

Basic Nanotechnology Processes

E SC 212

Unit 1

An Introduction to Processing

Lecture 1

Nanofabrication Processing

Outline

- Top-Down Manufacturing
- Bottom-Up Manufacturing

Nanofabrication Processing

- Makes “things” that have at least one dimension that is 100 nm or less
- These “things” vary broadly from nanoparticles for drug delivery or chemical processing catalysts to plasmon waveguides for light signal processing or transistors for microelectronics

How is Nanofabrication Processing Done?

- **Top-down nanofabrication**
- **Bottom-up nanofabrication**
- **Hybrid nanofabrication**

What are the basic differences among these approaches ?

- Top-down nanofabrication makes nano-structures by repeated use of steps that deposit films (additive processes) and take parts of them away (subtractive processes)
- Bottom-up nanofabrication builds up nano-structures from atoms, molecules, particles, or some combination of these
- Hybrid nanofabrication combines elements of top-down and bottom-up nanofabrication

Top-down Nanofabrication is like Sculpting



Start with a material supported on a substrate

Add some new material according to a pattern (lithography)



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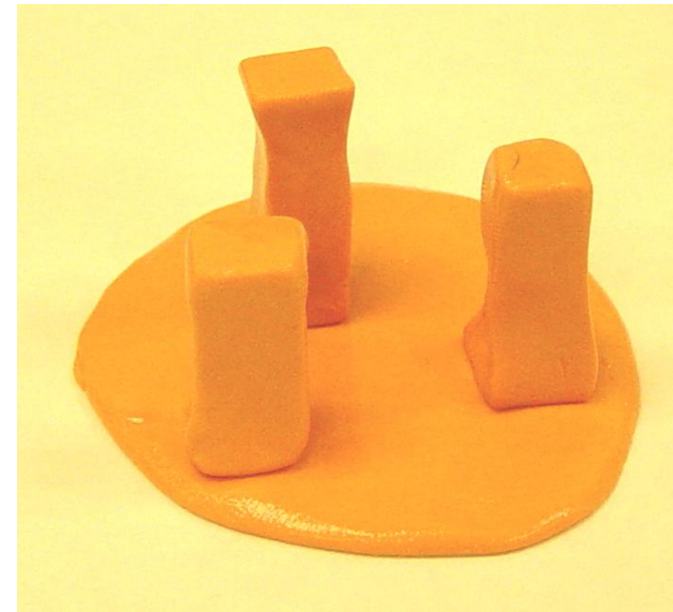
Top-down Nanofabrication is like Sculpting



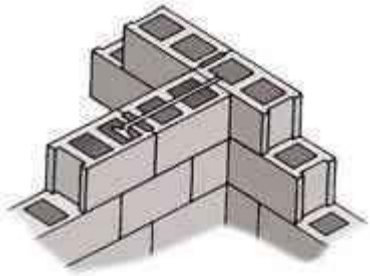
Subtract some of the material according to a pattern (process order is not important; can subtract before or after adding)

Repeat the adding/subtracting as needed following the pattern

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Bottom-up nanofabrication is like putting blocks together



The building blocks can go together in some inherent pattern dictated by shape, bonding, etc (self-assembly) or they can go together randomly

The building blocks can be atoms, molecules, or nanoparticles

Top-Down Vs. Bottom-Up Nanofabrication

Top-Down Nanofabrication

In “top-down” nanofabrication, one grows or deposits layers of materials and, by some combination of physical and chemical methods, creates the desired nanostructure, as you would make a statue from a block of marble. Top-down nanotechnology is based on the methods that are used to make microelectronics chips; i.e., structures of carefully controlled, limited dimensions are created by laying down layers of material, modifying properties as needed, and etching away those parts of each layer that are unwanted. These steps are guided by lithography.

Bottom-Up Nanofabrication

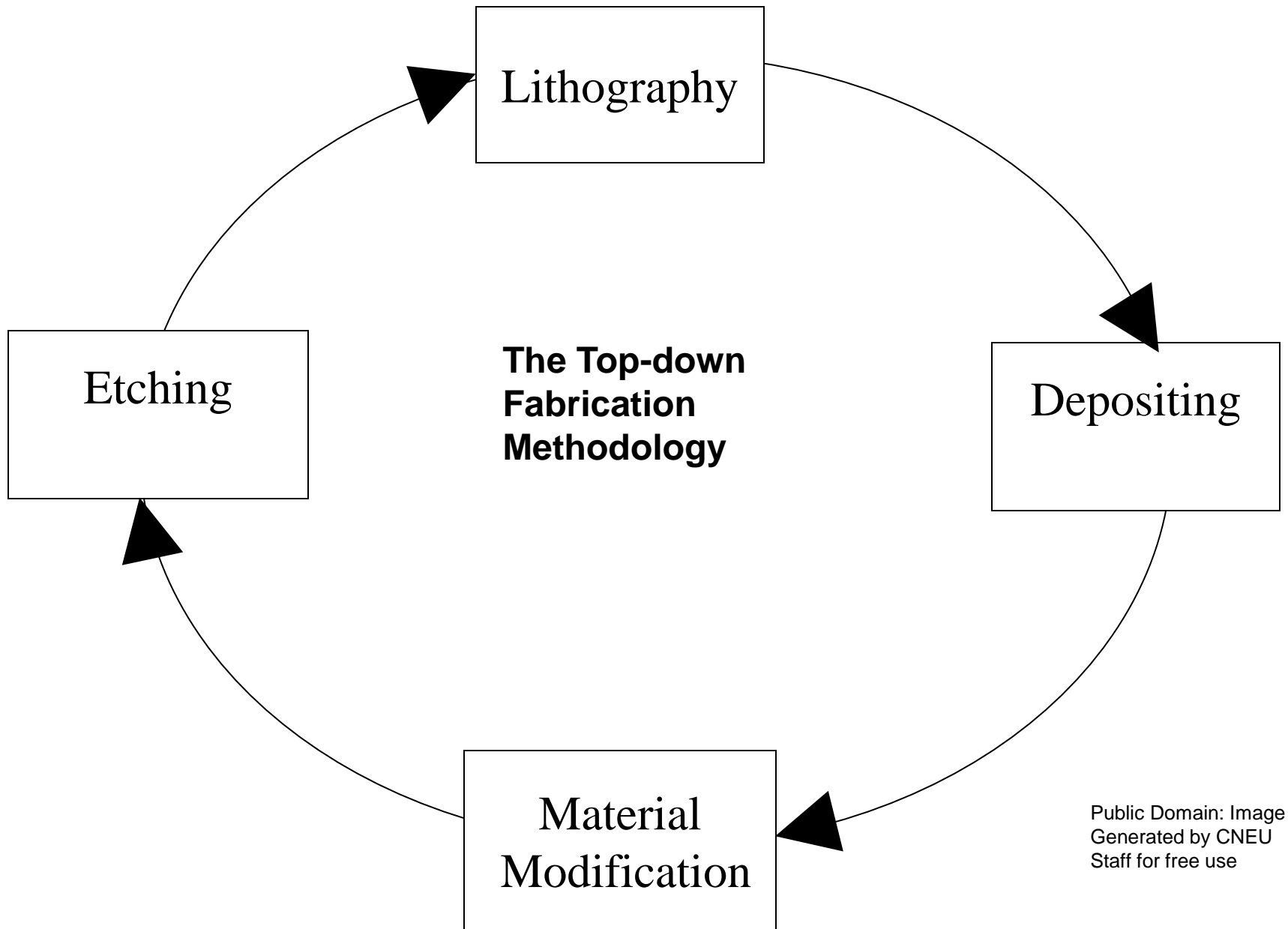
In “bottom-up” nanofabrication approaches, one starts with small components – for example, individual molecules and nano-particles – and then assembles these components to make the desired structure. Often the assembly is self-guiding; i.e., self-assembling.

Top-down nanofabrication always uses some combination of the following processes

- Lithography (Pattern transfer)
- Deposition (Addition process)
- Etching (Subtraction process)
- Materials Modification (Property tailoring)

Here's the way top-down nanofabrication is done:

- The four steps (lithography, addition, subtraction, and modification) are used in some sequence.
- Steps may be skipped. You can start with any step.
- The sequence usually starts with deposition of material.
- Lithography is the step which orchestrates all the others. It controls where materials stay and where they are “sculpted” (i.e., etched) away.



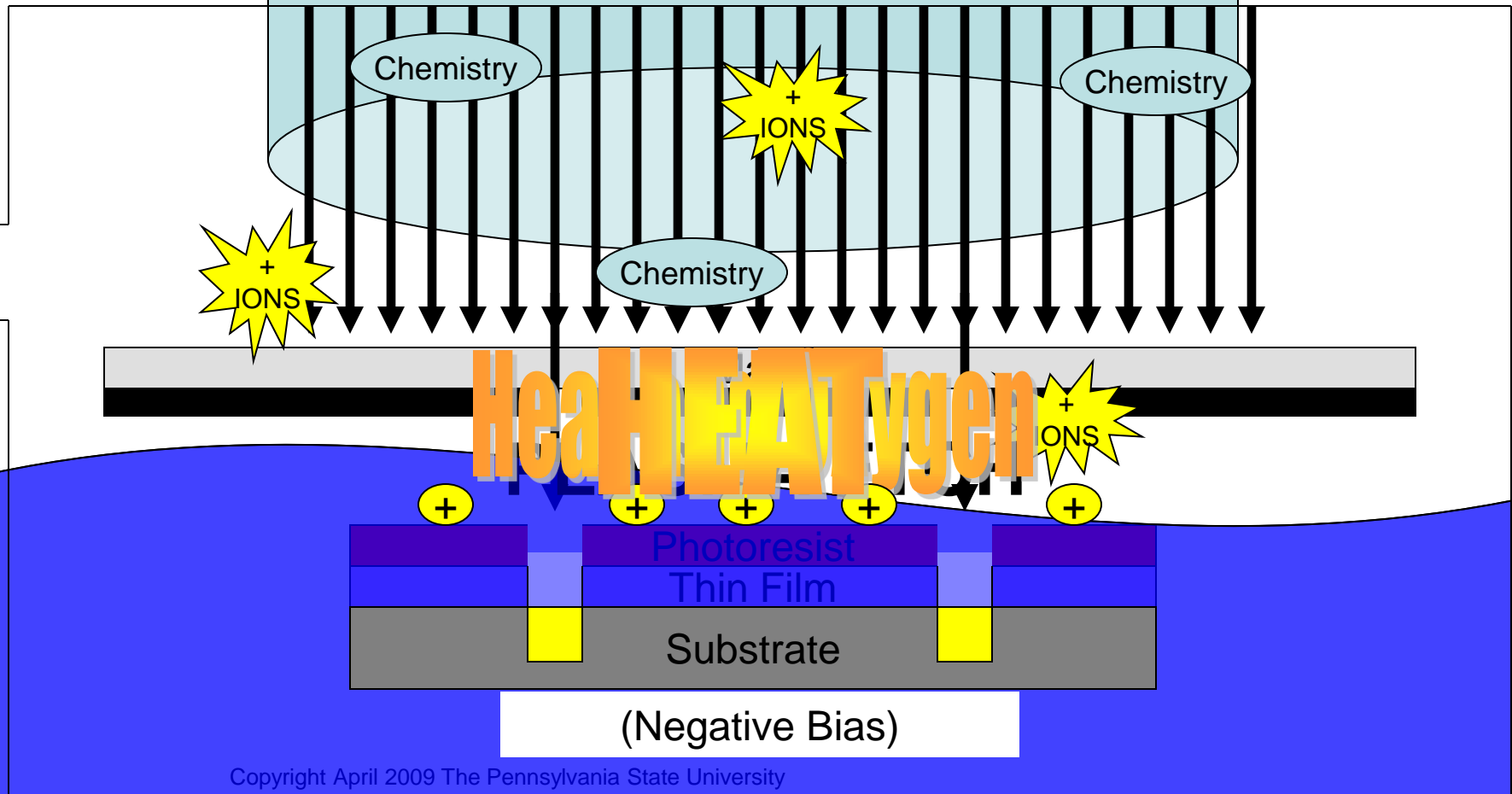
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Let's see an example of how top-down nanofabrication is used to make nano-scale structures.

An Example of a Top-Down Nanofabrication Processing Sequence

THIN FILM DEPOSITION

Film Growth Process: Physical Vapor Deposition (PVD) or Chemical Vapor Deposition (CVD)



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The preceding cartoon demonstrates the four basic steps of top-down nanofabrication:

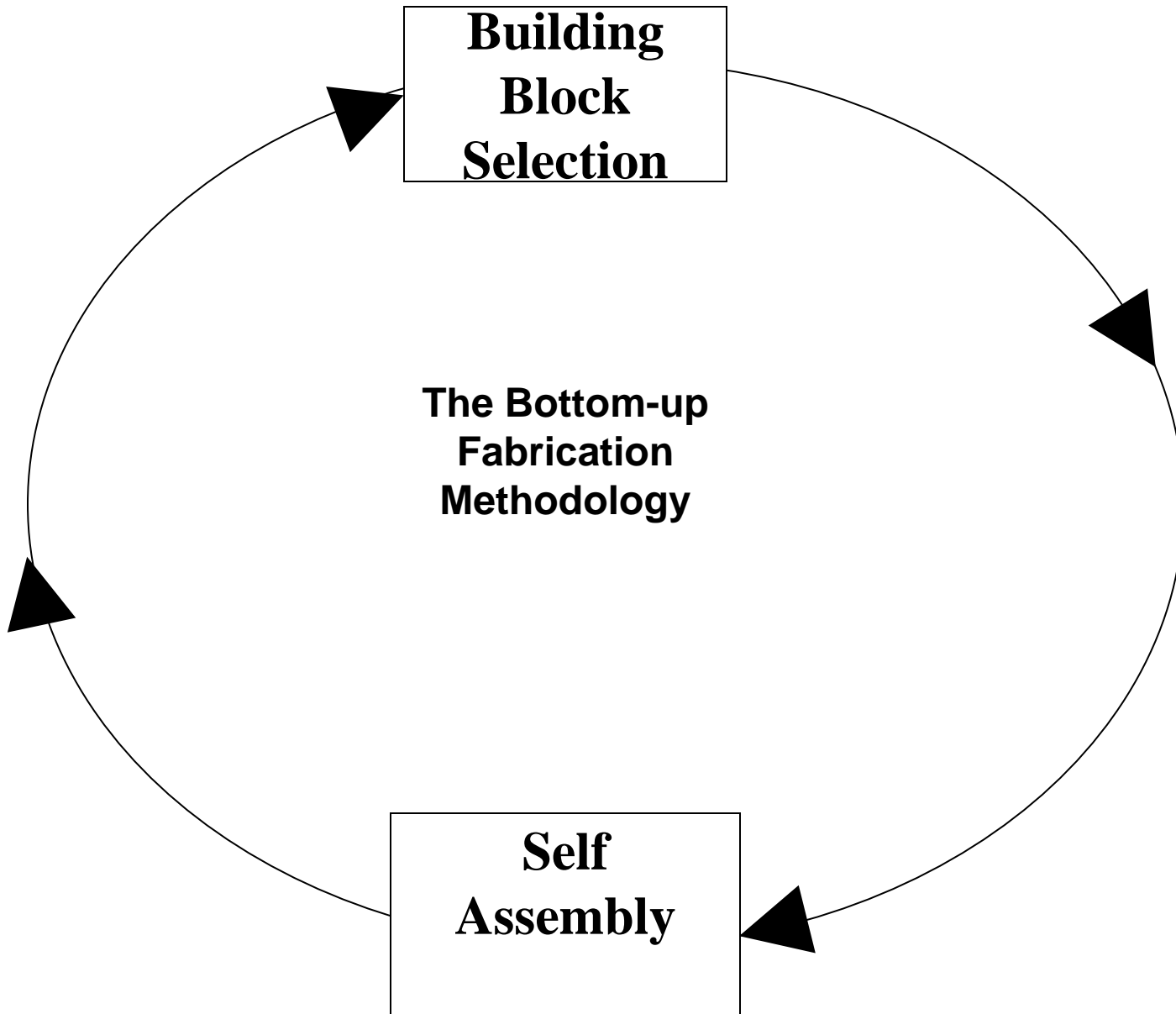
- Deposition (addition)
- Lithography (pattern transfer)
- Etching (subtraction)
- Material modification (to change electrical, optical, mechanical, or chemical properties in some region of a layer)

Bottom-up Nanofabrication generally uses some combination of:

- Building block (molecules, particles, and layers) selection
- Self assembly

Here's the way bottom-up nanofabrication is done

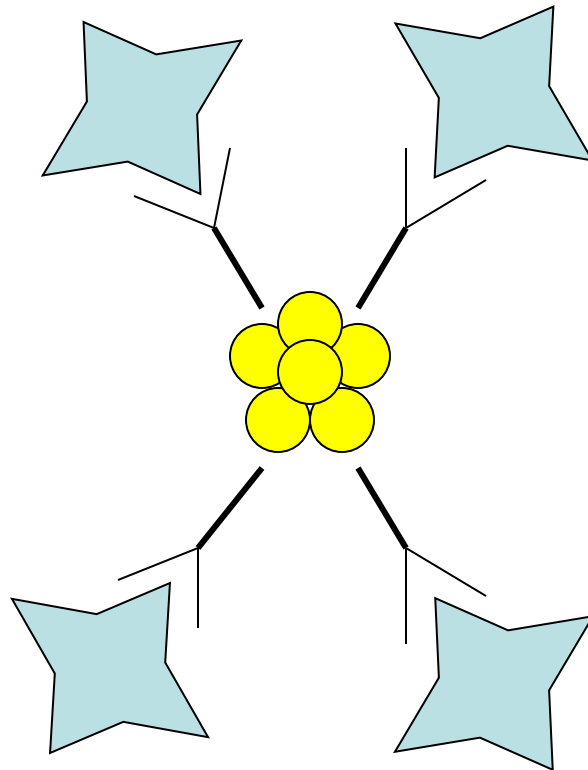
- The two steps (building block selection and self-assembly) are used in some sequence.
- Steps may be skipped.
- The sequence usually starts with building block selection.
- The pattern develops due to the size and/or shape of the building blocks.



Let's see an example of how bottom-up nanofabrication is used to make nano-scale structures.

An Example of a Bottom-Up Nanofabrication Processing Sequence

Synthesize Nanoparticle
Functionalize the Nanoparticle
Link with Antibodies
Antigen Attachment



The preceding cartoon demonstrates the two basic steps of bottom-up nanofabrication:

- Building block selection (molecules, particles, or layers)
- Assembly of the building blocks into functioning nanostructures. This step is usually termed self assembly.
- In this example, the shape of the product was dictated by the selection of chemical bonds.