

Advanced Design Methodologies for Directed Self-Assembly

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Block Copolymer Directed Self-Assembly

- **Block copolymer (BCP) directed self-assembly (DSA) is one of Next Generation Lithography (NGL) technologies**
 - Common material: PS-b-PMMA (polystyrene-block-polymethyl methacrylate)

● A-type monomer

● B-type monomer

Random Copolymer



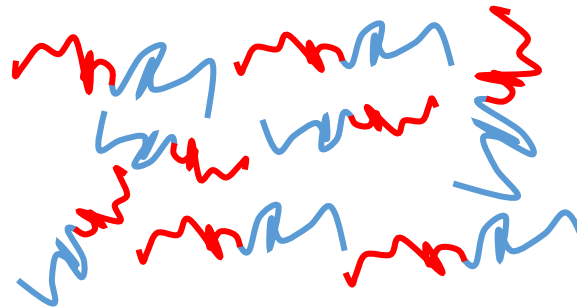
Block Copolymer (BCP)



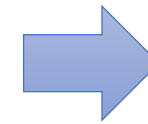
A-block

B-block

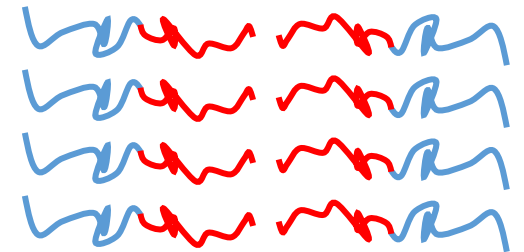
Disorder



Annealing



Microphase
Separation



Different DSA Morphologies

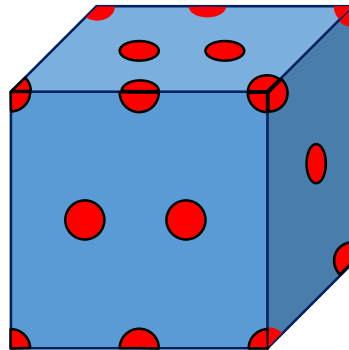
- Different proportions of block components form different DSA morphologies

(a) Spherical ($A \ll B$)

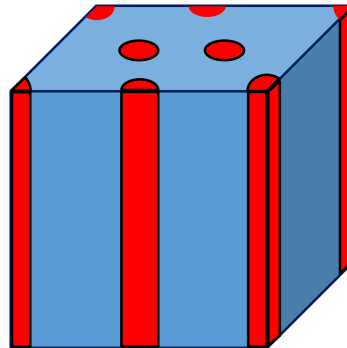
(b) Cylinders ($A < B$)

(c) Lamellae ($A \approx B$)

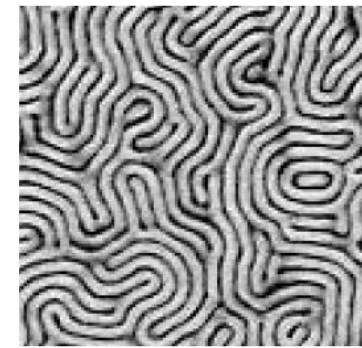
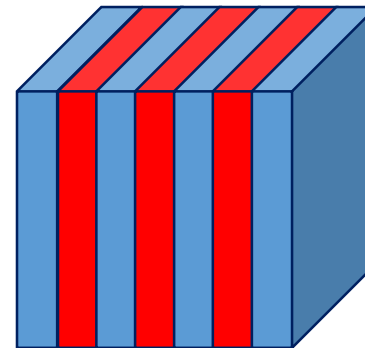
Spheres ($A \ll B$)



Cylinders ($A < B$)



Lamellae ($A \approx B$)

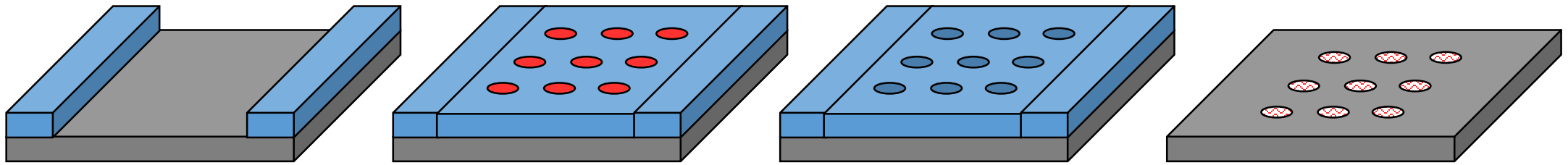


● A-type monomer

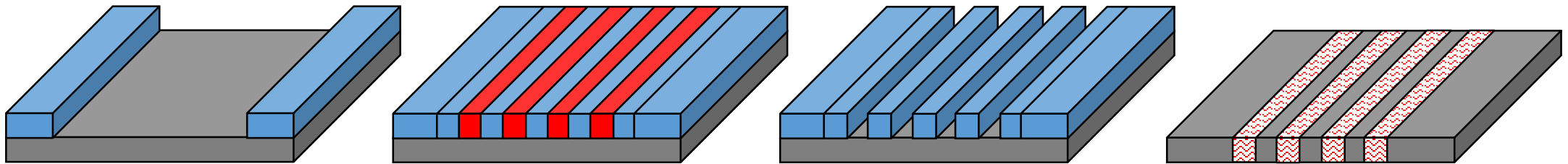
● B-type monomer

Guiding Templates in DSA

- Guiding patterns are used to provide additional driving forces to turn random fingerprints into highly orientated and aligned patterns



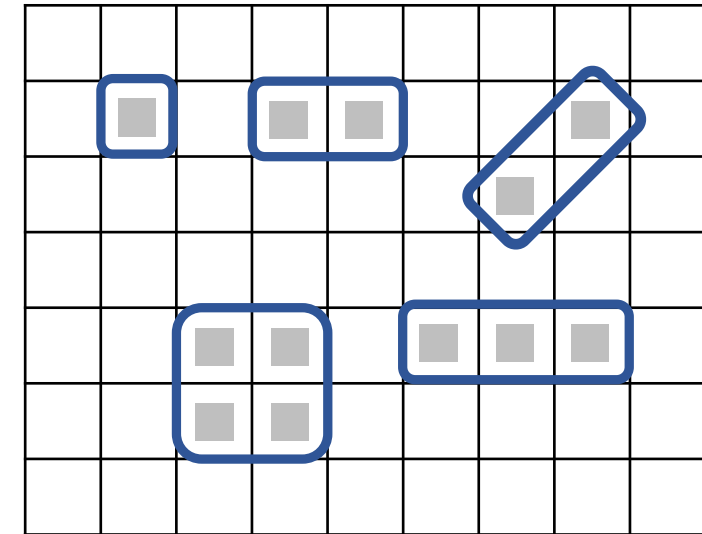
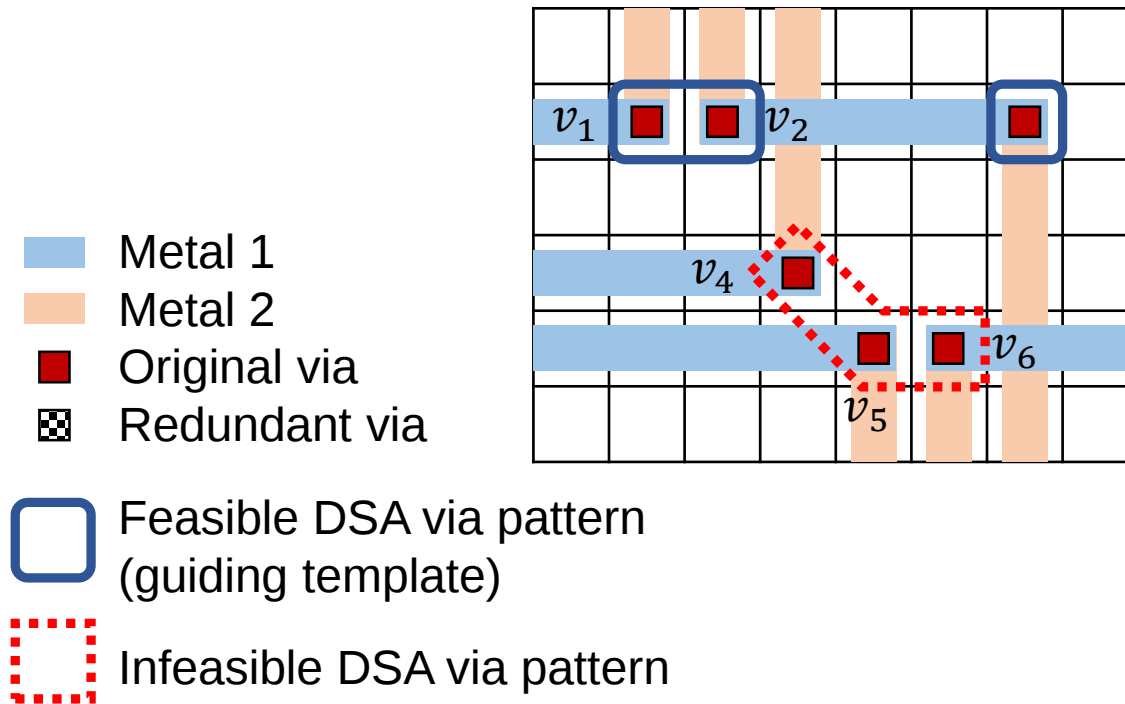
Cylindrical DSA



Lamellar DSA

Via Fabrication with Cylindrical DSA

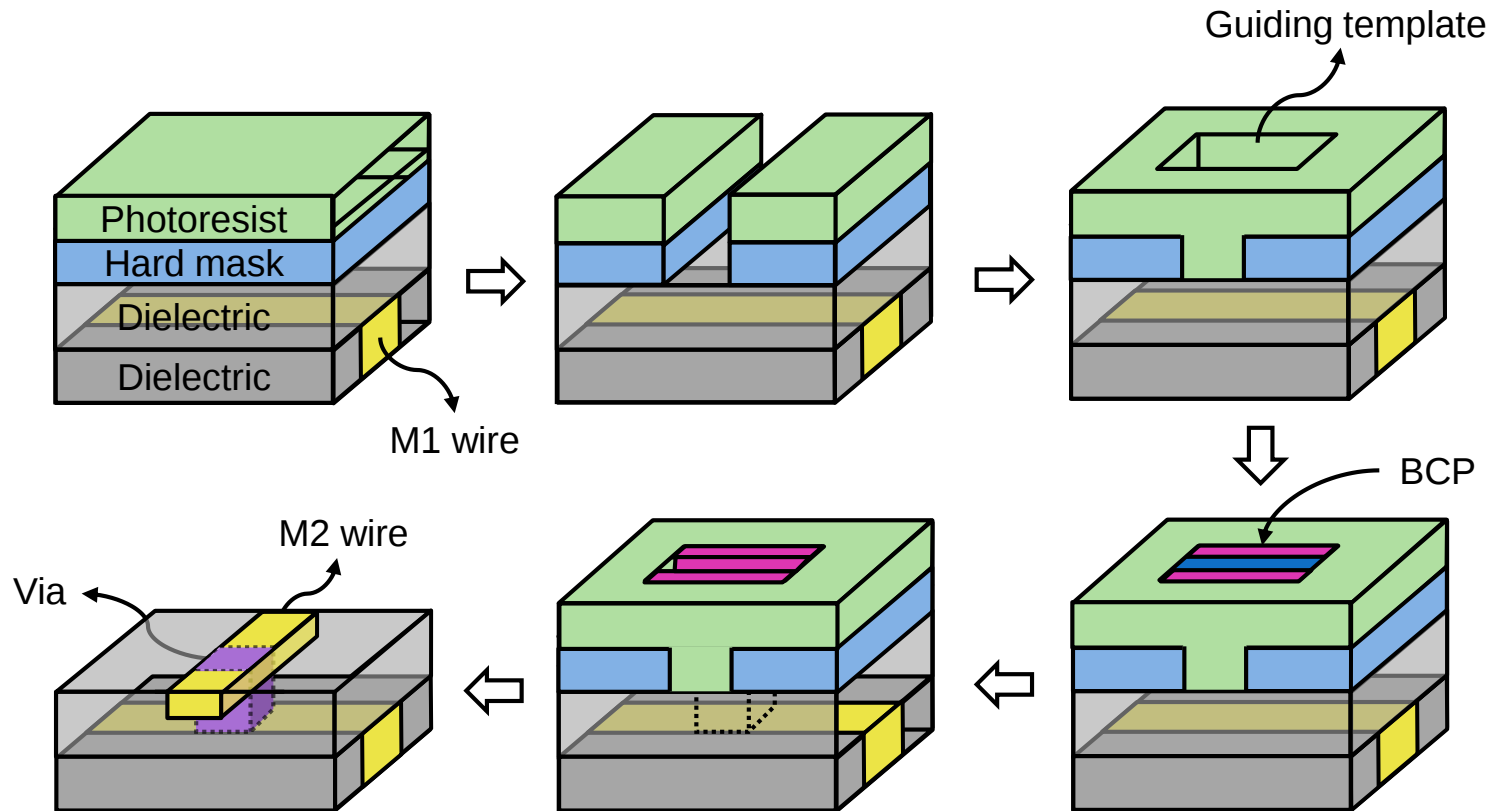
- Each via is generated with a single-hole or a multi-hole guiding template
- In a template, #holes $\uparrow$, shape complexity $\uparrow \Rightarrow$ overlay accuracy $\downarrow$



Common feasible via patterns in literature

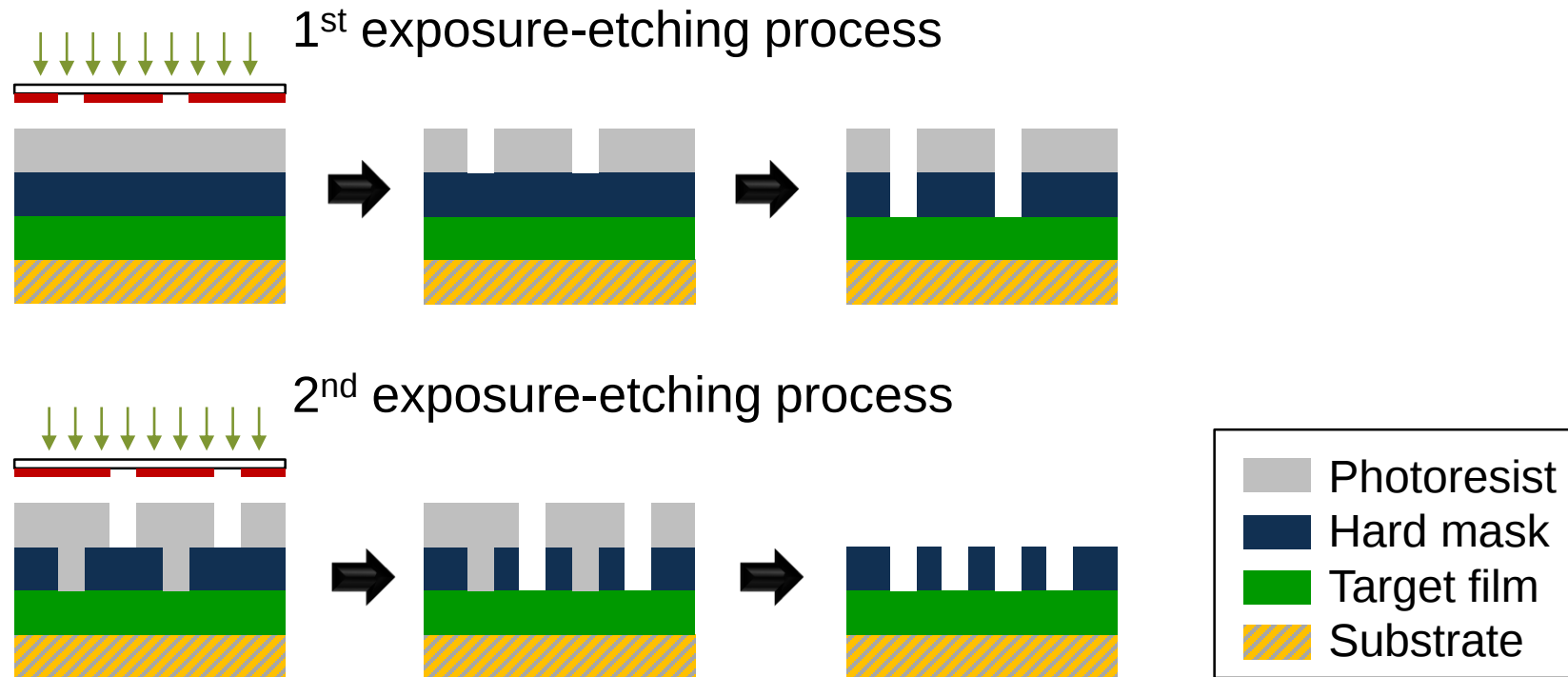
Via Fabrication with Lamellar DSA

- Must be adopted with the self-aligned via (SAV) process
- Holes are generated at the intersections of templates and upper-layer wires
- Templates should not be too short for yield opt.



DSA with Multiple Patterning

- The resolution of guiding templates is limited by conventional optical lithography $\Rightarrow$ use multiple patterning (MP)!!
- Litho-etch-litho-etch (LELE) multiple patterning lithography (MPL) has been widely used in industry



Existing Work on Cylindrical DSA

● Post-layout template design and mask assignment

- Badr et al., "Mask assignment and synthesis of DSA-MP hybrid lithography for sub-7nm contacts/vias," DAC'15
- Kuang et al., "Simultaneous template optimization and mask assignment for DSA with multiple patterning," ASPDAC'16
- Xiao et al., "Contact layer decomposition to enable dsa with multi-patterning technique for standard cell based layout," ASPDAC'16

● Template design considering multiple BCP materials

- Ou et al., "DTCO for DSA-MP hybrid lithography with double-BCP materials in Sub-7nm node," ICCD'16
- Wu and Fang, "Simultaneous template assignment and layout decomposition using multiple BCP materials in DSA-MP lithography," ICCAD'17
- Lin and Jiang, "Novel guiding template and mask assignment for DSA-MP hybrid lithography using multiple BCP materials," DAC'19

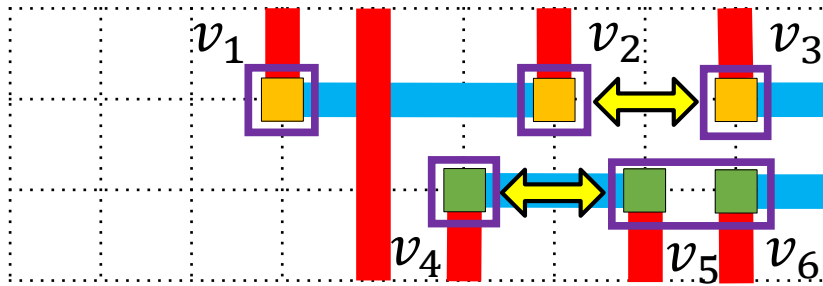
● Cylindrical DSA-aware detailed routing

- Ou et al., "DSAR: DSA aware routing with simultaneous DSA guiding pattern and double patterning assignment," ISPD'17
- Yu and Chang, "DSA-friendly detailed routing considering double patterning and DSA template assignments," DAC'18

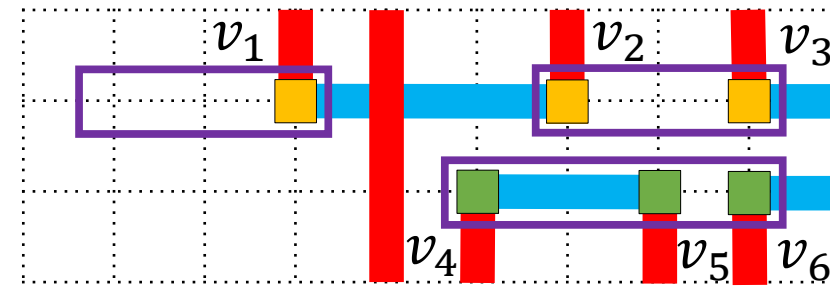
Existing Work on Lamellar DSA

- **Post-layout template design and mask assignment**

- Shih et al., “Guiding template design for lamellar DSA with multiple patterning and self-aligned via process,” ICCAD’20



Cylindrical DSA with Mask conflicts



Lamellar DSA with no conflict

- Via with Mask 1
- Via with Mask 2
- M1 routing wire
- M2 routing wire

- ↔ Mask conflict
- ✗ BCP violation
- Guiding template

Conclusion and Future Research Directions

- **This presentation**

- Introduce DSA as an advanced lithography technology
- Differentiate the processes of cylindrical DSA and lamellar DSA for via fabrication
- Briefly review the existing studies on the two technologies

- **Future research directions**

- Physical design methodologies/rules to facilitate DSA-compliant layout synthesis
- Multi-row template adoption in lamellar DSA