PAUL SCHERRER INSTITUT

Evaluation of EUV resist performance with interference lithography in the range of 22-7 nm HP

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Outline

- XIL-II: EUV-IL tool @ PSI
  - EUV-IL and its performance
- Evaluation of resists for 16 nm HP
  - 2 CARs and 4 inorganic resists
- Evaluation of resists towards 11 nm HP
- Conclusions and Outlook
  - Review and discussion of the current status and for 22-7 nm HP

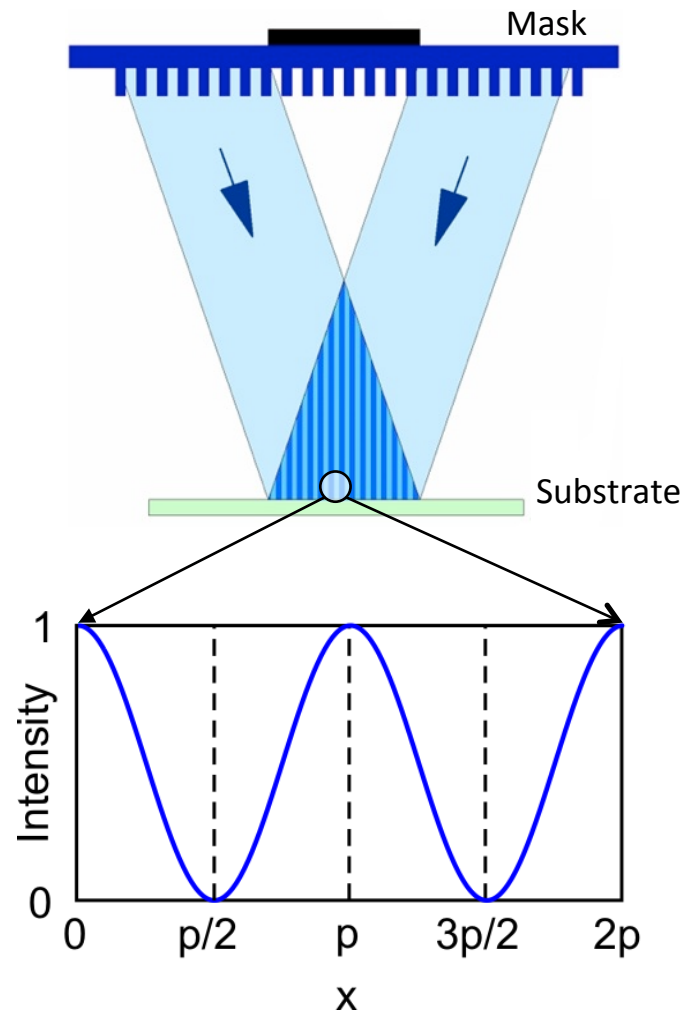
EUV Interference Lithography

- Source with spatial coherence
- Transmission diffraction gratings

- No depth of focus: Mask-to-wafer = 0.3-10 mm
- Well defined image: pitch independent areal image.
- High resolution:
  - Theoretical limit= 3.5 nm
  - Current limit = 7 nm (Limited by mask writing)
- *Variable wavelength:*

See in the poster session:

BEUV Lithography, Paper 8679-75



XIL-II: EUV-IL @ PSI

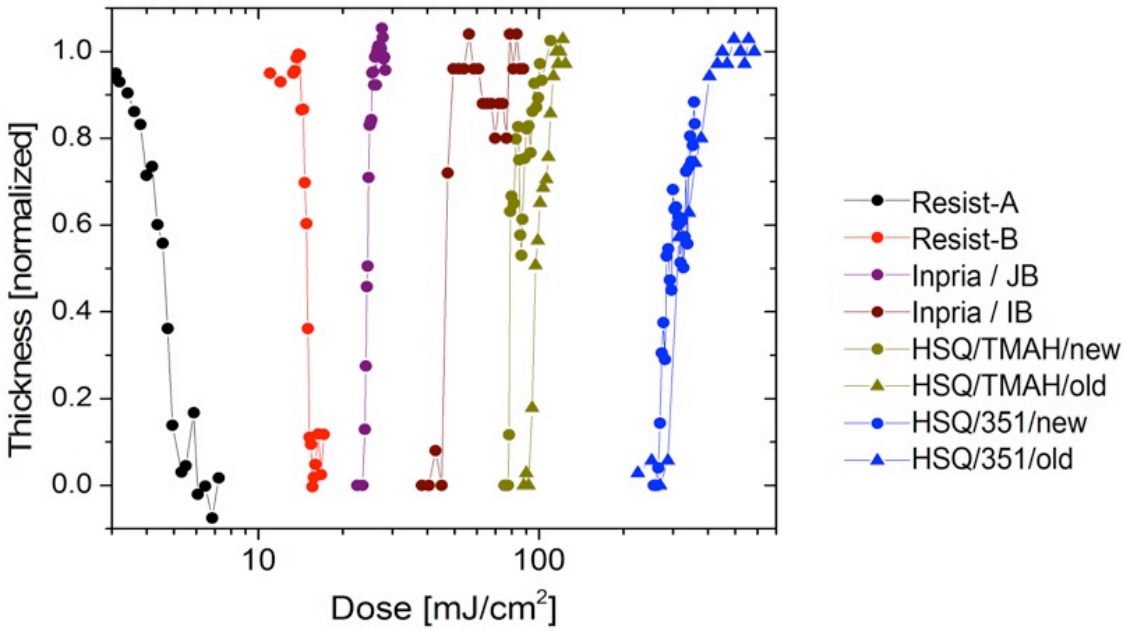
Control room

Process room

Exposure room

- On-site clean room:
  - Spin-coater, wet-bench, hot-plates, microscope, developer, optical thickness measurement
  - In clean room environment with amine filters.

Dose to clear curves

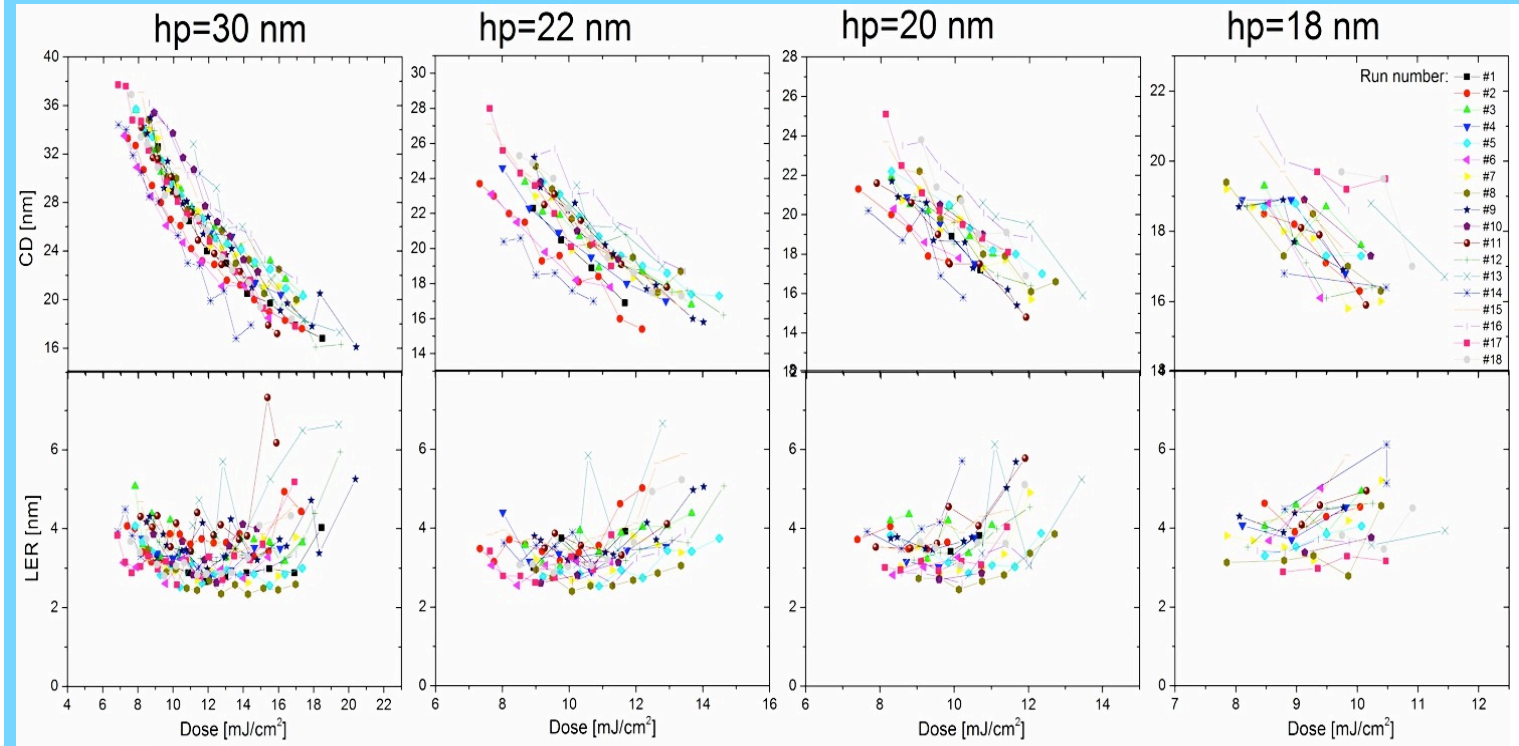


Resist name	Supplier	Thickness	Sensitivity(*) mJ/cm^2
Resist-A	Shin-Etsu	35 nm	4.5
Resist-B	JSR	30 nm	15
Inpria/X15JB	Inpria	20 nm	25
Inpria/XE15IB	Inpria	20 nm	47
HSQ/TMAH	Dow Chem.	35 nm	82
HSQ/351	Dow Chem.	35 nm	294

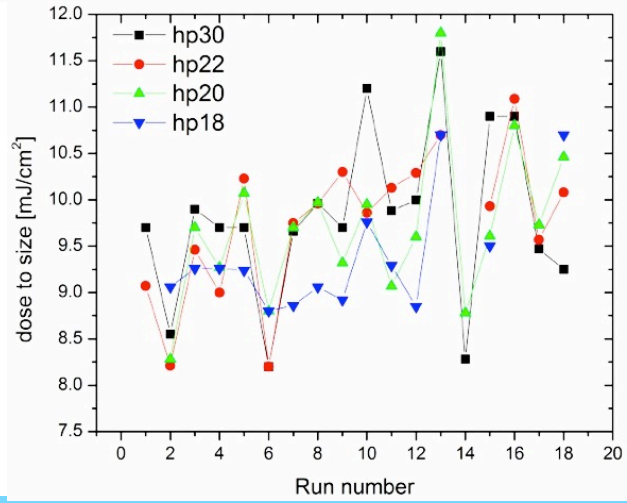
(*) Dose for 50% clearance

(**) aging of inroganic resists

Monitoring results during last 16 months: Resist-A

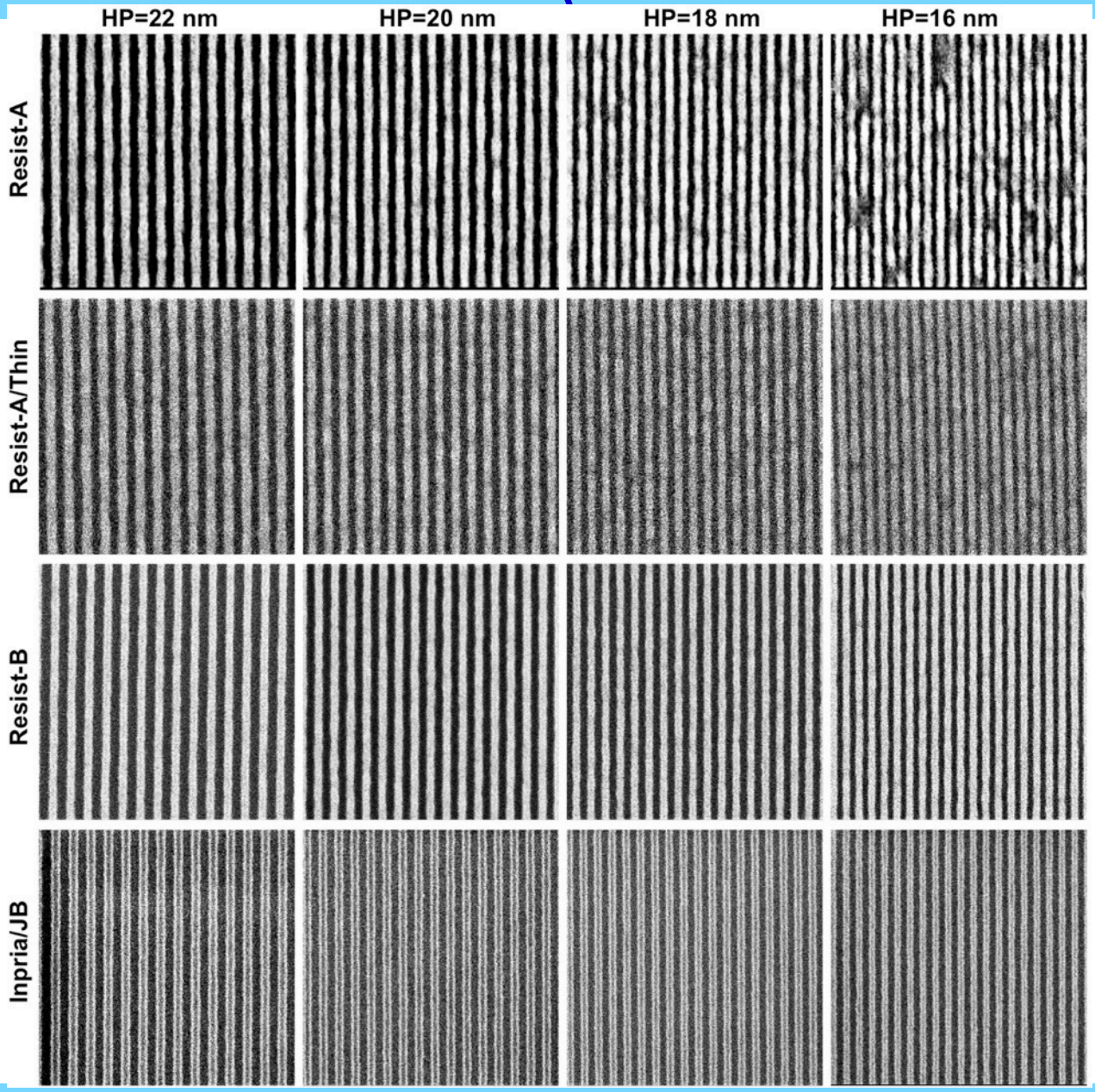


Thickness=35 nm
PAB: 105 °C/ 90 s
PEB: 90 °C/90 s
Dev: 2.38% TMAH/ 30s



	HP 30 nm	HP 22 nm	HP 20 nm	HP 18 nm
Average dose [mJ/cm^2]	9.80	9.65	9.71	9.51
Standard deviation	0.94	0.87	0.79	0.67
Systematic error	0.98	0.97	0.97	0.95

Comparison of Resists (22 nm to 16 nm HP)



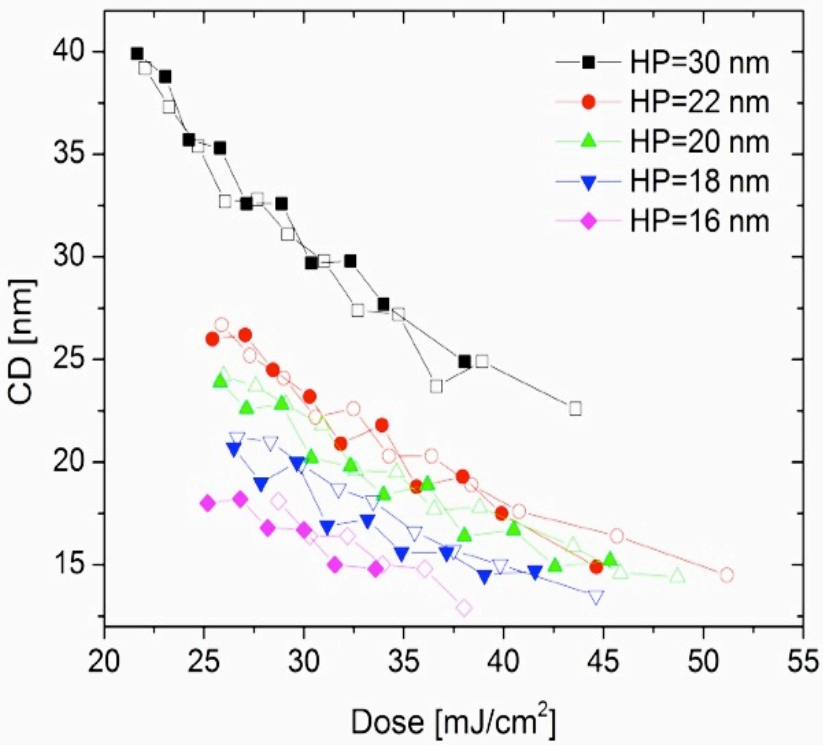
t=35 nm

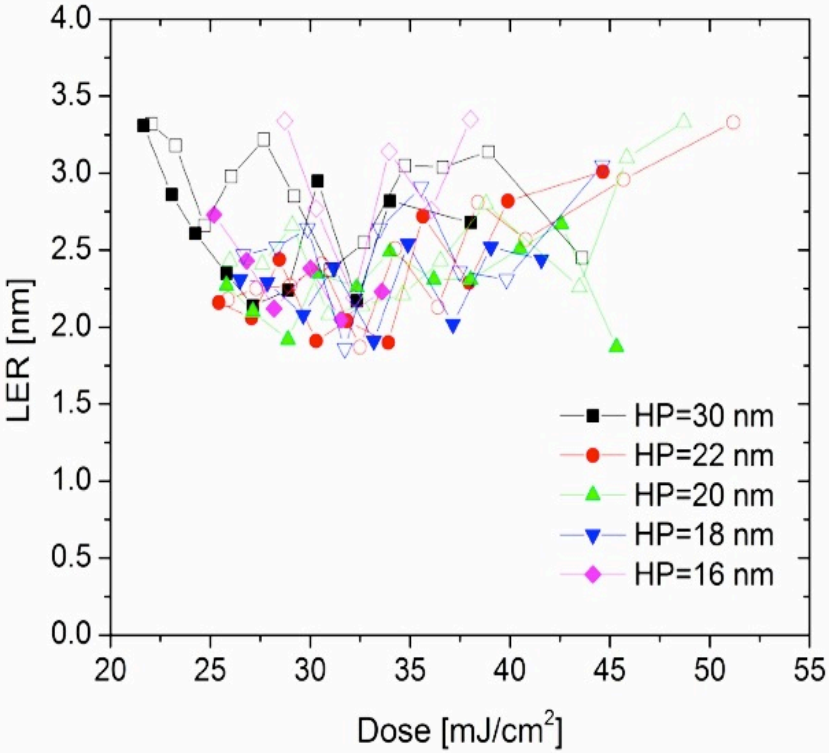
t=30 nm

t=25nm

t=20 nm

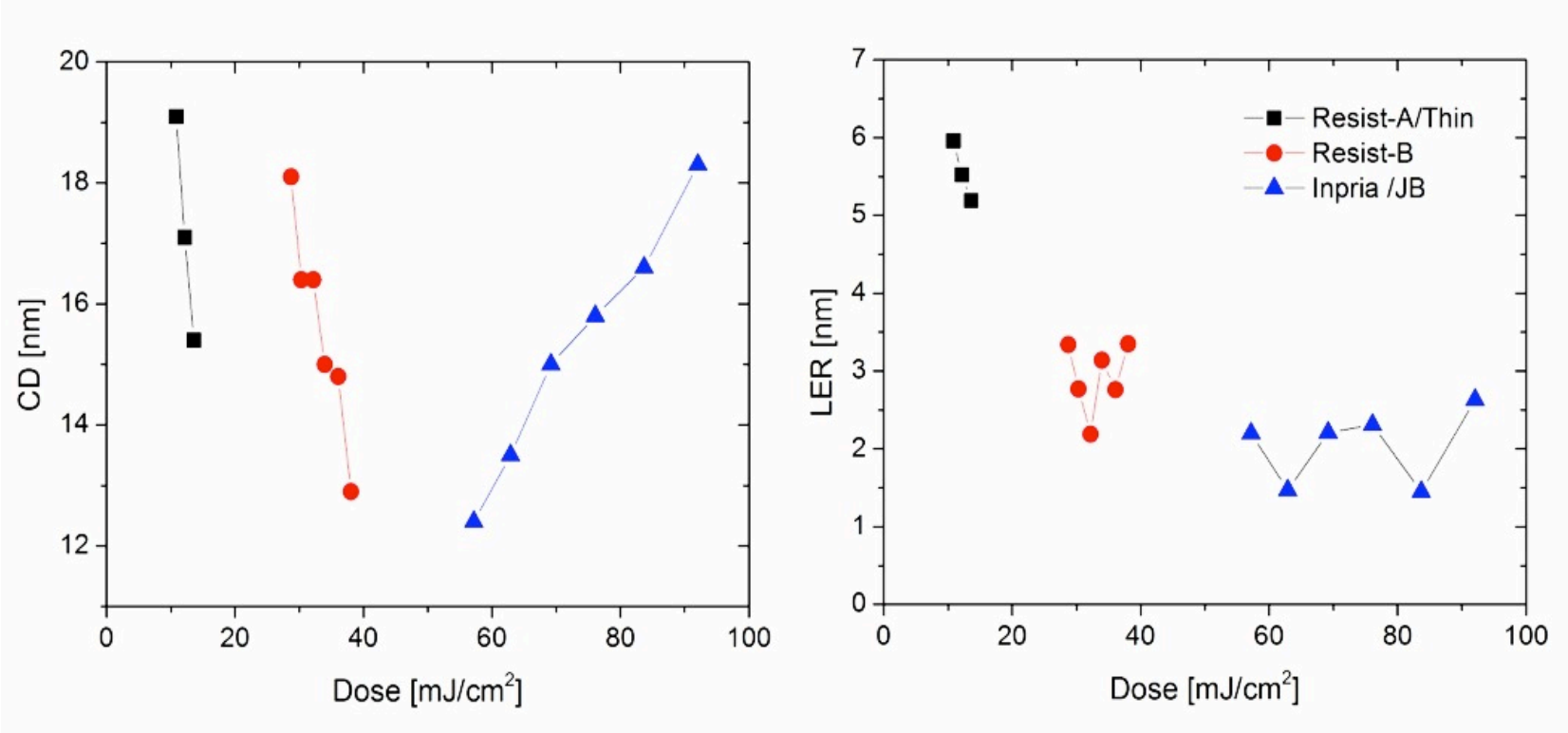
Resist-B



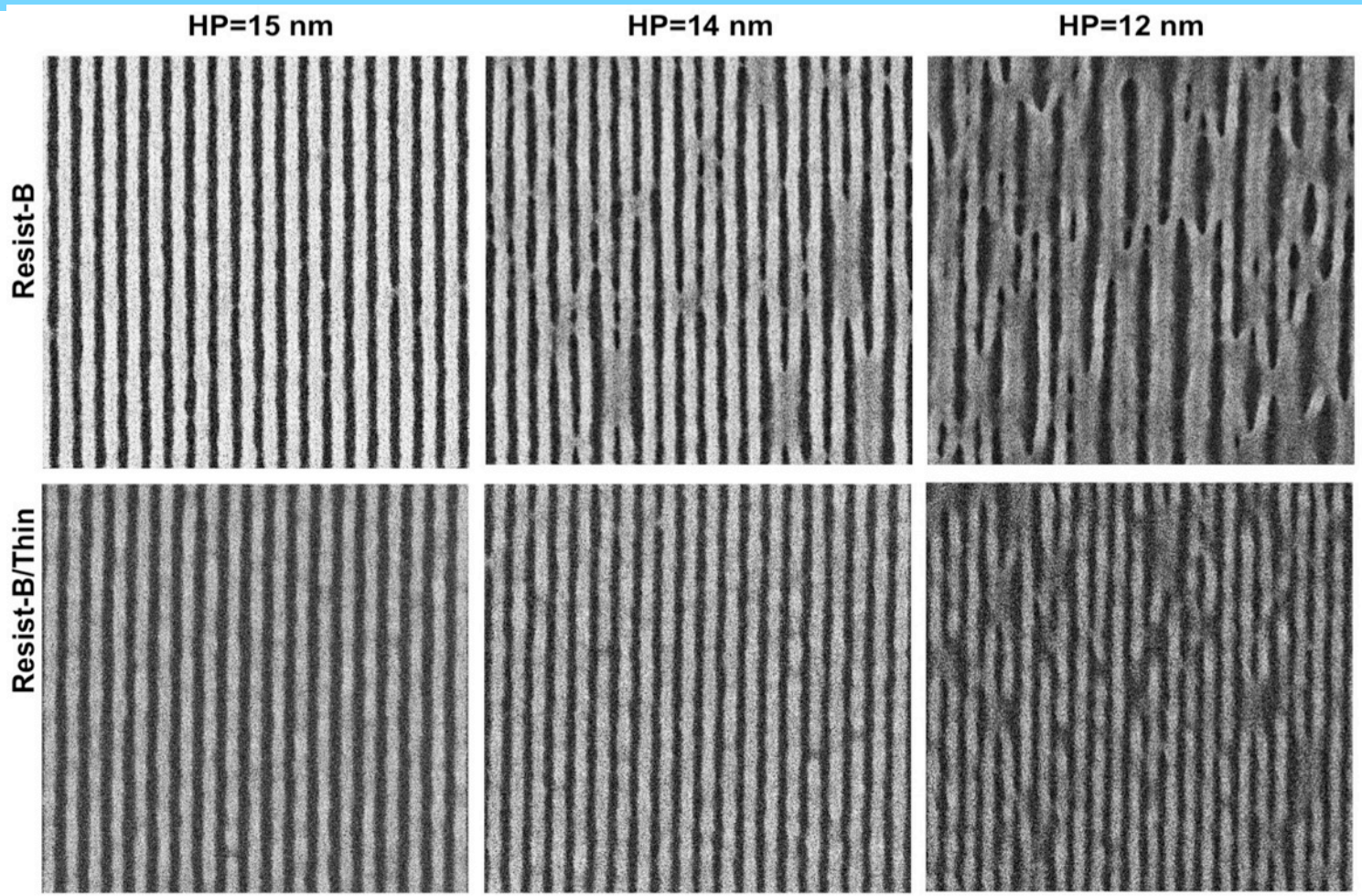


Thickness=30 nm
PAB: 130 °C / 60 s
PEB: 100 °C / 60 s
Dev: 2.38% TMAH/ 30s

State of the art for 16 nm HP



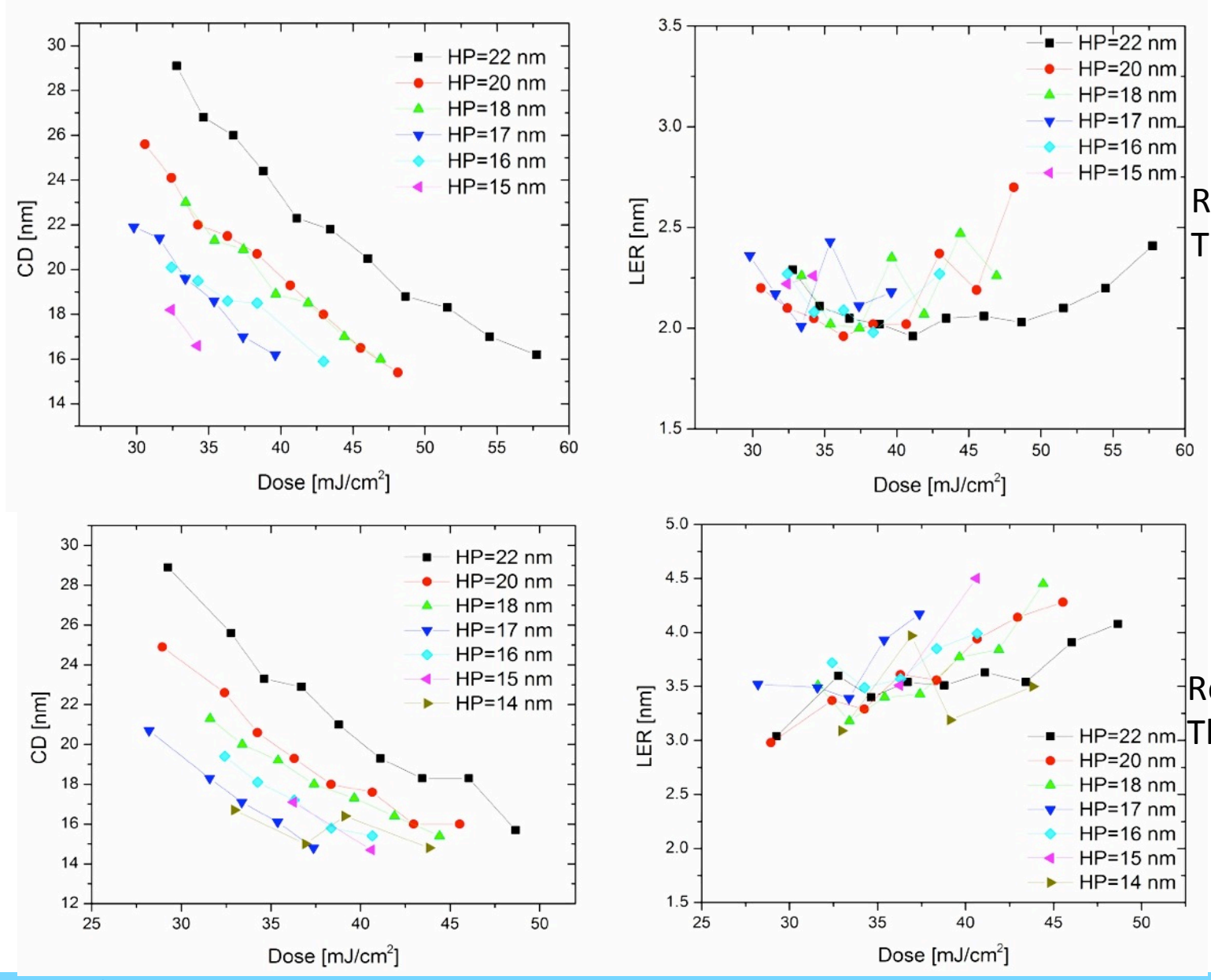
CARs towards 11 nm HP?



Resist-B
Thickness= 30 nm

Resist-B
Thickness= 25 nm

Resist-B: CD, LER



Resist-B
Thickness= 30 nm

Resist-B
Thickness= 25 nm

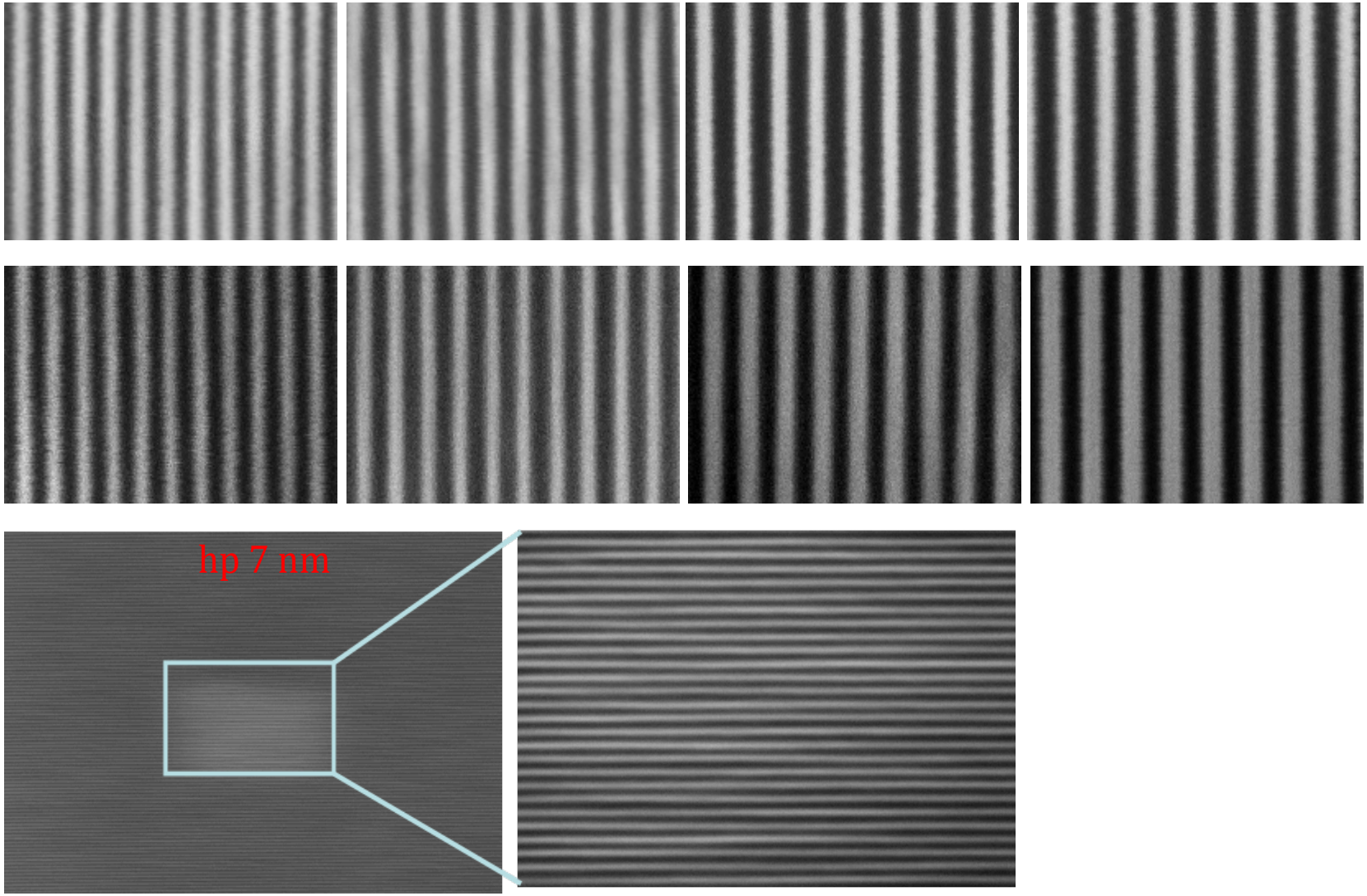
Inorganic resists

hp 8nm | hp 9 nm | hp 10 nm | hp 11 nm

Inpria/IB

HSQ

HSQ

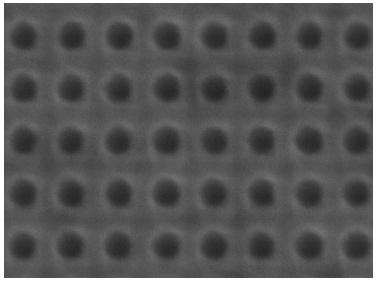


Contact holes

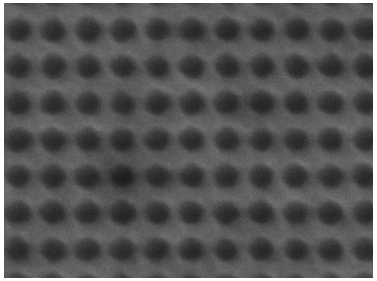
Negative tone resists

CHs In HSQ

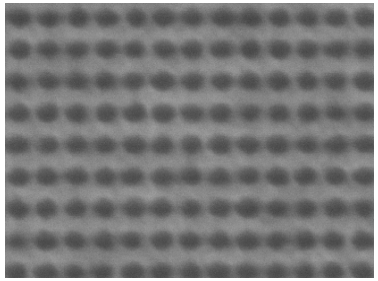
HP 25 nm



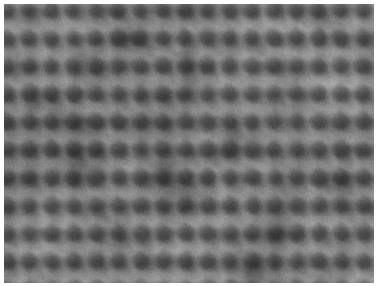
HP 16 nm



HP 14 nm

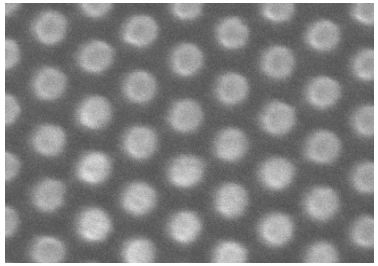


HP 11 nm

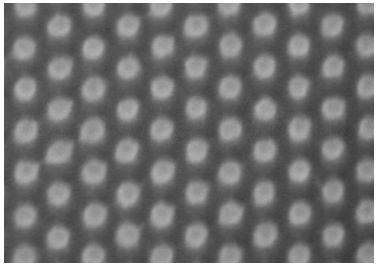


Dots In HSQ

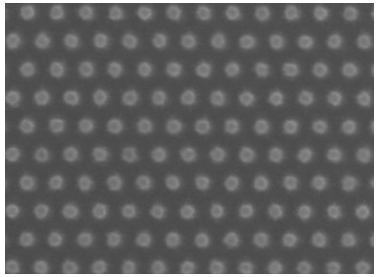
HP 23 nm



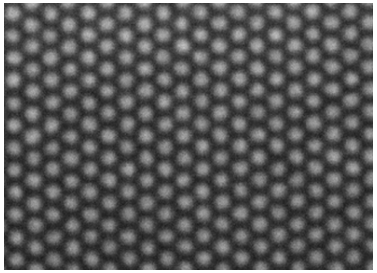
HP 20 nm



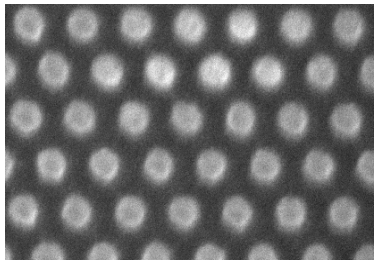
HP 15 nm

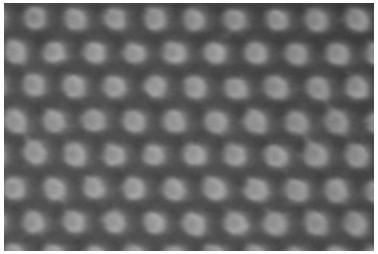


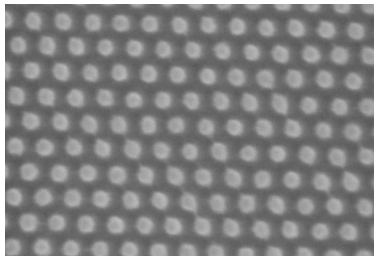
HP 11 nm

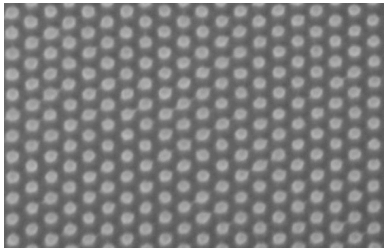


Dots In Inpria

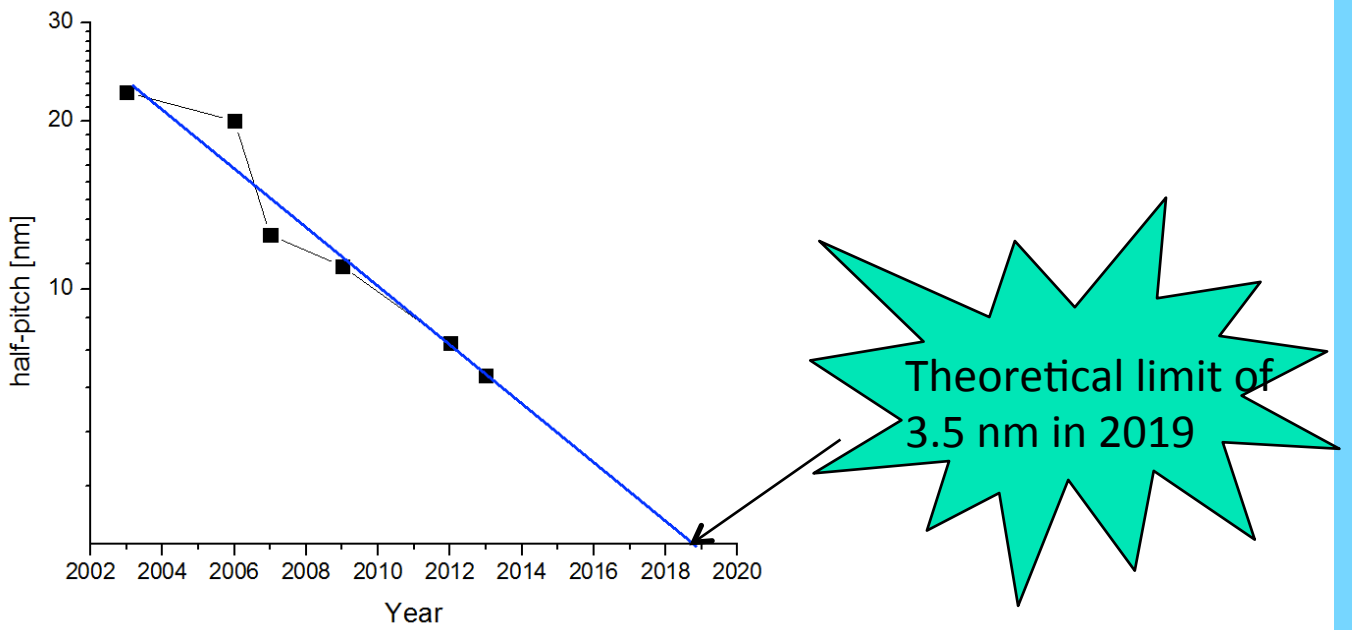






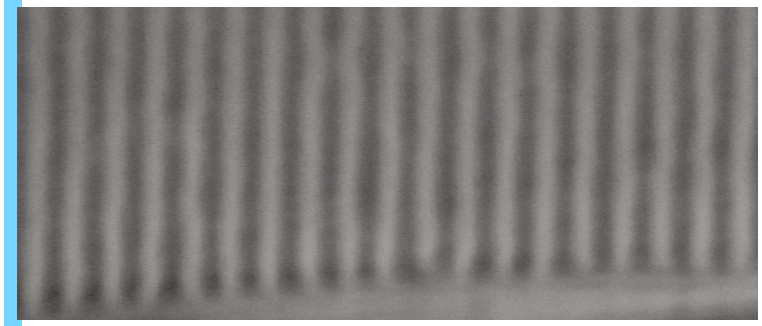


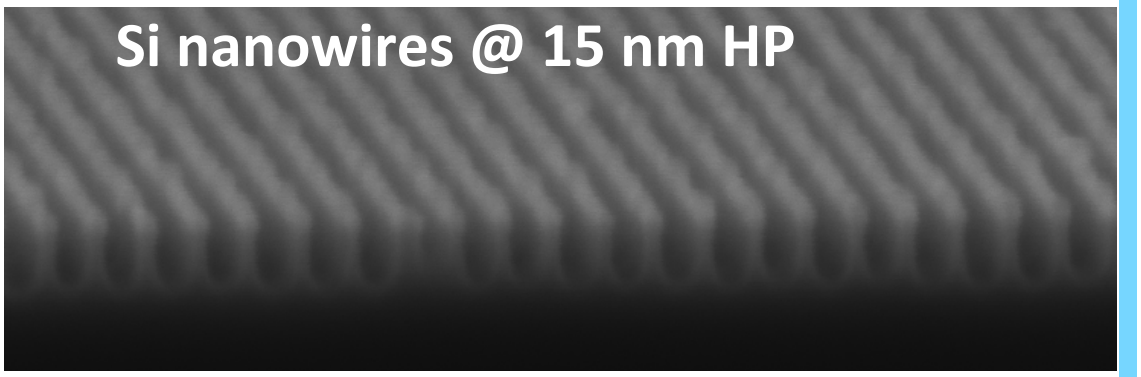
Progress of PSI's tool

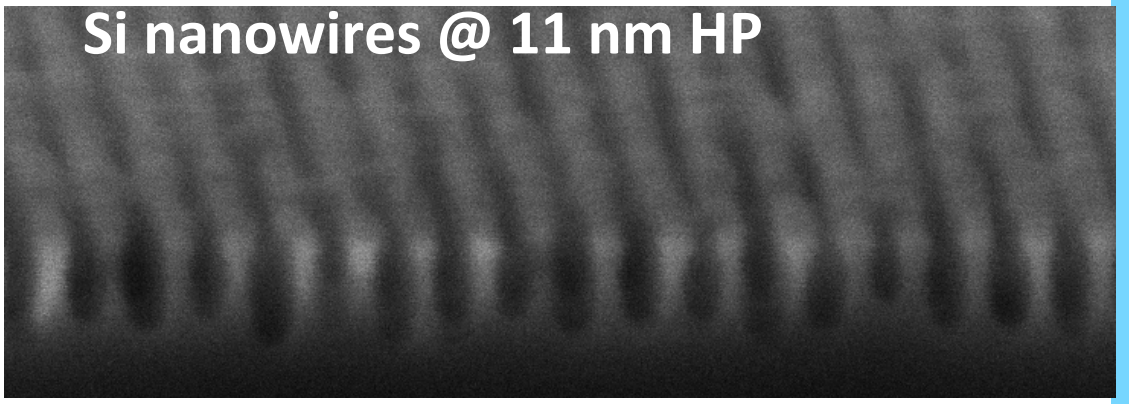


Cross-sections and etching: preliminary results

HSQ lines @ 8 nm HP

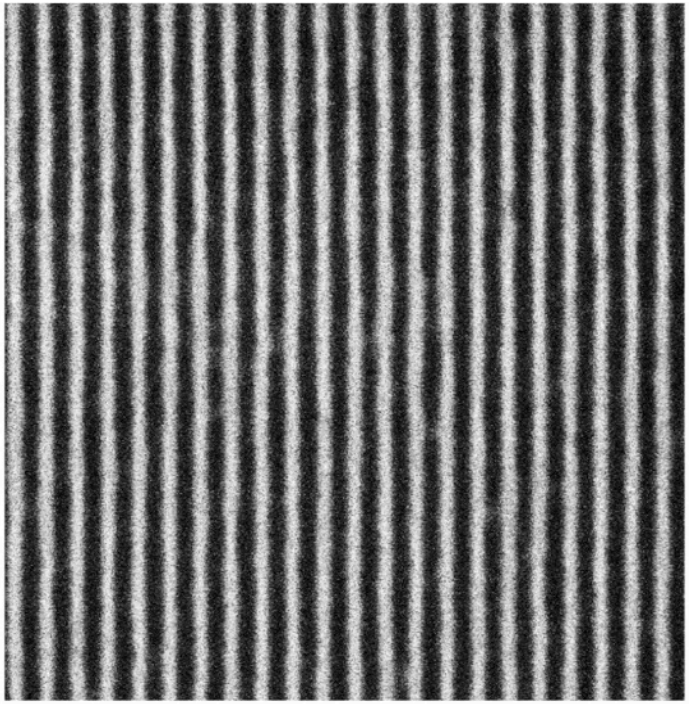






EUV-sensitive inorganic resists

HP 12 nm
Inpria/JB



E-size=75-80 mJ/cm^2

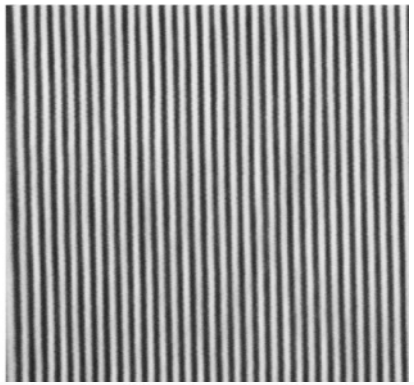
HP 8 nm
Inpria/IB

E-Size=160-200 mJ/cm^2

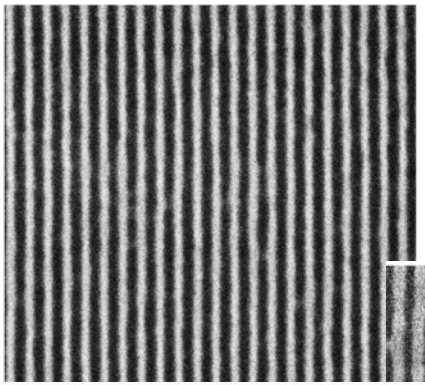
IB will probably can go well below 8 nm HP

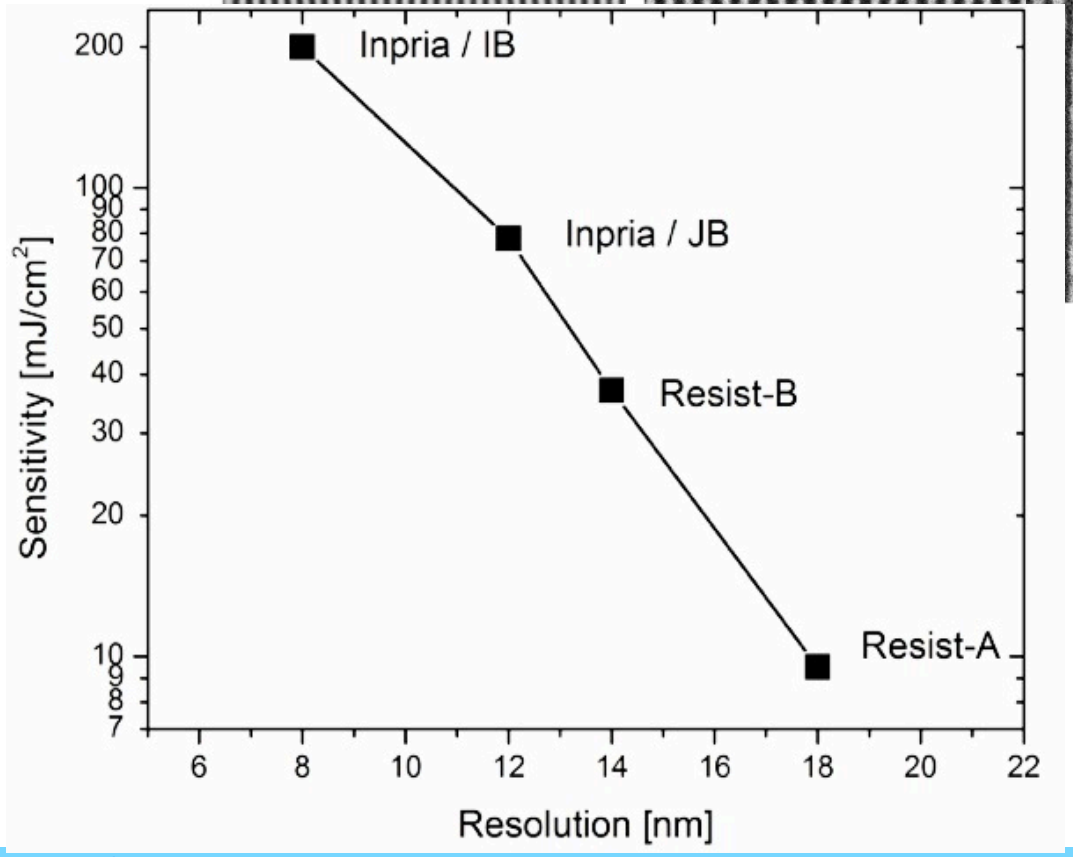
EUV resists: State of the art

HP 8 nm
Inpria/IB

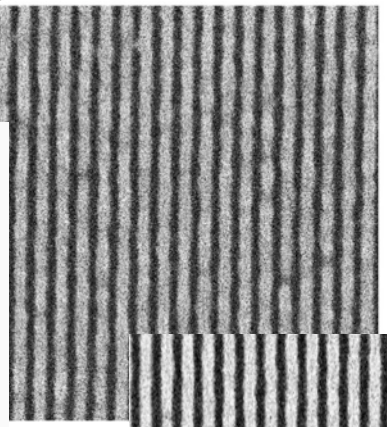


HP 12 nm
Inpria/JB

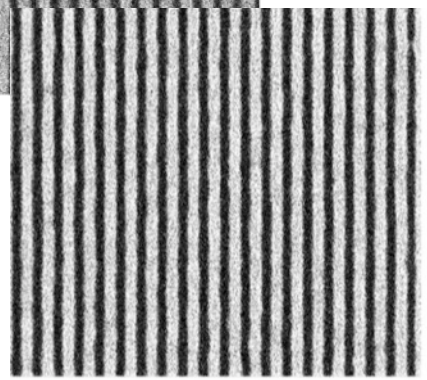




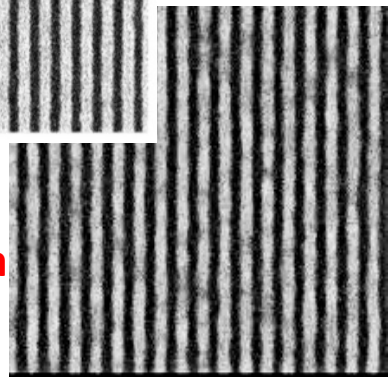
HP 14 nm
Resist-B



HP 16 nm
Resist-B

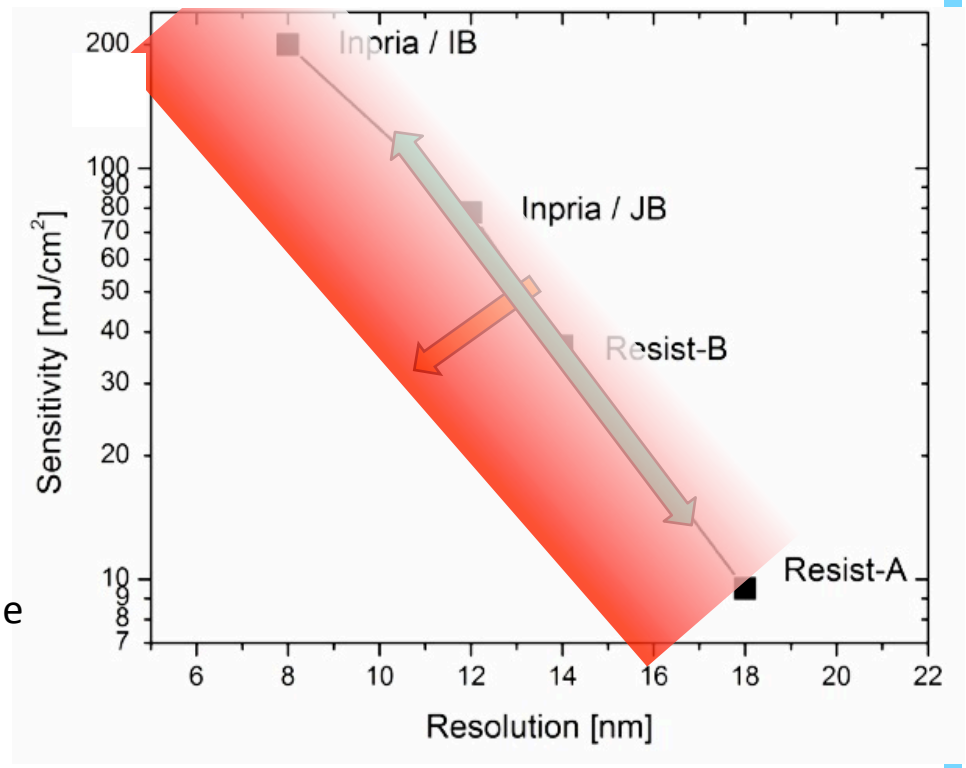


HP 18 nm
Resist-A



Conclusions & Outlook

- Demonstration of patterning down to 7 nm HP
  - *EUV photons can do it.*
  - *EUV-sensitive materials available*
  - *Tools available*
- State-of-the-art is very promising and highly advanced.
- State of the art defines the measure of the progress:
  - *(1) Tuning of dose-HP*
  - *(2) Progress in dose and HP*
- Is there any CAR in future?
- With decreasing HP: pattern collapse becomes the limiting factor
  - *Pattern collapse mitigation will improve the LER and can decrease the HP for same dose.*
- Future targets should be realistic:
  - *For 16 nm HP: Esize = 10- 30 mJ/cm²*
  - *For 11 nm HP: Esize = 40- 80 mJ/cm².*
  - *For 7 nm HP: Esize = 80- 200 mJ/cm².*



Acknowledgments: We thank the resist suppliers: Inpria, Shin Etsu, and JSR.

Thank you for your attention!