Lithography and Electrodeposition

2015 Nano Education Institute at UMass Amherst
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”
Making Small Smaller
Computer Microprocessors

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

*(controlling lateral dimensions, 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

- resist
- ↓ expose
- ↓ scission, cross-linking
- ↓ develop
- ↓ deposit & liftoff

Exposed region results in presence of structure

Negative Resist

- resist
- ↓ expose
- ↓ scission, cross-linking
- ↓ develop
- ↓ deposit & liftoff

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 ($\lambda$)
  - 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)

- Deposition Template (physical or electrochemical)
- Etching Mask
- Nanoporous Membrane
- Remove polymer block within cylinders (expose and develop)

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, 936 (2008)
Next....

....Electrodeposition...

....another convenient way to make nanofilms
Nanofilm by Electrodeposition

(V) I

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

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

If using an inert Pt electrode:

2 H_2O \rightarrow O_2 + 4H^+ + 4e^-

Working Electrode (WE) -- Counter Electrode (CE)
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: