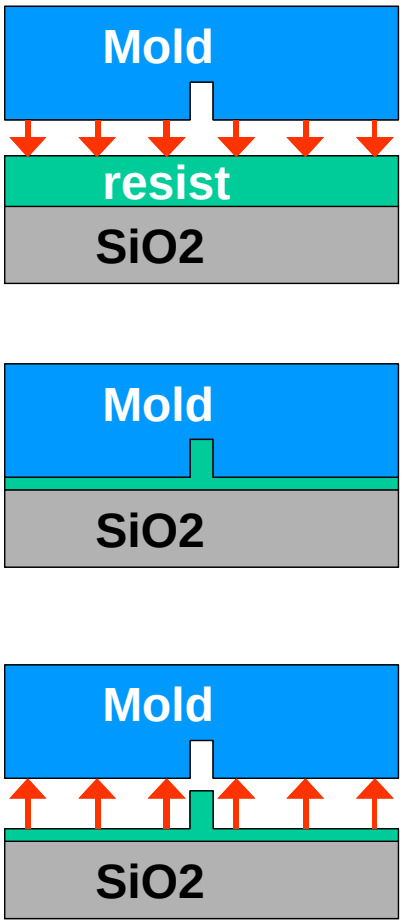
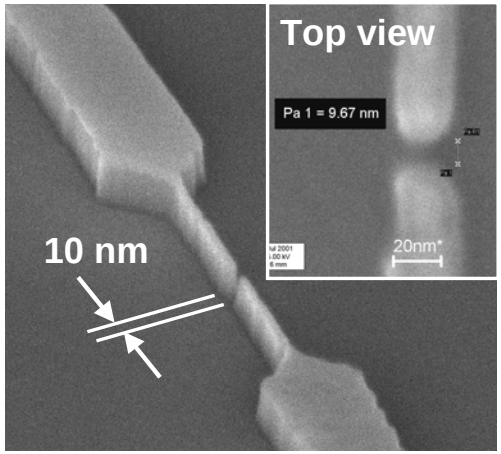
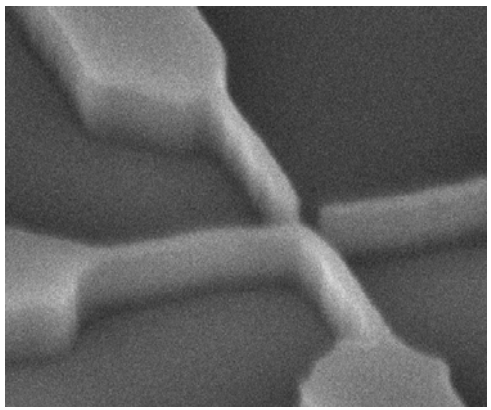
Nanocontacts (6 nm) for Molecular Devices

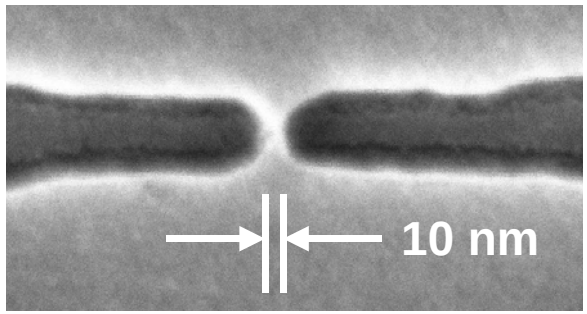


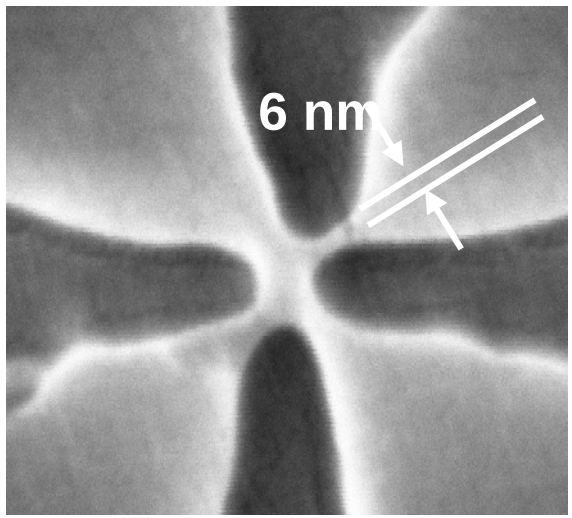
NIL Molds



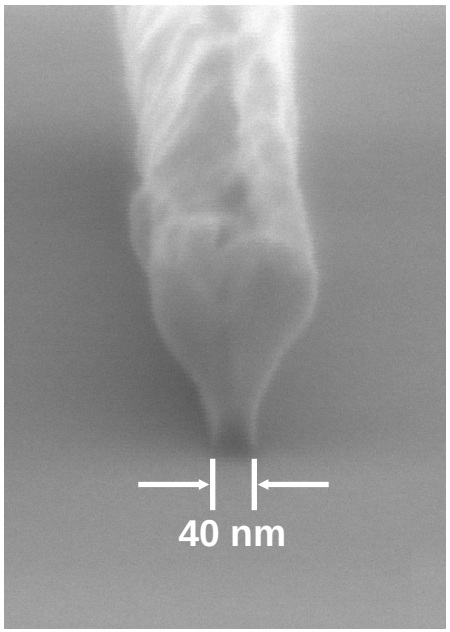


Imprints



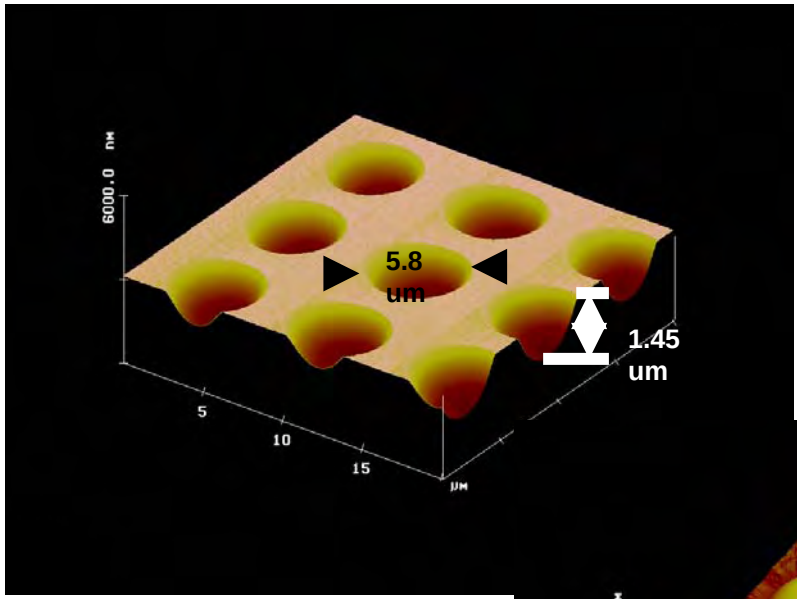


3D Complex Structure Patterning by Nanoimprint



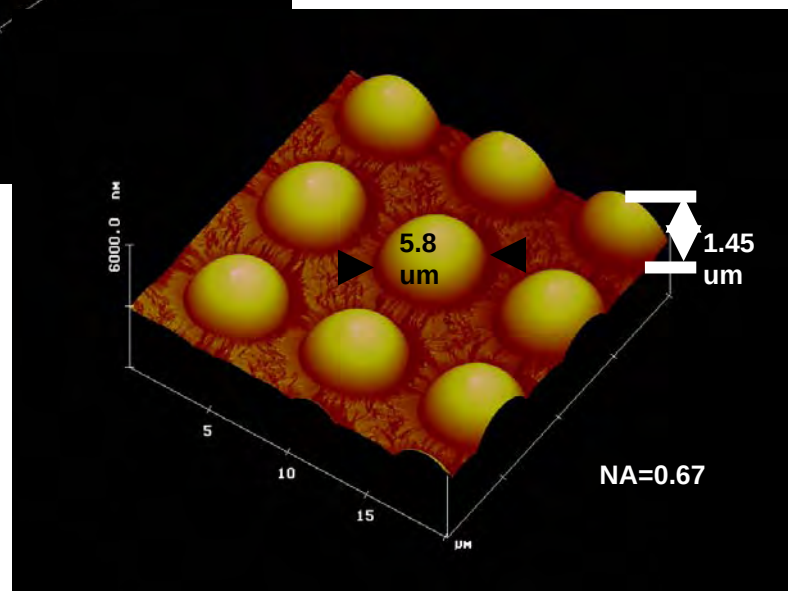
T-Gate (Imprint & Lift-off) (2001)

Li, Chen, Chou, "Direct three-dimensional patterning using nanoimprint lithography," *Applied Physics Letters,* 78 (2001) 3322

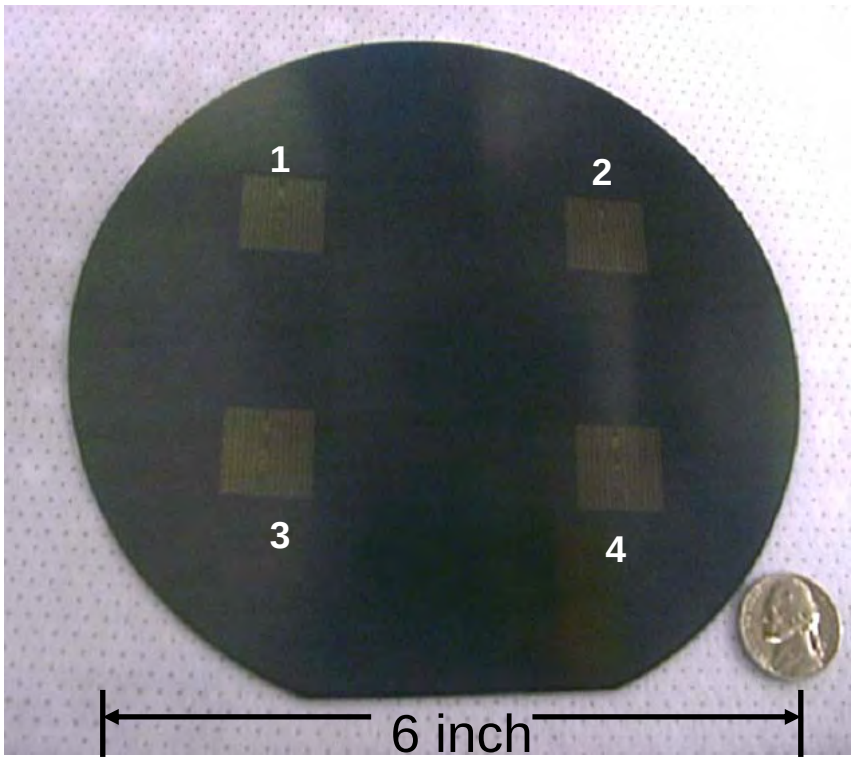


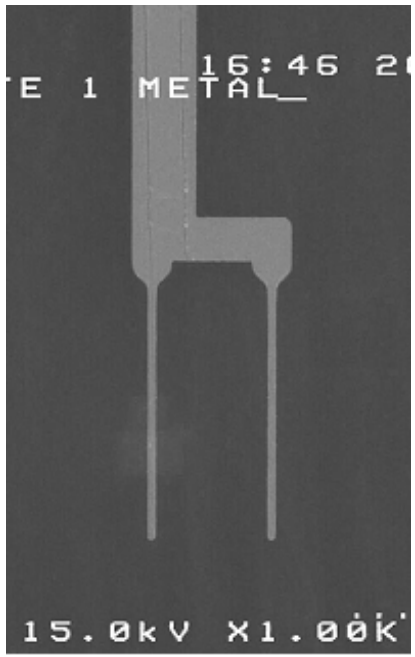
Mold

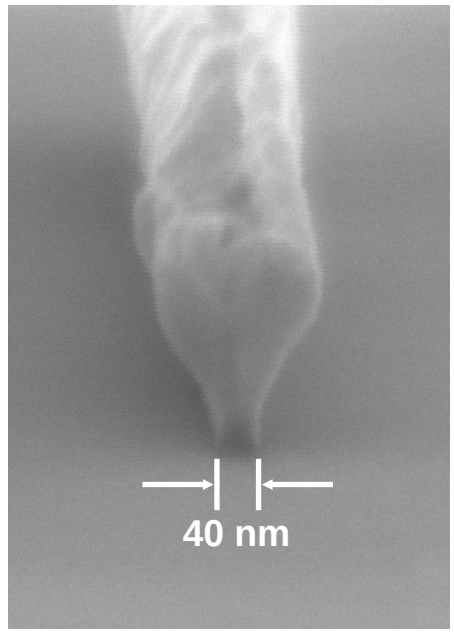
Direct Imprinted Lens Array



Low-Cost, High-Throughput Manufacturing of High Frequency Circuits By Nanoimprint Lithography







Entire 6” Wafer

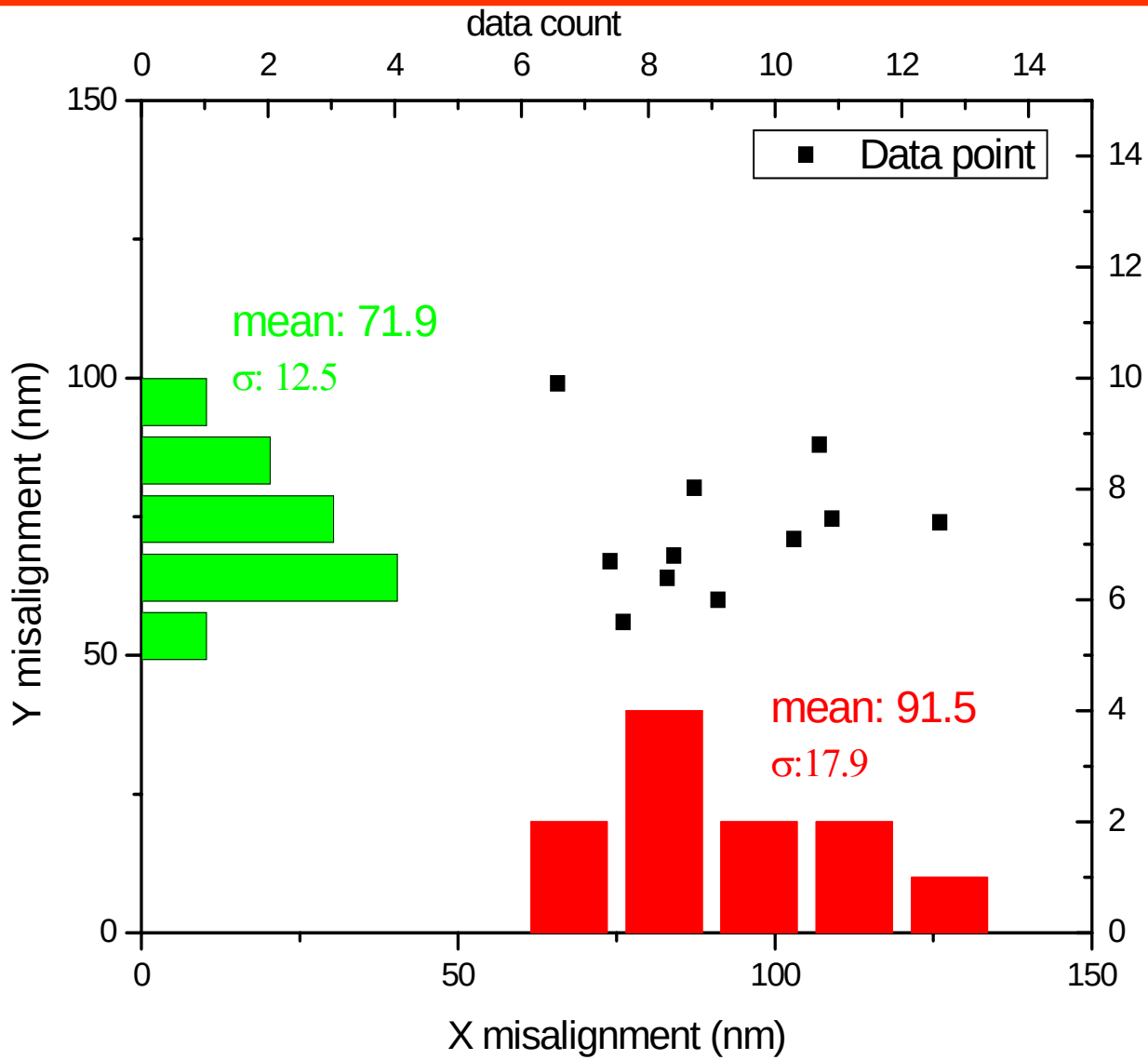
700X View of Gate

60,000X View of Gate

ANADIGICS

Mingtao Li, Lei Chen, Stephen Y. Chou, APL, **78**, 3322, 2001.

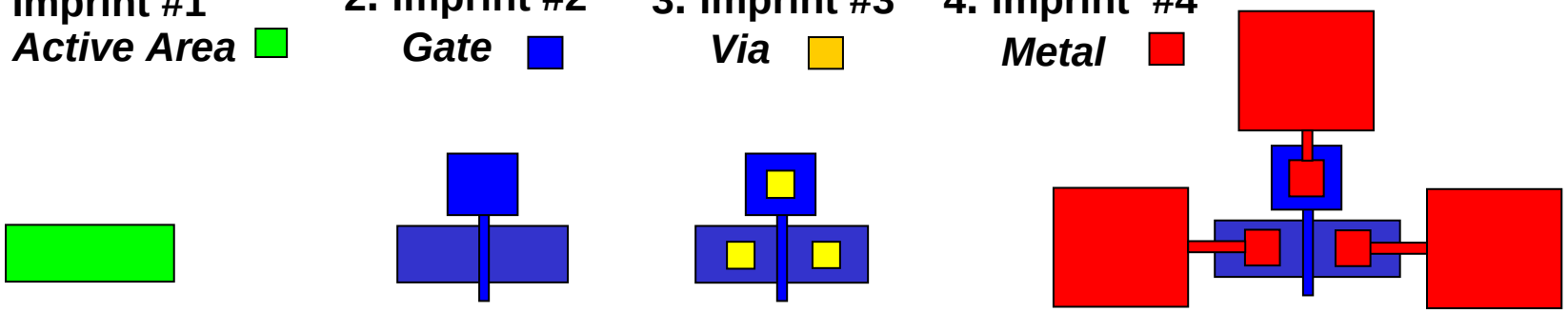
Preliminary Result of Alignment with Sub-20 nm (1 σ)

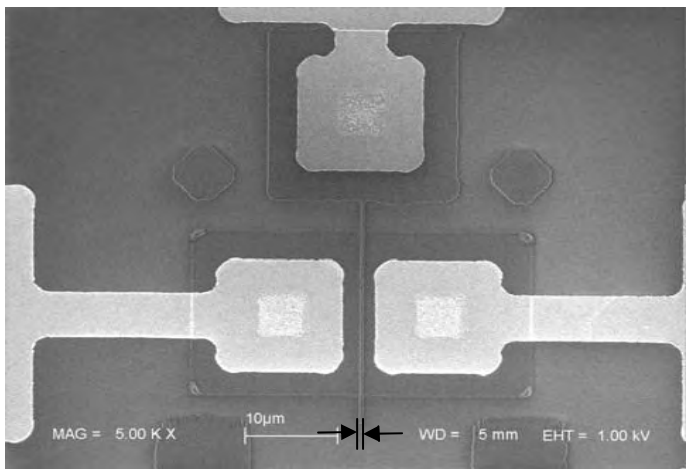


Li, Wu, Chou,
Nano Lett 2006

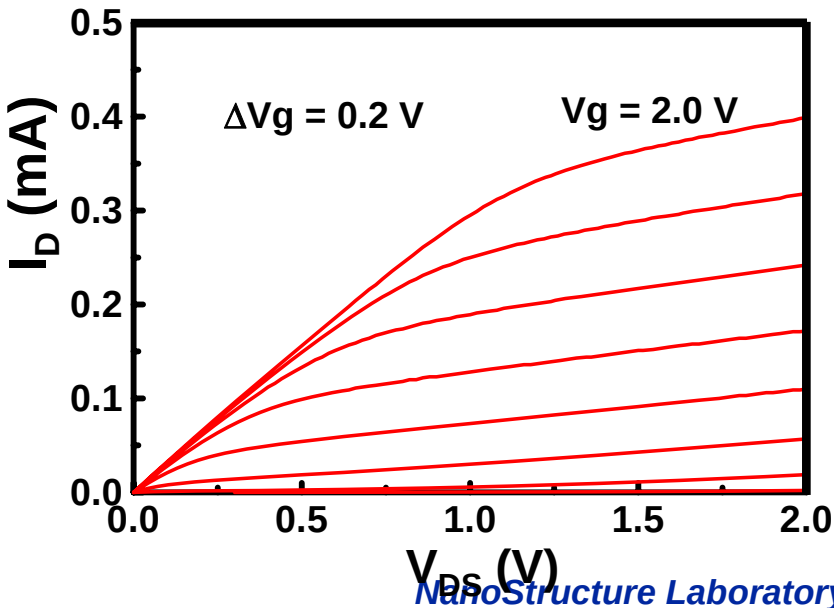
Microchip Fabrication Using Nanoimprint Lithography At All Lithography Levels

1. Imprint #1 *Active Area*
2. Imprint #2 *Gate*
3. Imprint #3 *Via*
4. Imprint #4 *Metal*

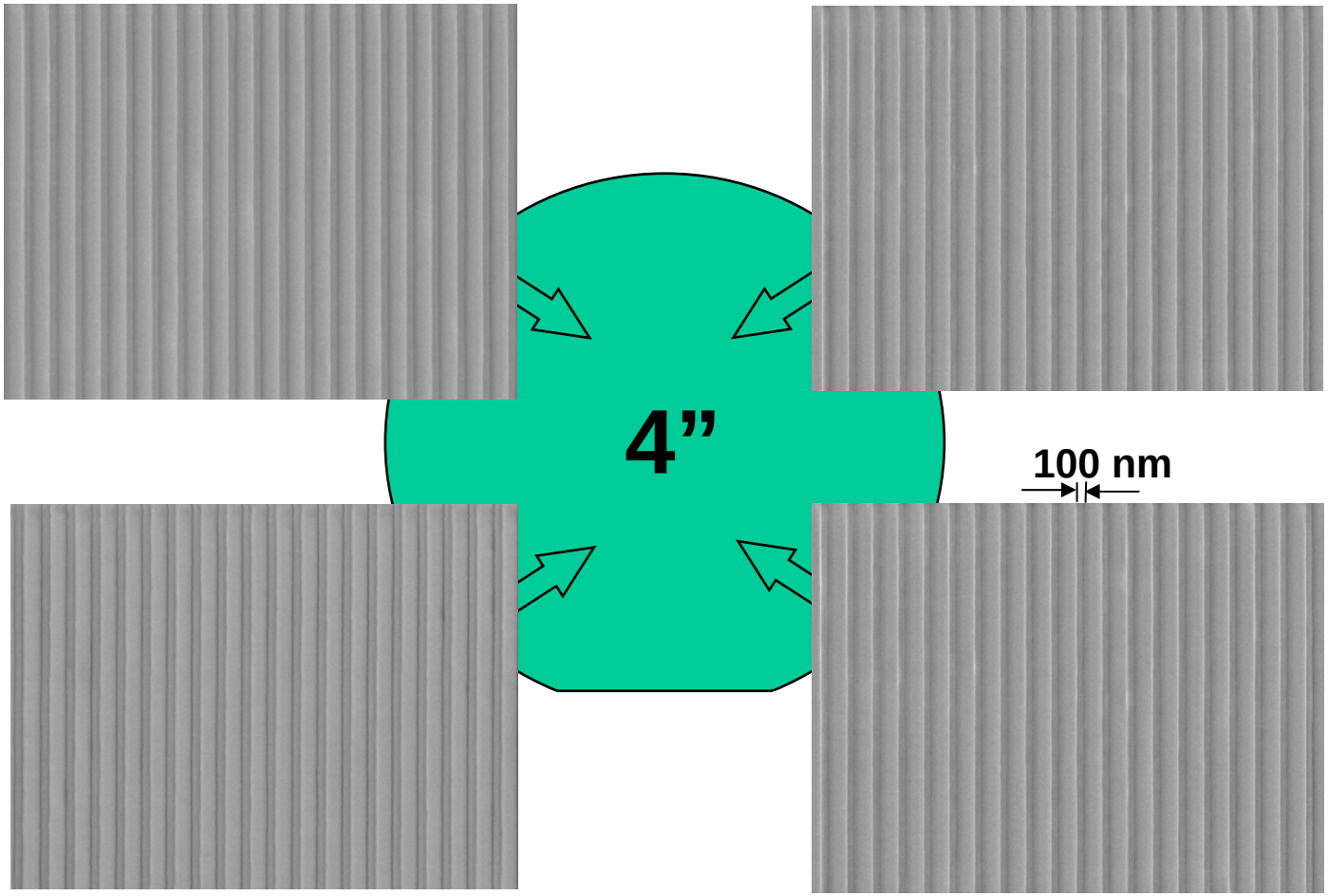




60 nm channel MOSFETs on 4" wafer

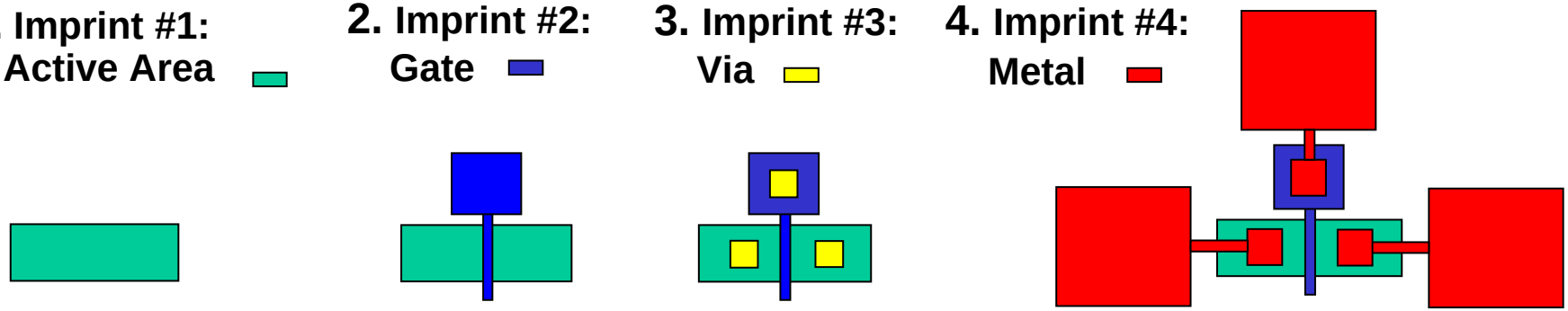


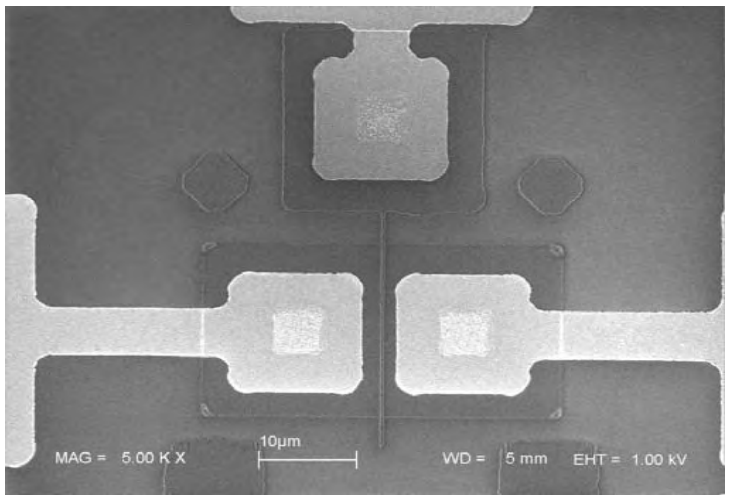
Uniform 100nm PMMA Line over 4” Wafer Imprinted by TOM



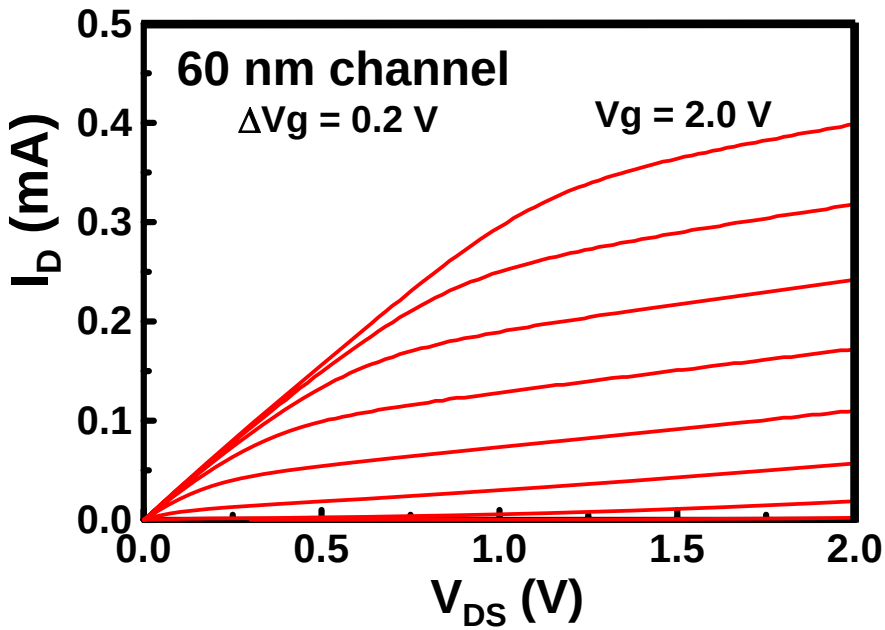
60 nm Channel MOSFETs on 4” wafers with All (4) Layers Fabricated by Nanoimprint Lithography (NIL)

1. Imprint #1: Active Area
2. Imprint #2: Gate
3. Imprint #3: Via
4. Imprint #4: Metal



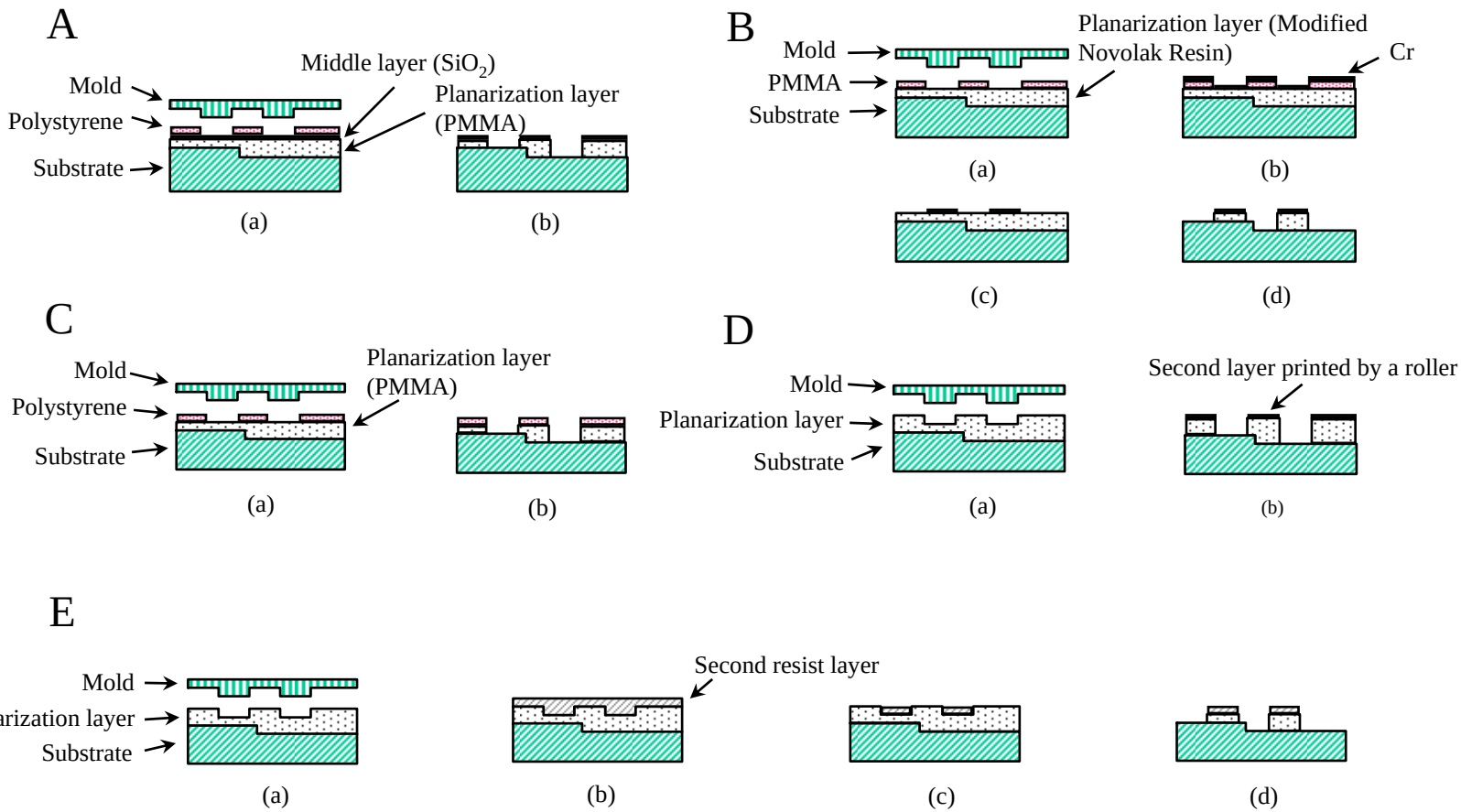


60 nm channel



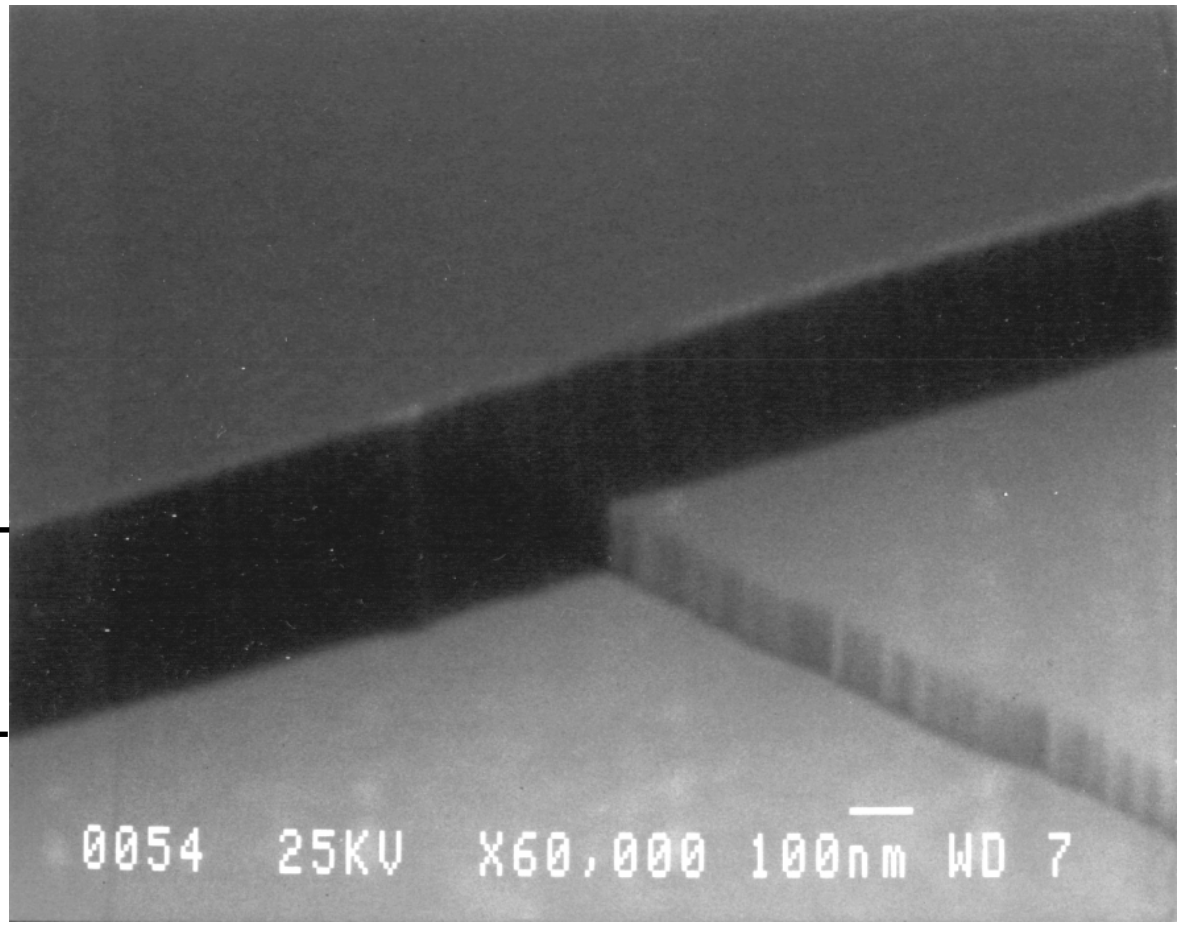
Supported by DARPA

Five Schemes for Nanoimprint Lithography on Non-Flat Surfaces



X. Sun, L. Zhuang, W. Zhang and S.Y. Chou, J VAC SCI TECHNOL B 16: (6) 3922-3925, 1998

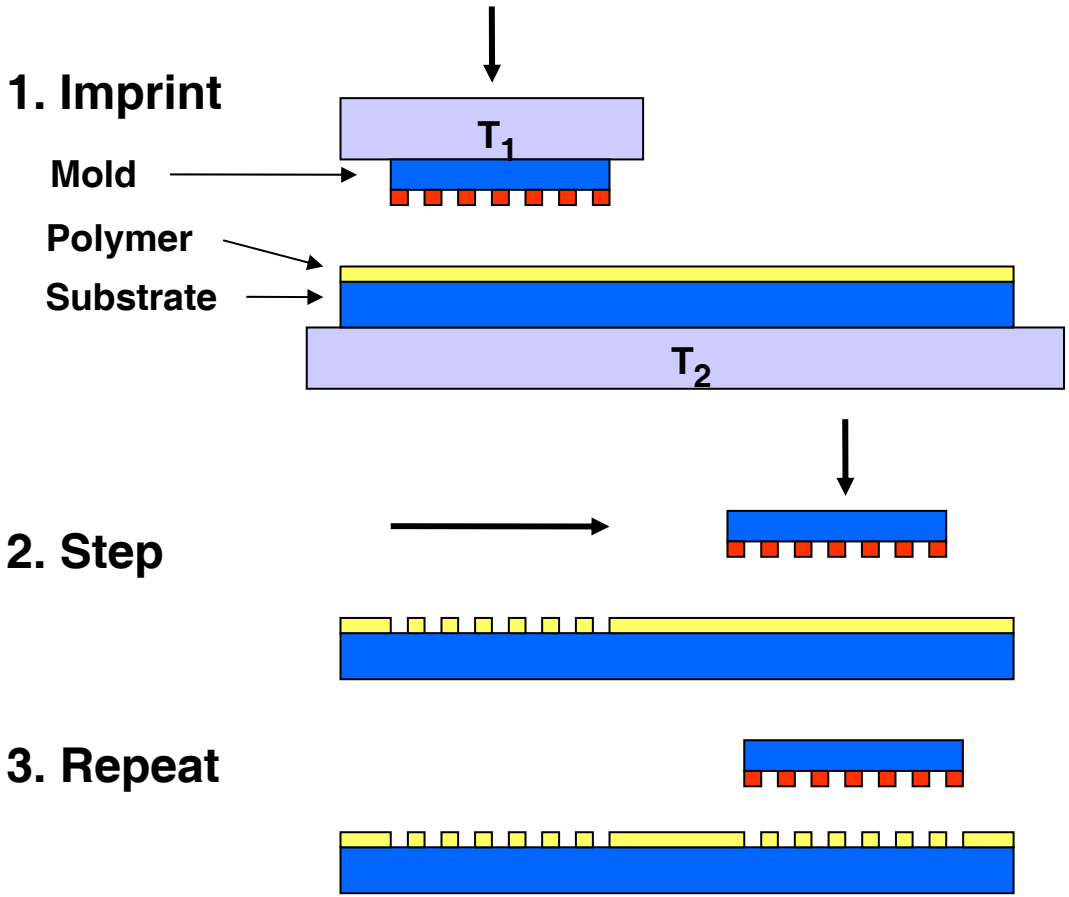
Resist on SiO_2 step by Imprint & lift-off & RIE



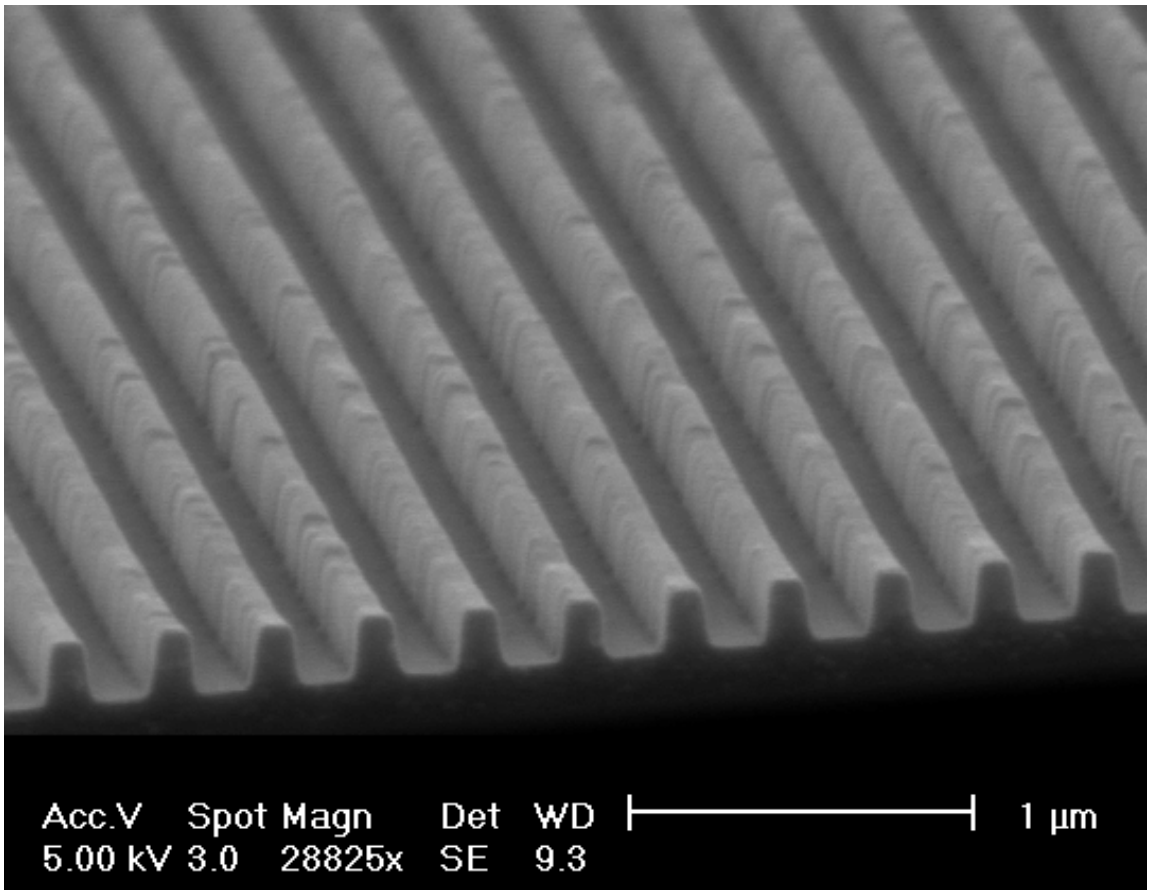
300nm Resist

100nm

Step-and-Repeat NIL Machine

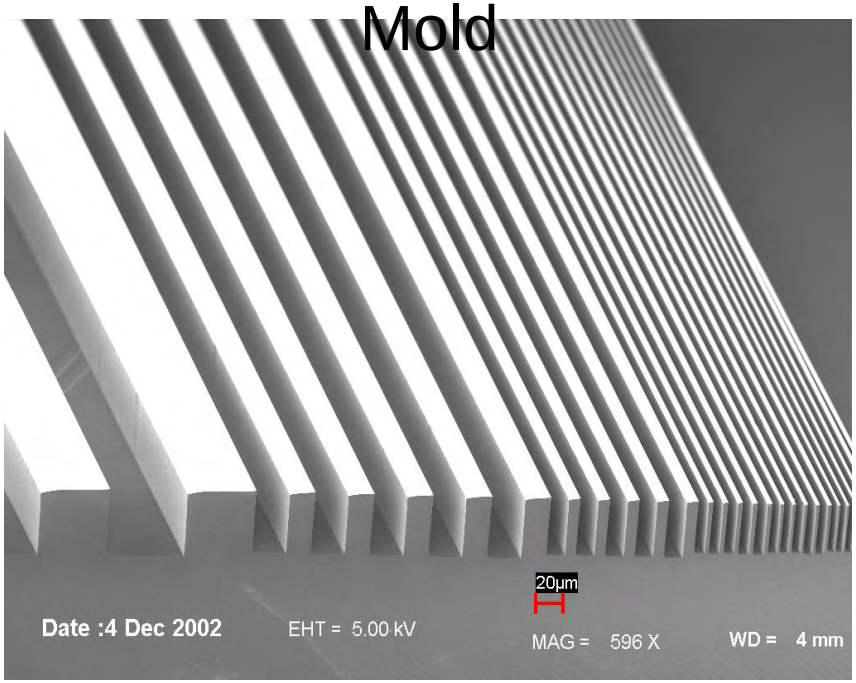


300 nm Period Grating in PMMA

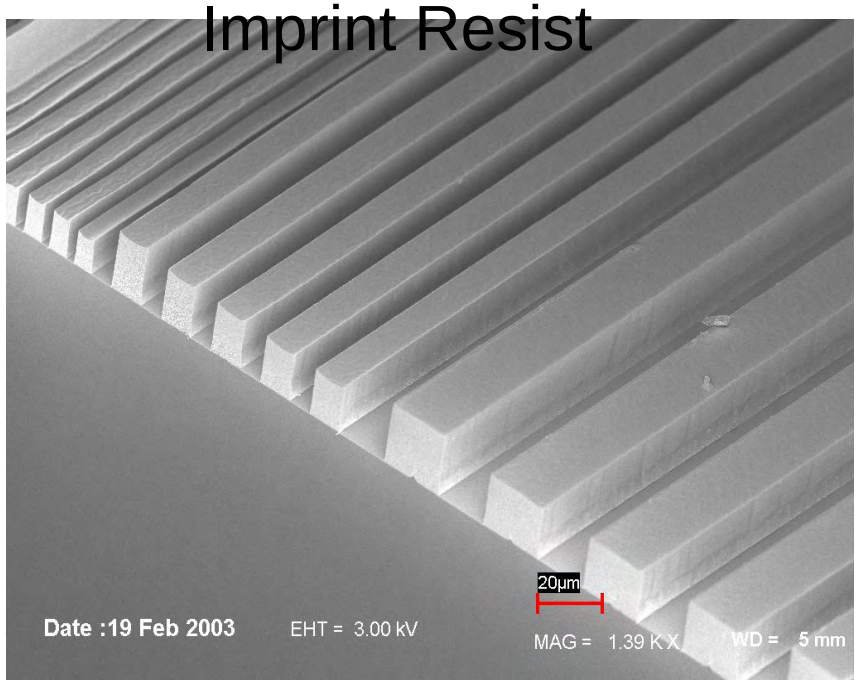


Deep Imprint

Mold



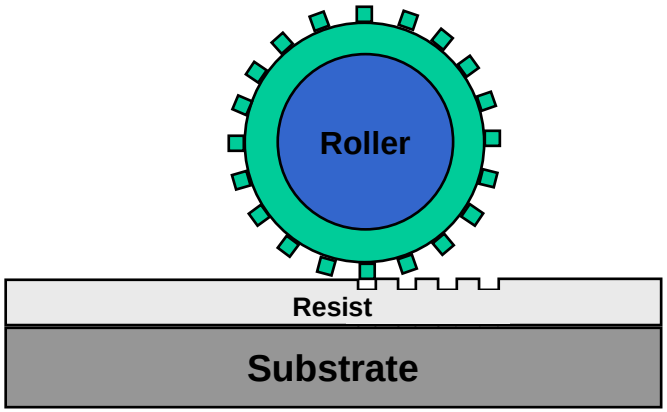
Imprint Resist



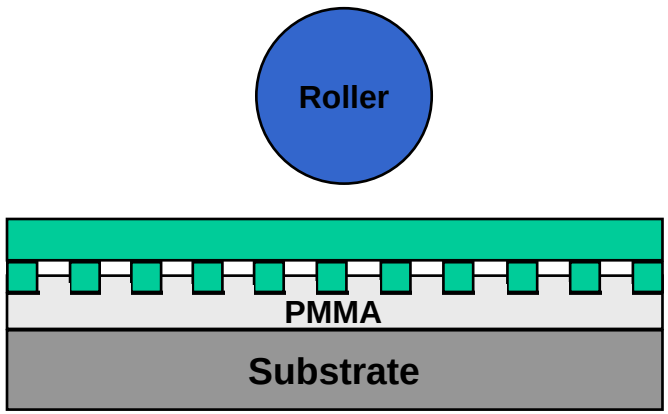
Depth: ~40 μm

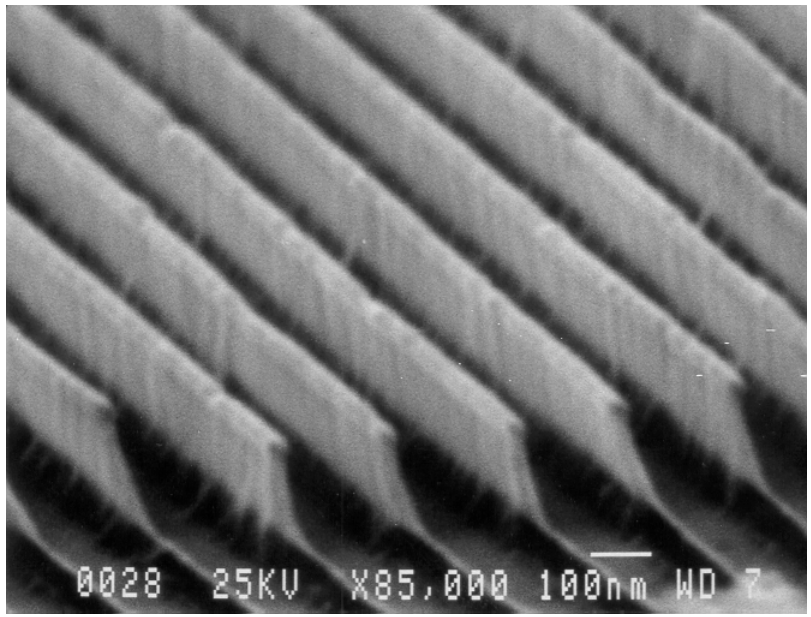
Roller Nanoimprint

Imprint using a cylinder mold



Imprint using a flat mold

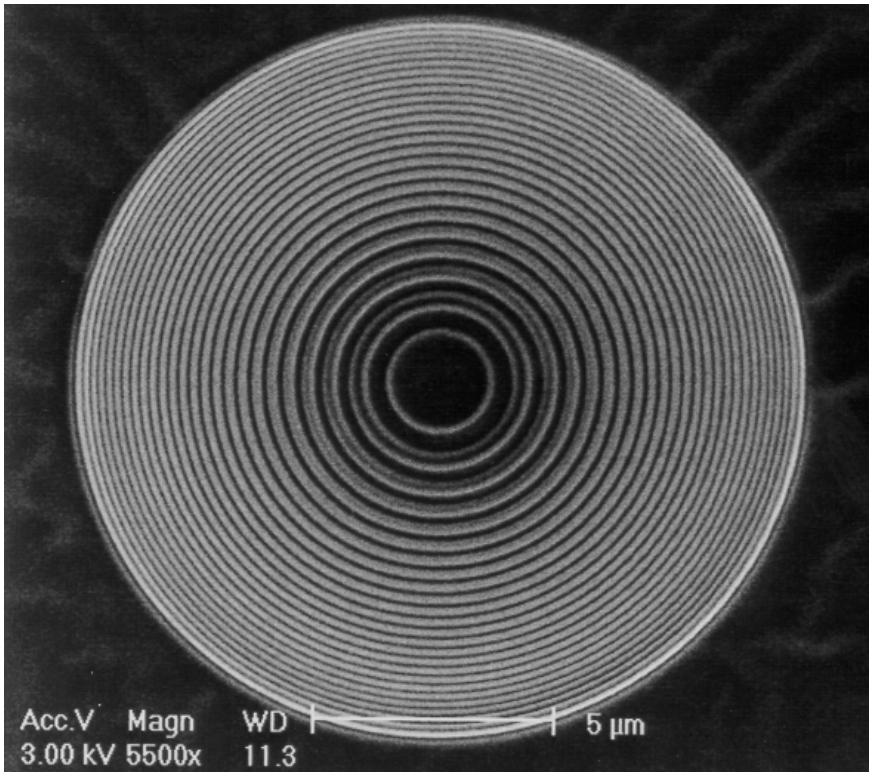


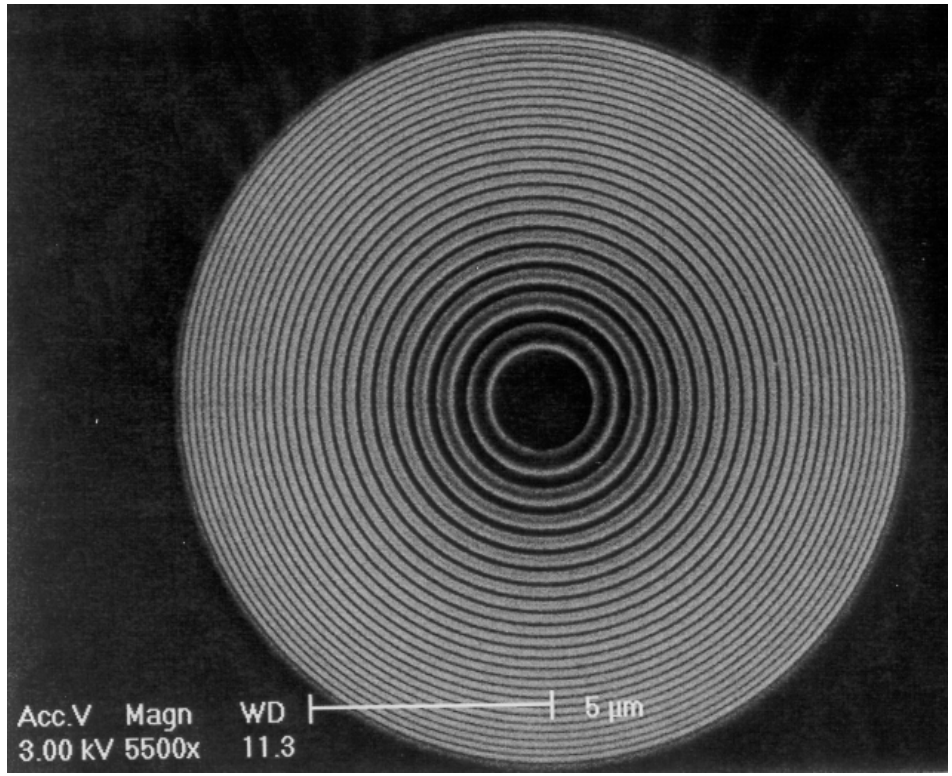


30 nm Wide Resist Grating (200 nm Period) by Roller Nanoimprint (RON)

H. Tan, A. Gilbertson, S.Y. Chou, *JVST B*, **16** (6) 3926-3928 1998

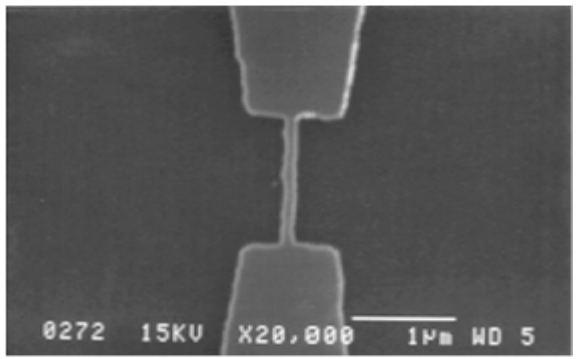
Zone Plate (70 nm Min. Feature Size) by Roller Nanoimprint (RON)

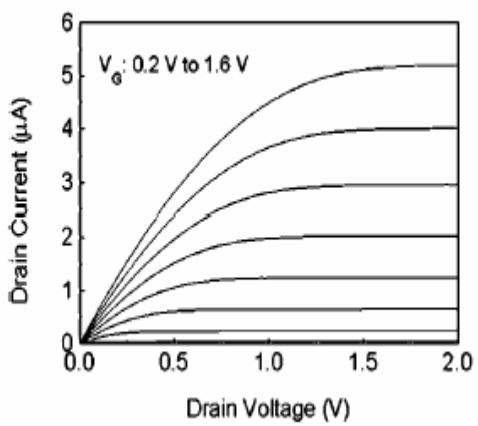




NIL Applications

Si nano-transistor

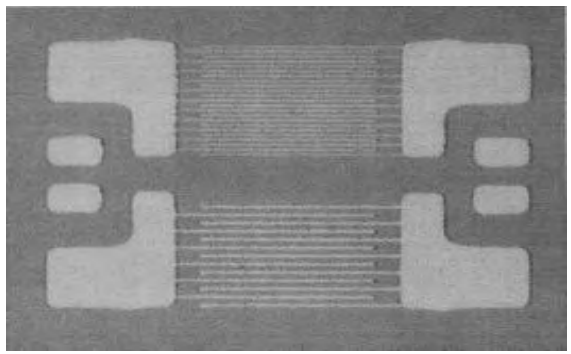


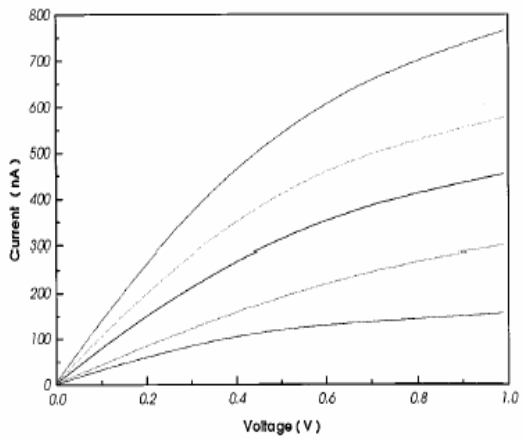


Chou, et al., J. Vac. Sci. Tech. B, 1997

Photodetector

300 nm and 600 nm finger spacing

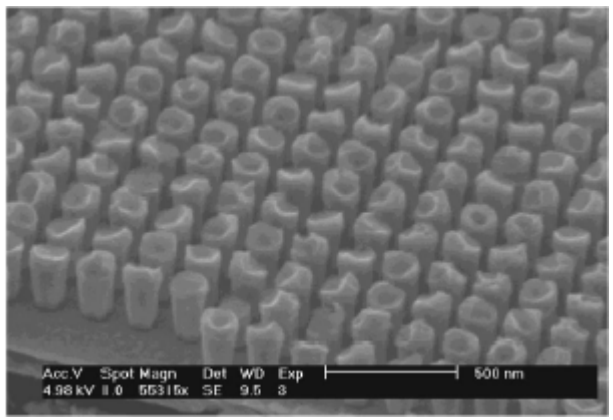




Yu, et al., App. Physics Lett., 1999

NIL Applications (continued)

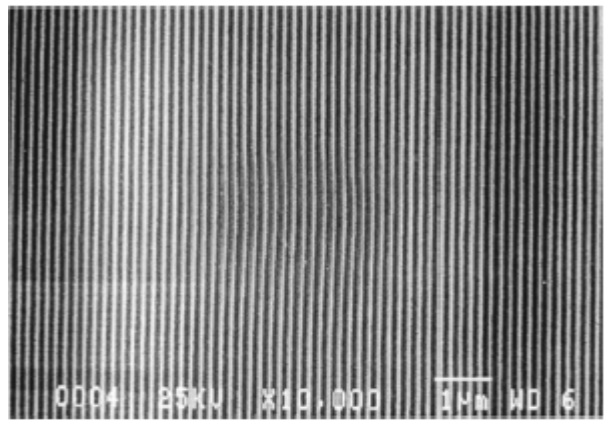
Magnetic data storage



18 Gbit/in.^{2}
QMD

Wu, et al., J. Vac. Sci. Tech. B, 1998

Passive optical elements

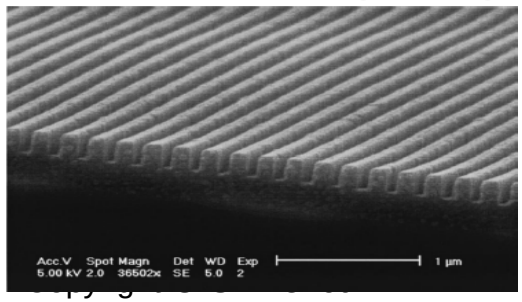


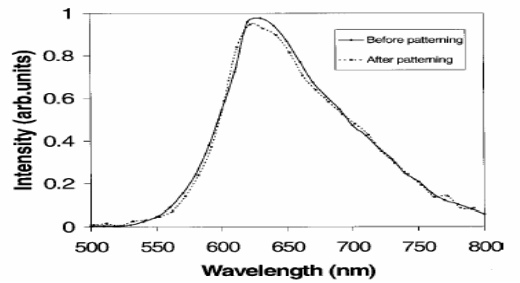
190 nm period grating

Yu, et al., App. Physics Lett., 2000

Organic light-emitting structures

200 nm period grating

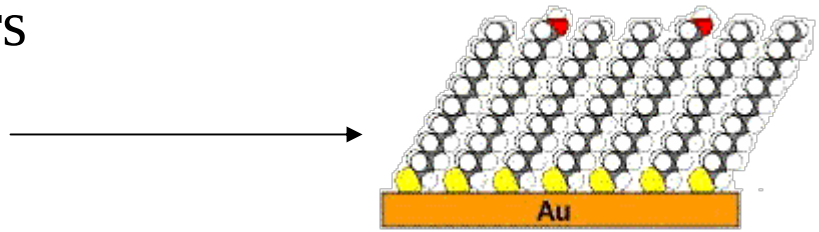




Wang, et al., App. Physics Lett., 1999

What is Guided Self-Assembly?

- Self-assembly refers to a physical or chemical process in which features spontaneously order.
  - Self-assembled monolayers
  - Phase-separation
  - Colloidal crystallization

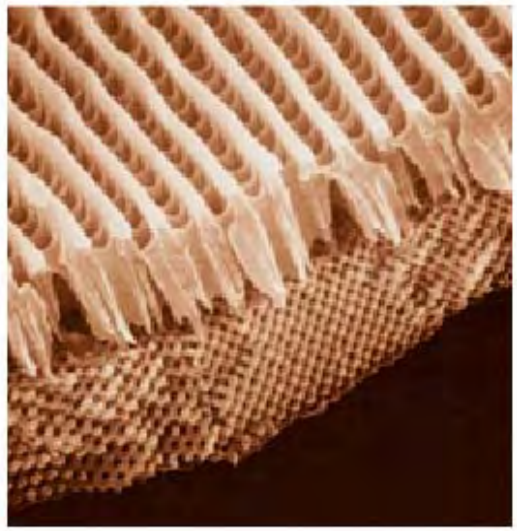


- Guided self-assembly seeks to influence or control the self-assembly process to create patterns that are pre-determined.

- Create patterns smaller than that which creates them
  - Demagnification

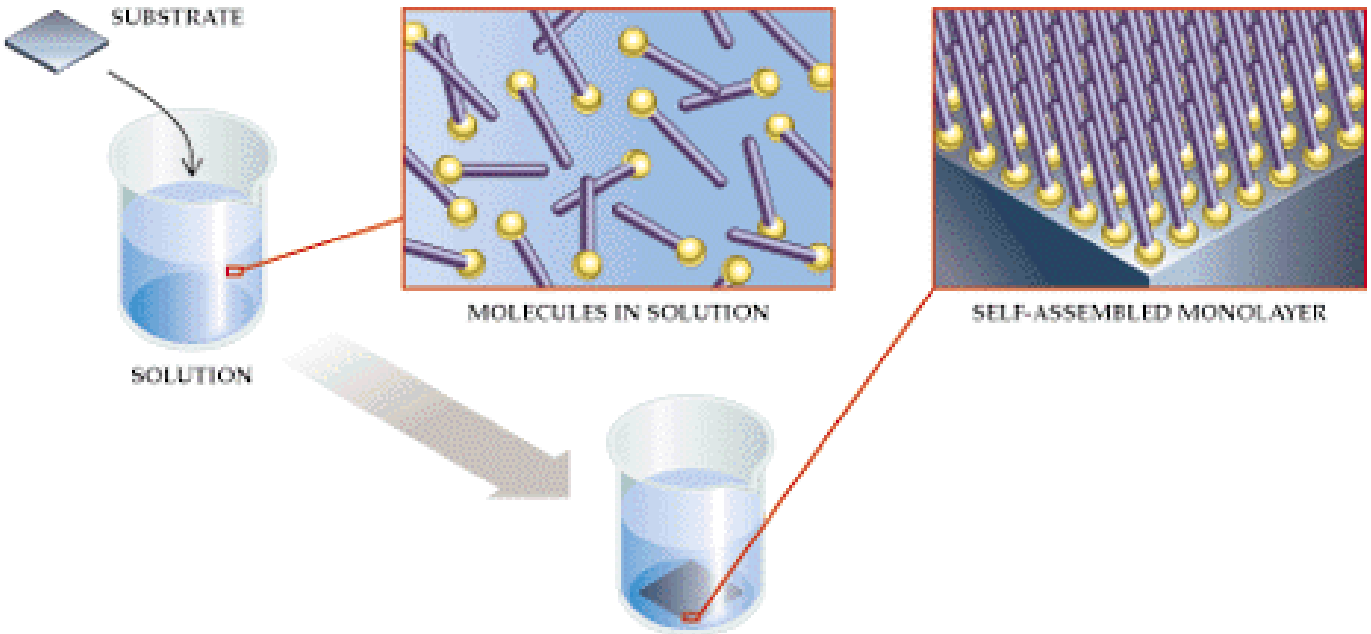
Self Assembly

Nature has already made perfect photonic crystals…

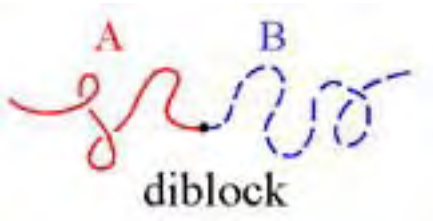

E. Yablonovitch, *Sci. Am.* 285, 46 (2001)

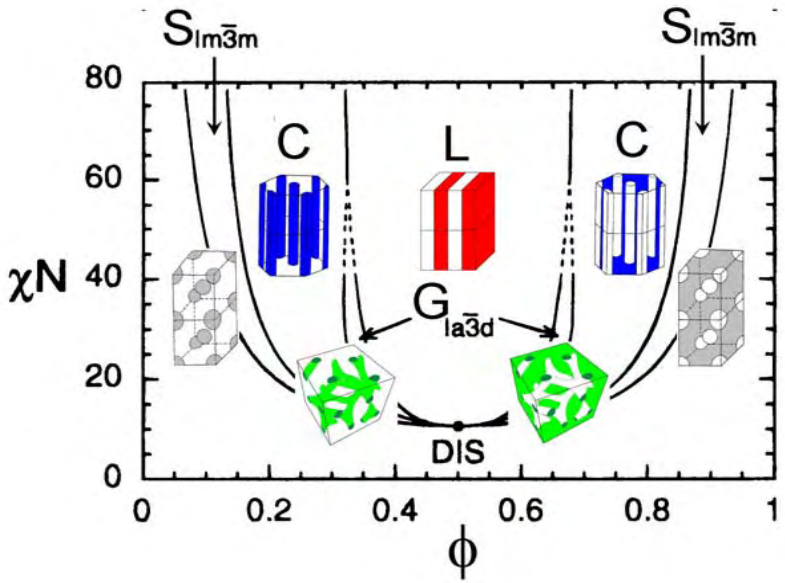
Self Assembled Monolayers

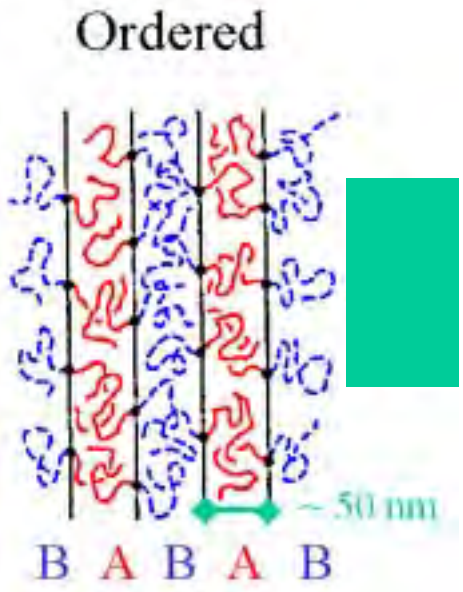


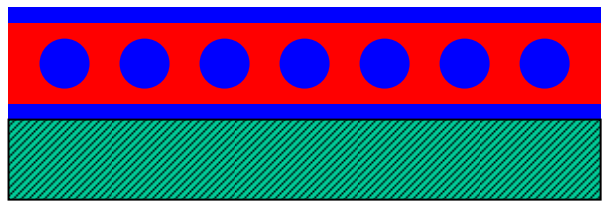
Weiss, Scientific American, June 2000

Di-Block Polymer Phase Separation and Self-Assembly



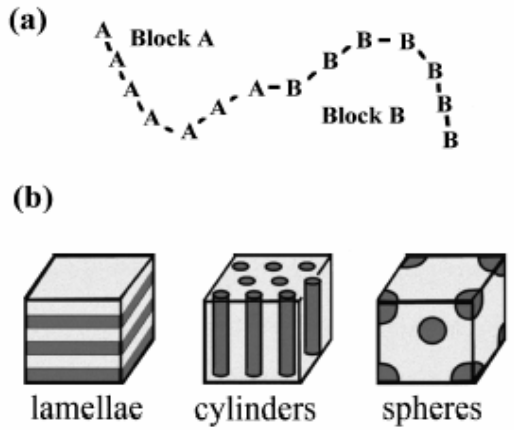


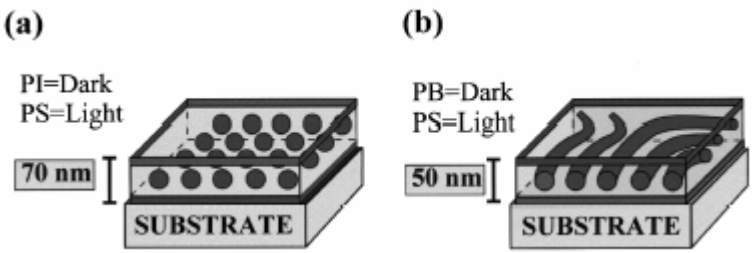




Fraction of each block in bulk determines the observed phase.

Block-copolymer Self-Assembly





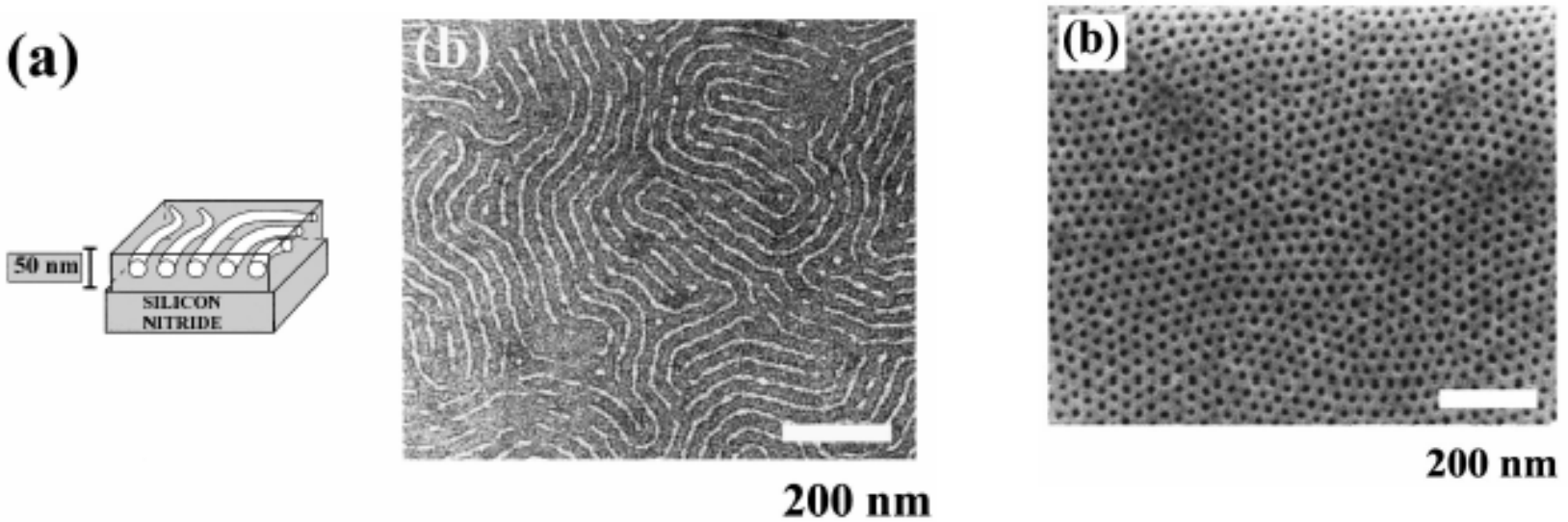
Take advantage of structures formed by spontaneous micro-phase separation of block copolymers to form disparate regions.

Selectively remove one phase and use other to etch substrate.

Make functional block copolymer and build devices?

Harrison, Park, Chaikin, Register, and Adamson, J. Vac. Sci. Technol. B, **16**, 544 – 552 (1998)

Examples of Self-assembly



Self-assembly alone forms structures 10 – 50 nm,
but does not give long-range order.

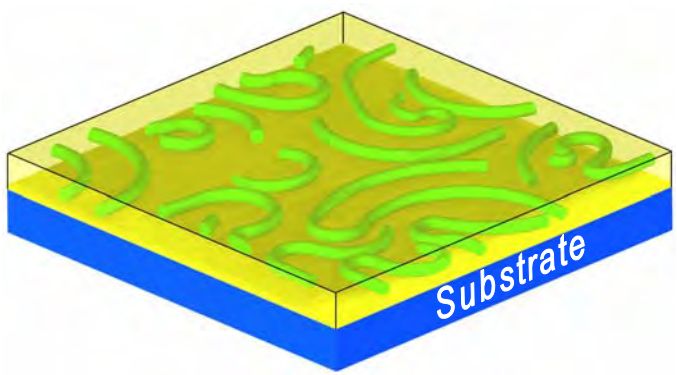
Need method to order the phases or guide the self-assembly.

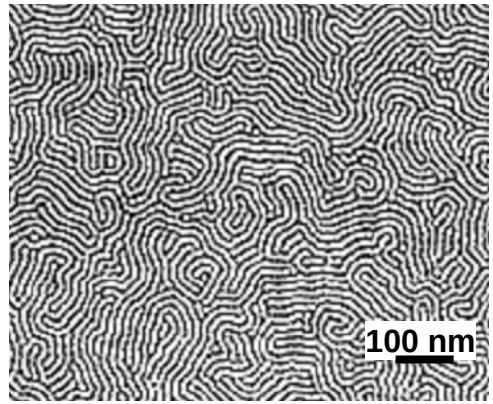
Temperature (see movie)
Electric Fields
Surface Wetting

Wafer Scale Alignment of 21 nm Copolymer Gratings By Shear-Force Guided Self-Assembly With A Flat Plate

Free Film

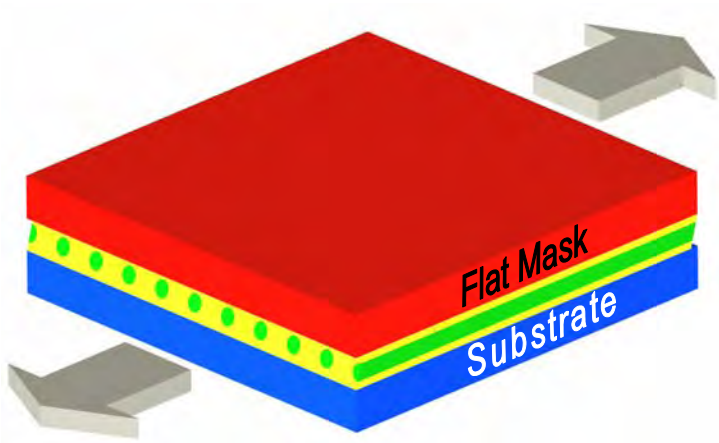
Without mask, cylinder phase forms randomly in a thin copolymer film.

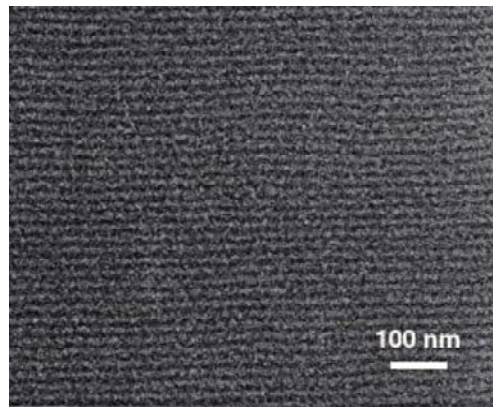




Shear Force Using Flat Plate

With a flat mask, a shear force is applied to align the cylinders over entire wafer





Zhuang, Deshpande, Register, Chaikin, Chou, Advanced Materials 2004