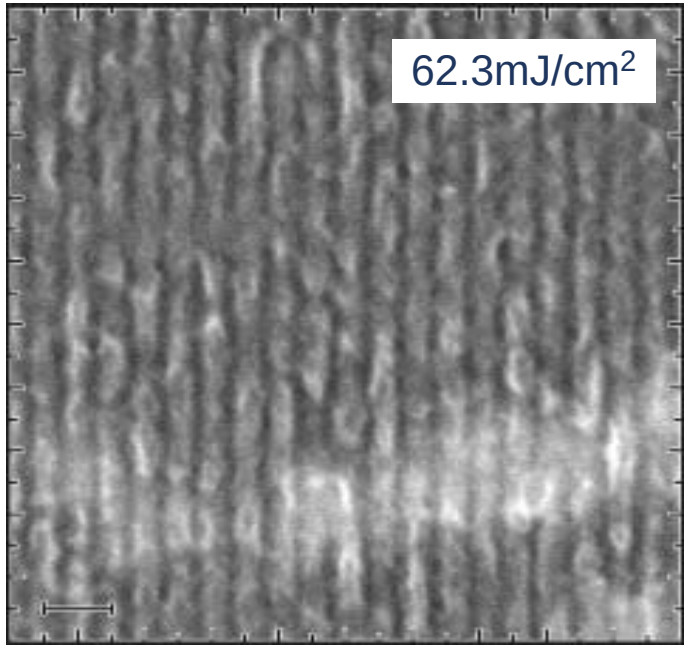
ESCAP platform

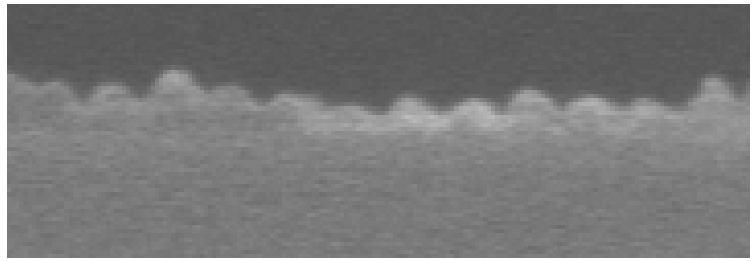
Lines/Spaces Performance
Resist A

30nm L/S



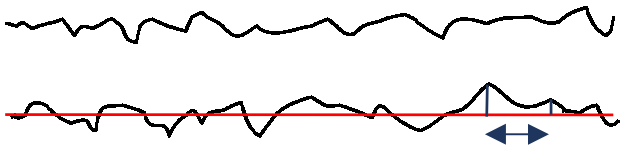
25nm L/S



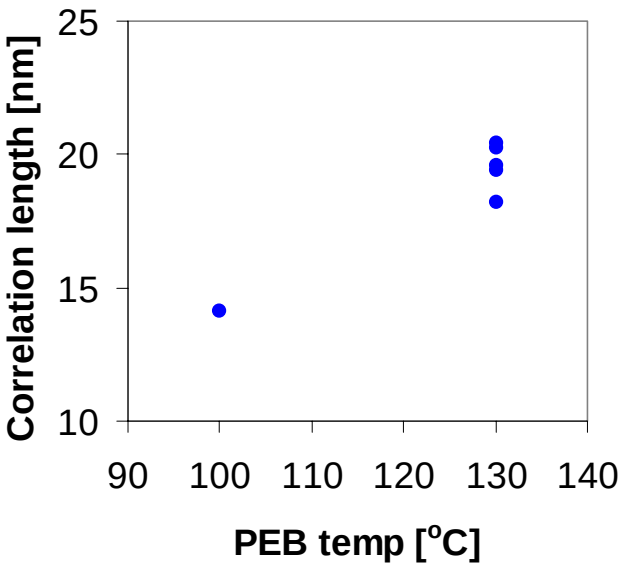


Film Thickness: 80nm

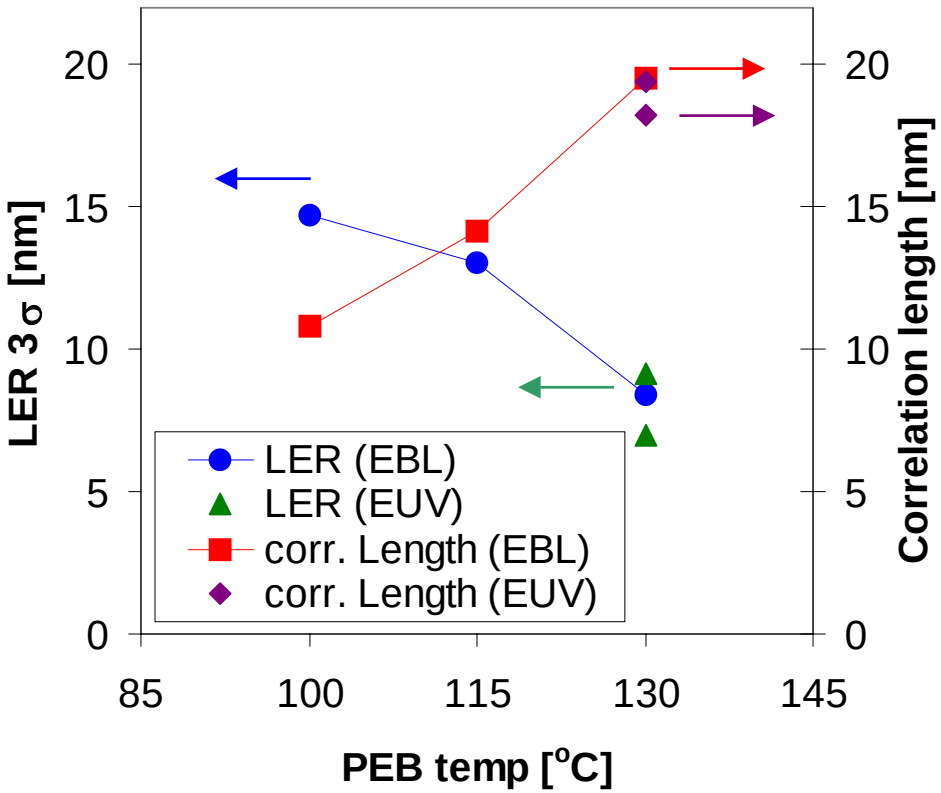
Line Edge Roughness Analysis
Resist A



Corr. Length ~ Acid Diffusion



Film Thickness: 100nm

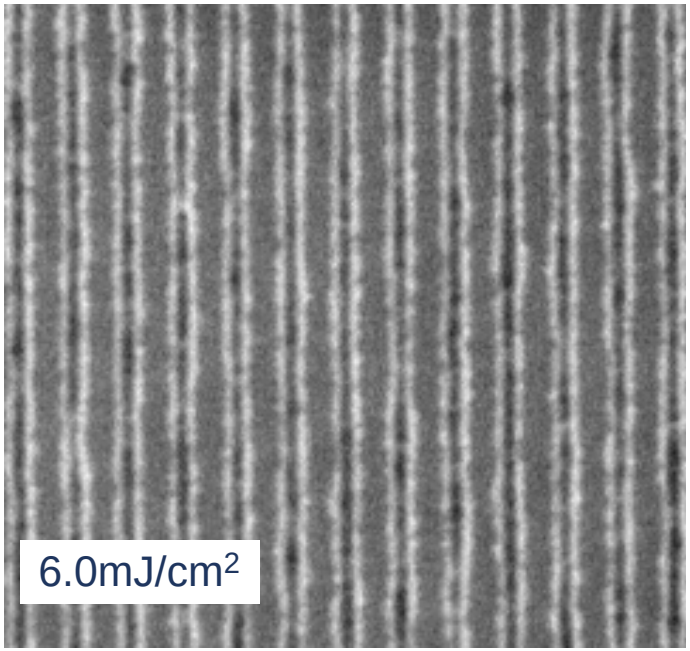


Film Thickness: 80nm

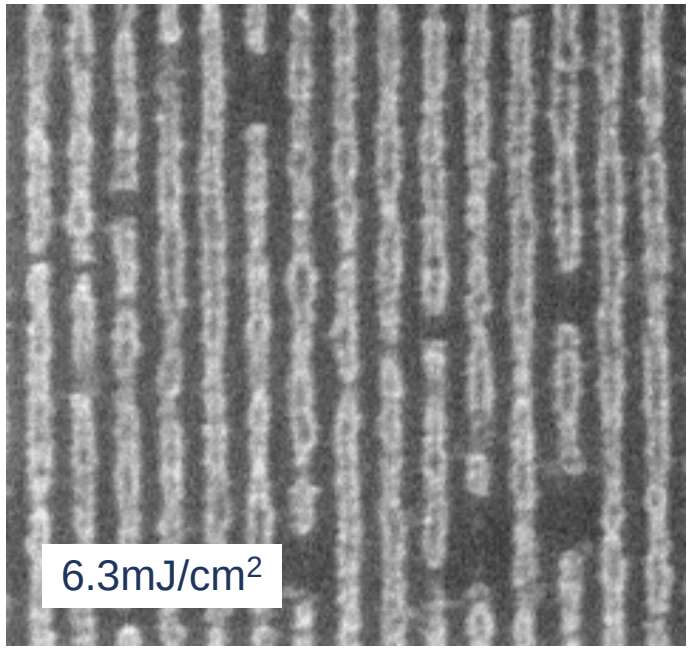
ESCAP platform

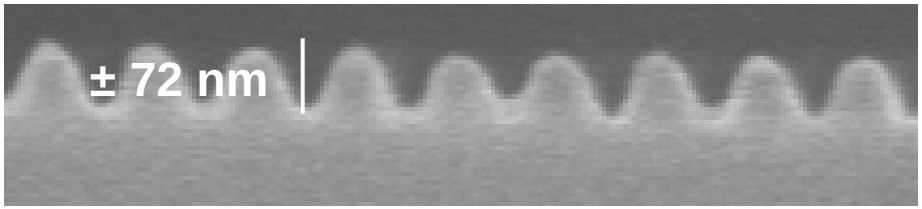
Lines/Spaces Performance
Resist B

40nm L/S



35nm L/S





Film Thickness: 100nm

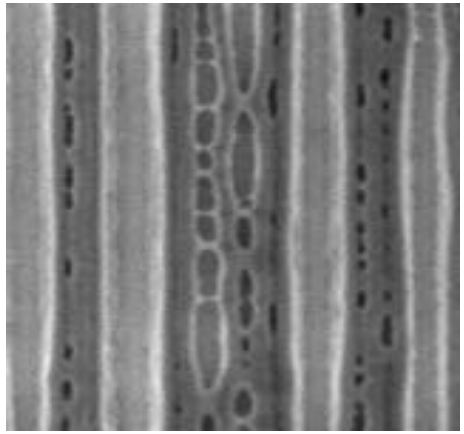
- Resist shows top loss
- Resolution not as good as for Resist A, but higher sensitivity

Lines/Spaces Performance
Resist C

Acrylate platform

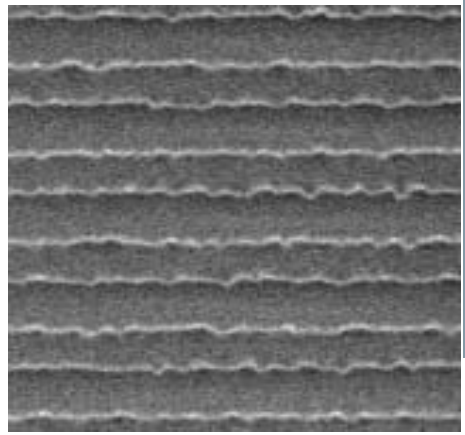
EUV Exposures

Non-interfaced

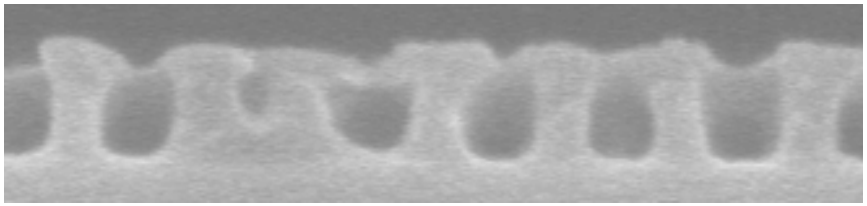


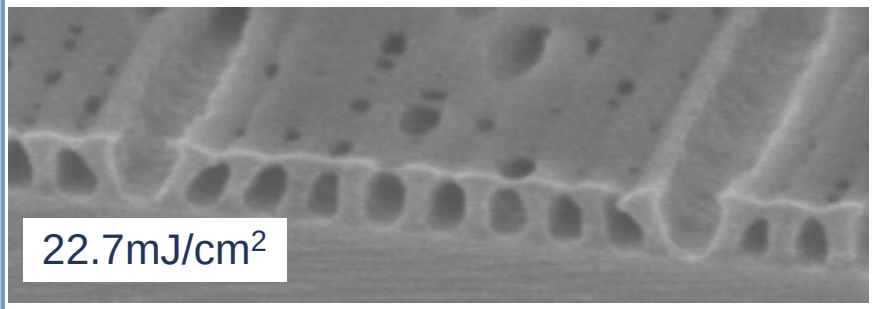
248nm Exposures

Interfaced

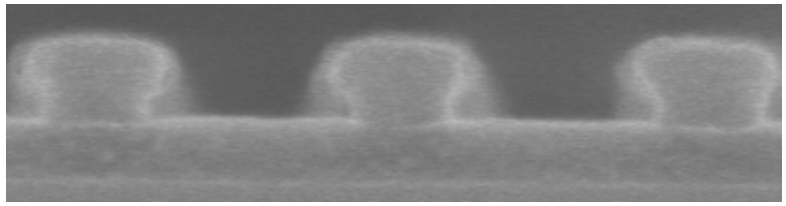


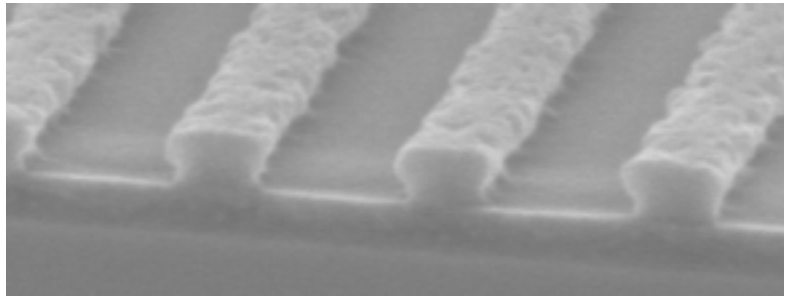
40nm L/S





130nm L/S

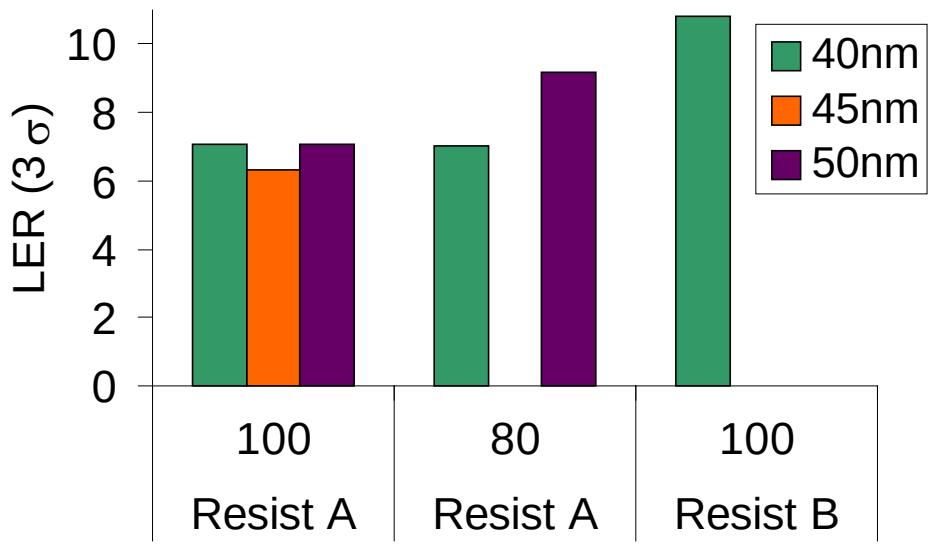


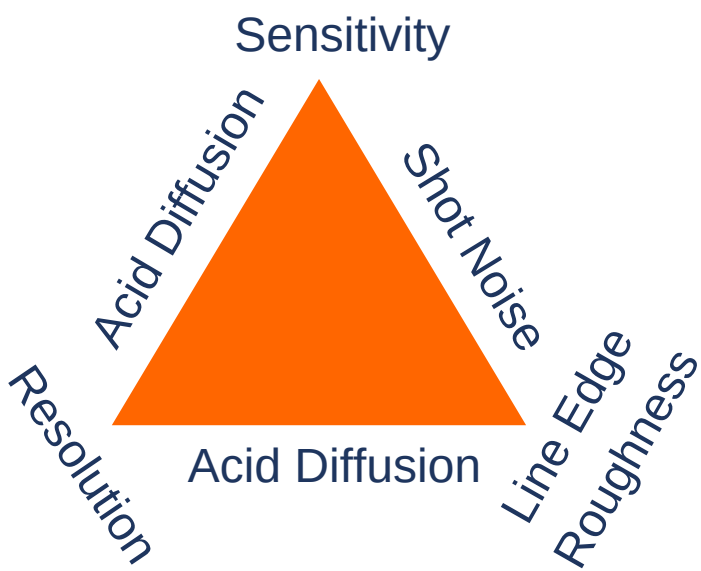


High surface inhibition?

Lines/Spaces
Comparison Resist A and B

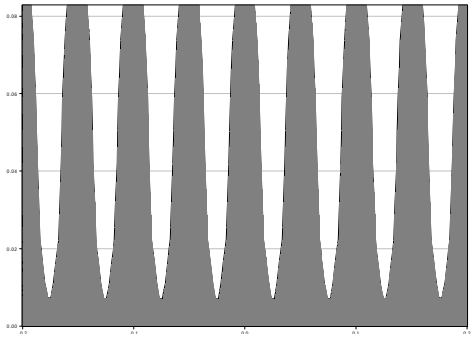
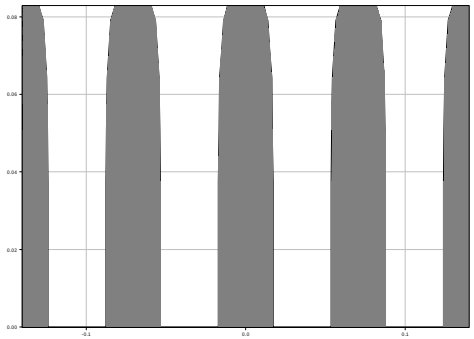
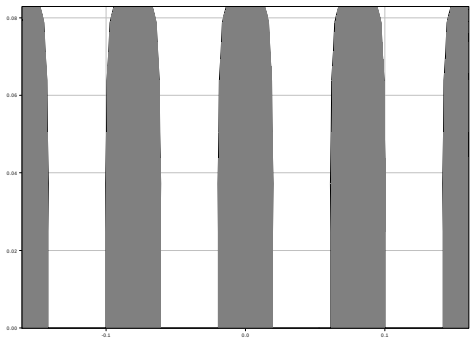
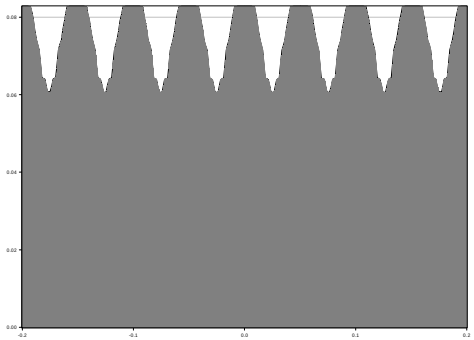
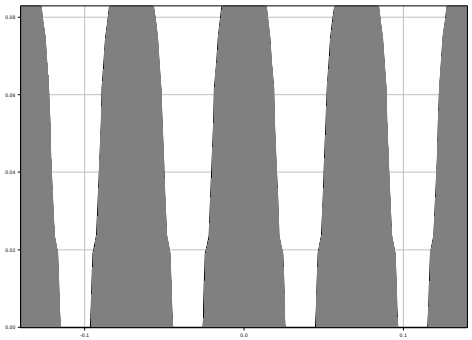
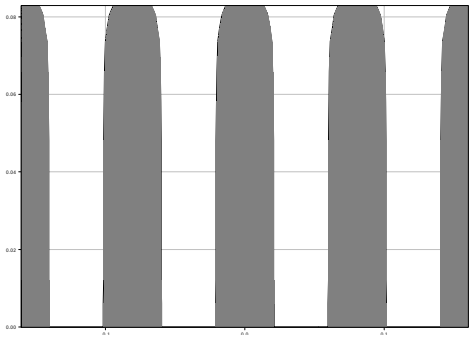
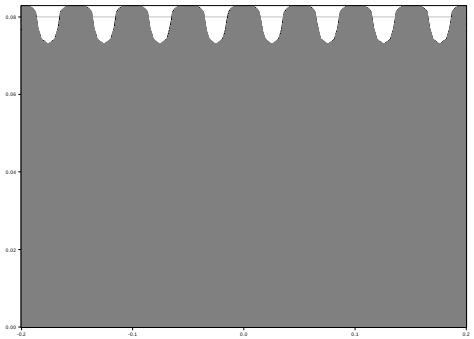
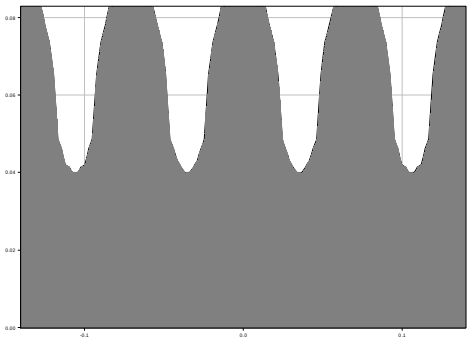
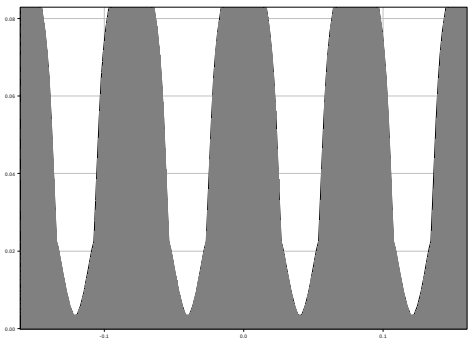
	LER (3σ; nm)	Correlation Length (nm)	Sensitivity (mJ/cm2)	Resolution (nm)
Resist A	7.1	20.2	33.6	35
Resist B	10.8	29.1	6.0	40
193nm resist	7.0	30.7	--	--





Lines/Spaces

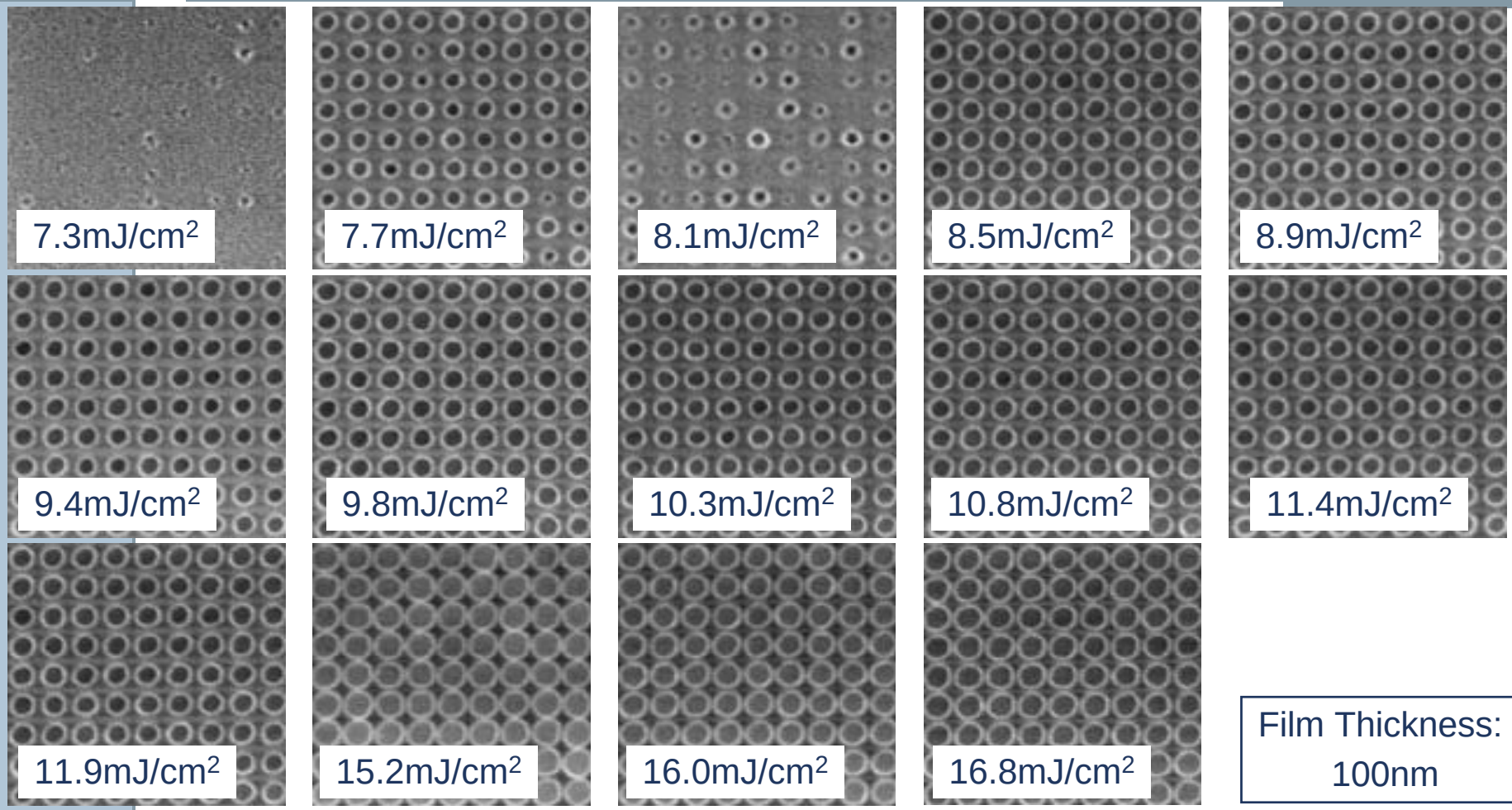
Simulation: Acid Diffusion vs Resolution

Acid Diff. Length	25nm L/S	35nm L/S	40nm L/S
5nm			
12nm			
15nm			

Contact Hole Performance

57nm CH

Resist A



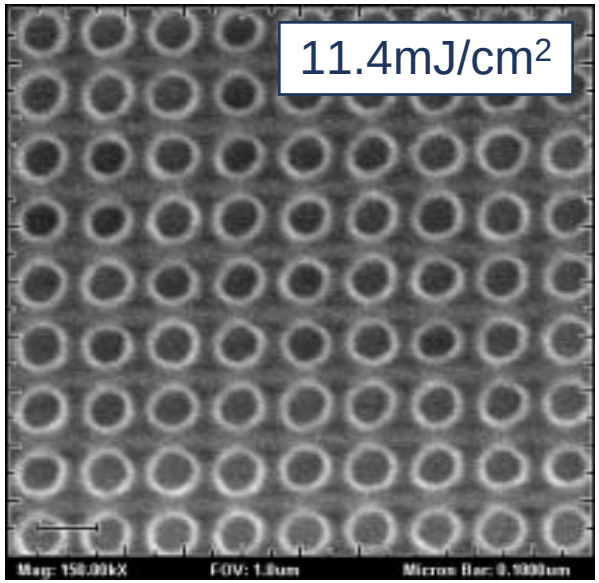
Film Thickness: 100nm

- Good printing performance over large dose range!
- Field-to-field dose variation caused by shutter. This has been fixed last week.

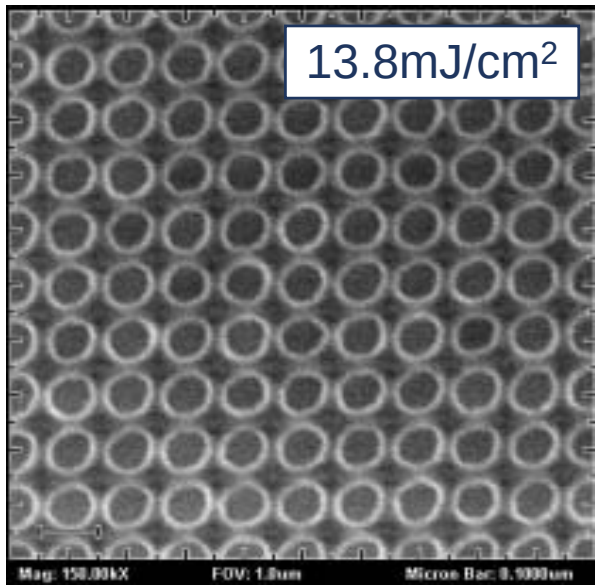
Contact Hole Performance

Resist A

57nm CH



50nm CH

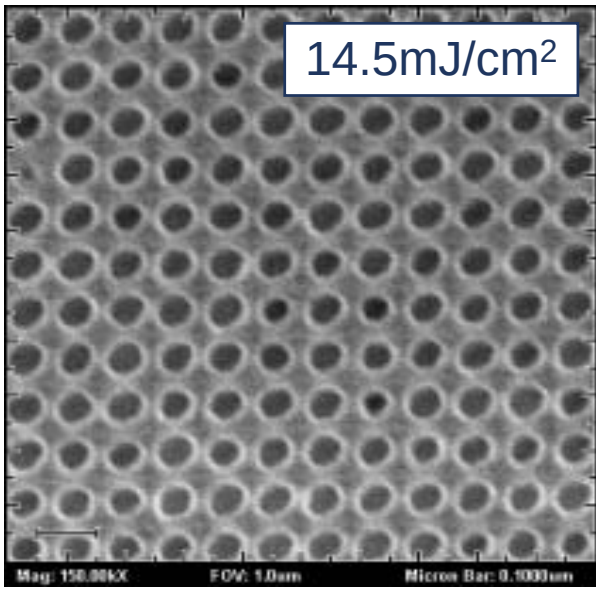


Film Thickness: 100nm

Contact Hole Performance

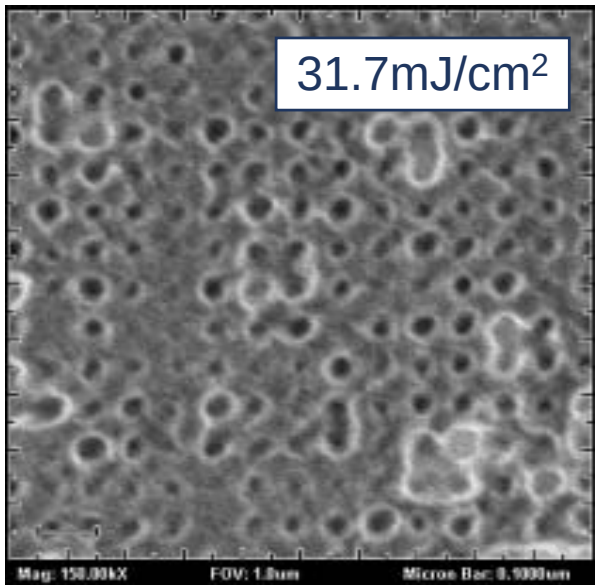
Resist A

42nm CH



Dense contact holes resolved down to 42nm!!!

35nm CH



35nm holes are not resolved

Film Thickness: 100nm

Summary

- Achromatic EUV interference lithography is a powerful method for at-wavelength resist evaluation.
- Decent line/space patterns down to 35nm and contact holes down to 42nm have been demonstrated in a CAR.
- For these materials the pattern quality rapidly deteriorates below 35nm. The resolution is limited by the acid diffusion length.
- Pattern quality dominated by resist performance, NOT by instrument.
- Careful resist optimization towards Sensitivity, Line Edge Roughness, Resolution and Acid Diffusion is needed.

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Resist Suppliers

MEDEA+ T406: ExCiTe

European Commission: More Moore

20 imec YEARS

Celebrating ongoing innovation

1st European Workshop on Resist Limitations

Date & Location: December 14th, 2004
Erlangen, GERMANY

Organization: Michael Sebald; Infineon
Wolf-Dieter Domke; Infineon
Peter Zandbergen; Philips

Scope of Workshop: Discussion and ranking of fundamental resist limitations with regard to sub-50 nm nodes, not necessarily limited to EUV (EB, 193i, etc).

Expected Outcome: Requirements for future resist nodes; Definition of plans for future resist work; Collection of issues to be presented at ISMT workshop early 2005

Participants: Members of MEDEA+ ExCITe, and on personal invitation (max. 3 participants/company)

Program Draft

User's Litho Roadmaps
Tool Roadmaps
Resist Roadmaps

Resist Brick Wall: Examples and Outlook

Discussion and Ranking in Breakout Sessions

1st European Workshop on Resist Limitations

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