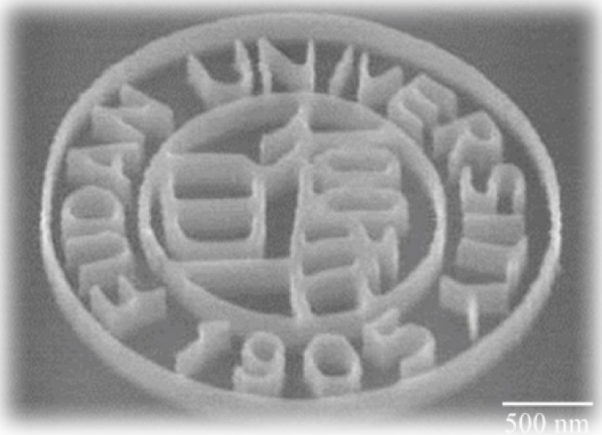


Directed Self-Assembly for Sub-10nm Fabrication

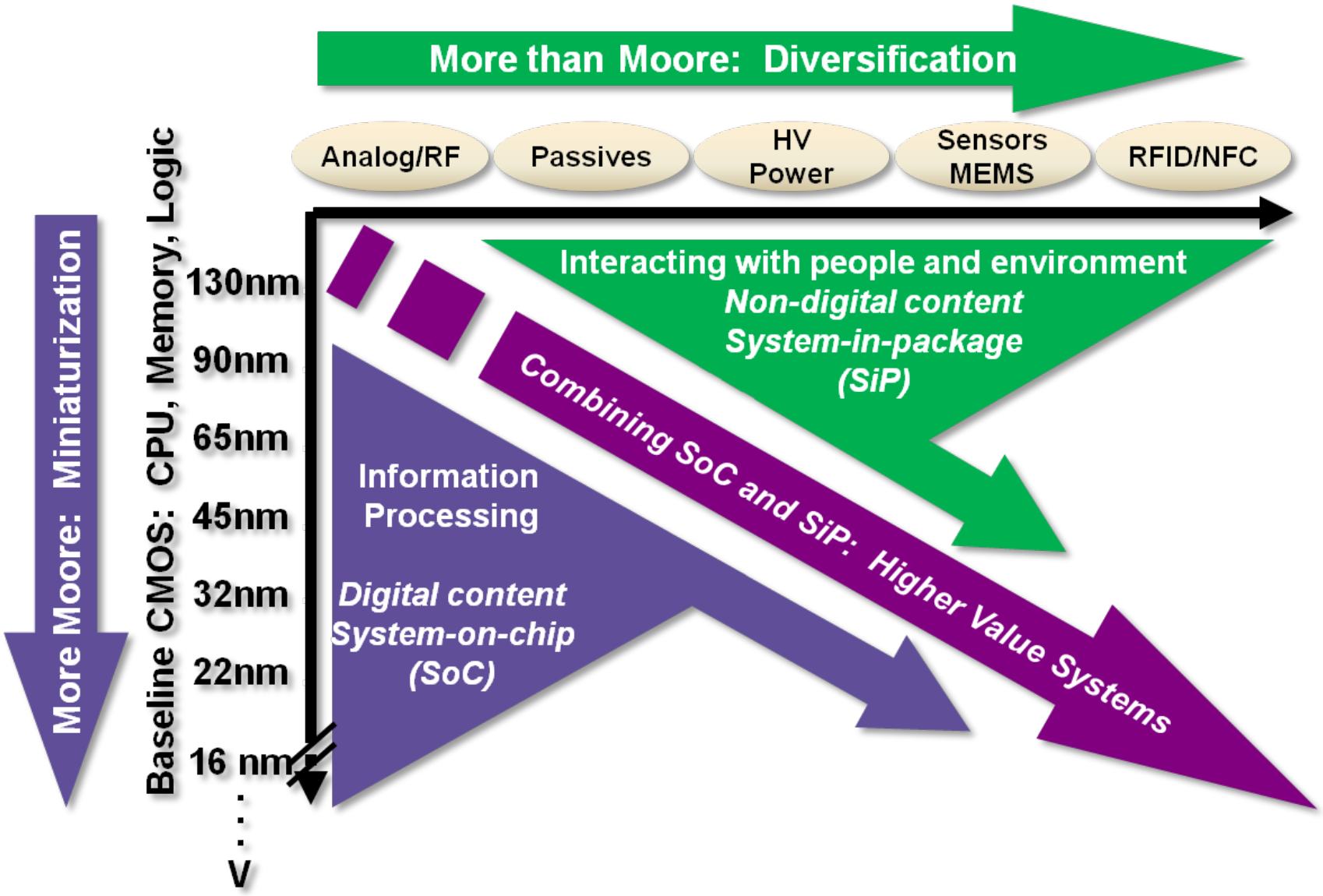
熊诗圣

@IWAPS 2018.10.19

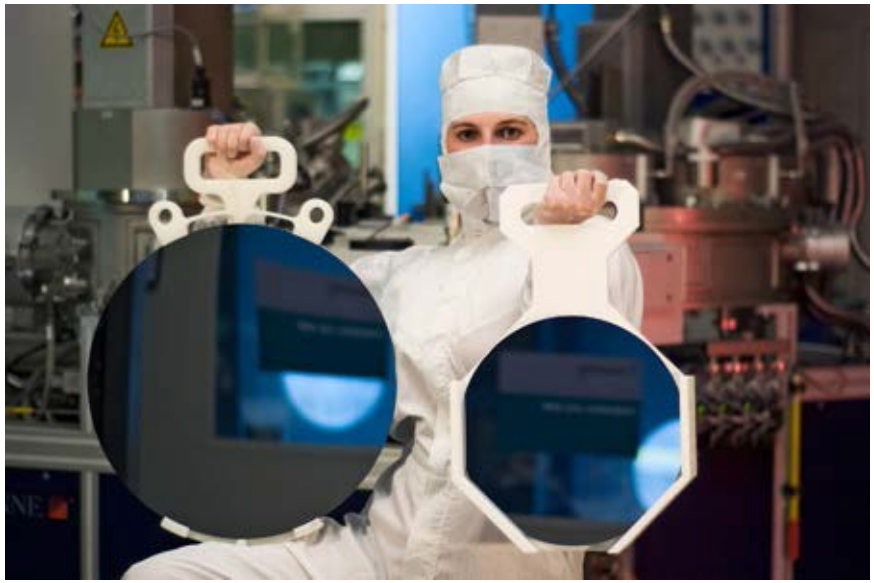
復旦大學

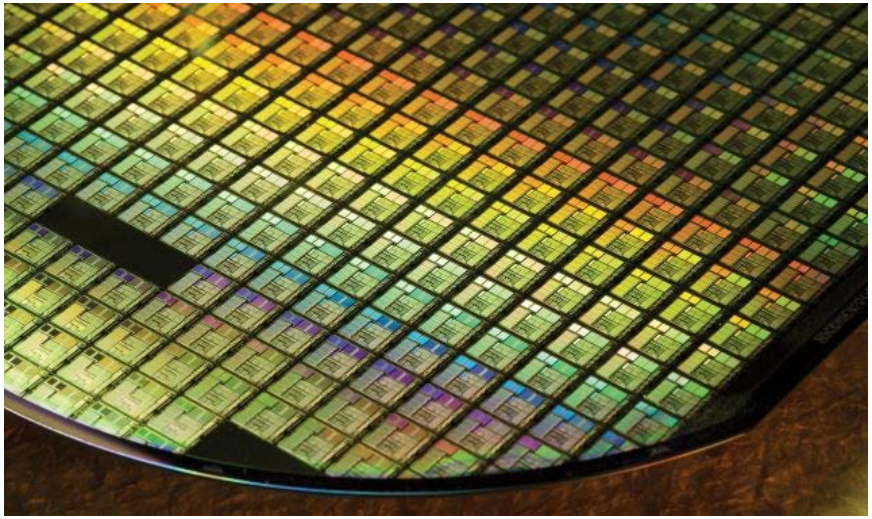
内容 Outline

Extending Moore's Law



继续推进摩尔定律 More Moore



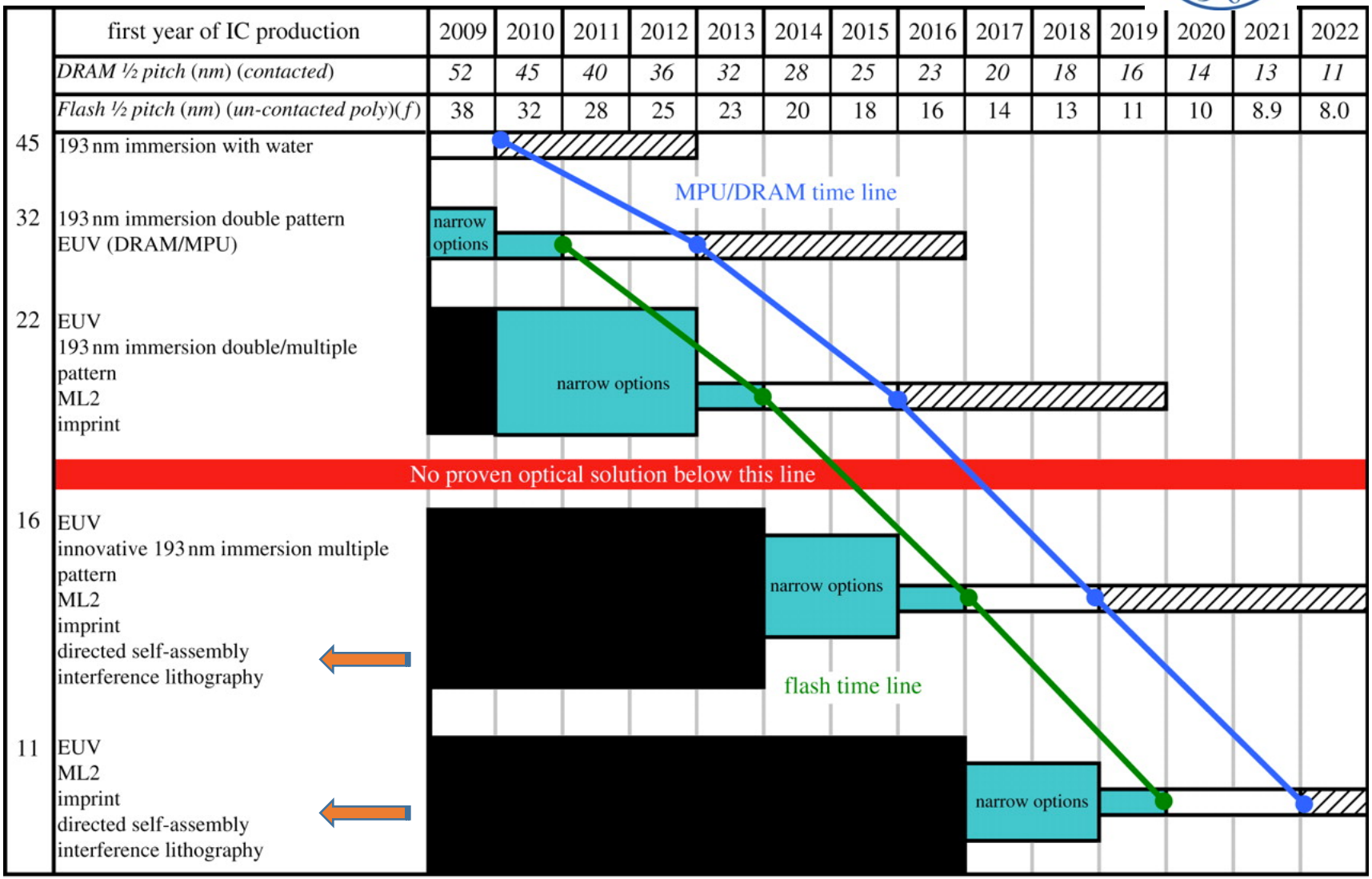


7.5 Billion people in the world

- **> 5 Billion transistors per CPU**
- **100's of CPU per wafer**

At least 100 times more devices on one wafer than there are people in the world （百倍于人类总人数）

国际半导体光刻发展路线图 (ITRS Roadmap)



the key indicates the time during which research, development and qualification/pre-production should be taking place for the solution.

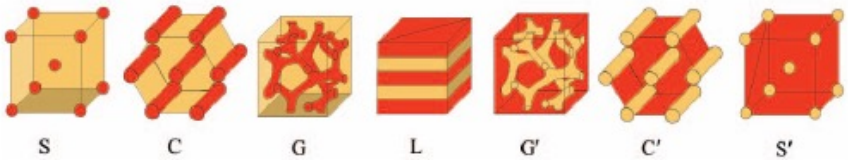
research required
development underway

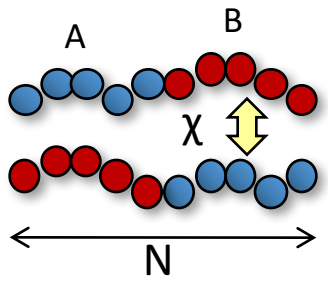
qualification/pre-production
continuous improvement

How does DSA work 工作原理

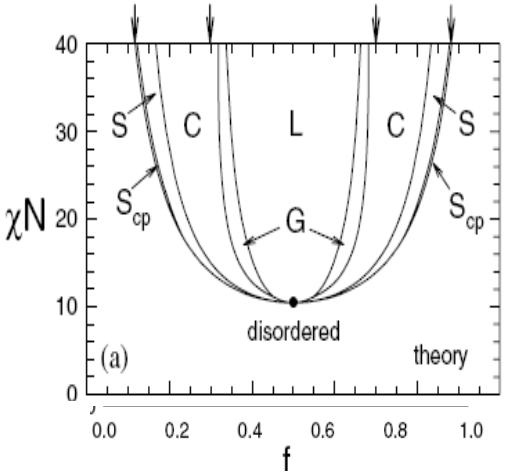
宏观相分离 Macrophase separation

Oil + Water



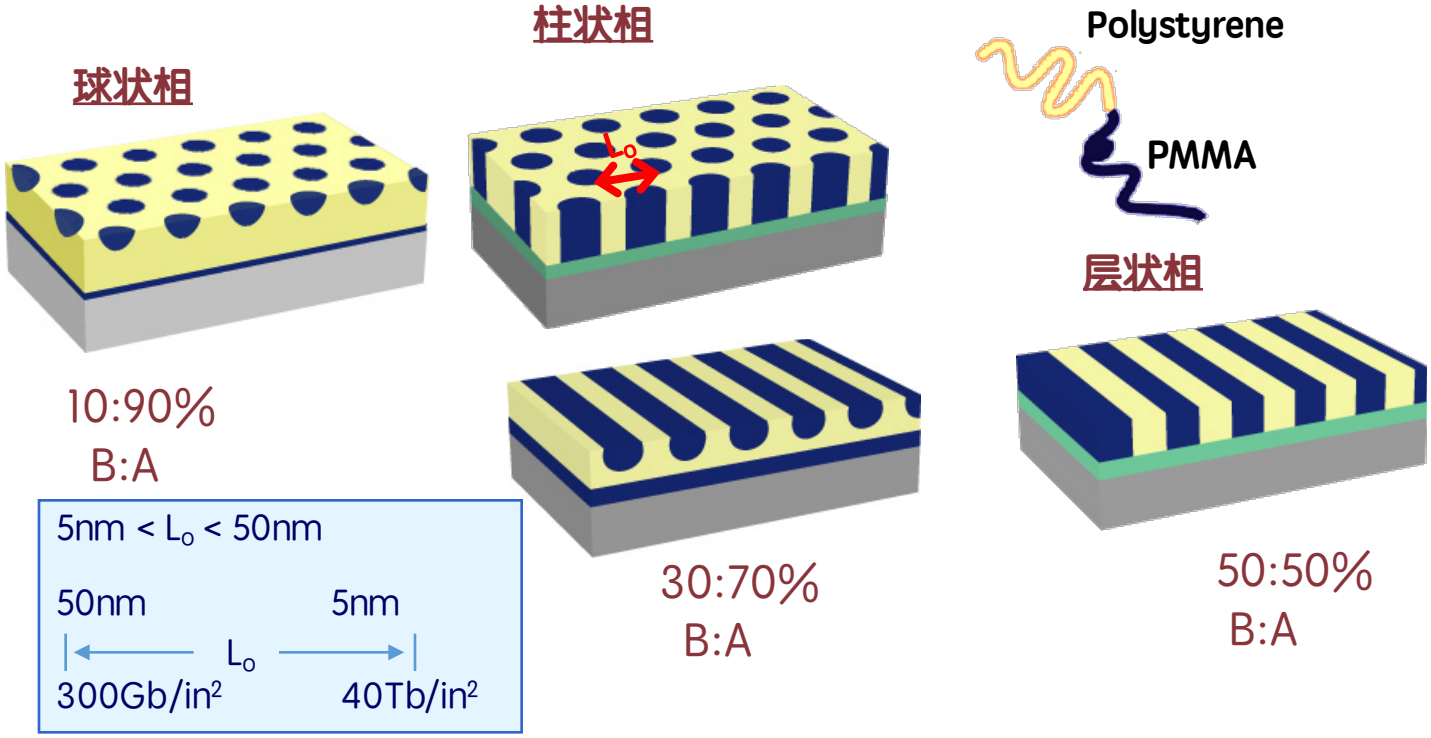


微观相分离
Microphase separation



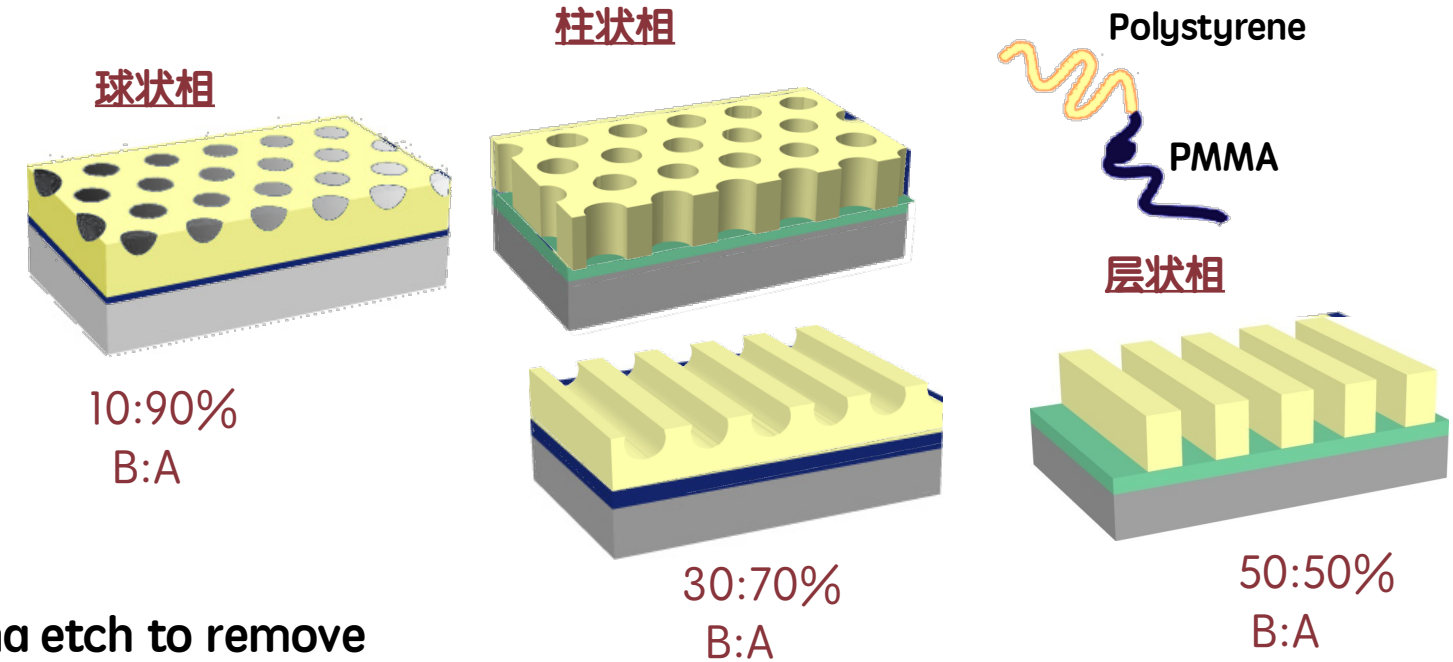
Directed self-assembly 自组装工艺

嵌段高分子共聚物薄膜
Block copolymer thin film



目标: 嵌段共聚物具有光刻胶的功能

Directed self-assembly 自组装工艺

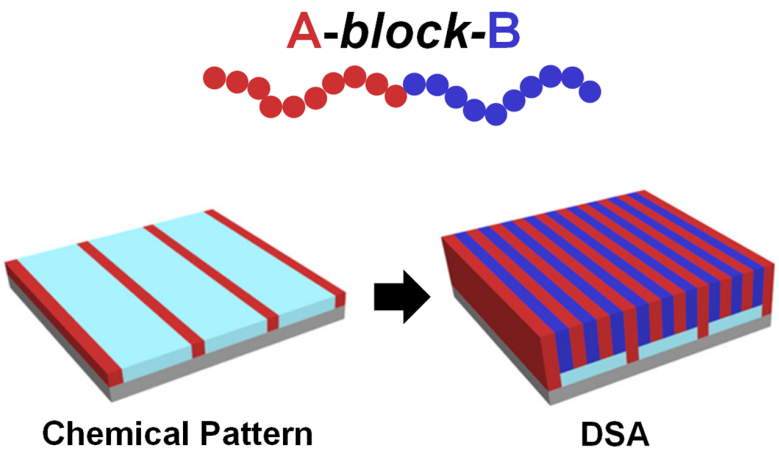


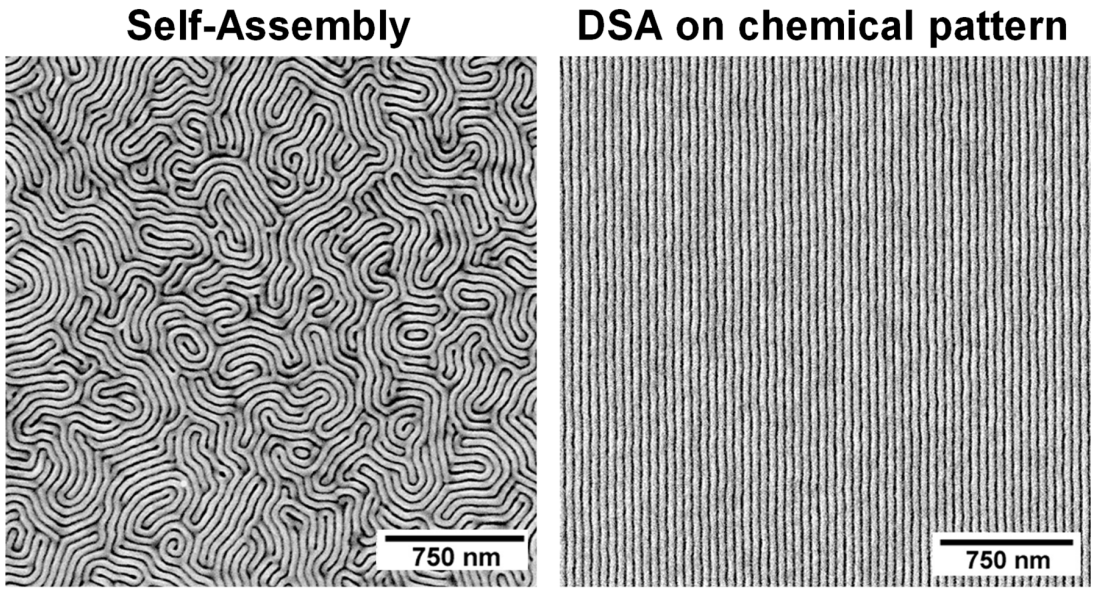
Plasma etch to remove one domain

目标: 嵌段共聚物具有光刻胶的功能

Directed self-assembly 自组装工艺

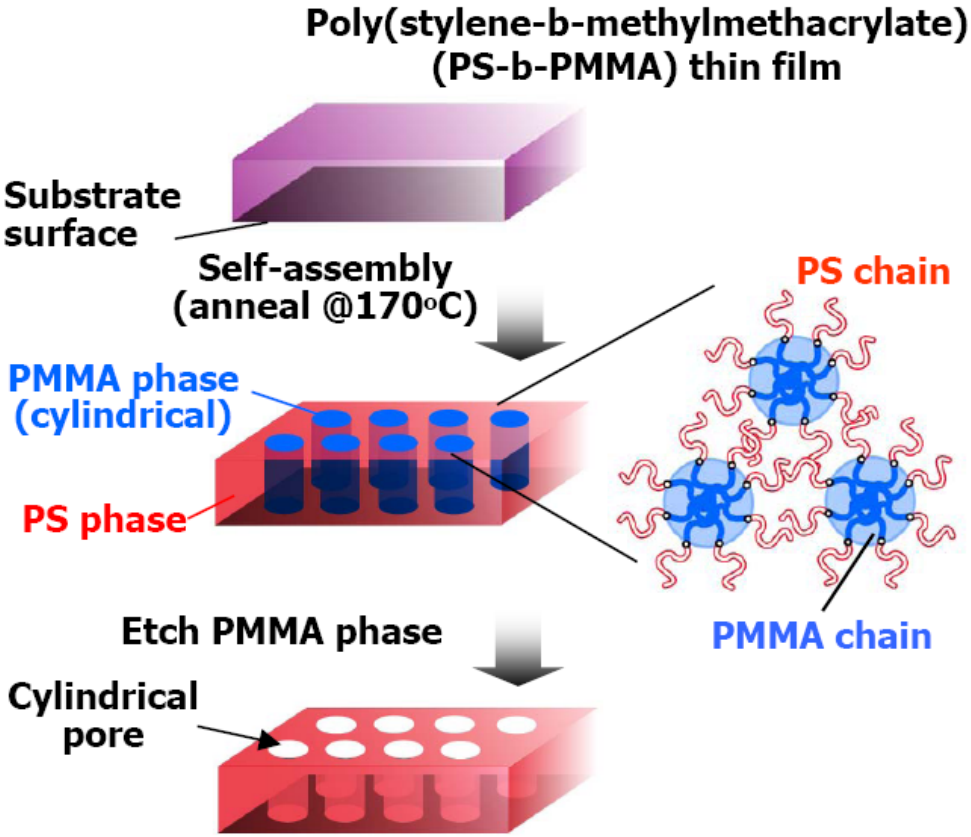
嵌段高分子共聚物薄膜(层状相)
Block copolymer thin film (Lamellae)

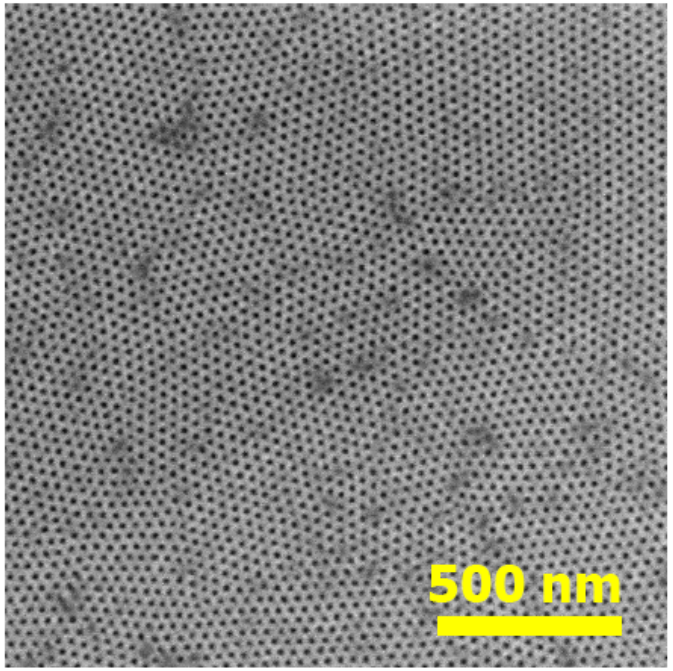




热退火：导向自组装（Nealey et. al. Nature 2003）

Directed self-assembly 自组装工艺

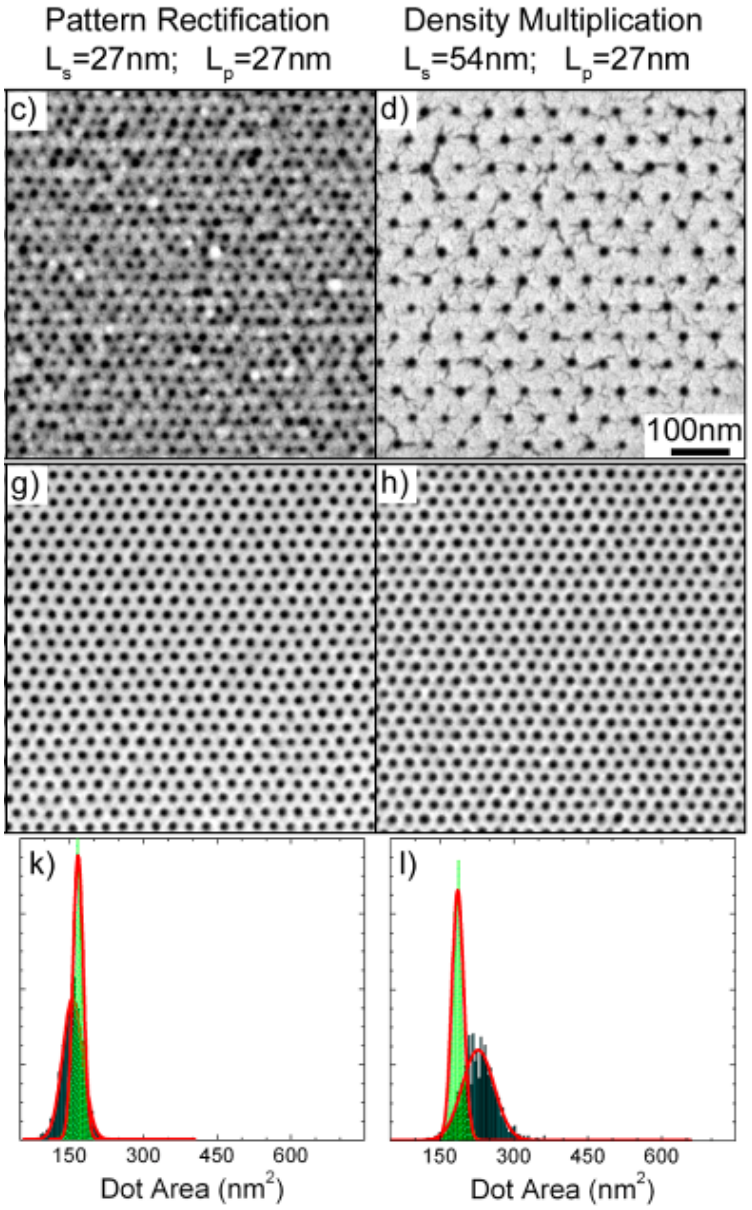




- Short range order: hexagonal close-pack
- Long range: disordered (without guiding)

10

Directed self-assembly 自组装工艺



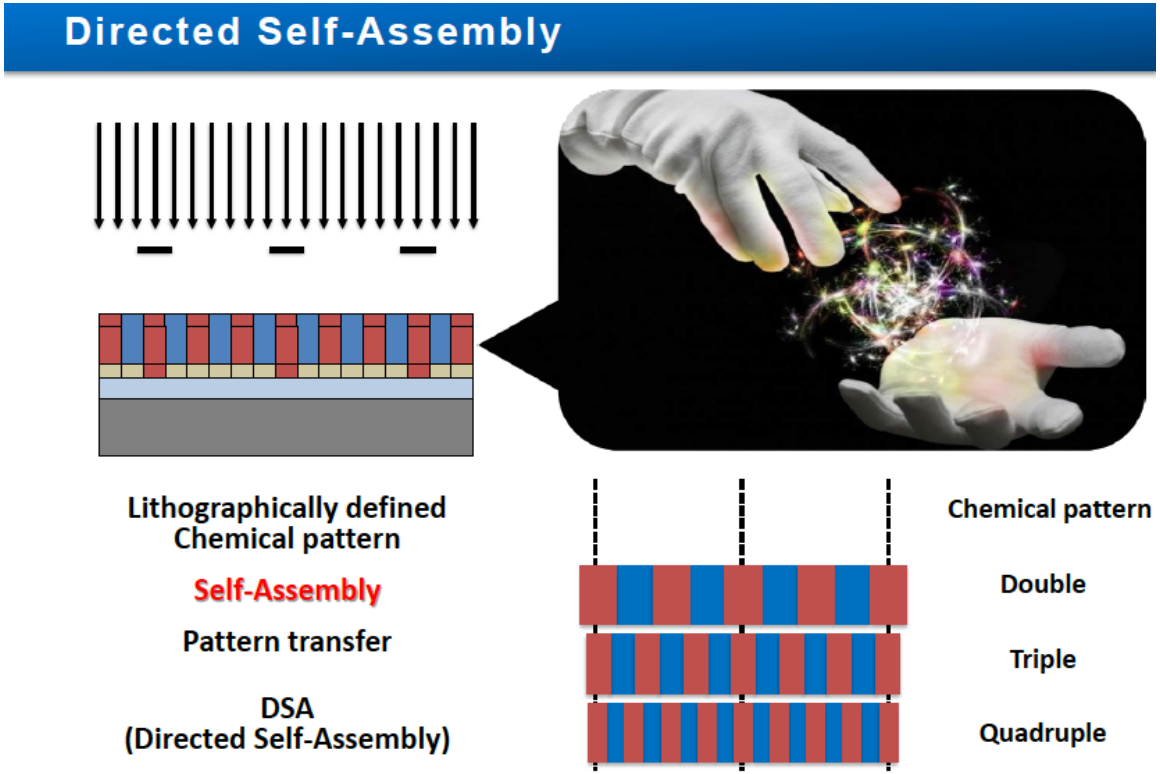
Advantages of block copolymer directed self-assembly:

- Improved island uniformity
- Improved placement tolerance
- Density multiplication
  - beyond e-beam resolution
  - saves exposure time
- Compatible with circular tracks

(1000 Gb/in^2)

R. Ruiz, H. Kang, F. A. Detcheverry, E. Dobisz, D. S. Kercher, T. R. Albrecht, J. J. de Pablo, P. F. Nealey, **Science 2008**, 321, 936.

My DSA Journey 研究回顾

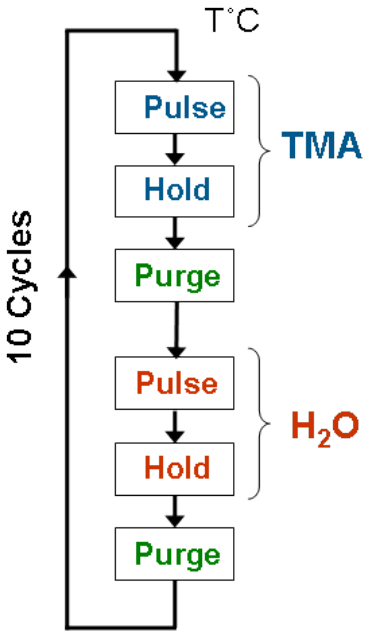


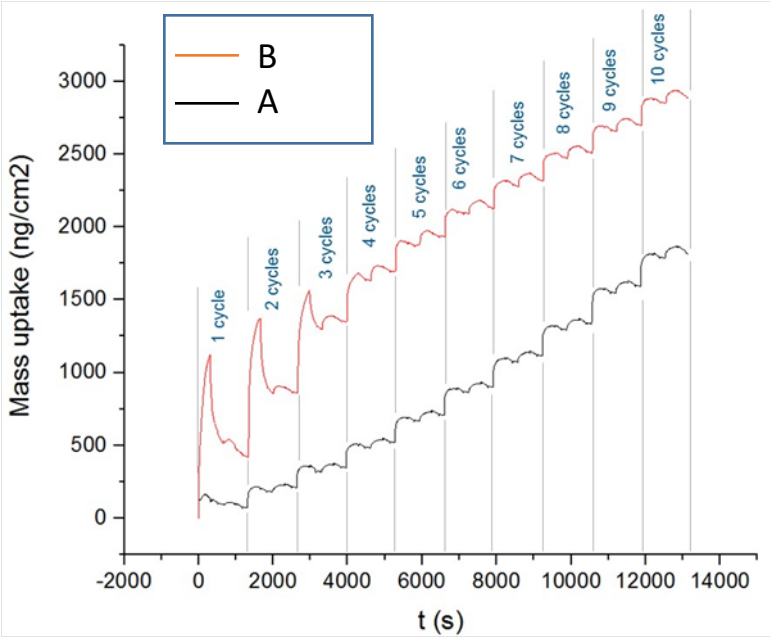
A downscaling story:

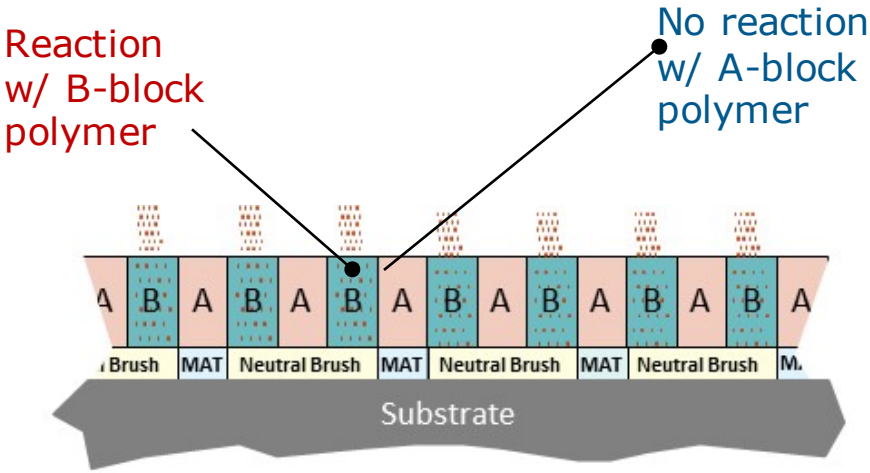
10nm,
9nm,
8nm,
6nm,
5nm,
…

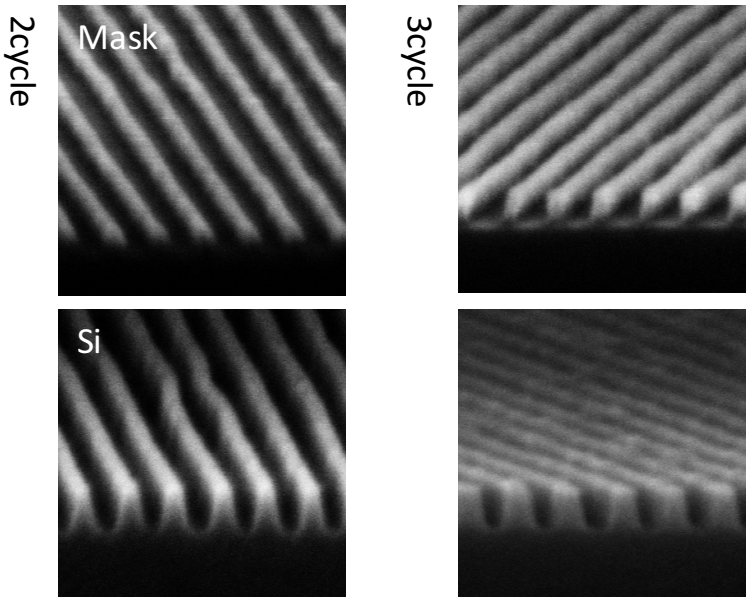
基于high Chi polymer，降低分子量，逐步缩小图案尺寸！

Making a hard mask using SIS

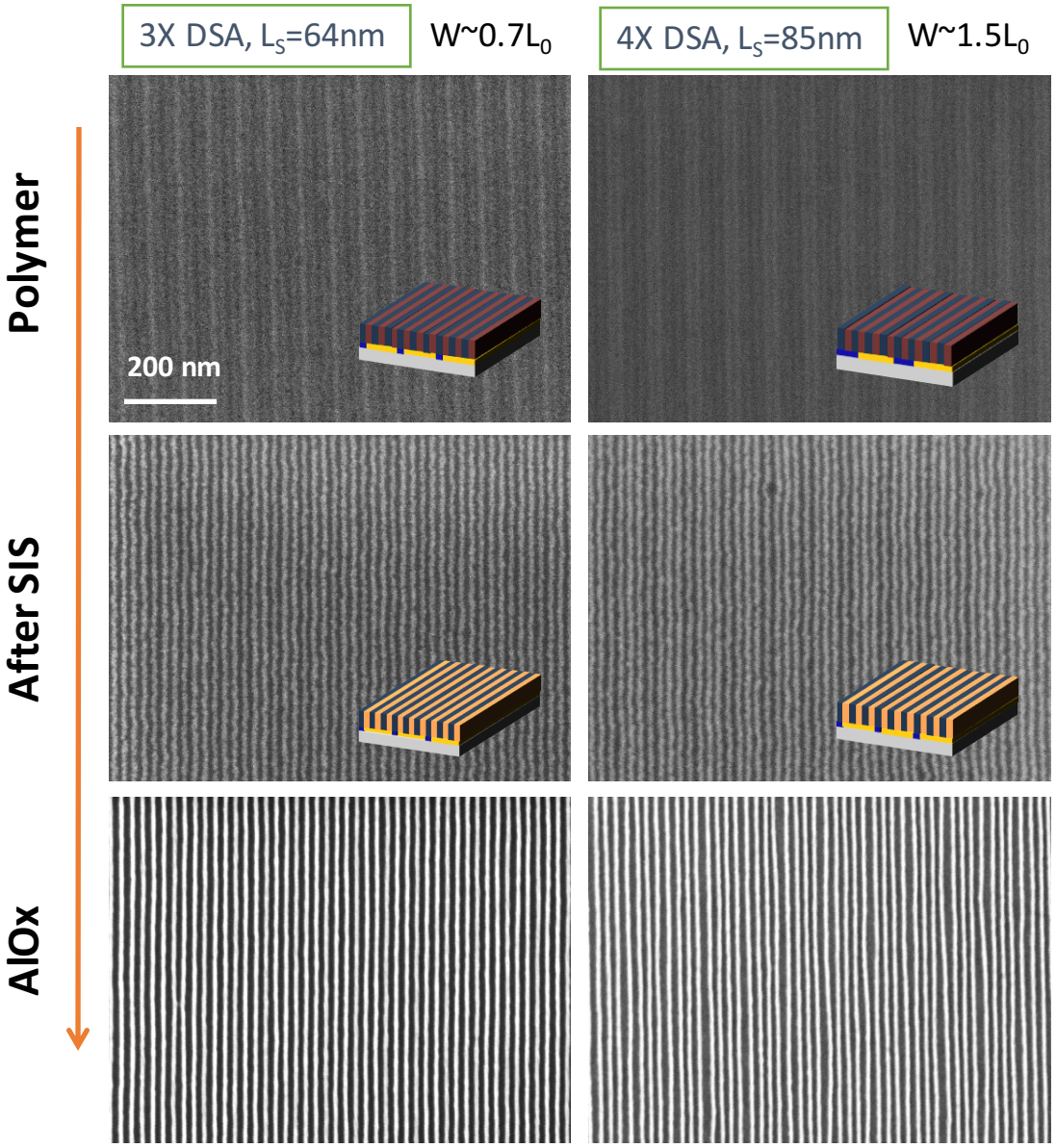


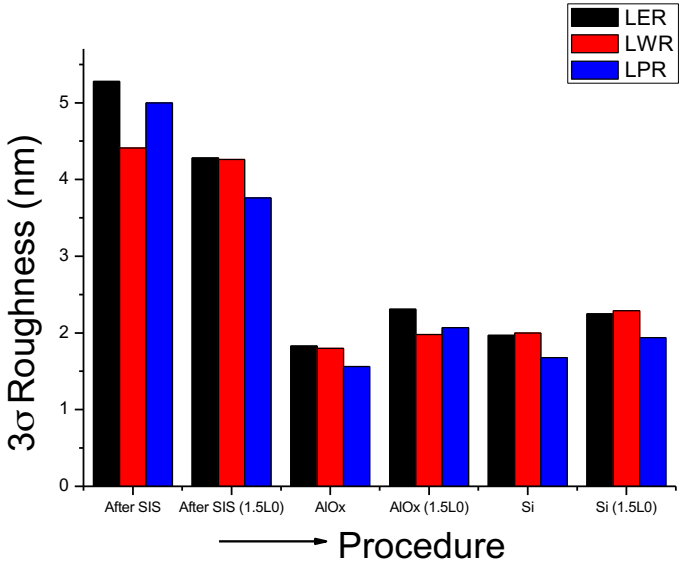


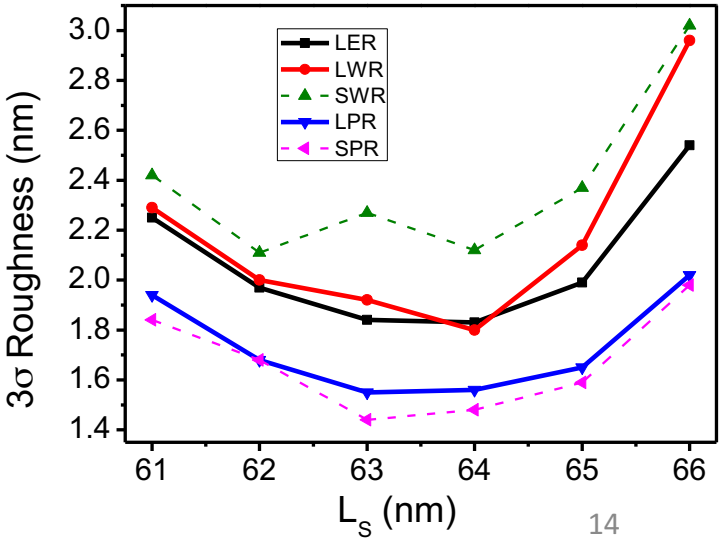




DSA w/two different guiding strategies



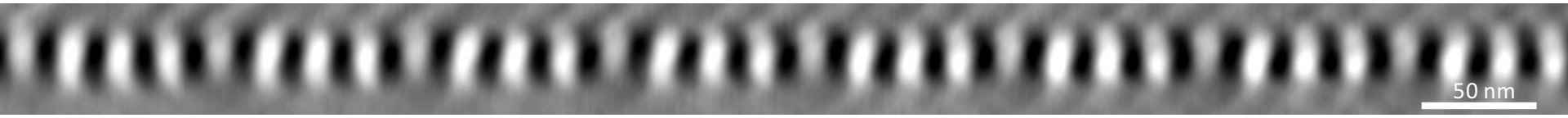




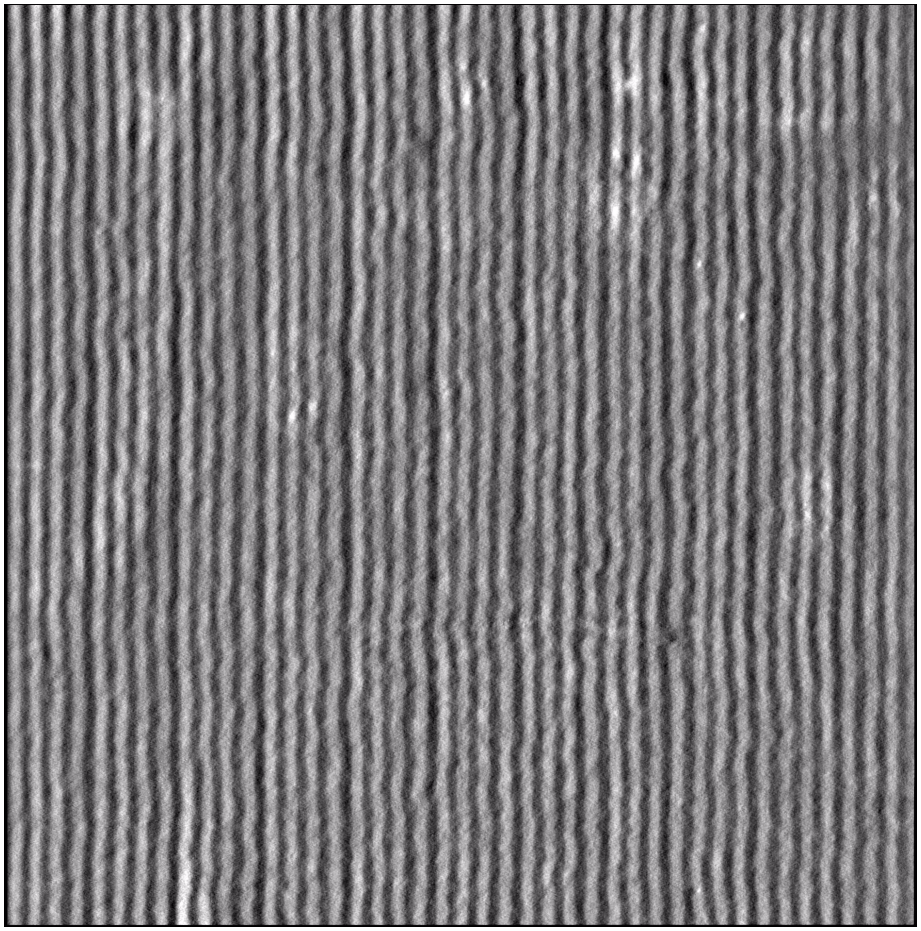
3D characterization by TEM tomography

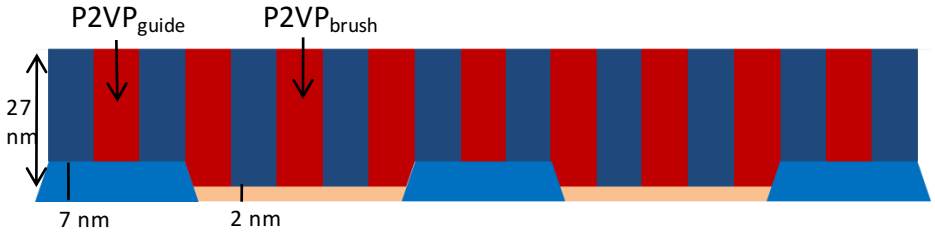
L_0=21.3 nm, 4X density multiplication, W=1.5L_0, back filled with short PS brush

Averaged cross section:



Reconstructed structure- movie:



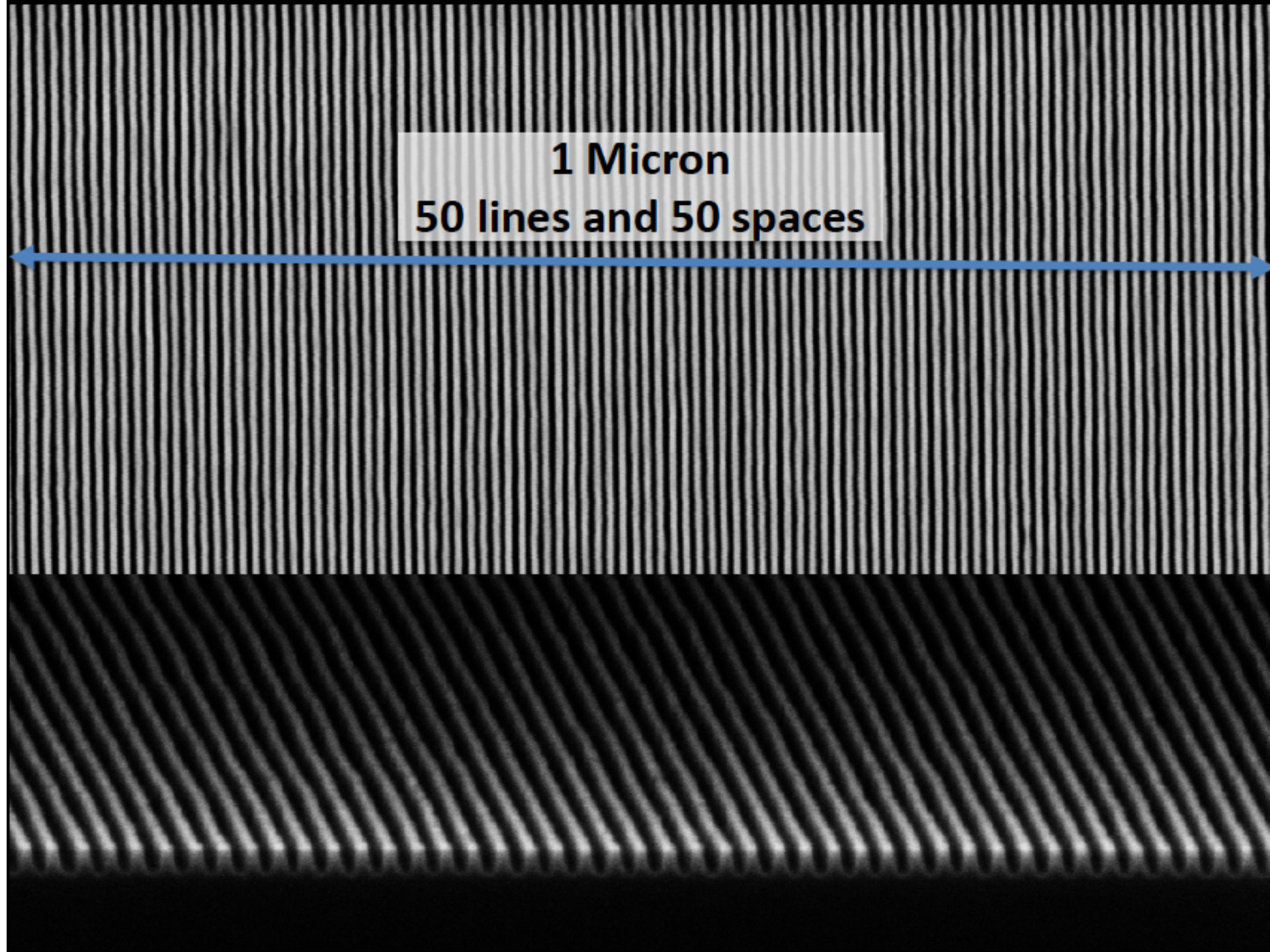


Averaged cross section analysis:

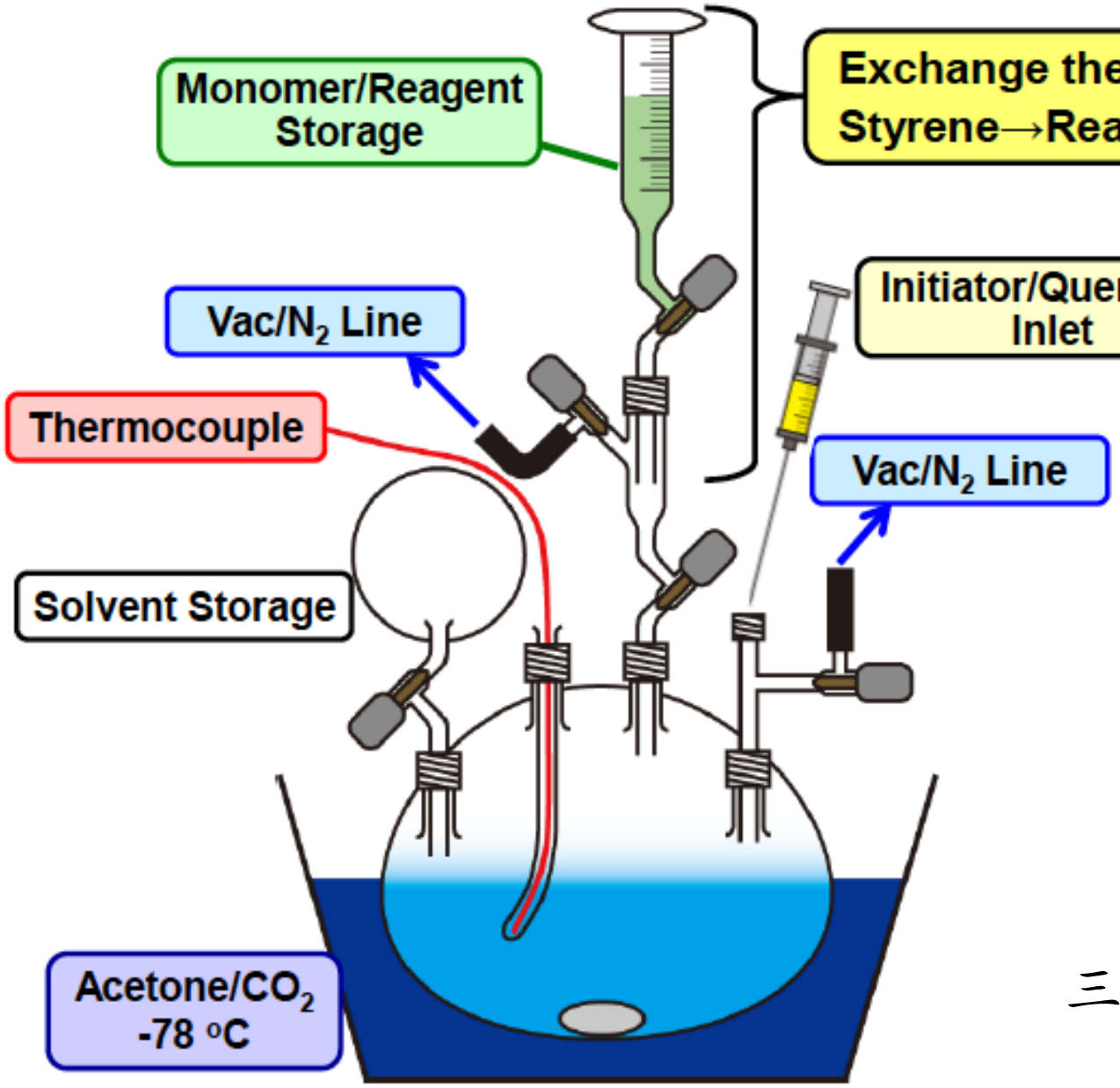
- P2VP$_{guide}$ lamellae are ~ 5 nm shorter than P2VP$_{brush}$, in good agreement with the height difference in the chemical pattern.
- FWHM of P2VP$_{brush}$ width= 11.5 nm

  FWHM of P2VP$_{guide}$ width= 12.5 nm

  This indicates the LER of P2VP$_{guide}$ is larger than P2VP$_{brush}$. Analysis of the entire 3D structure is currently conducted.


1 Micron
50 lines and 50 spaces

Polymerization System: Shlenk System with Inert Gas (N_2)



阴离子聚合

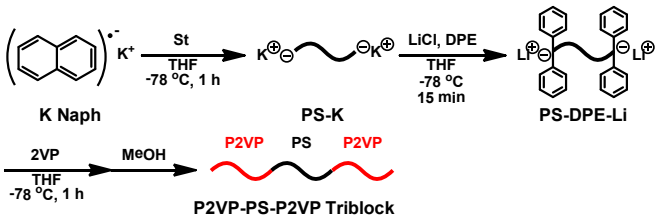
降低分子量

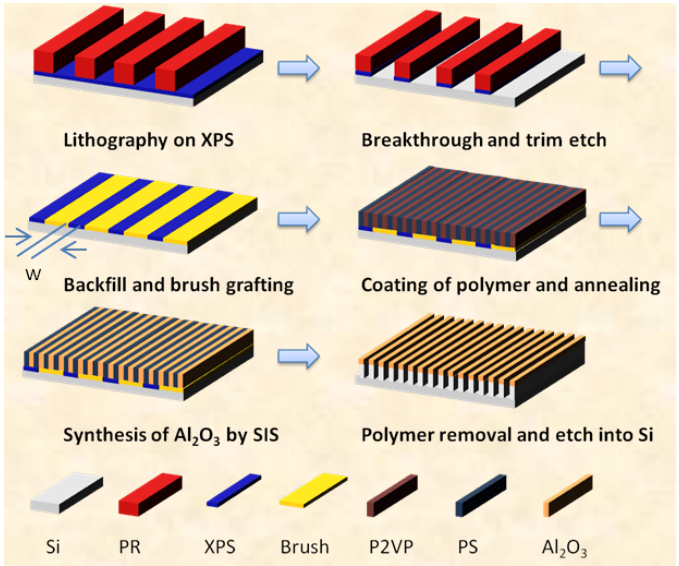
三嵌段高分子共聚物

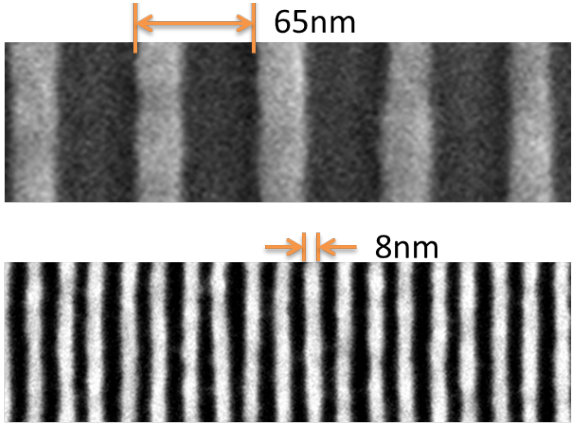
ACSNANO
www.acsnano.org
ARTICLE

Directed Self-Assembly of Triblock Copolymer on Chemical Patterns for Sub-10-nm Nanofabrication *via* Solvent Annealing

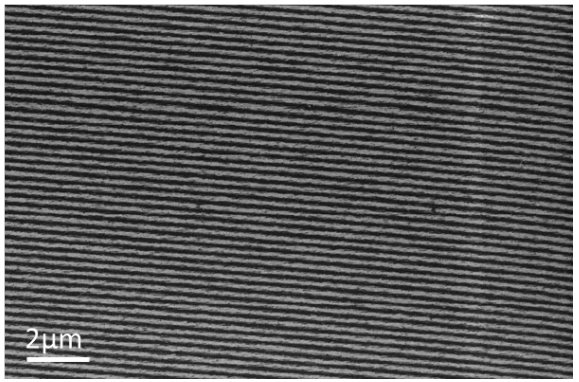
Shisheng Xiong,[†] Lei Wan,[‡] Yoshihito Ishida,[†,§] Yves-Andre Chapuis,[‡,⊥] Gordon S. W. Craig,[†] Ricardo Ruiz,[‡] and Paul F. Nealey*[,†]



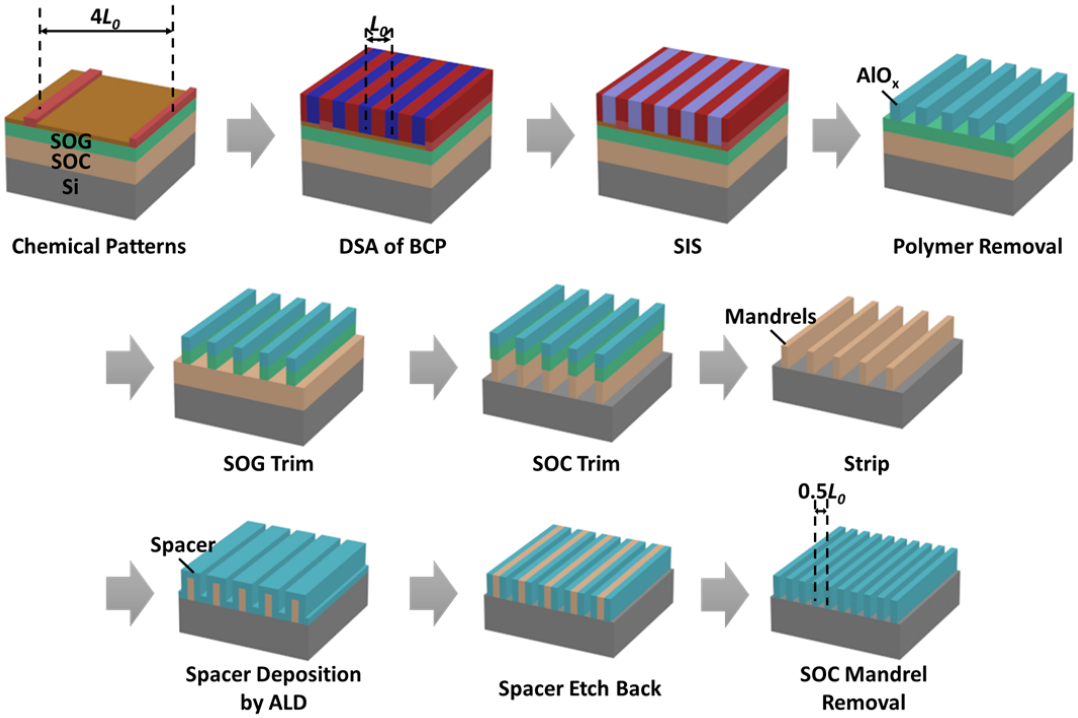


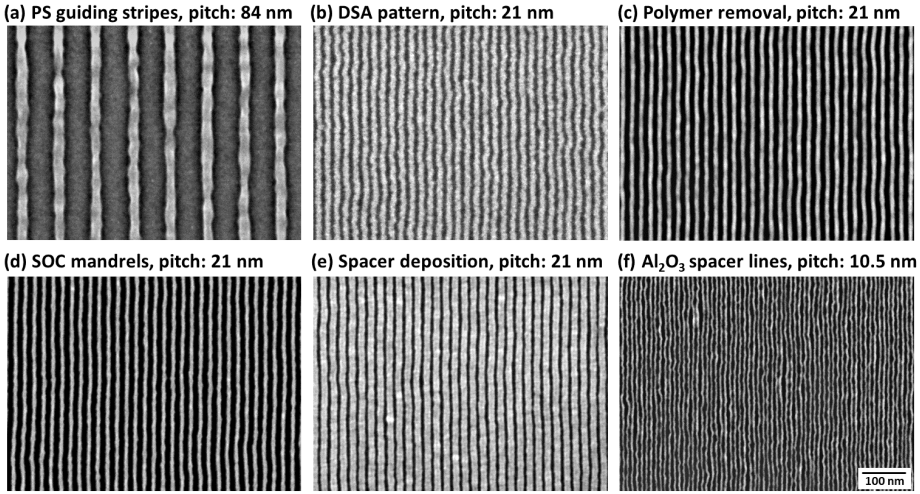


b

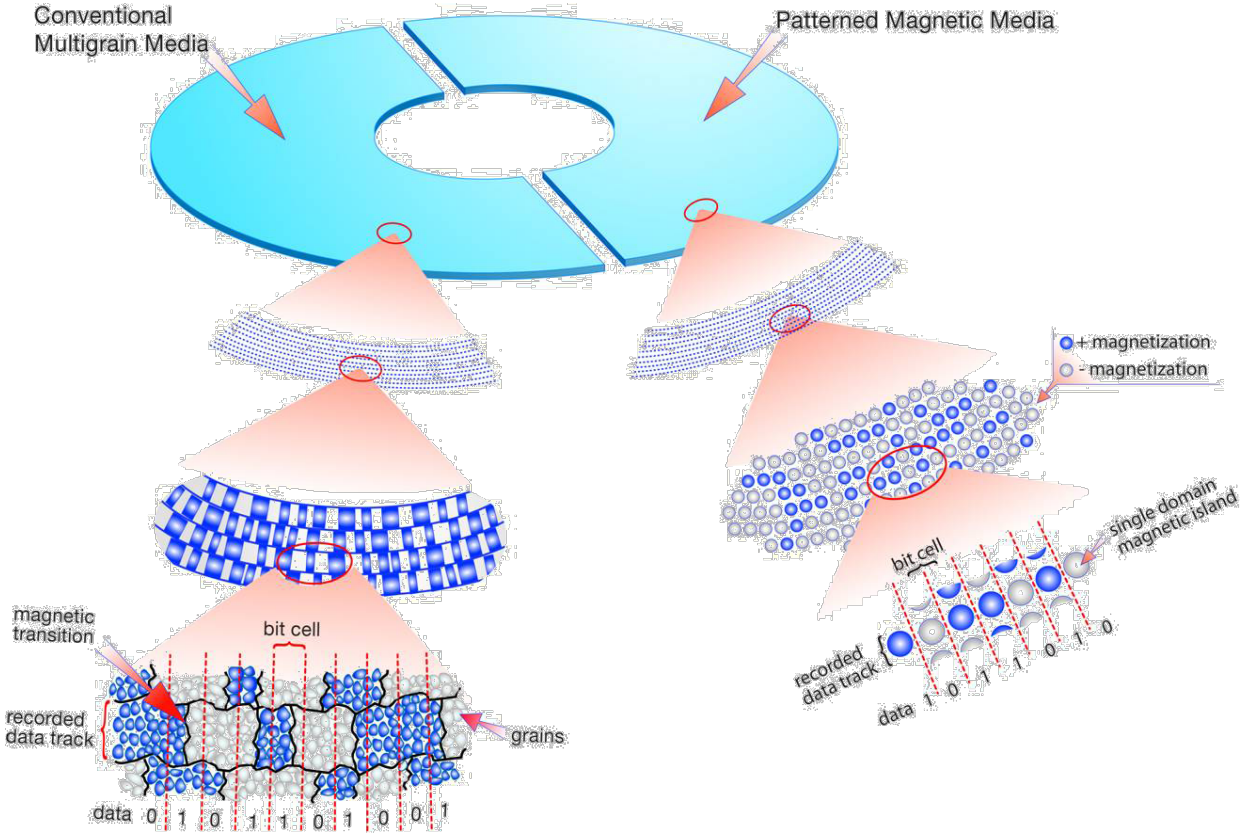


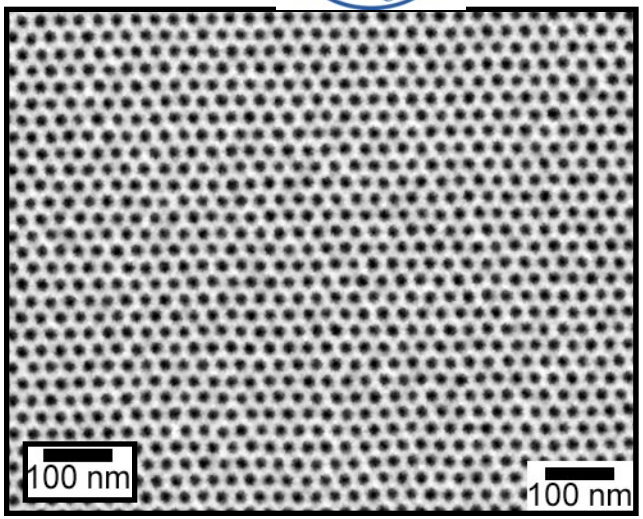
DSA+SADP for 5nm lithography!





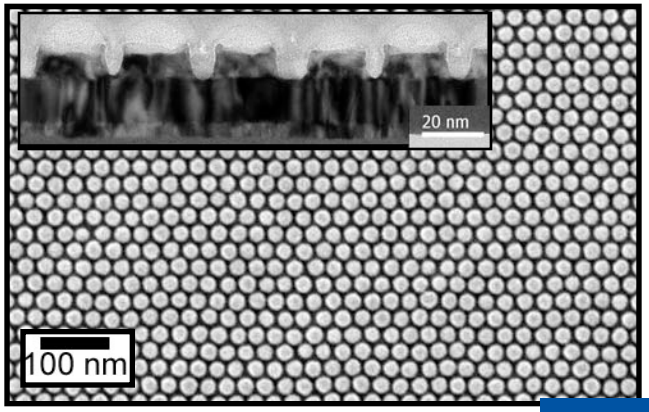
Bit Patterned Media via DSA (w/WD)





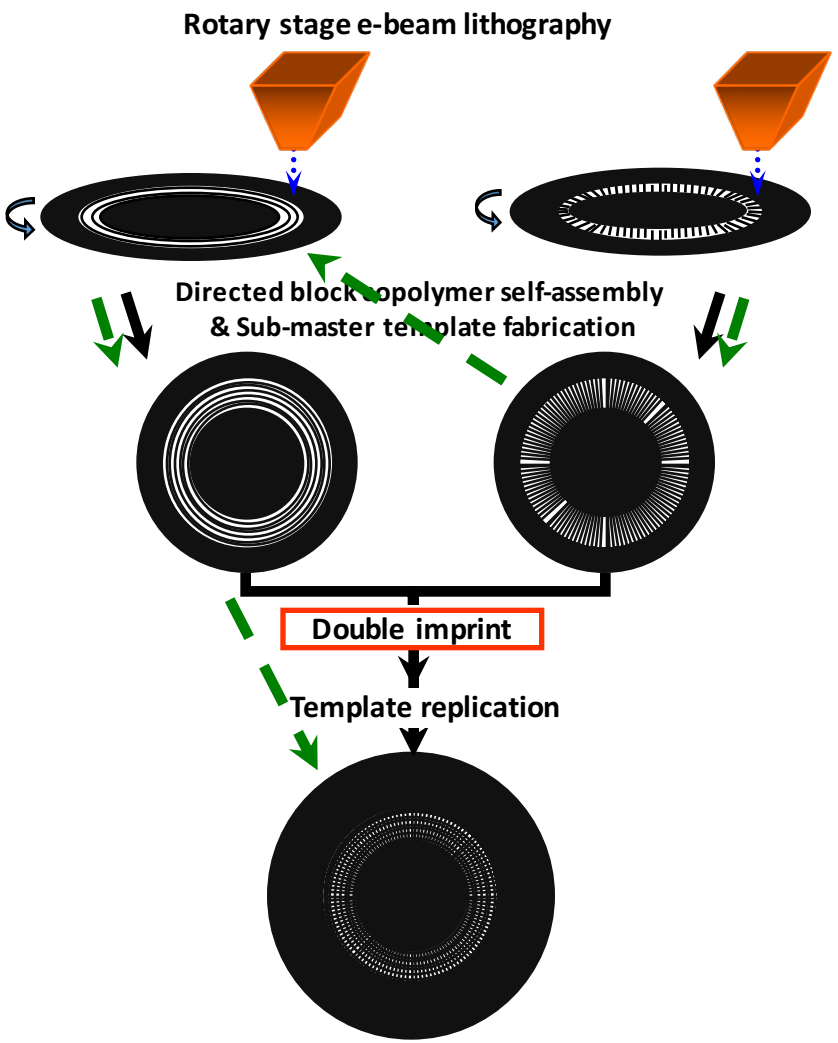
BLOCK COPOLYMER
嵌段高分子自组装图案

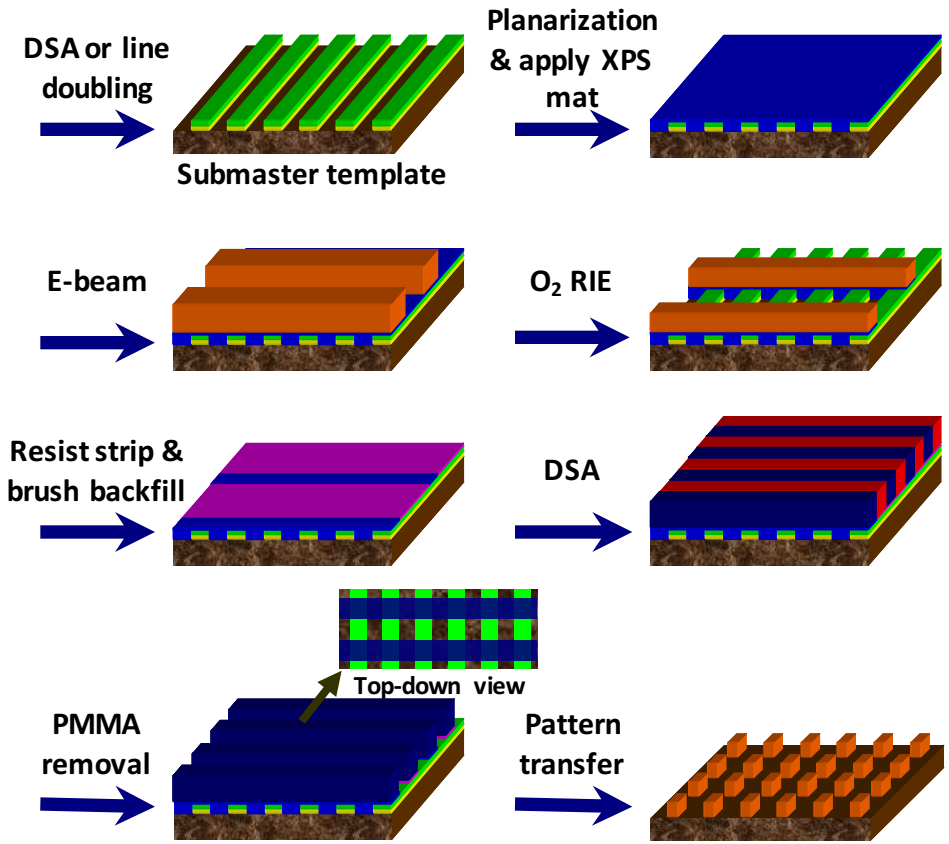
FINISHED MAG ISLANDS 磁介质图案



The semiconductor industry will not provide a lithography solution in time for patterned media

Double DSA 串联自组装工艺

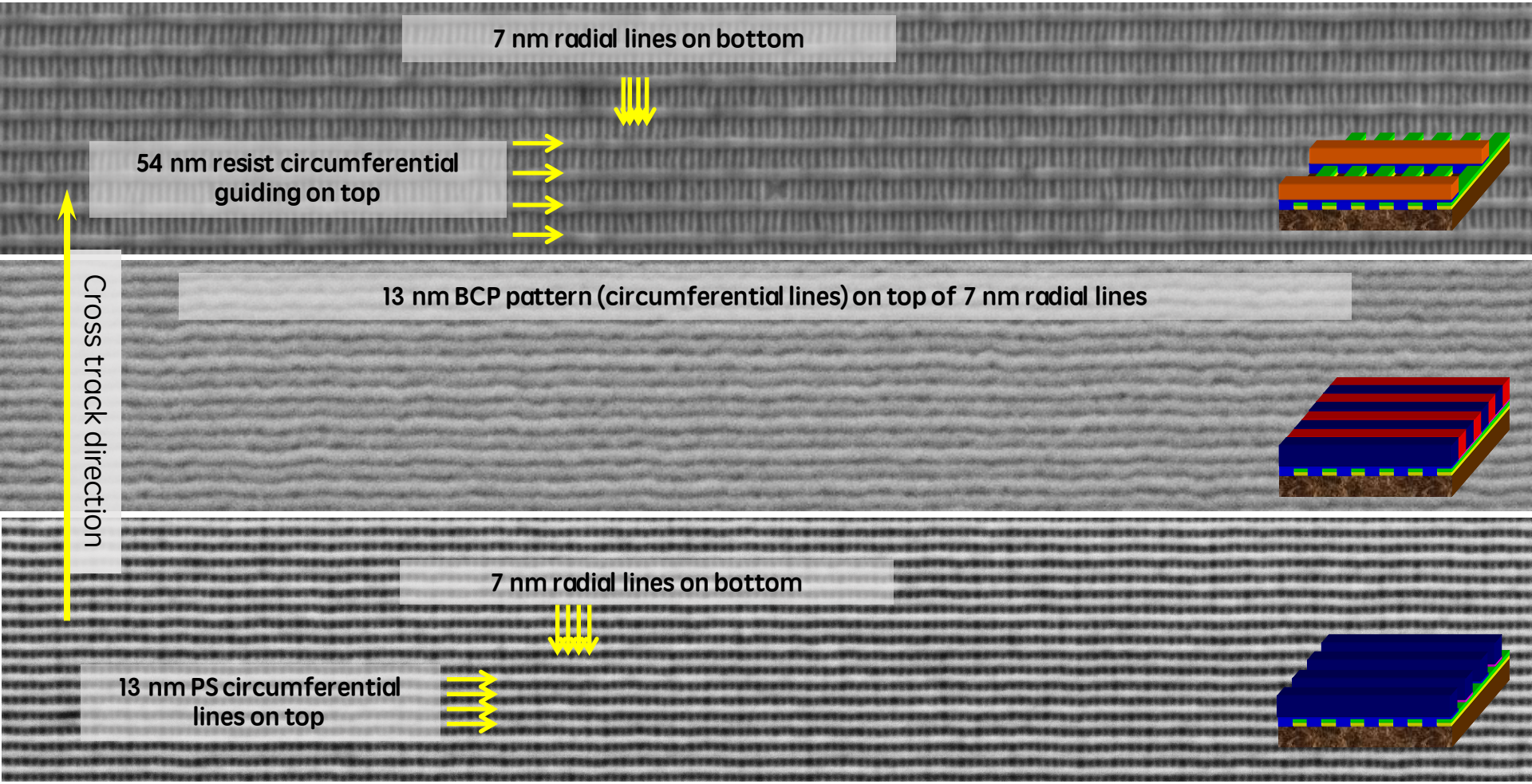




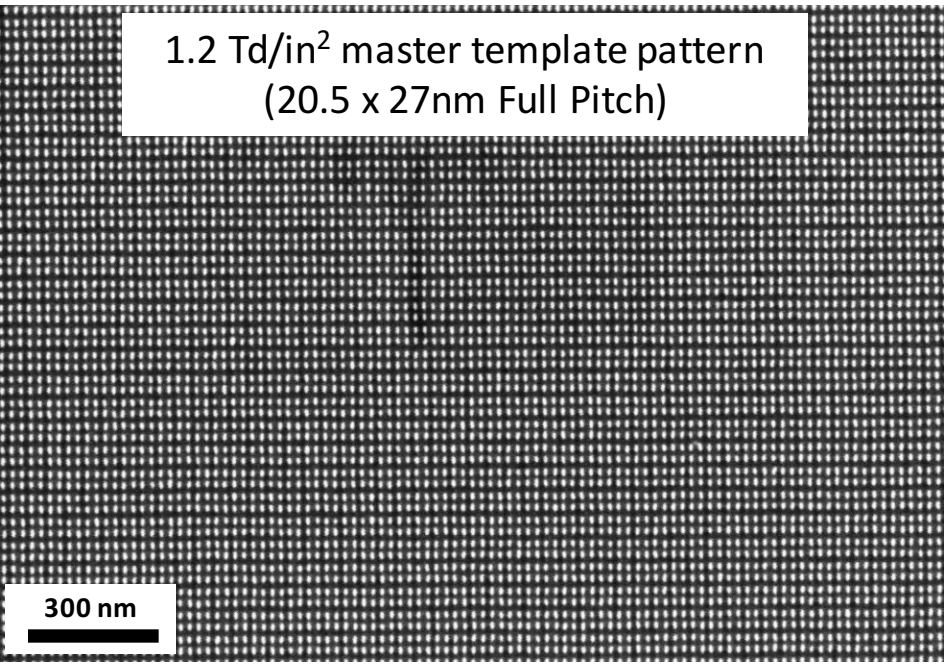
Alternative process flow: linear

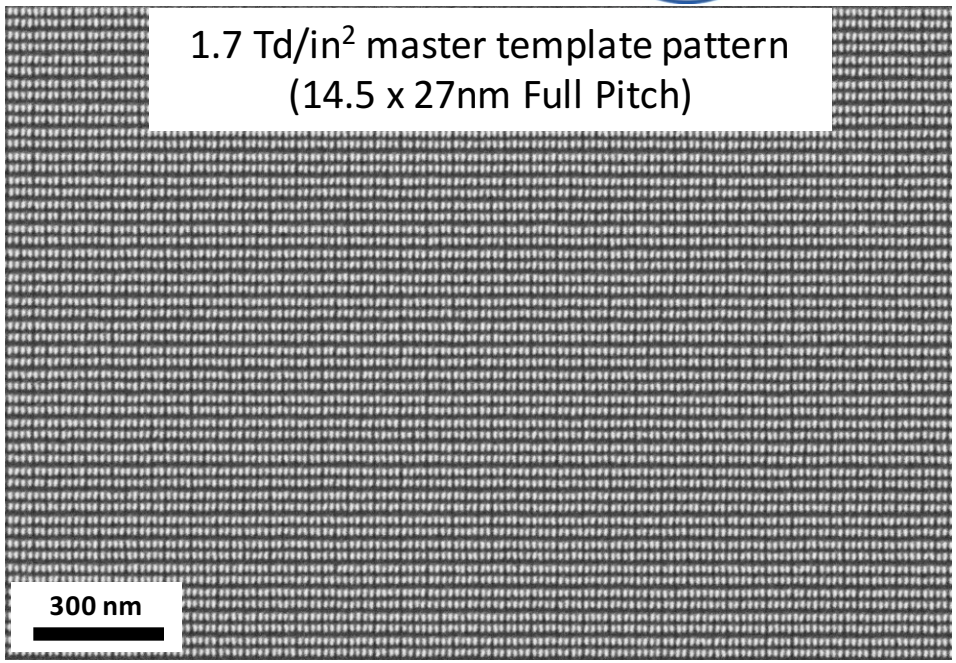
1. DSA/line doubling is robust enough for this high risk process
2. Needs alignment in e-beam tool

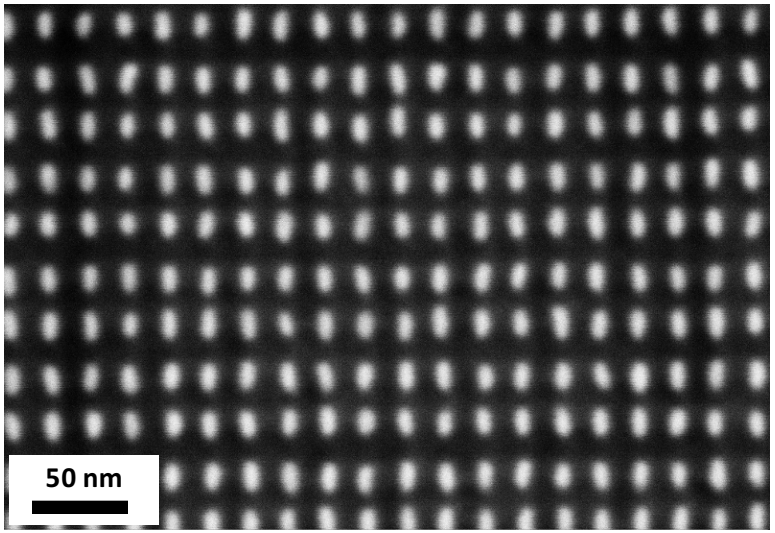
Double DSA 串联自组装工艺

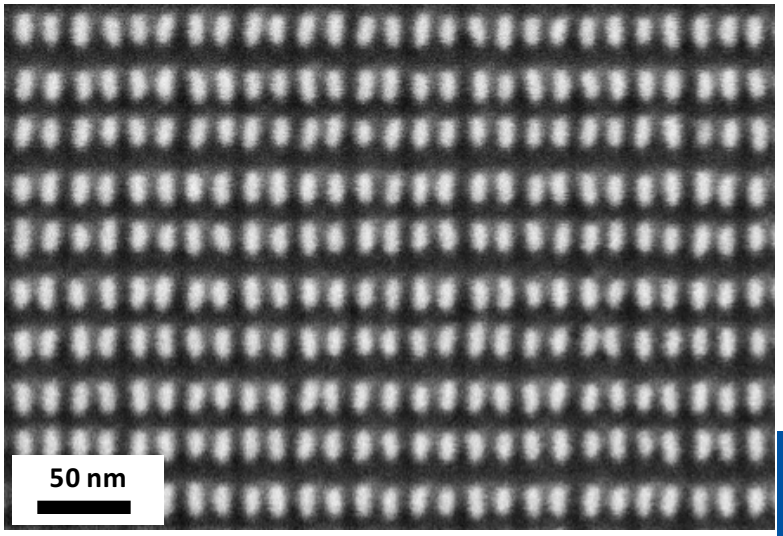


Bit Patterned Media via DSA



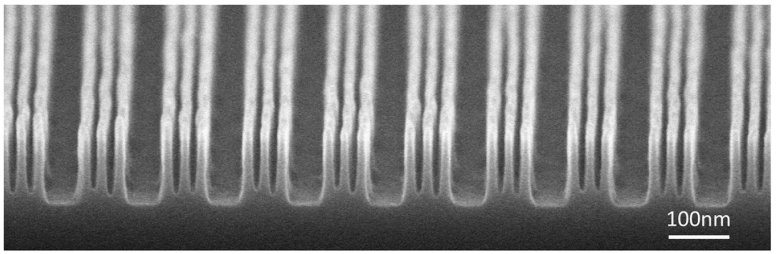




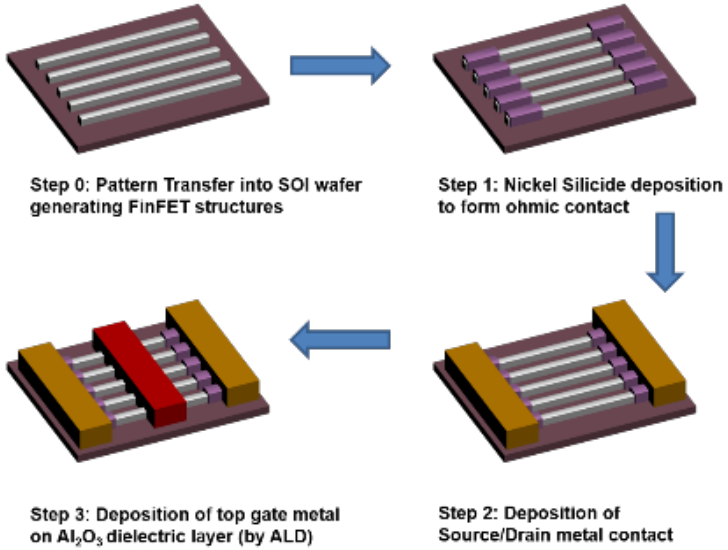


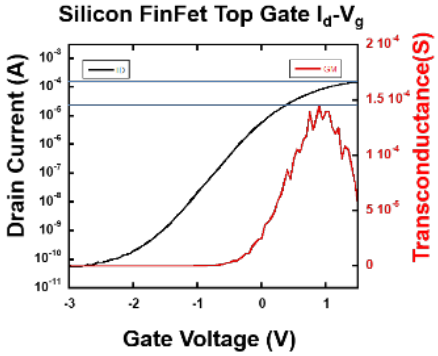
More DSA Applications 应用

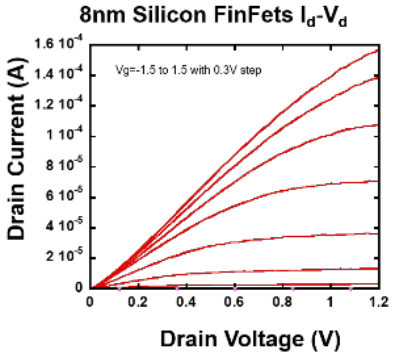
❖微纳电子器件



FinFET 鳍状场效应晶体管







开关比>10^6

参考文献

nature nanotechnology ARTICLES
PUBLISHED ONLINE: 27 MARCH 2017 | DOI: 10.1038/NNANO.2017.34

Sub-10-nm patterning via directed self-assembly of block copolymer films with a vapour-phase deposited topcoat

Hyo Seon Suh[1,2†], Do Han Kim[3†], Priya Moni[3], Shisheng Xiong[1,2], Leonidas E. Ocola[4], Nestor J. Zaluzec[5], Karen K. Gleason[3*] and Paul F. Nealey[1,2*]

ACS Macro Letters Letter
pubs.acs.org/macroletters

Evolutionary Optimization of Directed Self-Assembly of Triblock Copolymers on Chemically Patterned Substrates

Gurdaman S. Khaira,[†] Jian Qin,[†] Grant P. Garner,[†] Shisheng Xiong,[†] Lei Wan,[‡] Ricardo Ruiz,[‡] Heinrich M. Jaeger,[§] Paul F. Nealey,[†,∥] and Juan J. de Pablo[*,†,∥]

Macromolecules Article
pubs.acs.org/Macromolecules

The Solvent Distribution Effect on the Self-Assembly of Symmetric Triblock Copolymers during Solvent Vapor Annealing

Shisheng Xiong,[*,†] Dongxue Li,[‡] Su-Mi Hur,[∥] Gordon S. W. Craig,[§] Christopher G. Arges,[⊥] Xin-Ping Qu,[‡] and Paul F. Nealey[*,§]

NANO LETTERS Letter
pubs.acs.org/NanoLett

InAs Nanowires Grown by Metal–Organic Vapor-Phase Epitaxy (MOVPE) Employing PS/PMMA Diblock Copolymer Nanopatterning

Yinggang Huang,[†] Tae Wan Kim,[†] Shisheng Xiong,[‡] Luke J. Mawst,[*,†] Thomas F. Kuech,[‡] Paul F. Nealey,[†] Yushuai Dai,[§] Zihao Wang,[§] Wei Guo,[§] David Forbes,[§] Seth M. Hubbard,[§] and Michael Nesnidal[∥]

ACSNANO www.acsnano.org ARTICLE

Quantitative Three-Dimensional Characterization of Block Copolymer Directed Self-Assembly on Combined Chemical and Topographical Prepatterned Templates

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Directed Self-Assembly of Triblock Copolymer on Chemical Patterns for Sub-10-nm Nanofabrication *via* Solvent Annealing

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Pathways to Mesoporous Resin/Carbon Thin Films with Alternating Gyroid Morphology

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Directed Self-Assembly of Polystyrene-*b*-poly(propylene carbonate) on Chemical Patterns via Thermal Annealing for Next Generation Lithography

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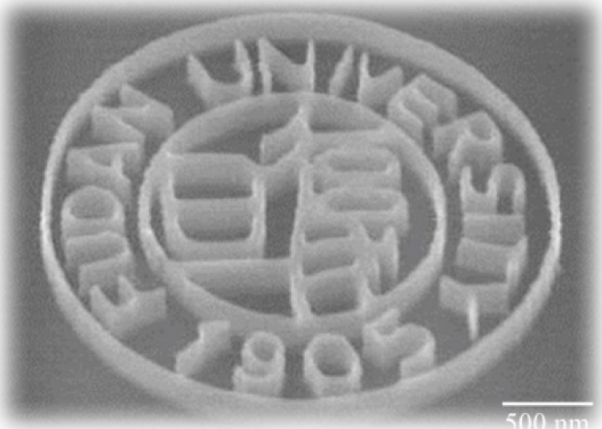

Thank you!

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