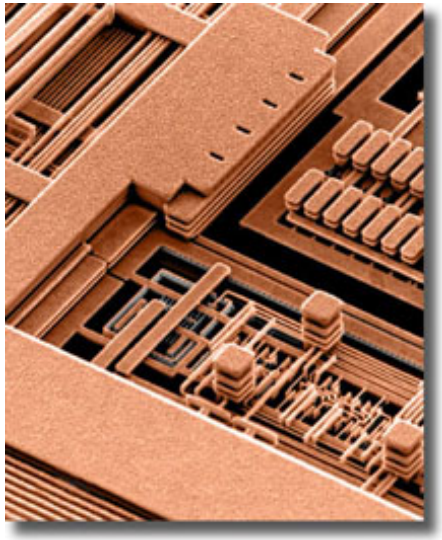
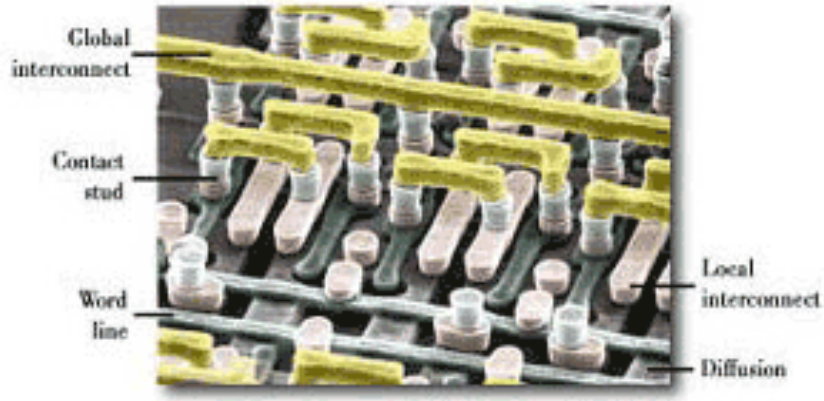
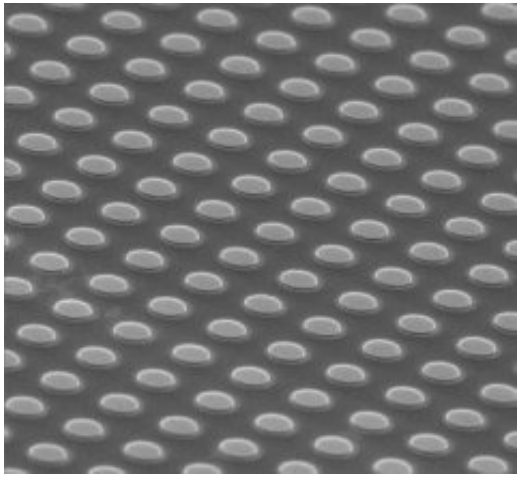
Lithography and Electrodeposition



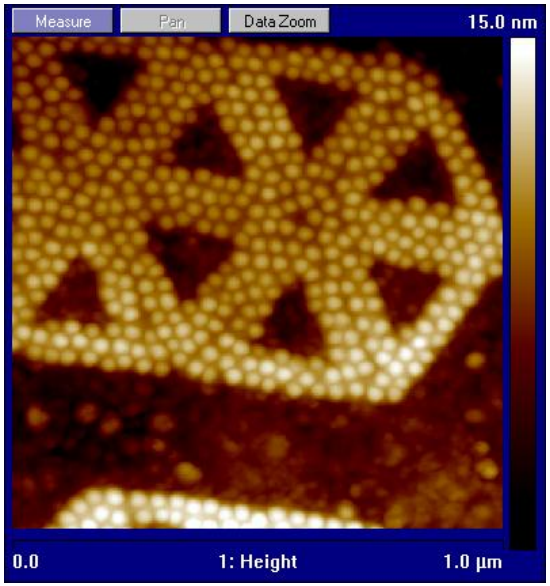
ibm



bnl



manchester



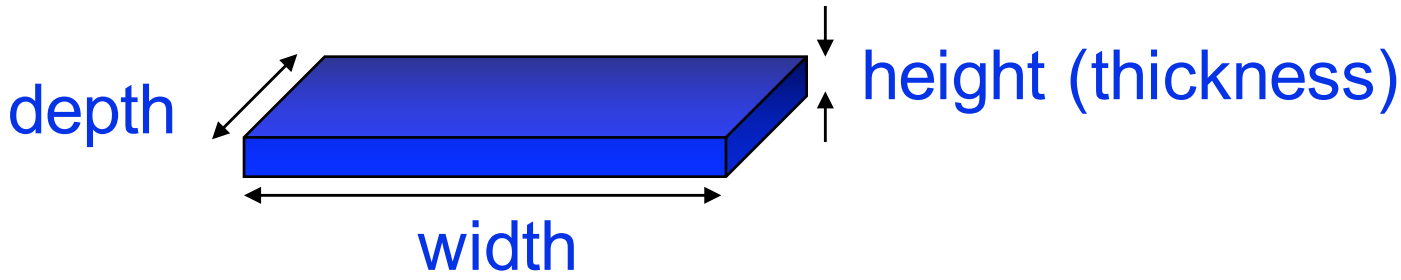
UMass

How do we control the shape and size of nanostructures?

Self Assembly
(inspired by nature)

Lithography
(designed by humans)

Nanostructure



Using conventional methods, controlling the thickness (deposition) at the nanoscale is much easier than controlling the width or depth (lithography)

Computer

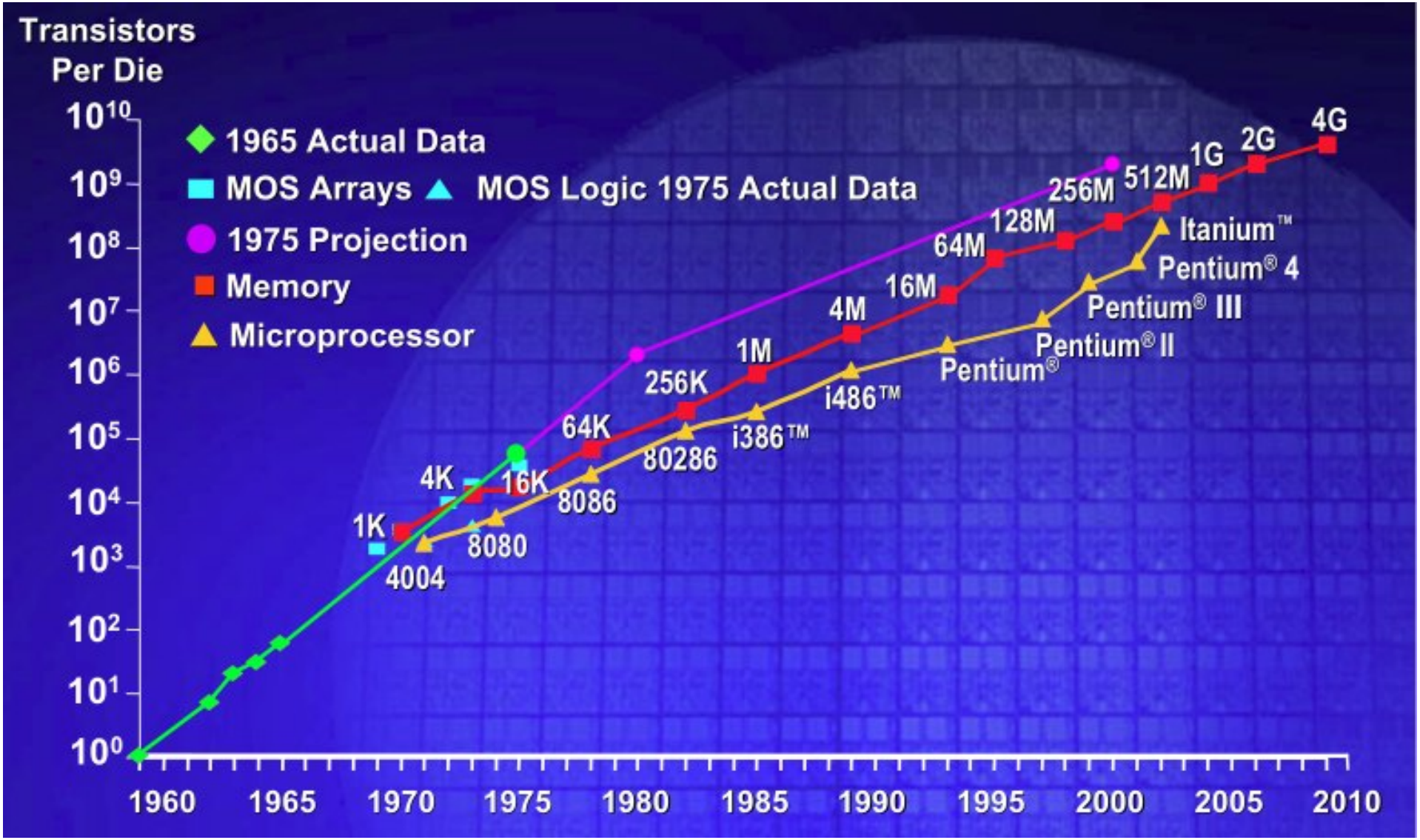
Microprocessor

"Heart of the computer"

Does the "thinking"

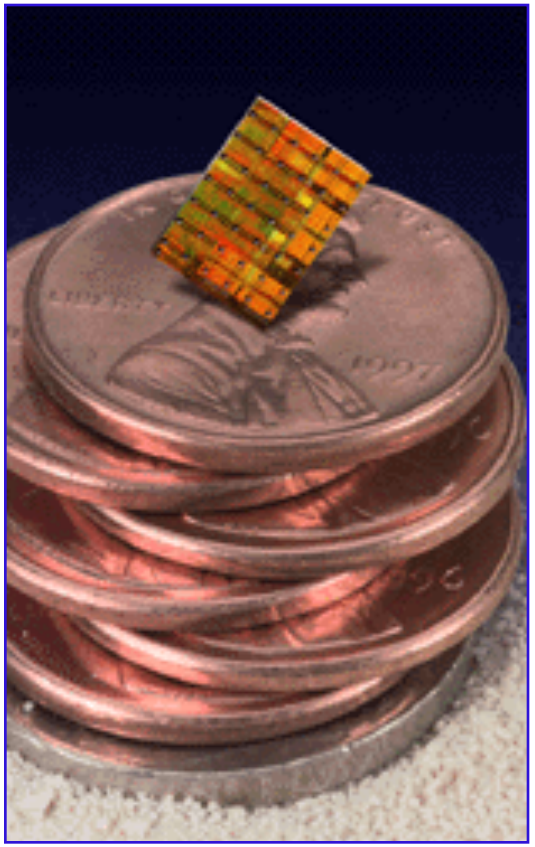
Uses **transistors** to create "logic" (computational units)

“Moore's Law”

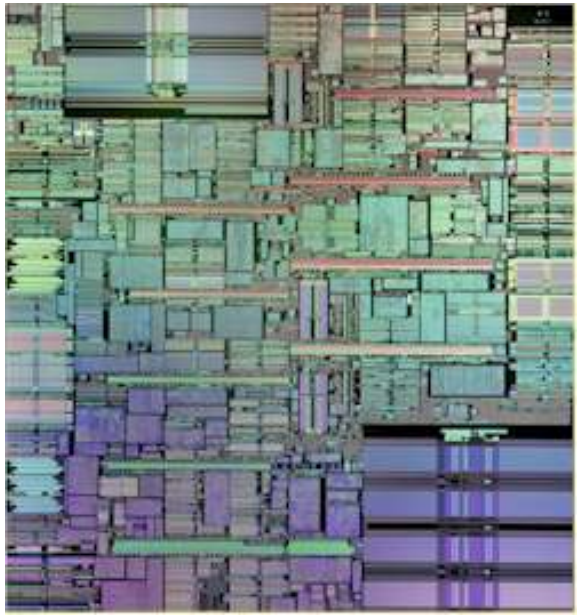

Transistors
Per Die
1965 Actual Data
MOS Arrays
MOS Logic 1975 Actual Data
1975 Projection
Memory
Microprocessor
1K
4K
16K
64K
256K
1M
4M
16M
64M
128M
256M
512M
1G
2G
4G
4004
8080
8086
80286
i386™
i486™
Pentium®
Pentium® II
Pentium® III
Pentium® 4
Itanium™
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010

Making Small Smaller
Computer Microprocessors

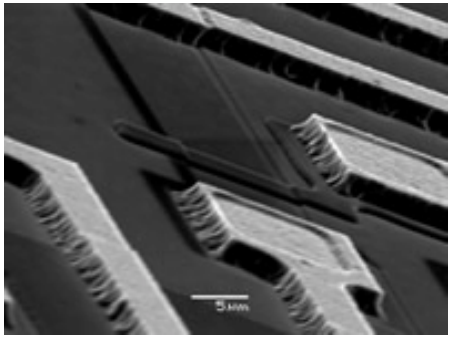
macroscale



microscale



nanoscale



ibm.com

The very small features on a computer's microprocessor and memory (RAM) are patterned with *photolithography*

Lithography

(controlling <u>lateral dimensions</u>,
by using stencils, masks, & templates)

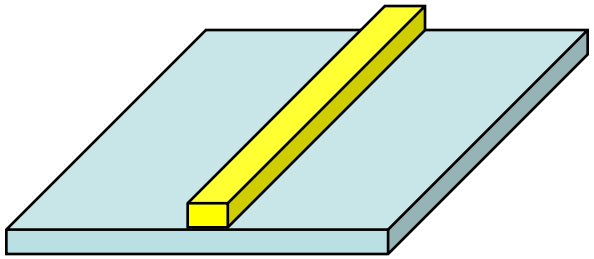
Lithography

Nanoscience Rocks!

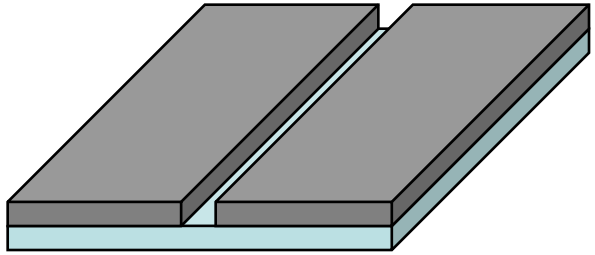
(Using a stencil or mask)

Lithography: Basic concepts

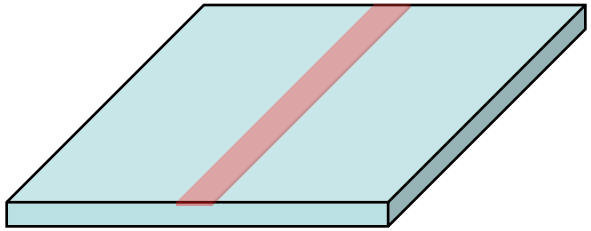
Some possible desired features



narrow line



narrow trench

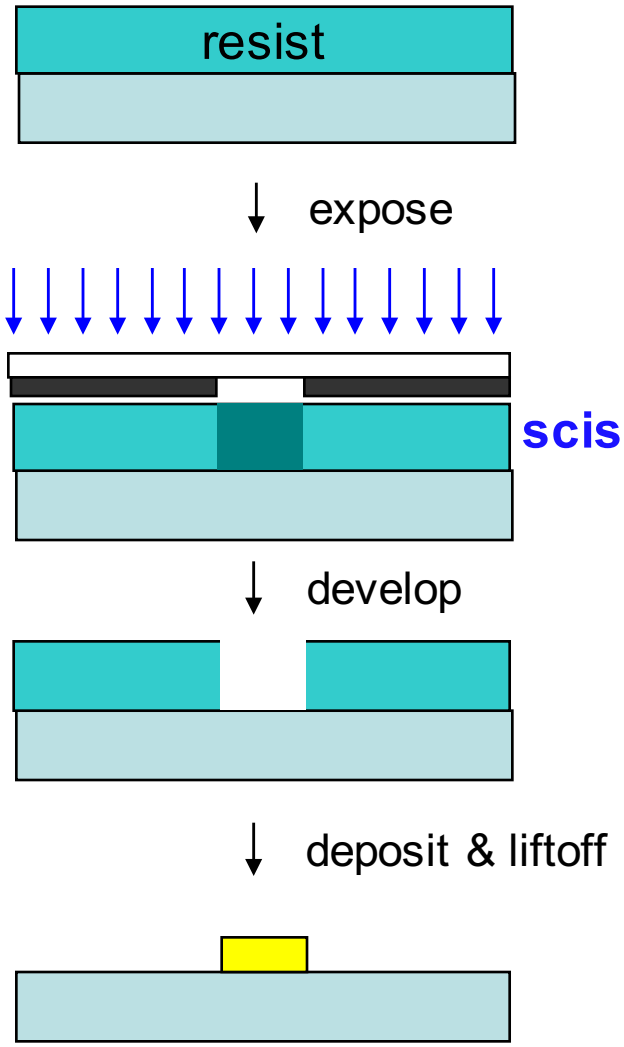


modified substrate

- **Photolithography**
- Electron-Beam Lithography
- X-ray Lithography
- Focused Ion-Beam Lithography
- Block Copolymer Lithography
- Nano Imprint Lithography
- Dip Pen Lithography
- Interference Lithography
- Contact Lithography
- EUV Lithography

Positive and Negative Resists

Positive Resist

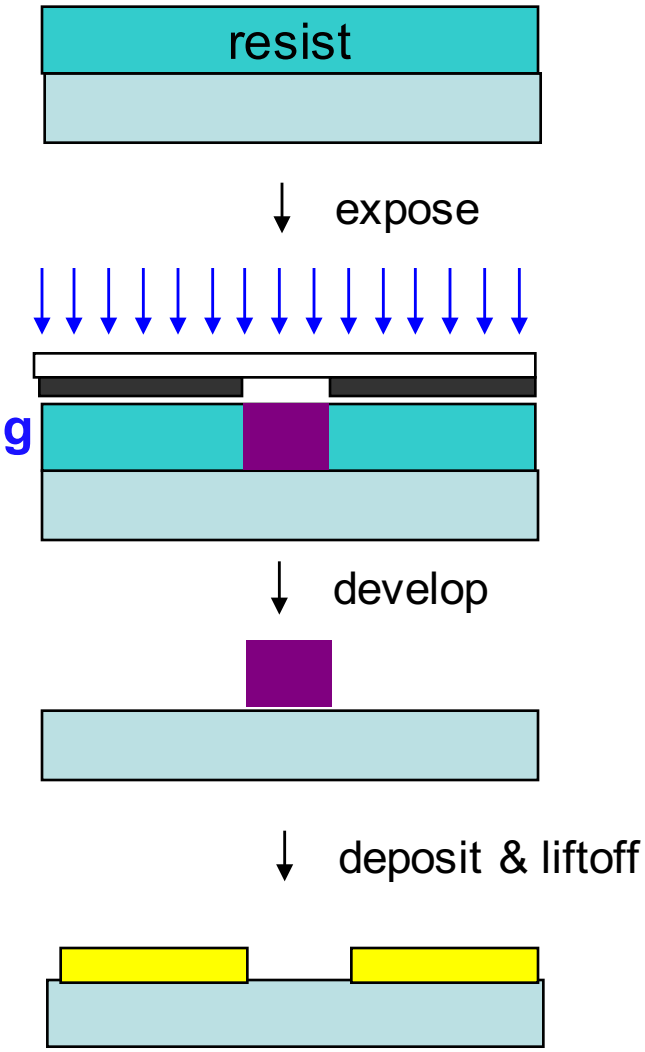


exposed region results in *presence* of structure

scission

cross-linking

Negative Resist

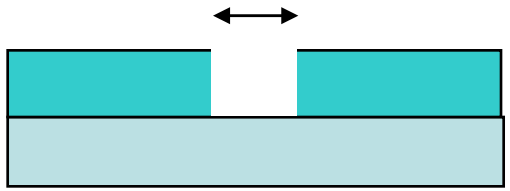


exposed region results in *absence* of structure
(generally poorer resolution)

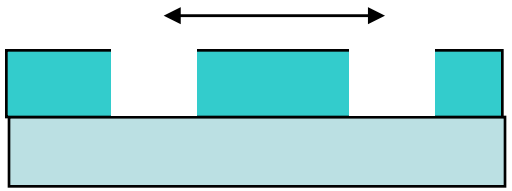
Resolution Limit of Photolithography

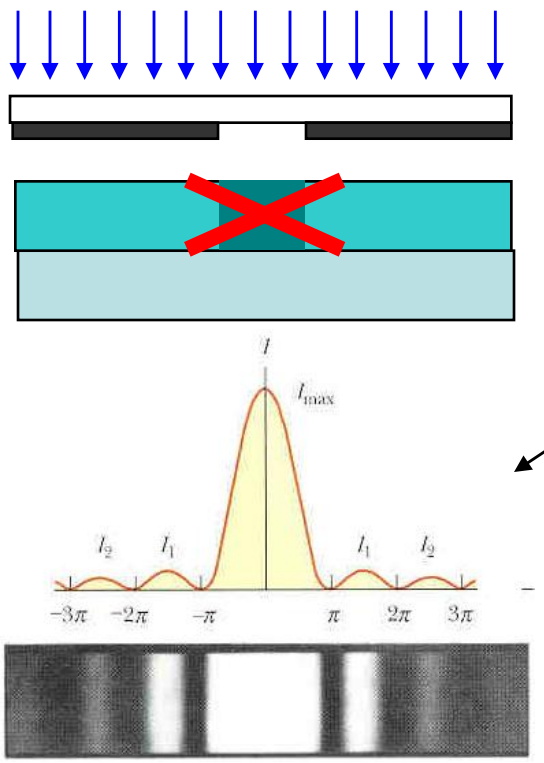
How low can you go?

minimum linewidth



minimum pitch



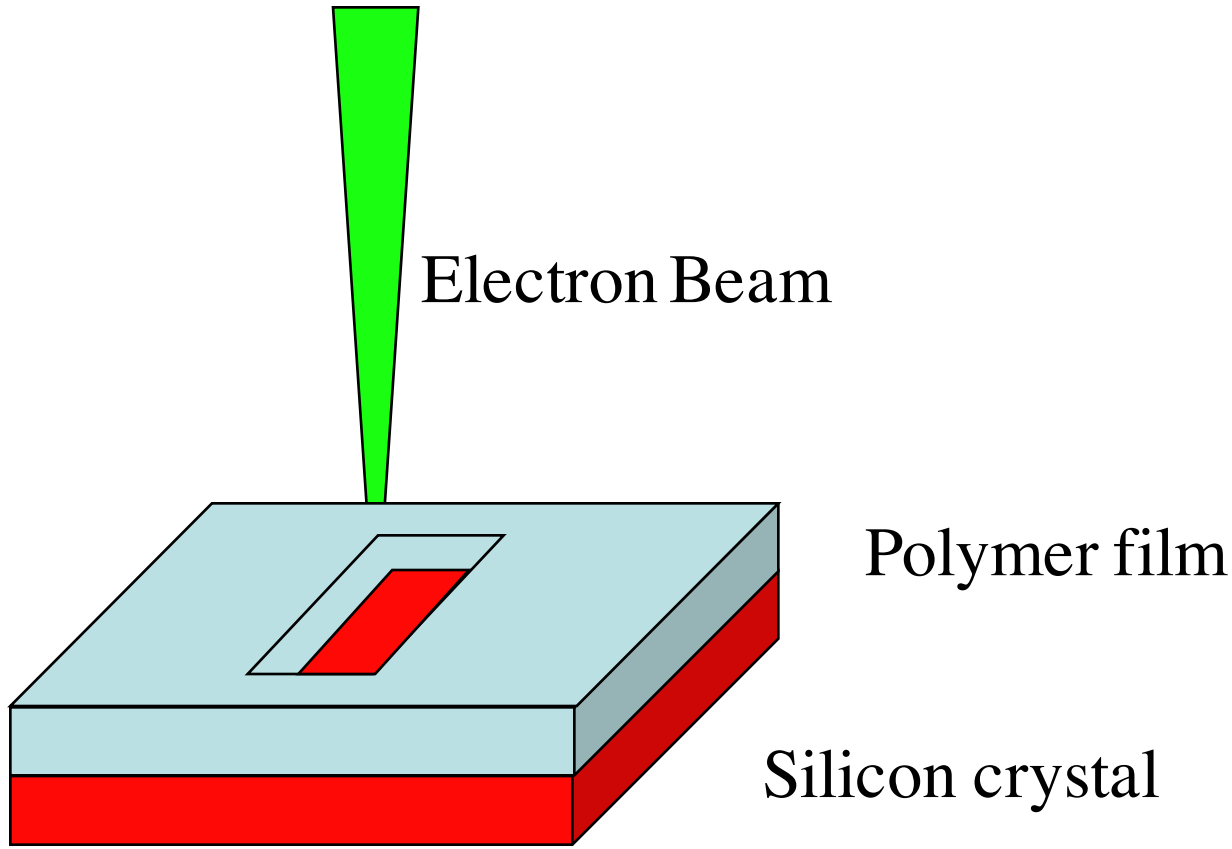


There are actually many contributing factors that limit the minimum linewidth:

- **optical diffraction ( )**
- **purity of light source**
- resist sensitivity
- depth of focus
- numerical aperture of lens

Using smaller wavelength enables smaller features
Visible light > UV > DUV > EUV > X-rays

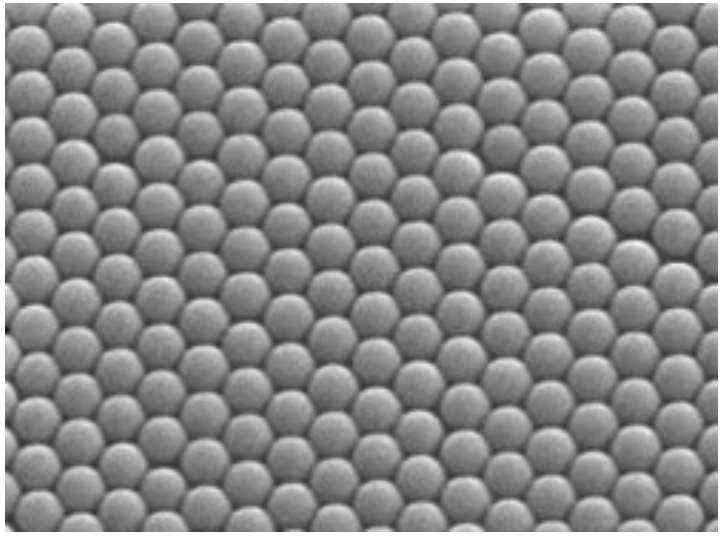
Electron-Beam Lithography



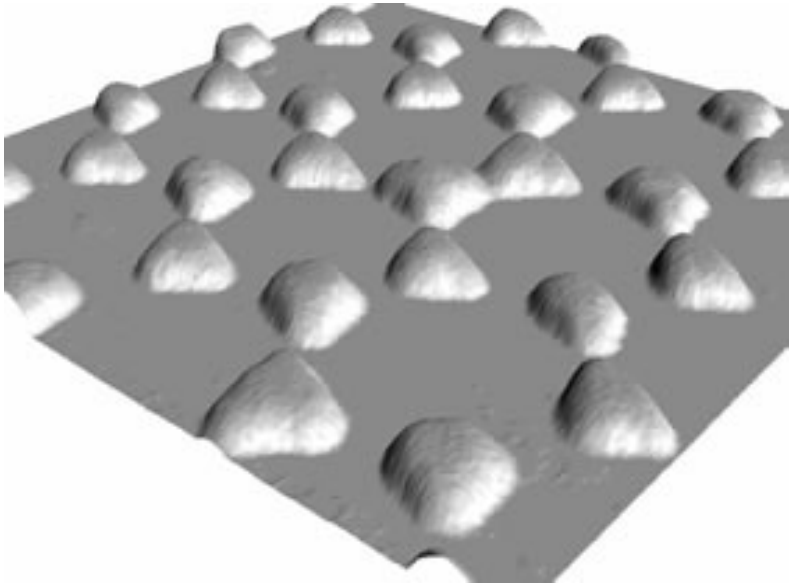
Nanoscopic Mask !

Down to 10 nm

Nanosphere Lithography

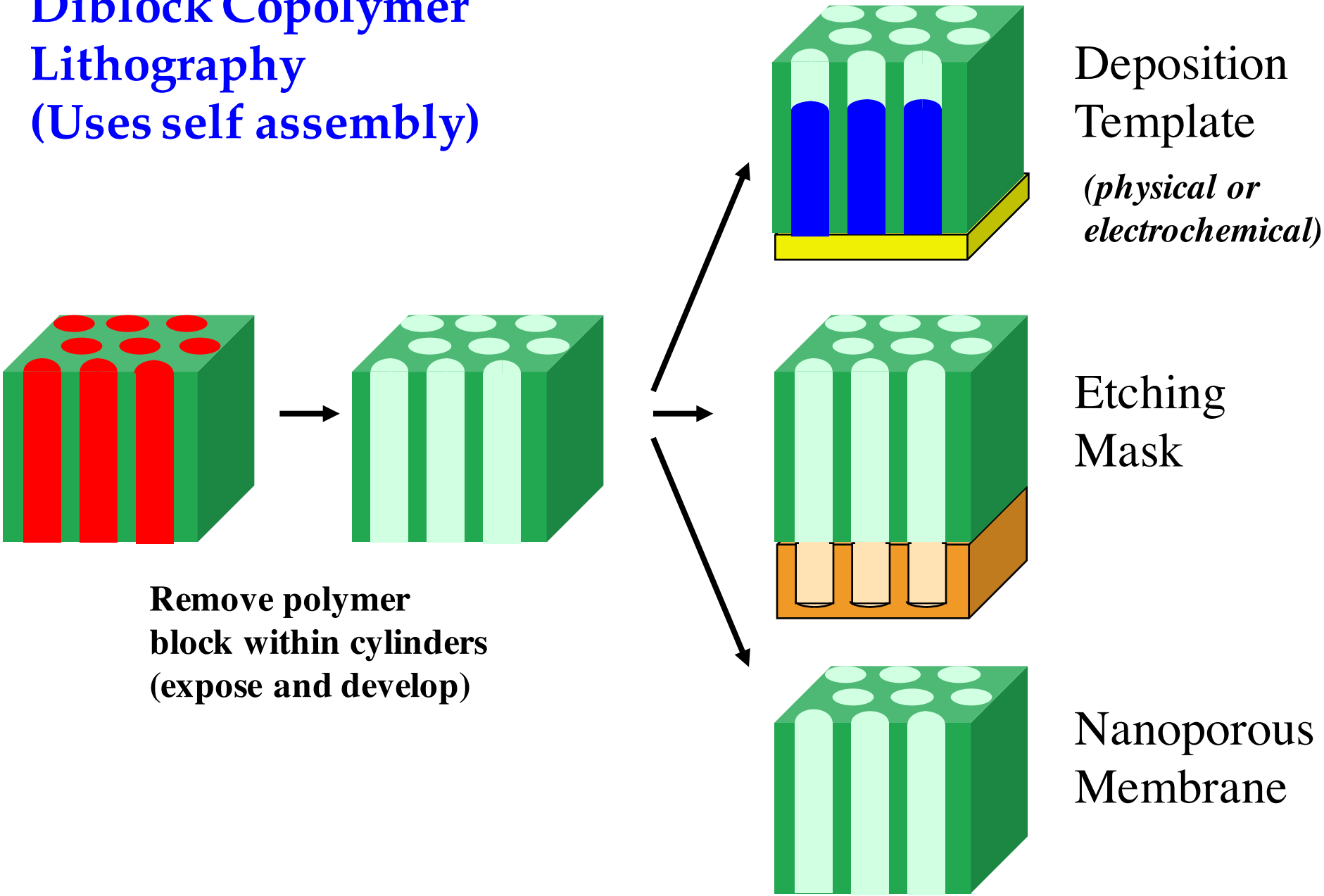


itrc.org.tw



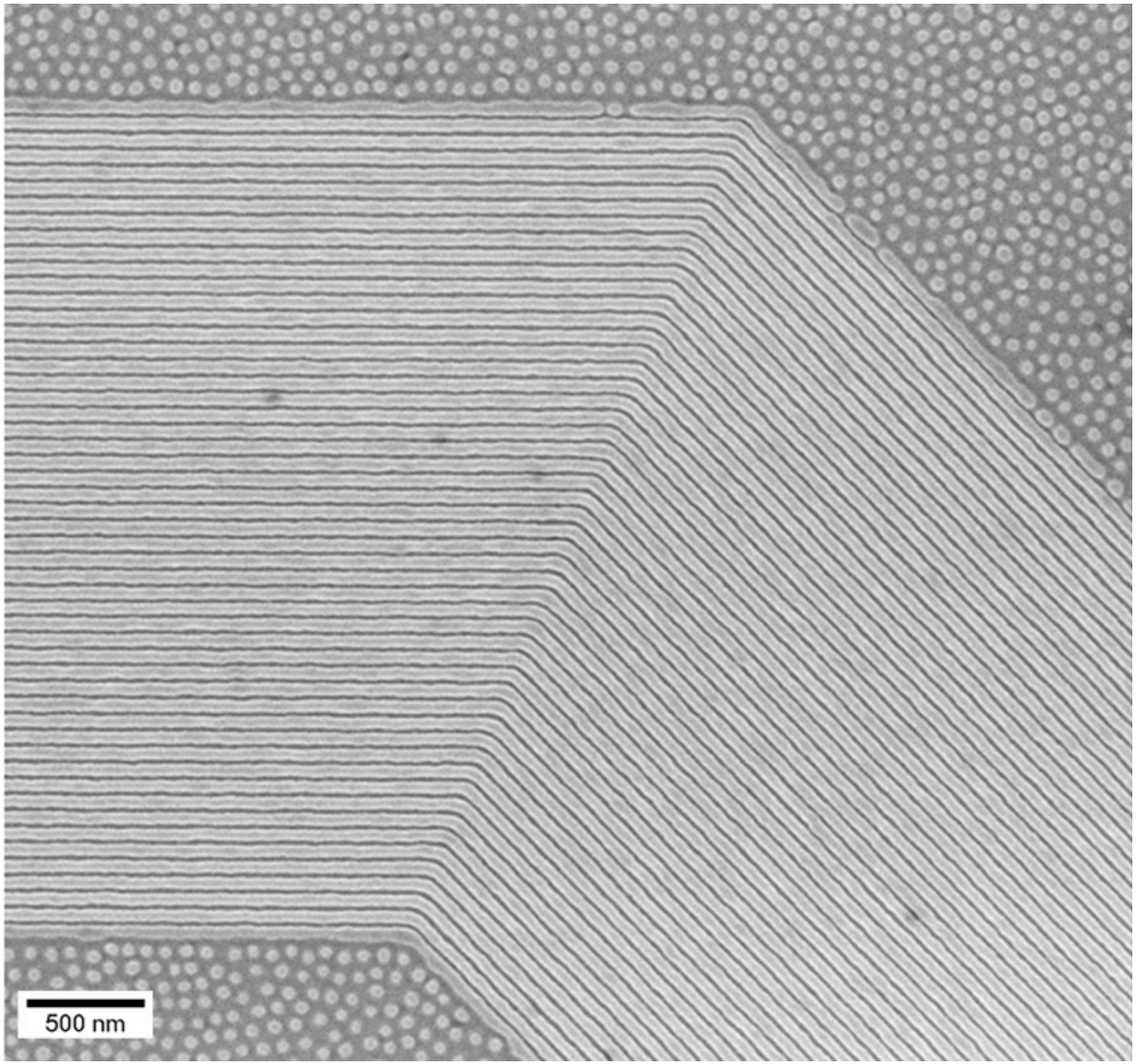
opticalproteomics.org

Diblock Copolymer Lithography (Uses self assembly)

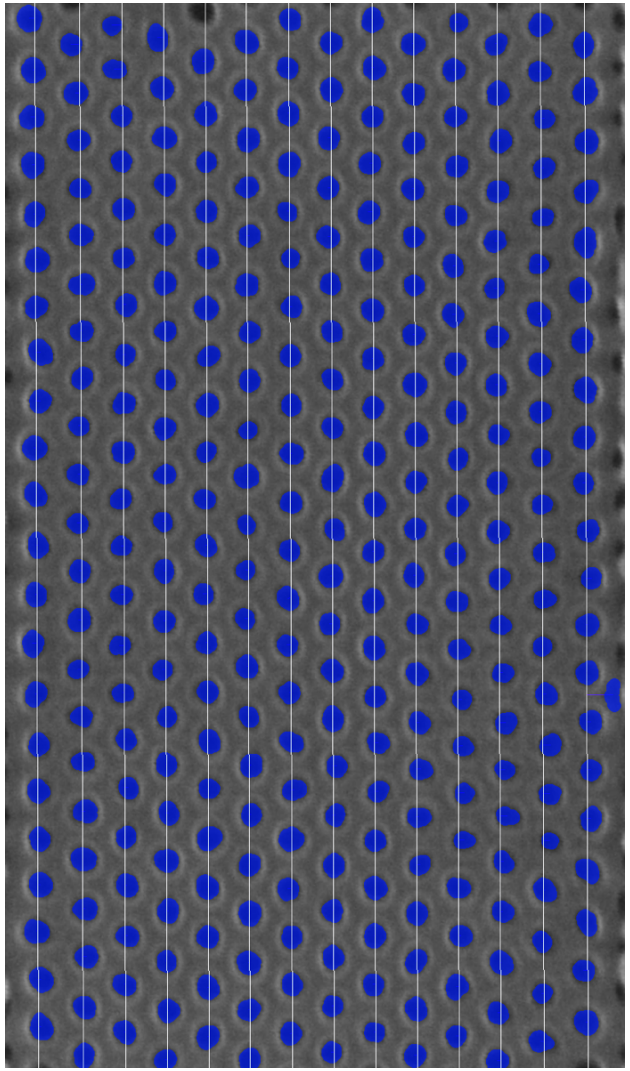


Down to 3 nm

Diblock Copolymer Lithography

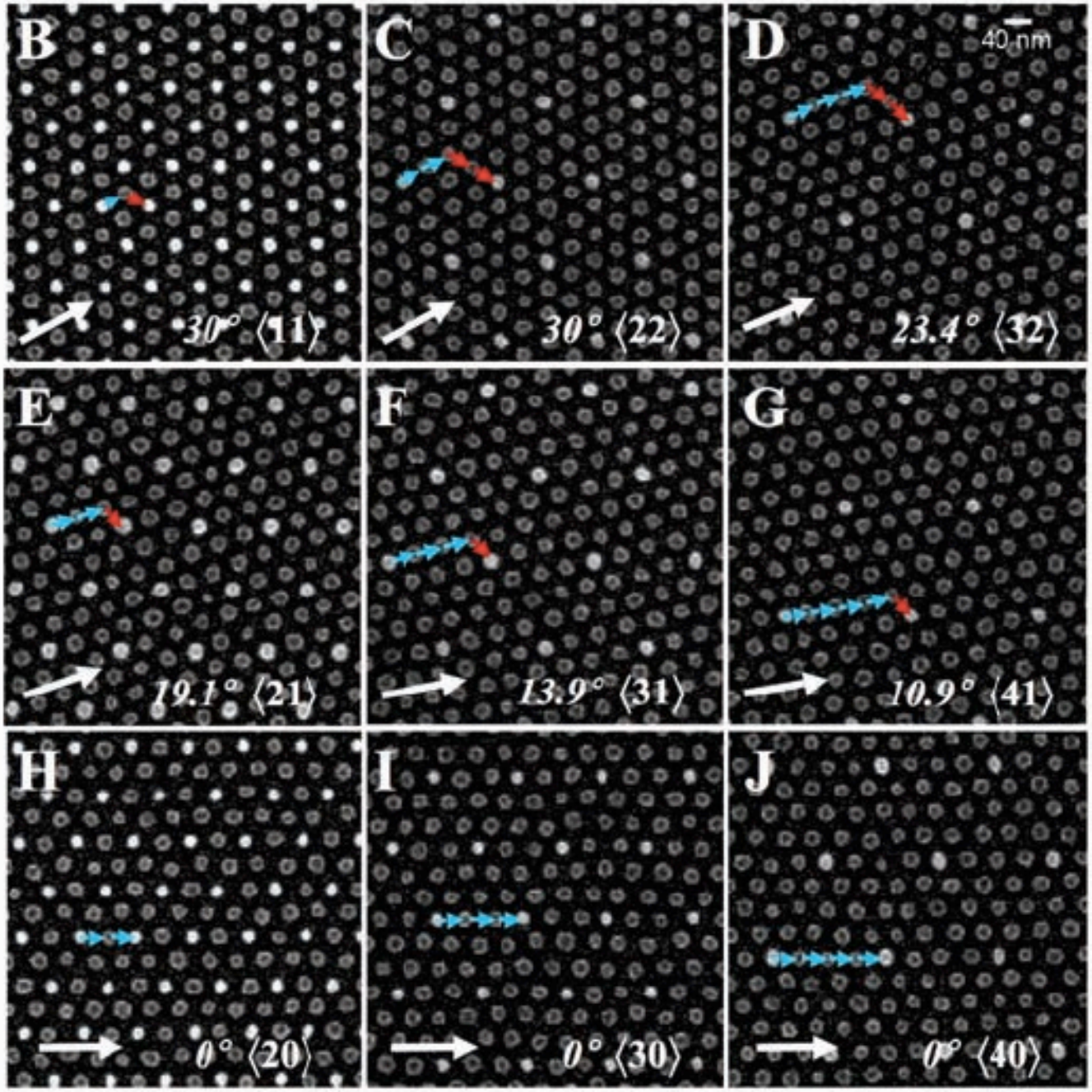


U. Wisconsin



UMass-Seagate

Density Multiplication using Diblock Copolymers (MIT)



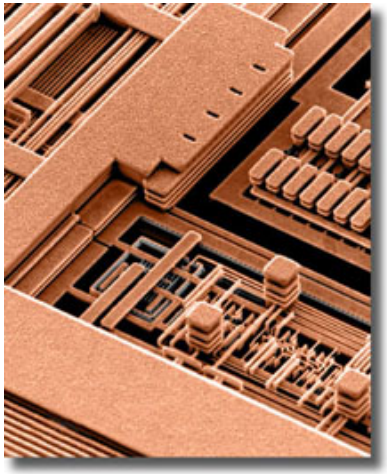
I. Bita, J.K.W. Yang, Y.S. Jung, C.A. Ross, E.L. Thomas, and K.K. Berggren
Science ***321****, 939 (2008).*

Also Hitachi/UW work*:*
R. Ruiz, H. Kang, F.A. Detcheverry, E. Dobisz, D.S. Kercher, T.R. Albrecht, J.J. de Pablo, and P.F. Nealey
Science ***321****, 936 (2008)*

Next....

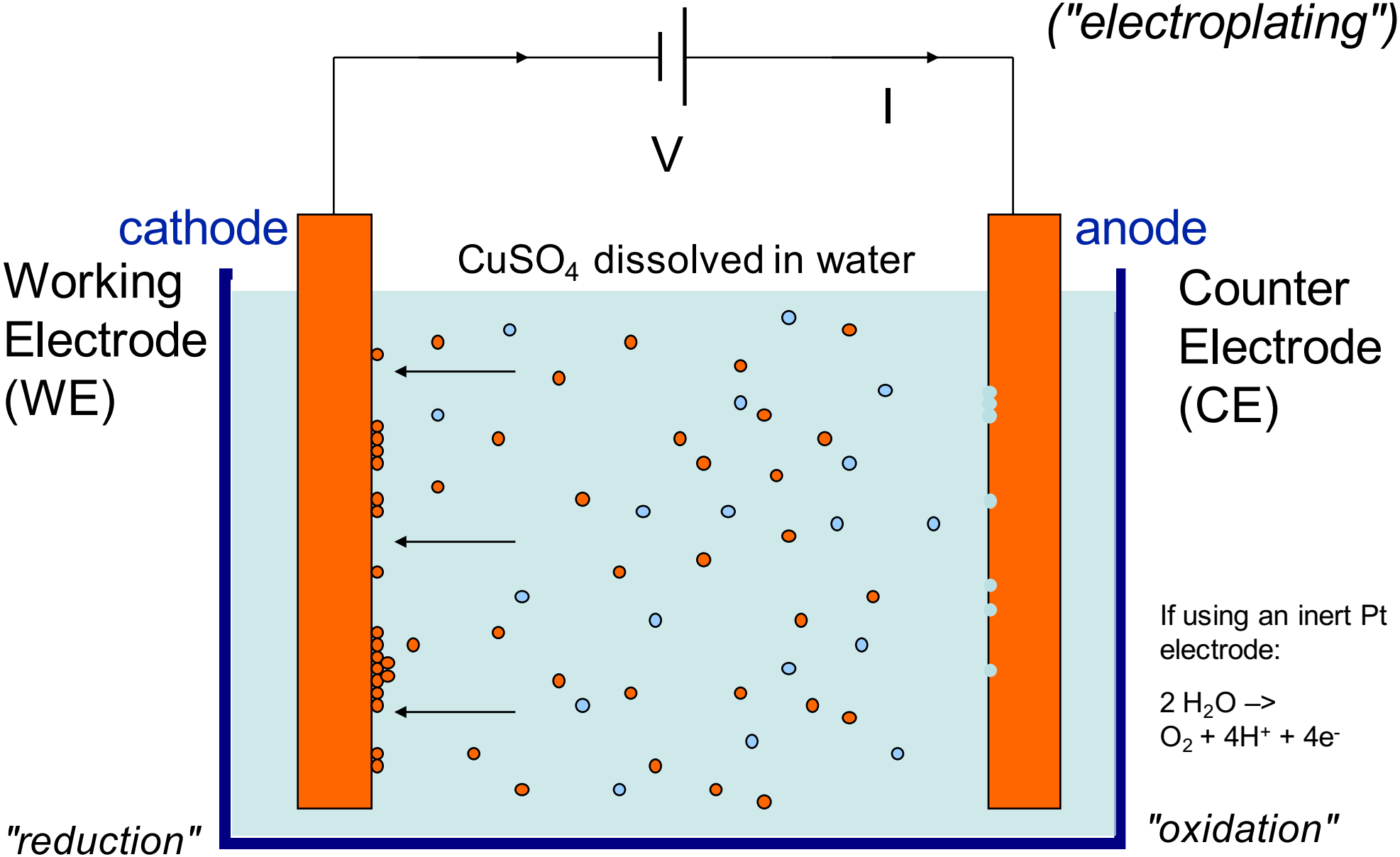
....Electrodeposition...

....another convenient way to make nanofilms



Nanofilm by Electrodeposition

("electroplating")

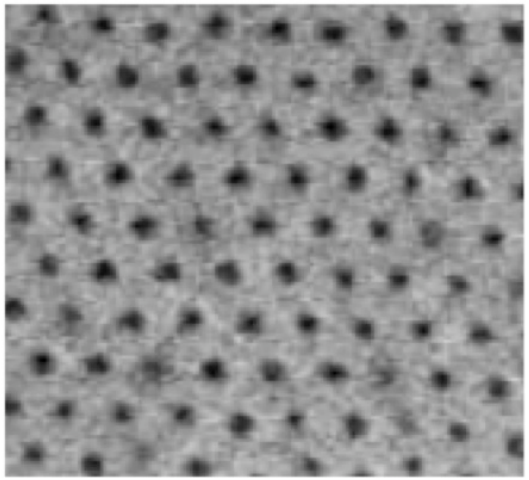


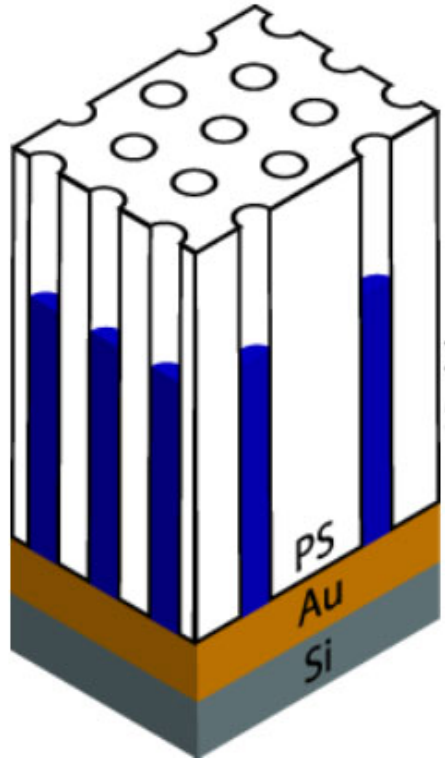
$Cu^{2+} + 2e^- \rightarrow Cu^{(0)}$

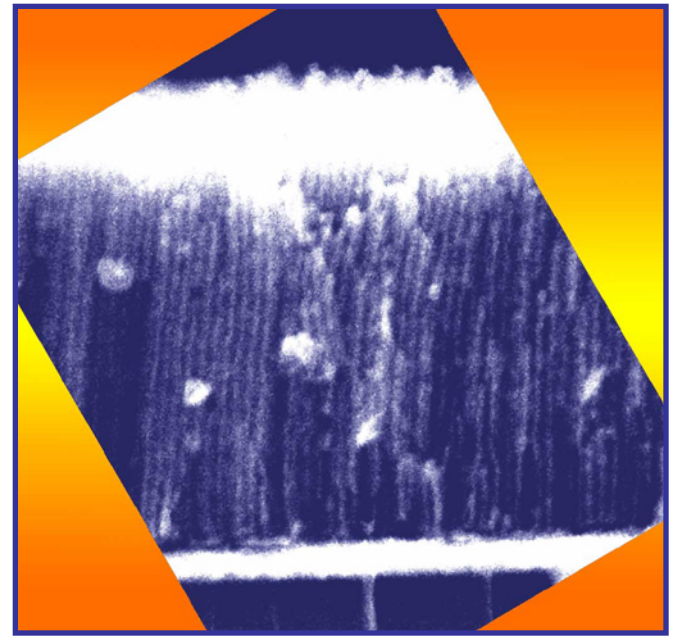
$Cu^{(0)} \rightarrow Cu^{2+} + 2e^-$

Electrodeposition into a Nanoscale Lithographic Template

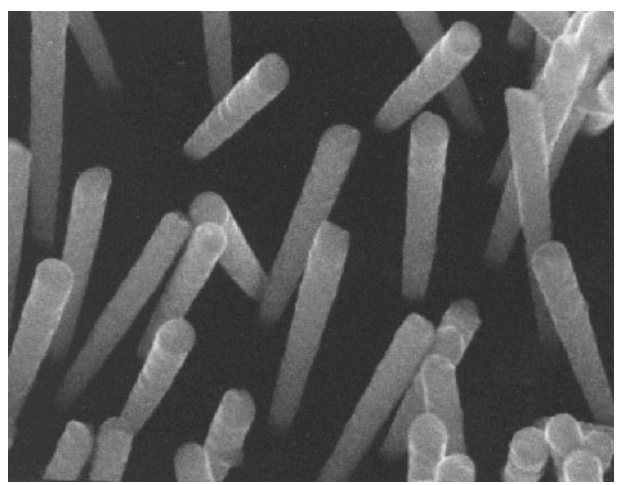
nanoporous template







nanowires in a polycarbonate filter



nanowires in a diblock copolymer template

Electrochemical Deposition

CHM video module at:
http://www.umassk12.net/nanodev/NanoEd/Electrochemical_Deposition/index.html