Selected Papers on Directed Self Assembly (DSA) SPIE'14

Yasmine Badr

PHYSICAL VERIFICATION AND MANUFACTURING OF CONTACT/VIA LAYERS USING GRAPHO-EPITAXY

Mentor Graphics (Andres Torres), Tokyo Electron, IMEC, Univ of Chicago

Templates Library

- Candidate approach: define **an alphabet of guiding patterns**.
  - Enumerate all different layout configs used by designed apriori
  - Pre-correct and compose any layout configuration by simply selecting the necessary patterns to generate any intended physical design.
  - Requires:
    - number of constructs needs to be manageable
    - Guarantee that placing certain patterns next to each other will not invalidate the design by introducing a new and uncharacterize layout

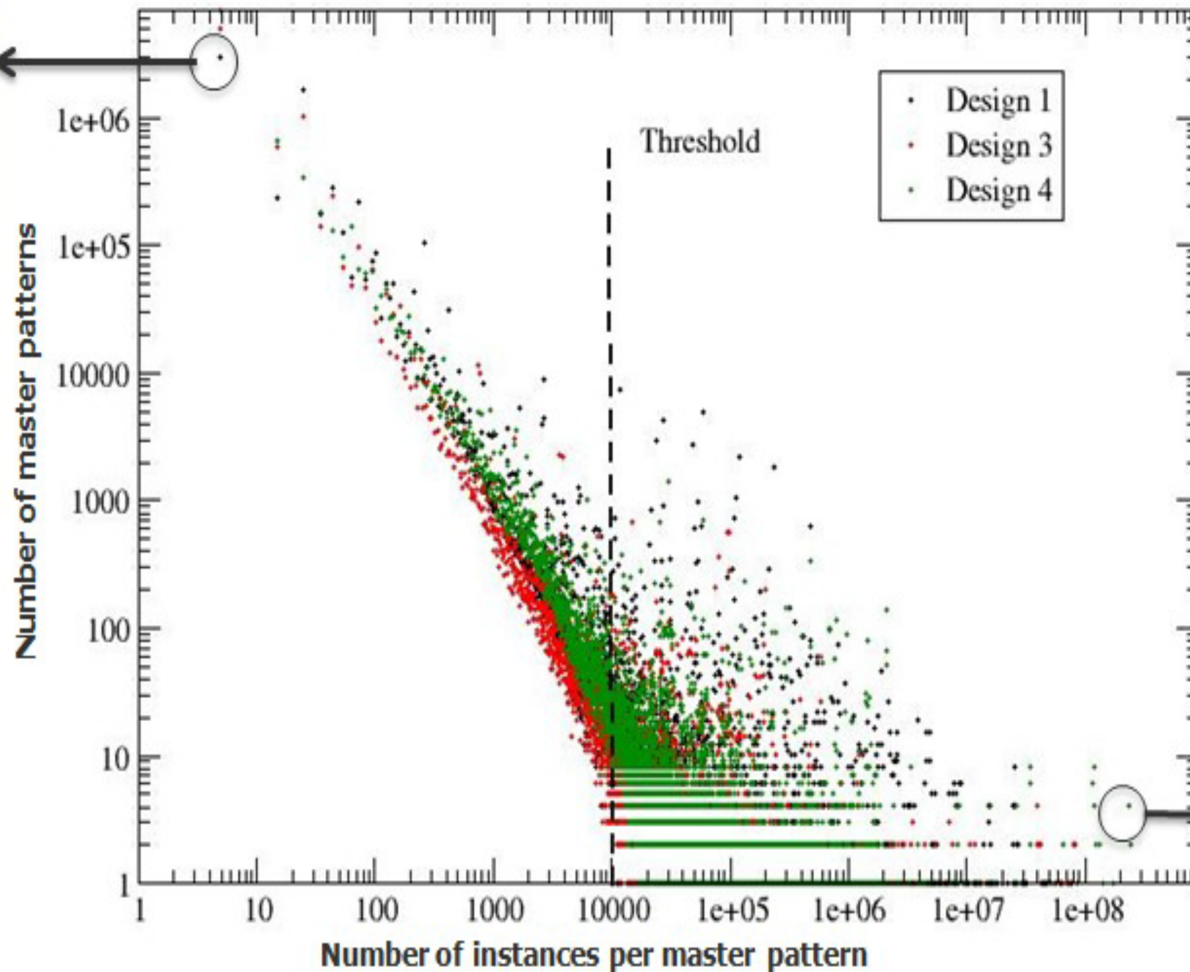
Templates Library

- Experiment: consider every contact as a pattern anchor location and a 400x400nm window is created
- Count instances of different patterns
- 3 full 20 nm designs, scaled to 14nm
  - Using single gate pitch, undirectional gates, undirectional metal except M1

➔A lot of unique patterns

Templates Library (cont'd)

There are millions of master patterns which are used less than 10 times in the layout

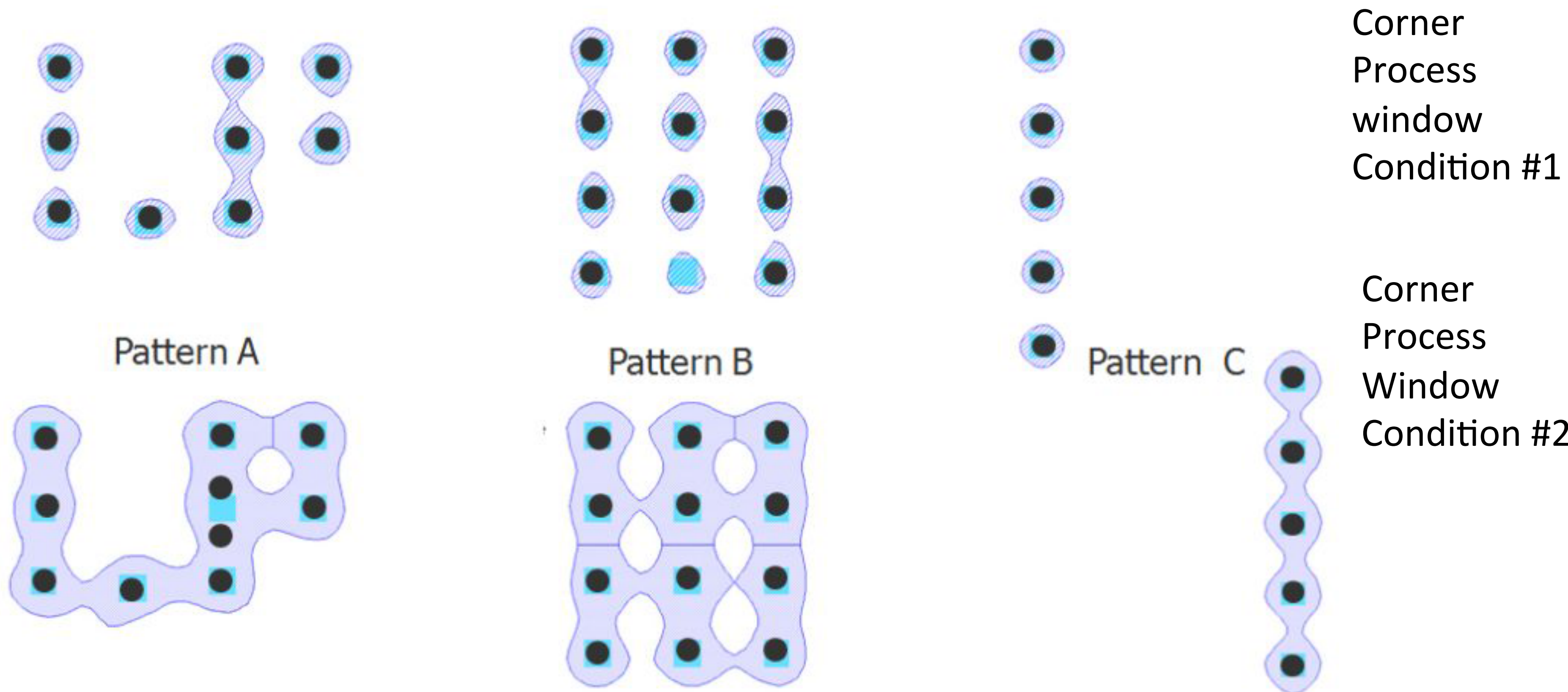


There are few master patterns which are used more than 100 million times in the layout

Lithographic Process Window Sensitivity

- Experiment: Litho simulation and placement of holes predicted using full physics Monte Carlo model

Blue Square: target contact hole
Purple: simulated guiding template



➔May not be able to create target under some PW

COMPUTATIONAL LITHOGRAPHY PLATFORM FOR 193I-GUIDED DIRECTED SELF-ASSEMBLY

IBM

Defects in DSA

1. Systematic by imperfect Guiding templates
2. Random defects in material itself
3. Process control: thickness of deposited material

TOWARDS ELECTRICAL TESTABLE SOI DEVICES USING DIRECTED SELF-ASSEMBLY FOR FIN FORMATION

IBM, Global Foundries, Tokyo Electron

Summary

- Manufactured 42nm and 28nm pitch fins using Chemo-epitaxy
- Line roughness in 42nm is worse than the 28nm

DSA Main benefit

- Its ability to be resilient to the shape of the guiding pattern across process window.
- The results suggest that directed self assembly can still be guaranteed even with high distortion of the guiding patterns when the guiding patterns have been designed properly for the target process.

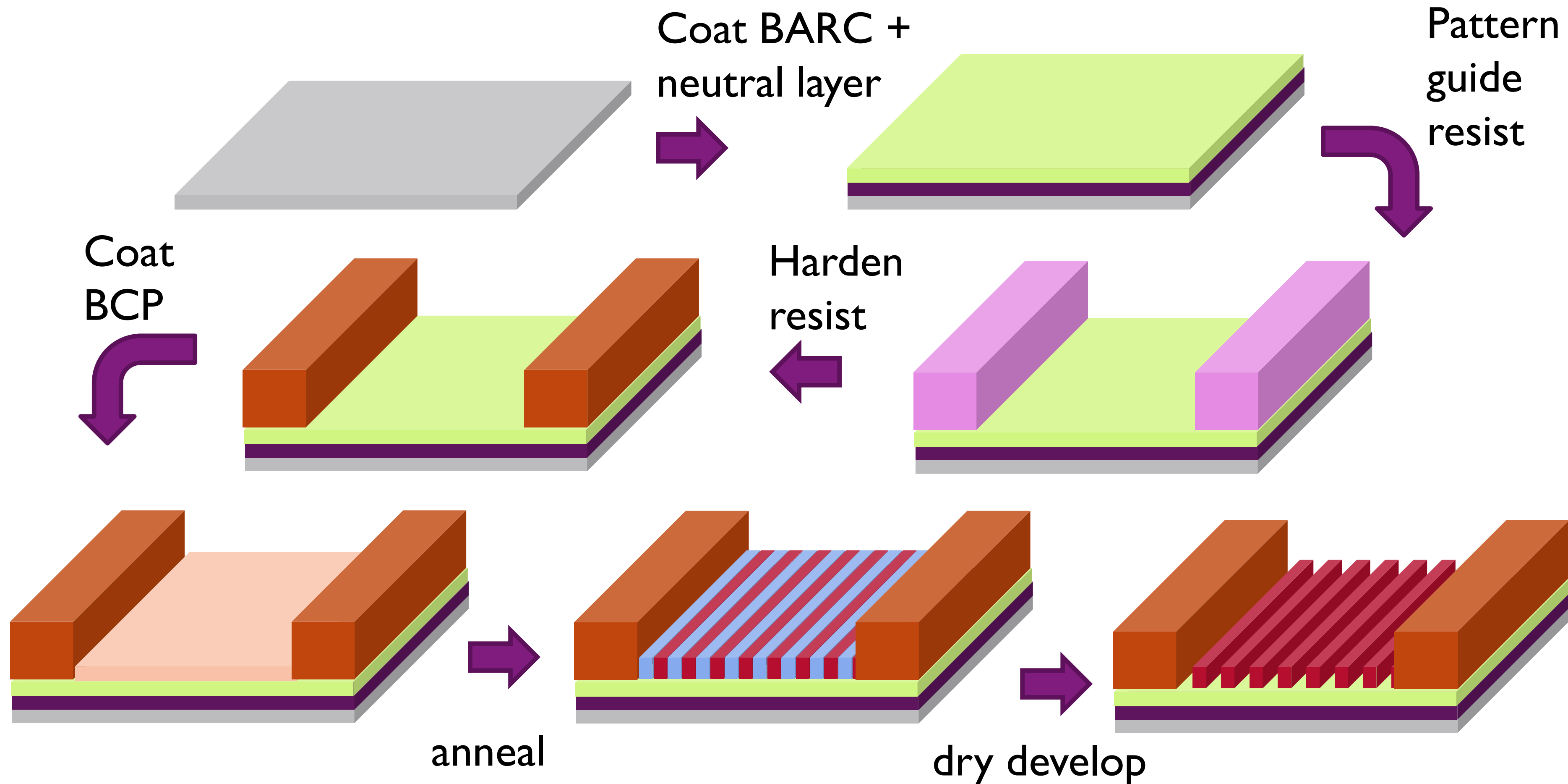
References

[1] Yi, He, et al. "Flexible Control of Block Copolymer Directed Self-Assembly using Small, Topographical Templates: Potential Lithography Solution for Integrated Circuit Contact Hole Patterning." *Advanced Materials* 24.23 (2012): 3107-3114.

BACKUP

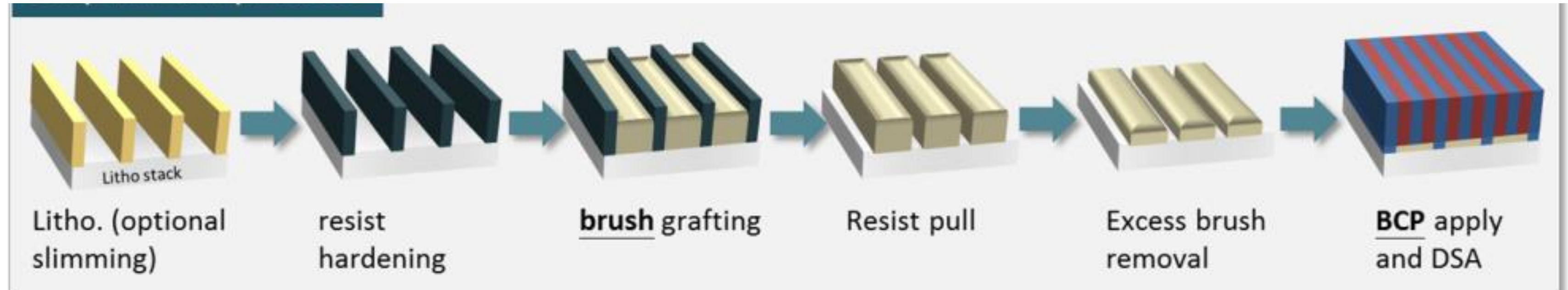
Grapho-eptiaxy vs Chemo-epitaxy

Grapho-eptiaxy
from IMEC



Grapho-eptiaxy vs Chemo-epitaxy

Chemo-eptiaxy from IBM



DSA

- Directed self assembly is the process by which a guiding structure chemical or topological, guide or direct the phase formation into orientations which can be exploited in the semiconductor lithographic process.
- Two types of guiding structures have been investigated and have led to two types of processes: Grapho-epitaxy, and Chemo-epitaxy.

DSA

- Microphase separation in diblock copolymer fi lms occurs through a minimization of free energy which drives the two polymer blocks apart from each other, while the covalent bond between them constraints the maximum separation distance [1]
- The generated nanoscale patterns mainly depend on diblock polymer type and the volume ratio between the two blocks.
- Unconstrained self-assembly without a guiding template typical results in large area uniform patterns that are periodic.

Intro to DSA

- the micro-phase separation of diblock copolymers. Because two very different species,
- typically Polystyrene and Poly(methyl methacrylate) phase segregate when in bulk, they form nanoscopic domains when
- two chains are bonded by covalent bonds. The molecular weight and the ratio of each of the species in the material
- define the phase diagram for a given diblock system.

Grapho-epitaxy vs Chemo-epitaxy

- In a grapho-epitaxy process (Gronheid, et al., 2012) the main mechanism by which the block-copolymer self organizes in useful domains, is dominated by the concept of confinement. Neutral walls or pillars prevent certain chain configurations which then lead to the polymer to adjust its periodic structures along a pre-determined axis.The benefit of this technique is that the guiding pattern can be very local and there is limited interdependency between different organization domains.
- A chemo-epitaxy process (Delgadillo, et al., 2012) defines the preferred direction by a chemical brush which changes the surface energy of the substrate, by doing so and due to the different chemical affinity of the different diblock species to the substrate, the material organizes in a preferential direction minimizing the energy required to achieve a specific configuration. The benefit of this technique is the ability to pattern dense gratings or arrays as the guiding patterns are underneath the block-copolymer

PREDICTING PROCESS WINDOWS FOR PATTERN DENSITY MULTIPLICATION USING BLOCK COPOLYMER DIRECTED SELF-ASSEMBLY IN CONJUNCTION WITH CHEMOEPITAXIAL GUIDING LAYERS

Georgia Tech

Conclusion

- Performed simulation to know the sensitivity of aligned of patterns to the width of the neutral strip in chemo-epitaxy
- When the relative ratio of the width of the pinning stripe to the width of the neutral stripe was varied while keeping a constant overall pitch for the guiding pattern, it was found that there is great tolerance for the width of the pinning stripe, from approximately 0.2Å~ L0 to 0.8Å~ L0 .