TEXAS
The University of Texas at Austin

UT DA

Patterning Aware Design Optimization of Selective Etching in N5 and Beyond

Yibo Lin[1], Peter Debacker[2], Darko Trivkovic[2],

Ryoung-Han Kim[2], Praveen Raghavan[2], David Z. Pan[1]

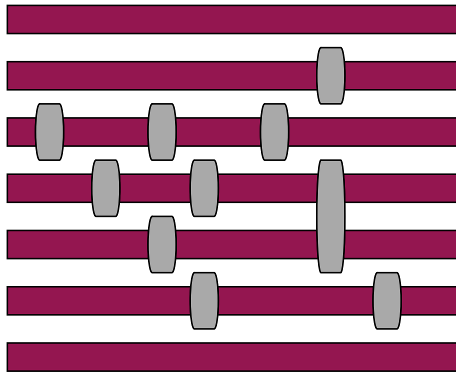
[1]ECE Department, University of Texas at Austin
[2]IMEC, Leuven, Belgium

TEXAS
The University of Texas at Austin

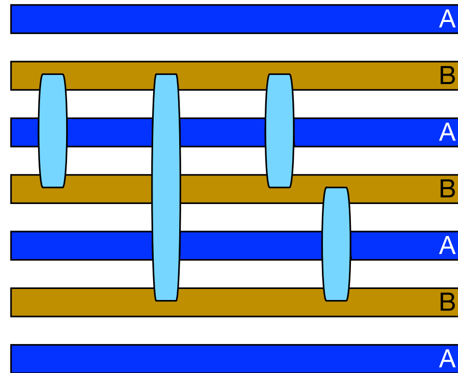
imec

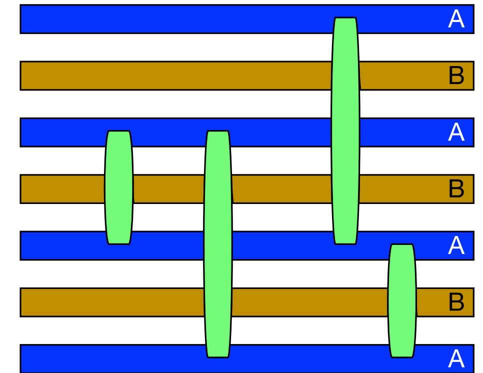
Conventional Blocks v.s. Self-Aligned Blocks (SAB)

Two approaches to obtain equivalent patterns



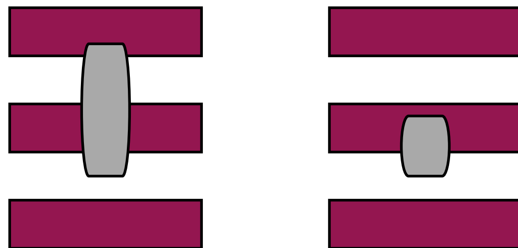
Conventional blocks

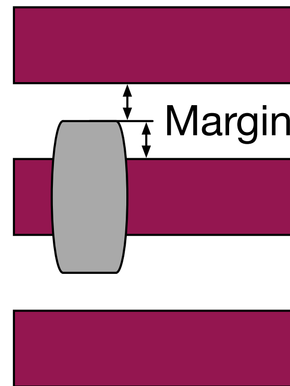




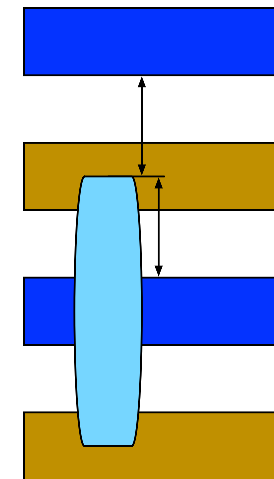
SAB enabled by selective etching

Process variation





EPE margin $= \frac{1}{4}P$



EPE margin $= \frac{3}{4}P$

EPE margin: margin to tolerate edge placement error

Problem Formulation

How large is the design space for SAB?

How to enable fast design closure for SAB?

Design rule exploration

- Given lithography options of SAB and technology definitions
- e.g., pitches and lithography spacing for blocks
- Define design rules with maximum solution space for design closure

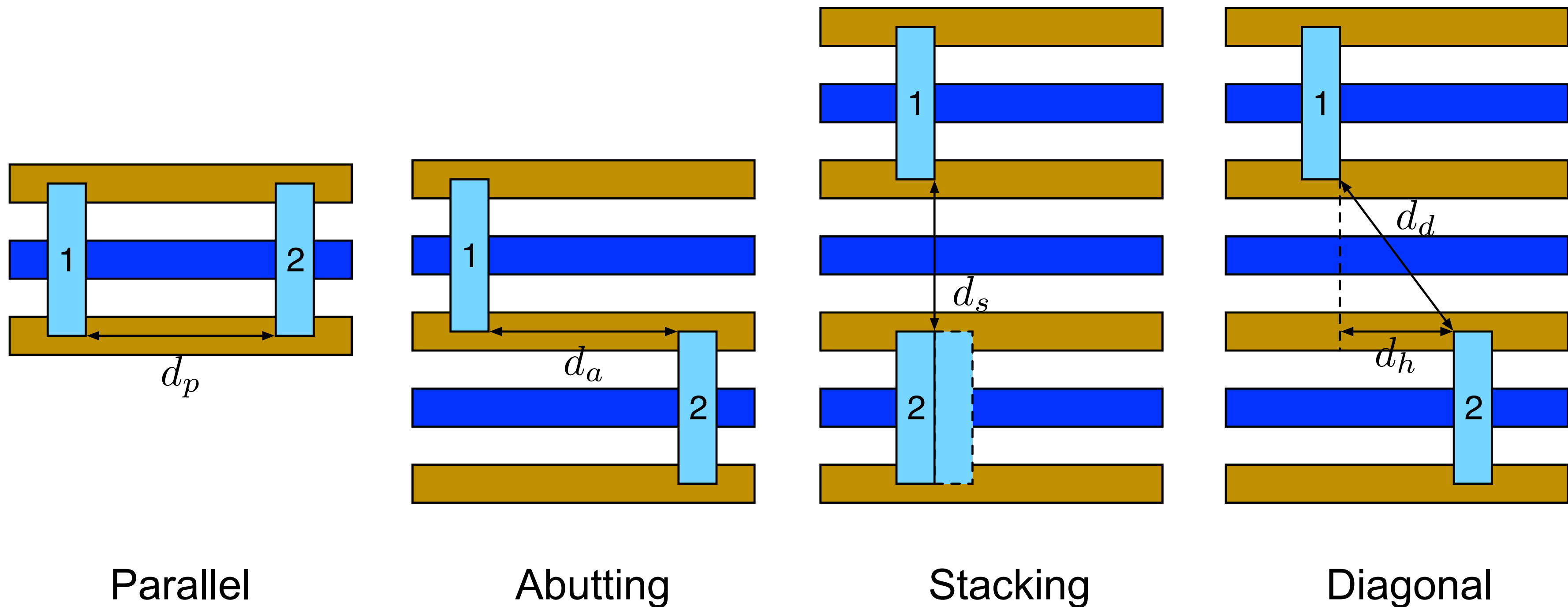
SAB mask optimization

- Given a set of design rules and designs
- Optimize blocks by redistribution to remove design rule violations
- Perform layout decomposition of blocks
- Minimize cost of redistribution, such as total line end extension

Patterns That Cause Conflicts

4 types of patterns that may result in conflicts

- Spacing rules



Patterns	Parallel	Abutting	Stacking	Diagonal
Required Distance	d_p	d_a	d_s	d_d, d_h

Simple and Complex Rules for SAB

Link design rules to line pitch P and lithography spacing s

Simple rules

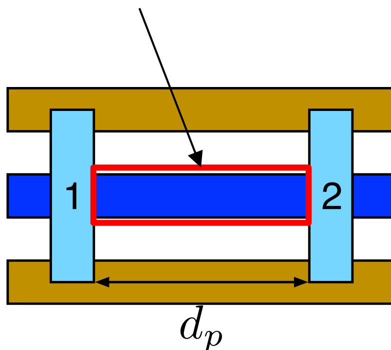
- $d_p = d_a = d_s = d_d$

Limited by parallel patterns

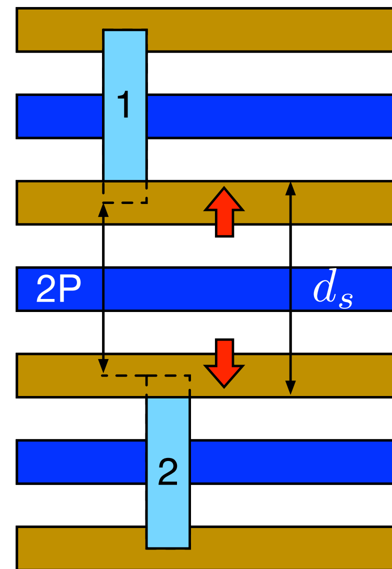
- Minimum area constraint
- Lithography spacing

Complex rules

- Allow different d_p, d_a, d_s, d_d
- NEGATIVE block end extension to enable stacking patterns



Parallel



Stacking

If $2P < d_s = s$

Tradeoff EPE margin for design space

Simple and Complex Rules for SAB

Link design rules to line pitch P and lithography spacing s

Simple rules

- $d_p = d_a = d_s = d_d$

Complex rules

- Allow different d_p, d_a, d_s, d_d
- NEGATIVE block end extension to enable stacking patterns

Assume 8nm EPE margin required [Han+,SPIE2016]

Approx. N5

		Conventional block	SAB simple rules	SAB complex rules
P	s	margin	margin	margin
24	84	6	**18**	0
	80			2
28	84	7	**21**	7
	80			**9**
32	84	**8**	**24**	**14**
	80			**16**
36	84	**9**	**27**	**21**
	80			**23**

Can complex rules enable larger design space than simple rules?

SAB Optimization

SAB redistribution to resolve conflicts

- A post optimization stage in existing physical design flow
- Simple rules v.s. complex rules

Simple (P=32, s=80) Complex (P=32, s=80) Complex (P=32, s=84)

10^5 10^4 10^3 10^2

#icn #cn

#icn: # of initial conflicts
#cn: # of final conflicts

- Simple rules results in 22x more final conflicts than complex rules
- Relaxing lithography spacing results in 10% more final conflicts

Conclusion

Design space exploration for SAB

- Design rules scalable with pitches and lithography spacing
- Post optimization for SAB
- Impacts of design rules to design closure

SAB is a promising and feasible option for N5 and beyond

- Provide insights to the further advancement of manufacturing process

Future work

- SAB friendly design flow
- Early stage consideration of SAB rules

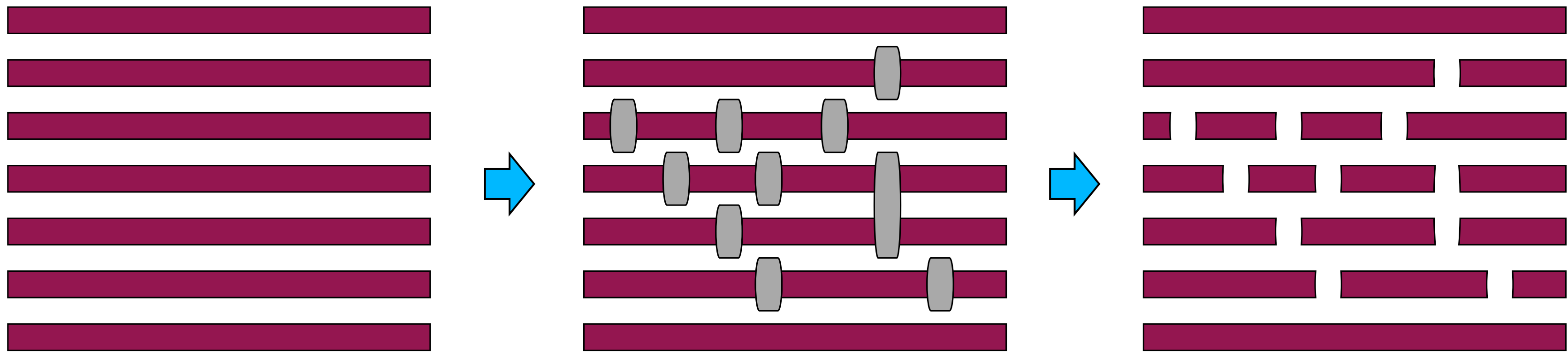
Thank you

Outline

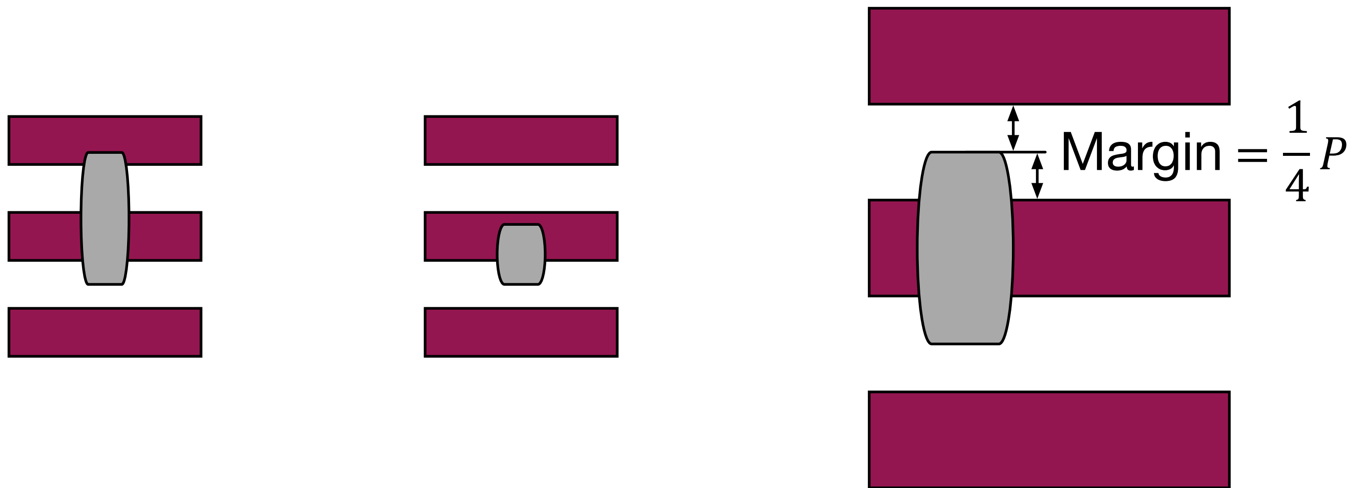
- Introduction
- Problem Formulation
- SAB Design Rule Exploration
- SAB Optimization
- Conclusion

1-D Gridded Layout – Lines and Blocks

Conventional blocks (cuts)



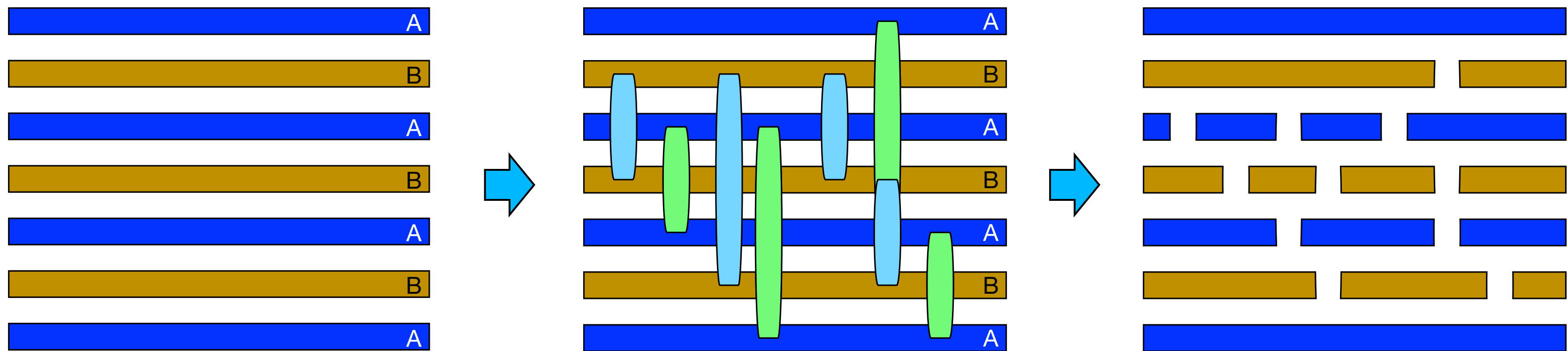
Process variation



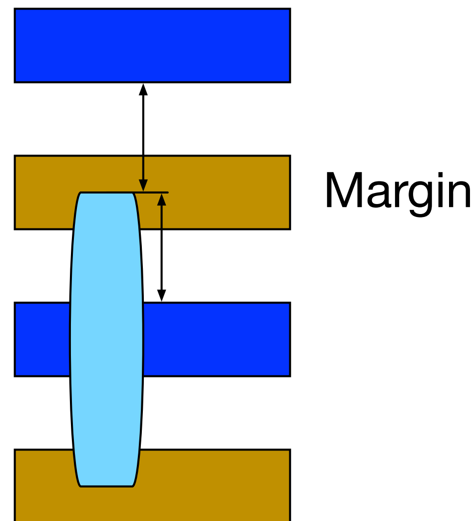
EPE margin: margin to tolerate edge placement error

1-D Gridded Layout – SAB Lines and Blocks

Self-aligned blocks (SAB)

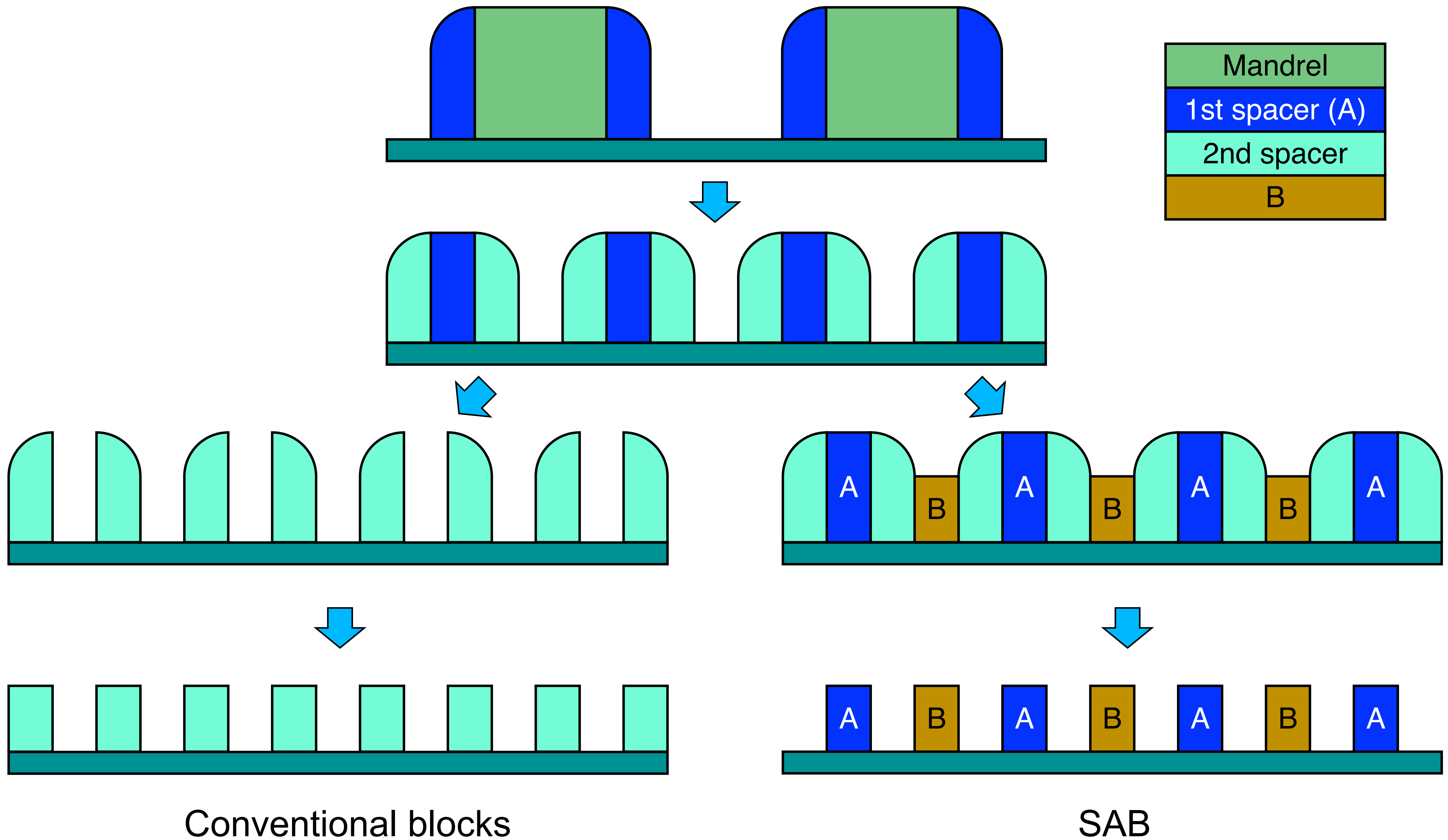


EPE margin$= \frac{3}{4}P$



Manufacturing Process of SAB

Non-selective etching v.s. selective etching



SAB Optimization

SAB redistribution to resolve conflicts

- A post optimization stage in existing physical design flow
- Simple rules v.s. complex rules

Simple (P=32, s=80) | Complex (P=32, s=80) | Complex (P=32, s=84)

#icn: # of initial conflicts
#cn: # of final conflicts

ext: line end extension

bext: block end extension

- Simple rules results in 22x more final conflicts than complex rules
- Relaxing lithography spacing results in 10% more final conflicts