나노 기술의 이해
(Understanding Nanotechnology)

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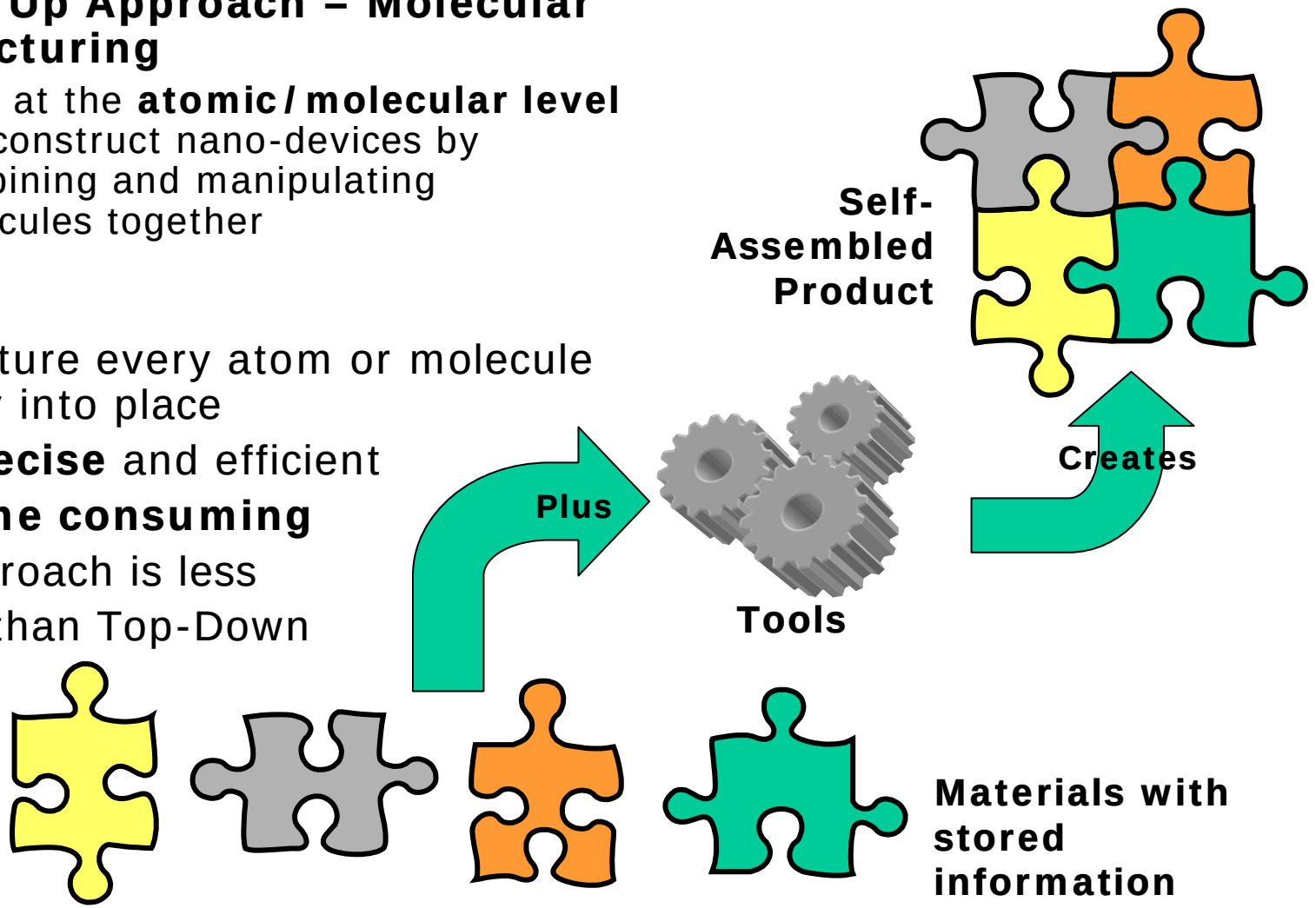
Lecture 10.
Bottom – Up Approaches

Bottom – Up Approaches

- **Bottom Up Approach – Molecular Manufacturing**
  - ✓ Start at the **atomic / molecular level** and construct nano-devices by combining and manipulating molecules together

- Manufacture every atom or molecule perfectly into place
- More **precise** and efficient
- More **time consuming**
- This approach is less mature than Top-Down



Bottom – Up Approaches

1) *Chemical Method*

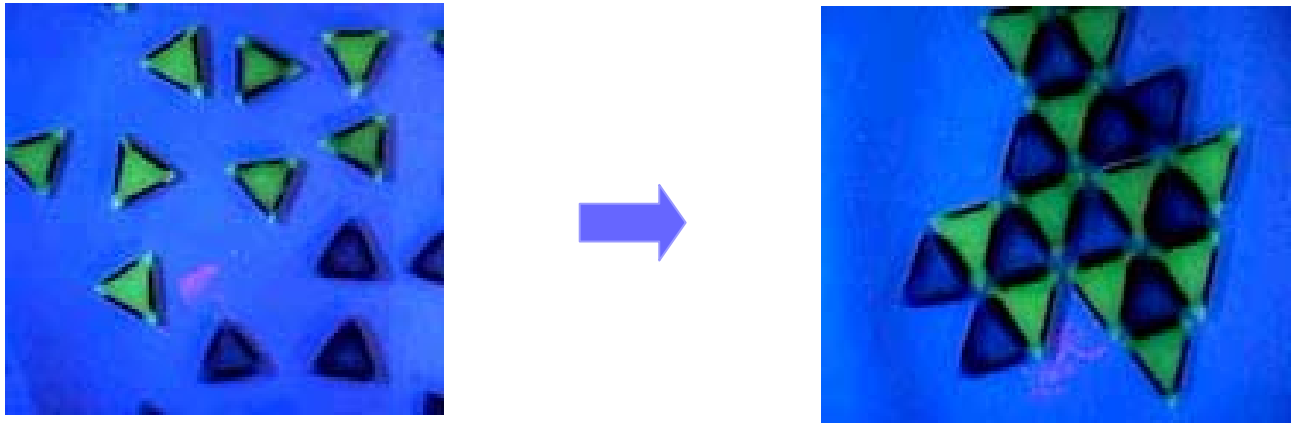
- **Intermolecular interaction**
  - ✓ SAM (self-assembled monolayer)
  - ✓ LbL (layer-by-layer) self-assembly
  - ✓ L-B (Langmuir-Blodgett) films
  - ✓ Spin self-assembly

- **Reduction or decomposition within confined regions**
  - ✓ Nanostructured template methods
  - ✓ Inversed micelle technique
  - ✓ Block copolymer technique

2) *Physical Method*

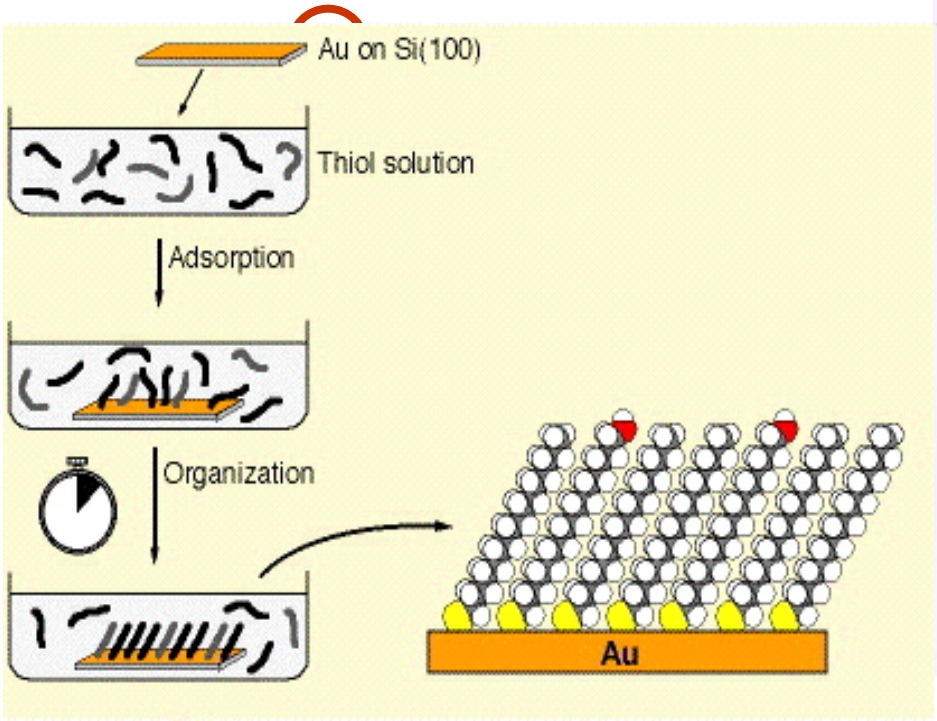
Self - Assembly

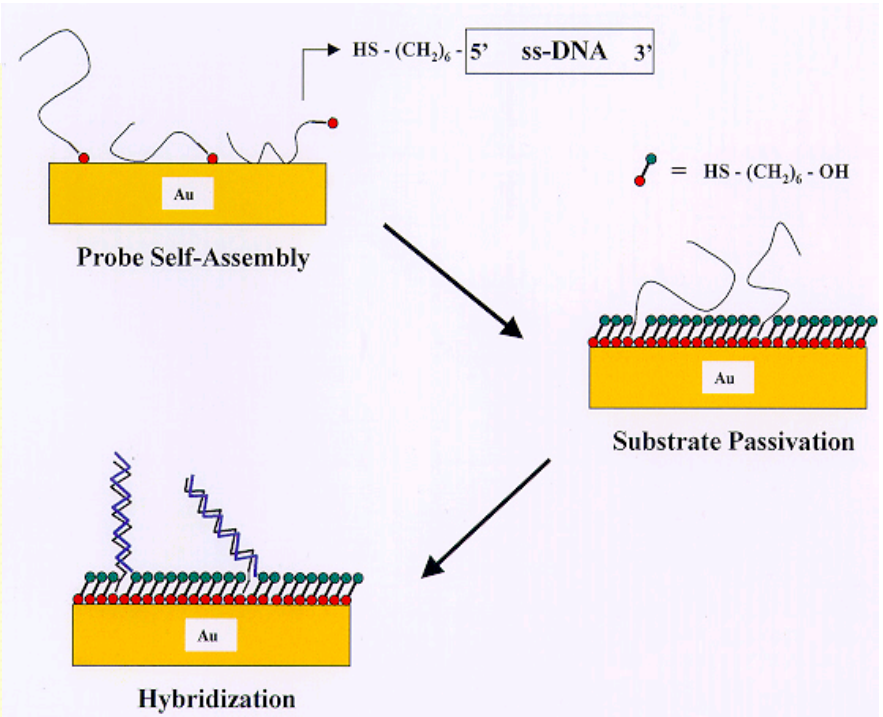
- Understand and control the intramolecular quantum behavior of specifically designed and synthesized molecules
- Using a surface to localize and stabilize them
- Self assembly occurs without any external forces or controls



SAM (self-assembled monolayer)

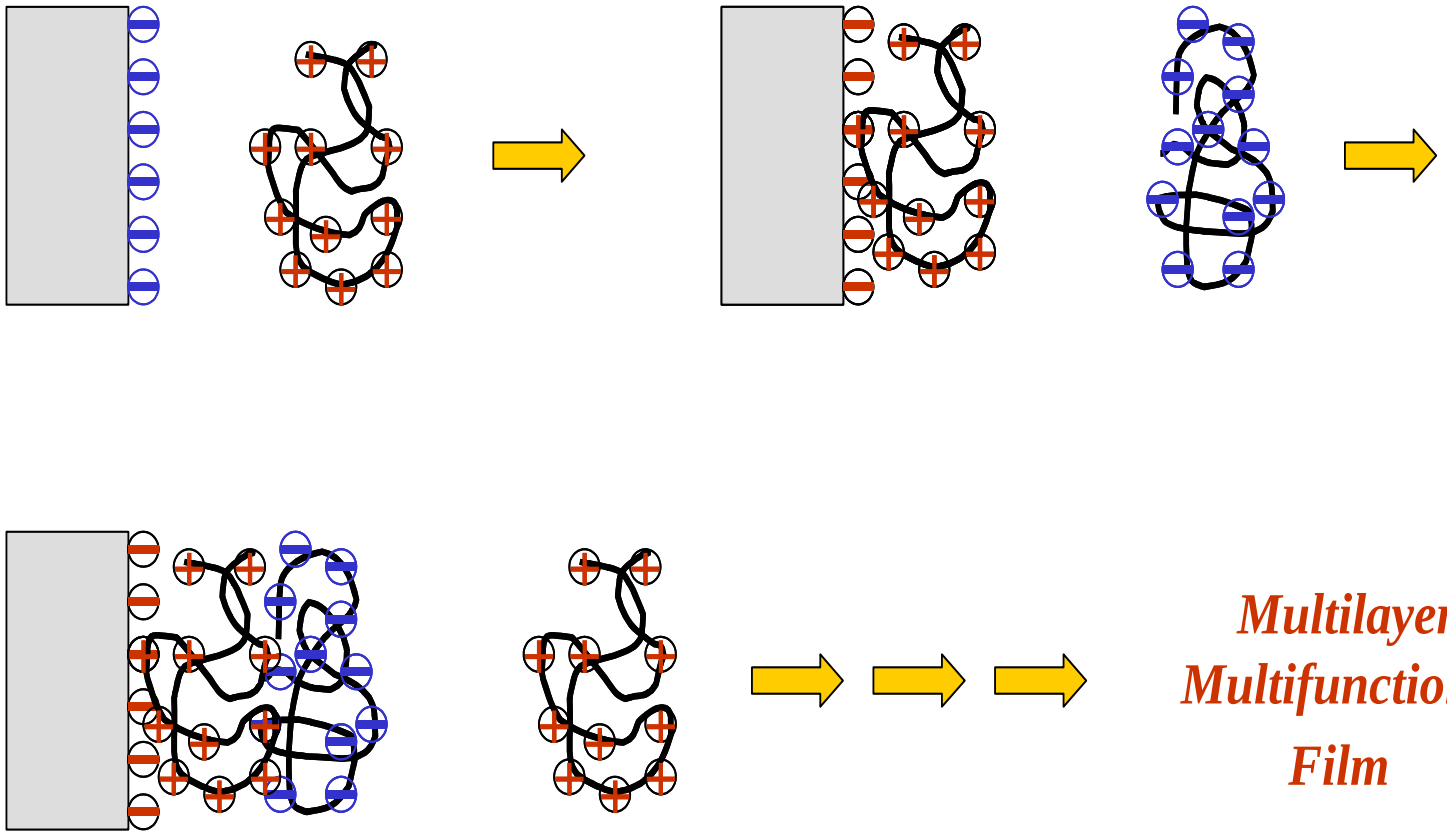
Chemical Method : Intermolecular interaction



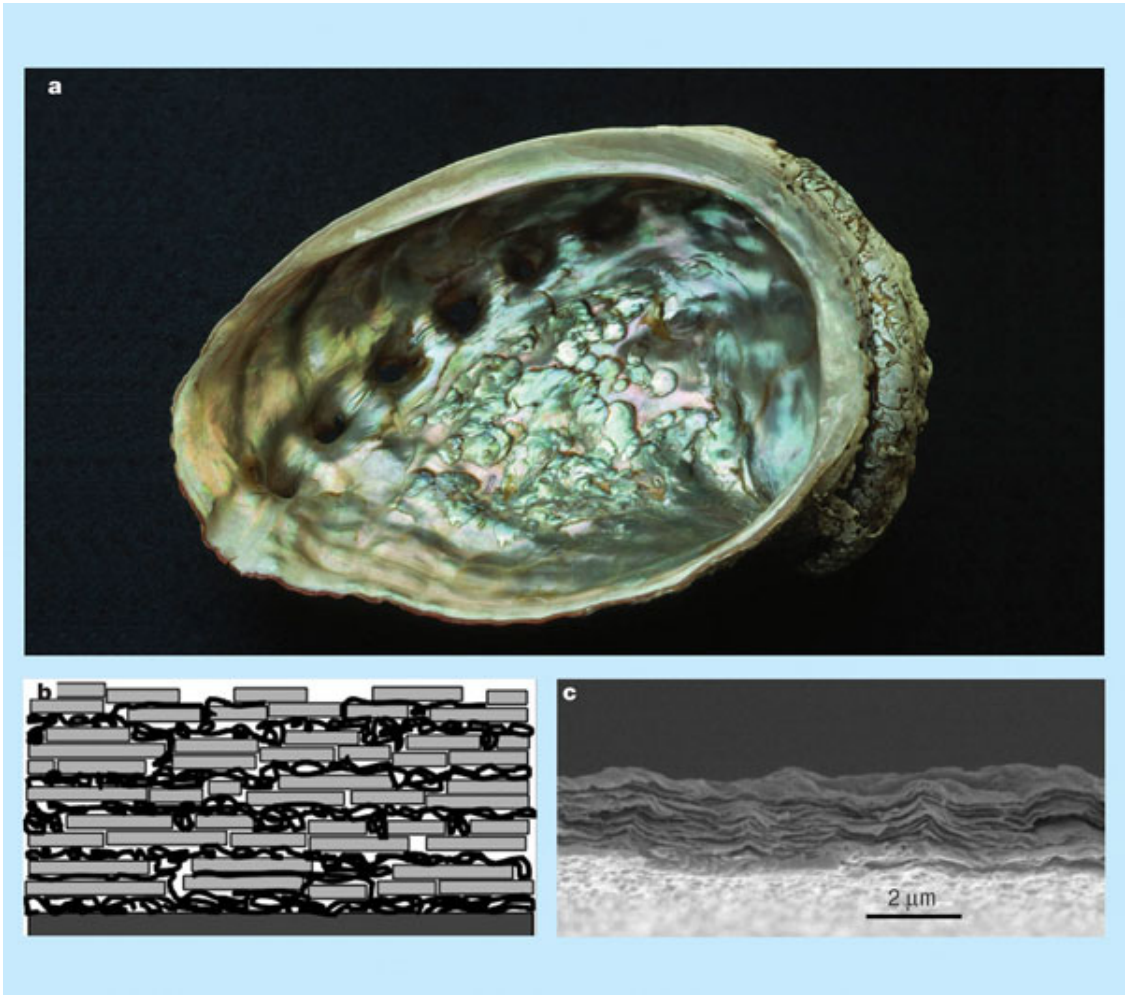


LbL (layer-by-layer) self-assembly

Chemical Method : Intermolecular interaction



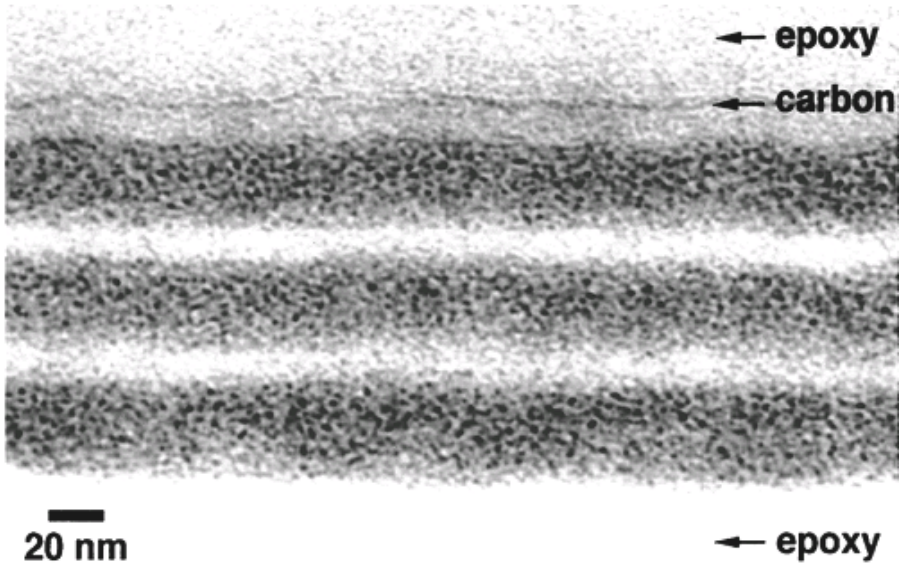
Examples of LbL (layer-by-layer) self-assembly



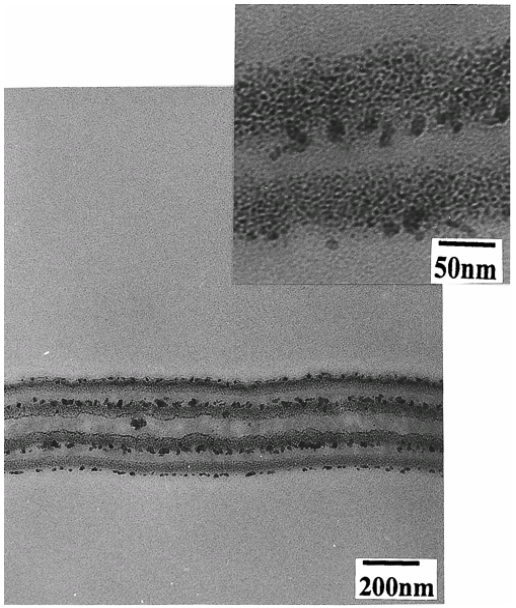
The 'bricks-and-mortar' approach. **a)** The natural strength, hardness and toughness of bone and shell are attributable to their nanoscale structure of calcium carbonate bricks and mortar-like protein layers. By mimicking this structure, Tang *et al*. have created a new material with mechanical properties similar to nacre, or mother-of-pearl. **b)** Montmorillonite bricks (0.9 nm thick) are deposited layer by layer above a silicon-wafer substrate, alternating with polymer chains of mortar. **c)** Structures that are many layers deep can be built — this one has 100 brick and polymer layers — although the process is slow.

Z. Tang *et al. Nature Mater.* **2003**, *2*, 413.

Examples of LbL (layer-by-layer) self-assembly



Cross-sectional TEM image of a multilayer heterostructure with alternating regions of PAH/PAA bilayers and PAH/SPS bilayers (final structure: epoxy/$((PAH/PAA)_{10}/(PAH/SPS)_{15})_3$/carbon film/epoxy). The three regions containing the PAH/PAA blocks appear dark because of the selective staining with Pb(II) ions.

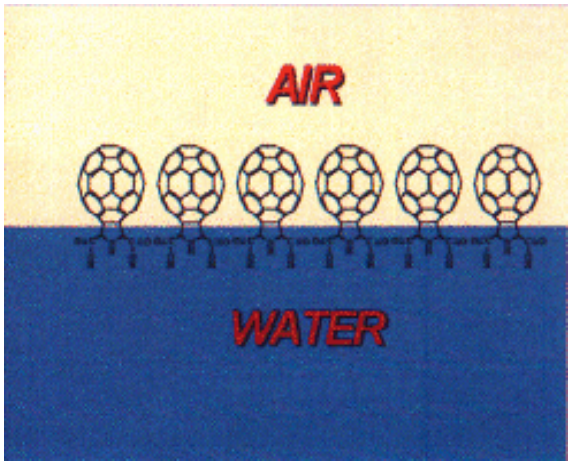


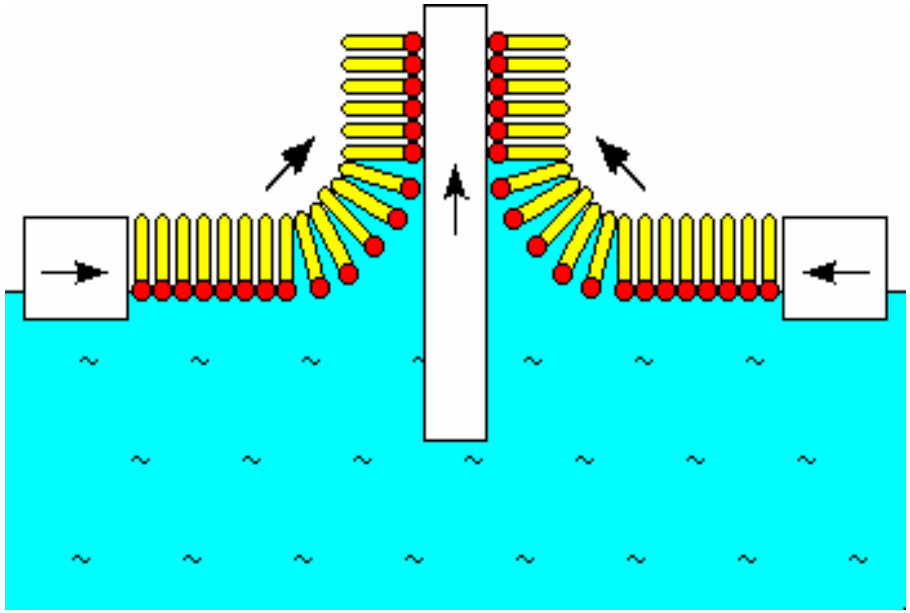
Cross-sectional TEM image of a $(PAH/PAA)_8/(PAH/SPS)_{45}/(PAH/PAA)_7/(PAH/SPS)_{45}$ film containing PbS nanoparticles within the PAH/PAA bilayer blocks.

R.E. Cohen & M. F. Rubner *et al. Langmuir* **2000**, *16*, 1354.

L-B (Langmuir-Blodgett) films

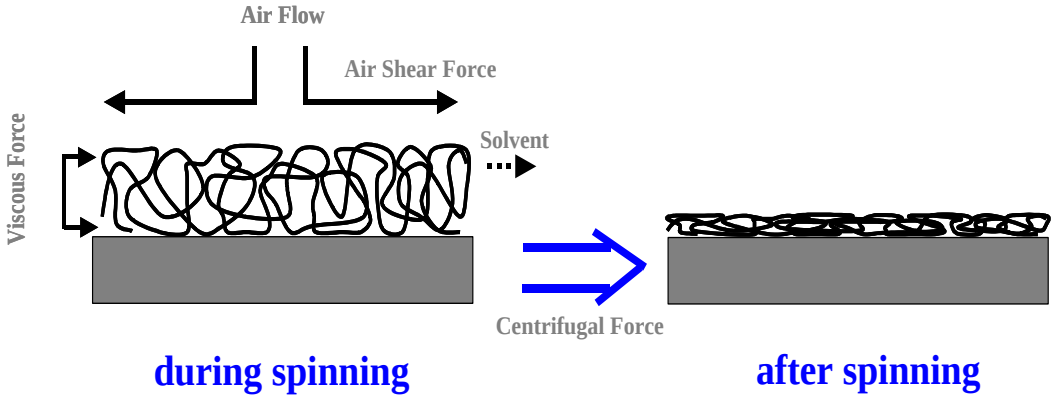
Chemical Method : Intermolecular interaction

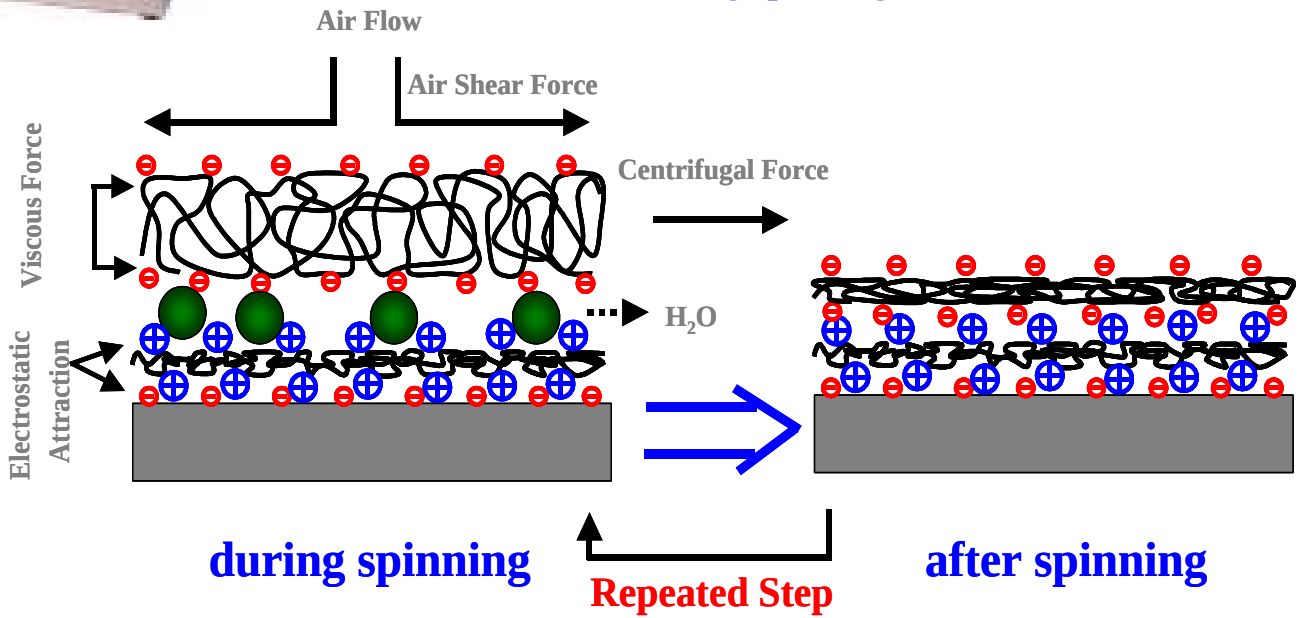




Spin self-assembly

Chemical Method : Intermolecular interaction

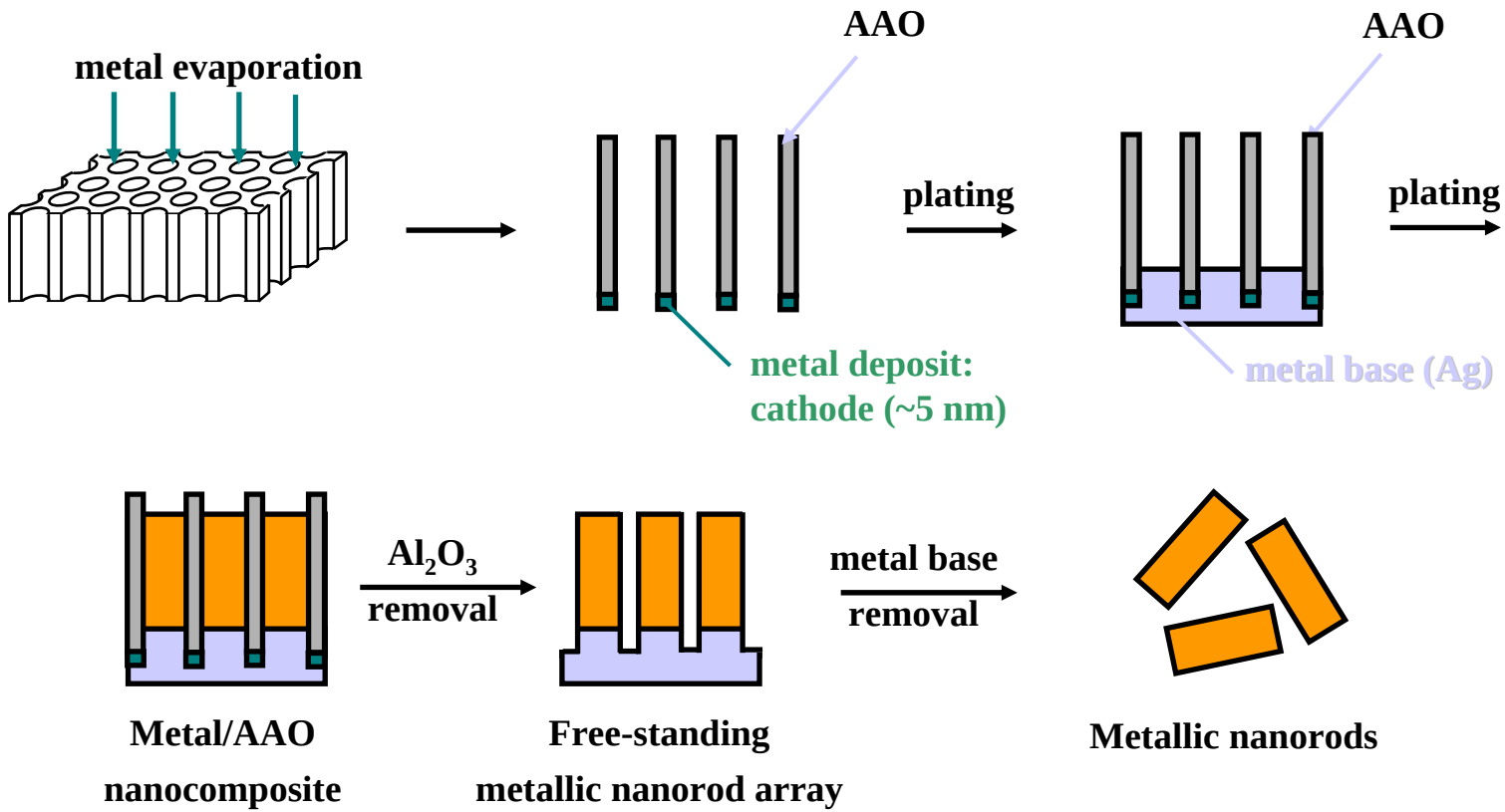




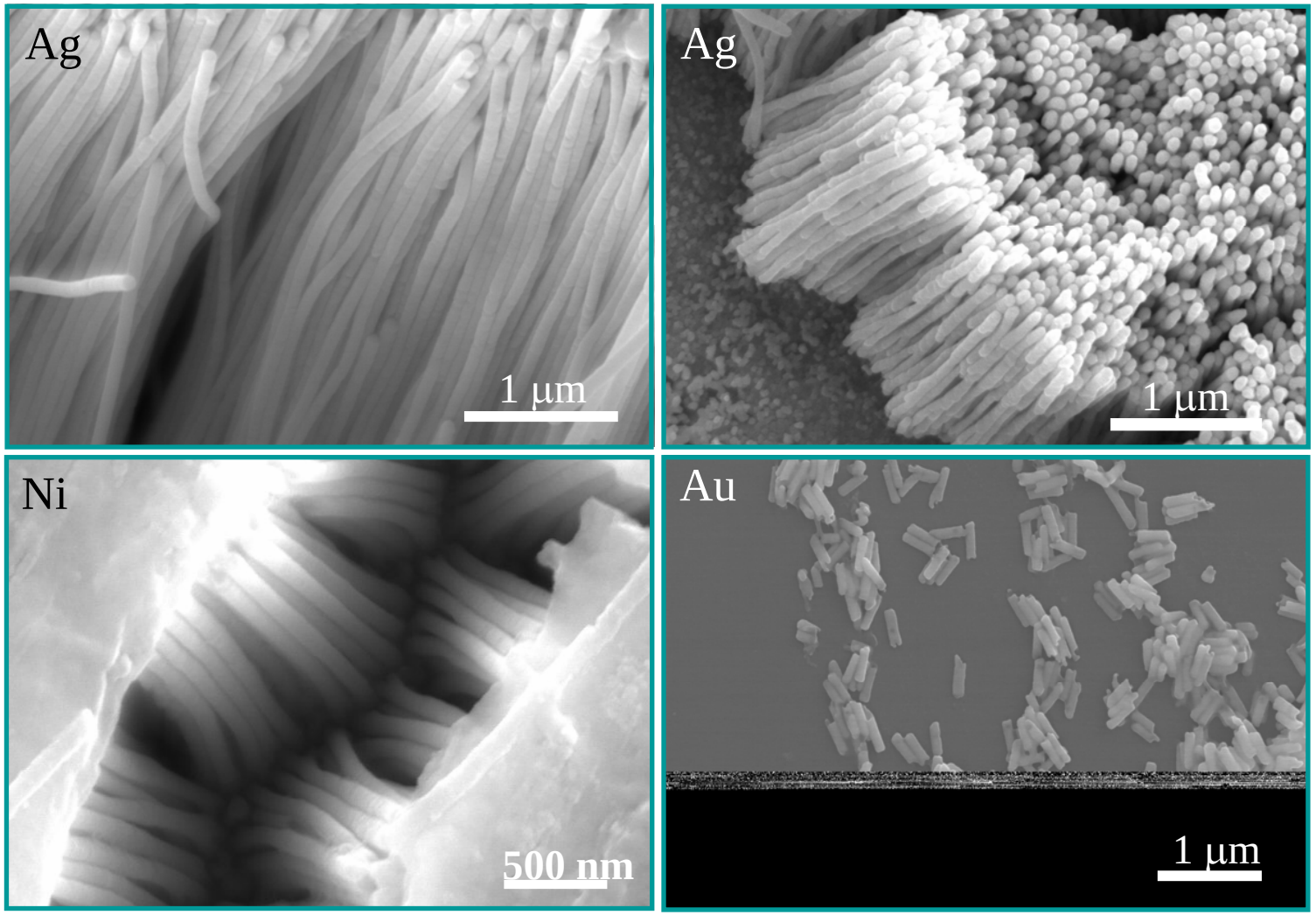
Nanostructured template methods :
Anodized aluminum oxide, AAO

Chemical Method : Reduction or decomposition within confined regions

❖ **Metal Nanorods**

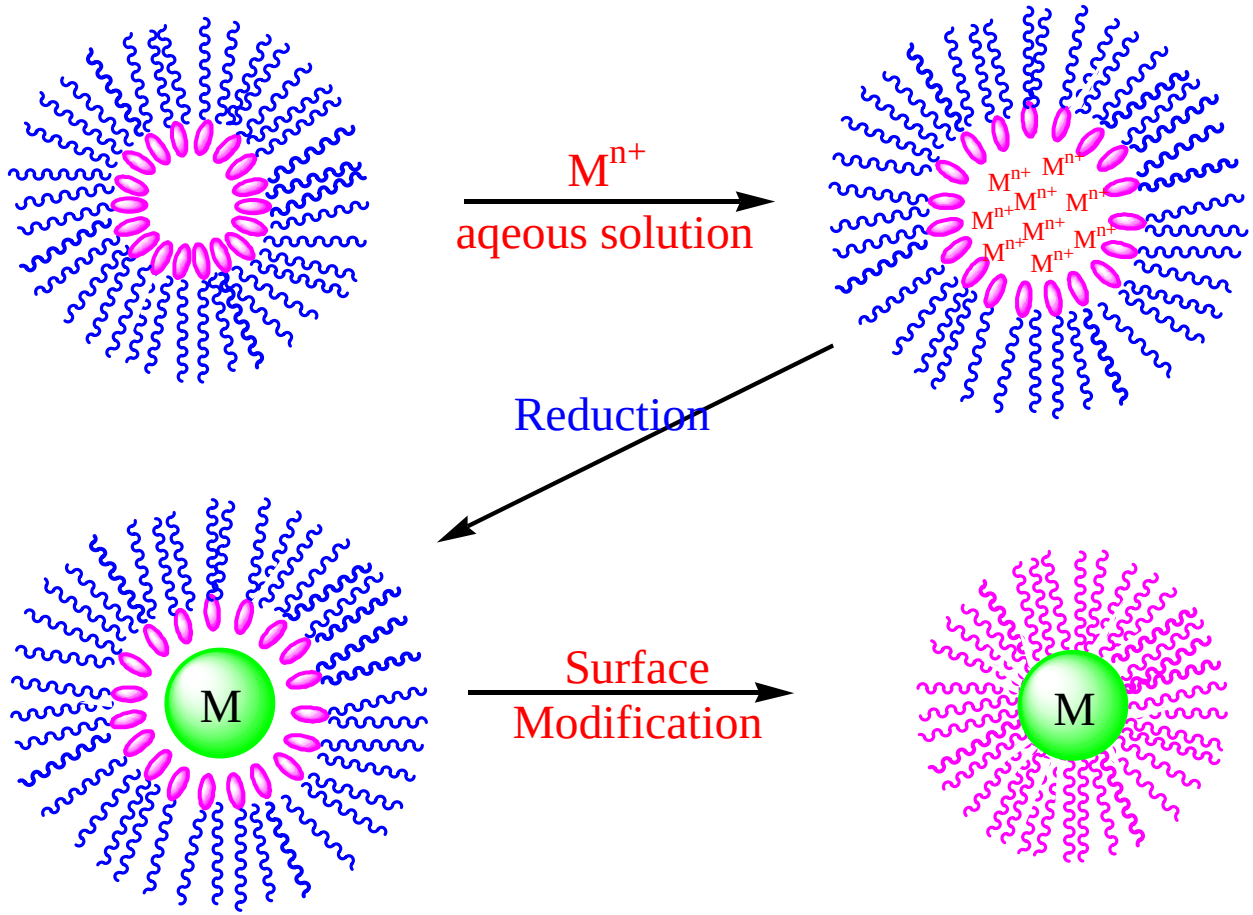


Examples of Metal Nanorods

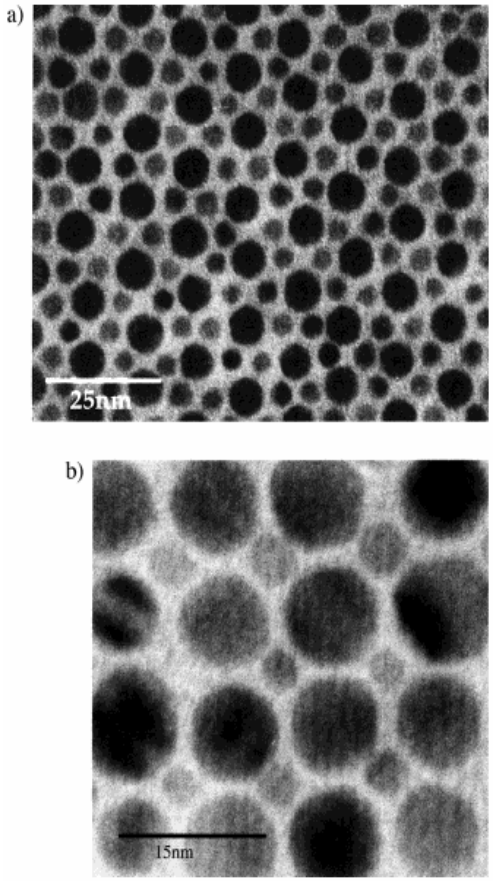


Inversed micelle technique

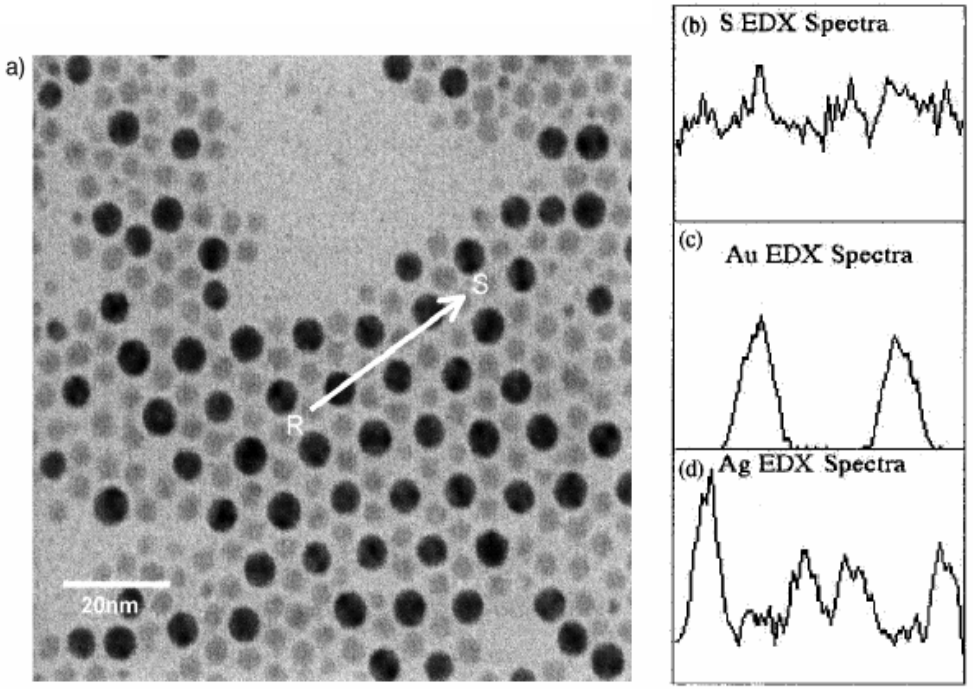
Chemical Method : Reduction or decomposition within confined regions



Examples of Inversed micelle technique



Rafts of bimodal Au nanoparticles forming superlattice arrays



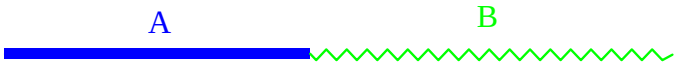
a) A bright field image of an ordered Au/Ag colloidal nanoalloy raft. Also shown are EDX line scans taken along the line RS using b) the 2.307 eV S Ka, c) the 9.711 eV Au La, and d) the 2.984 eV Ag La X-ray emission lines.

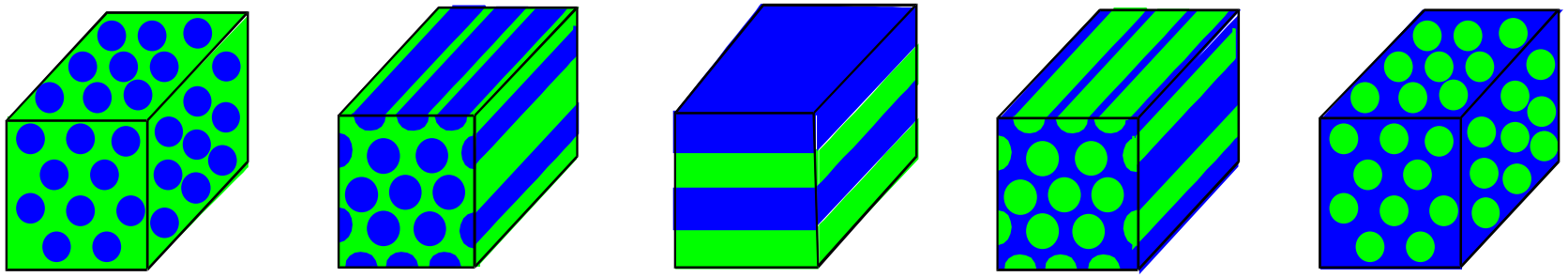
C. J. Kiely *et al. Adv. Mater.* **2000**, *12*, 640.

Block copolymer technique
: Nano structured template methods

Chemical Method : Reduction or decomposition within confined regions

Diblock copolymer (A-B)

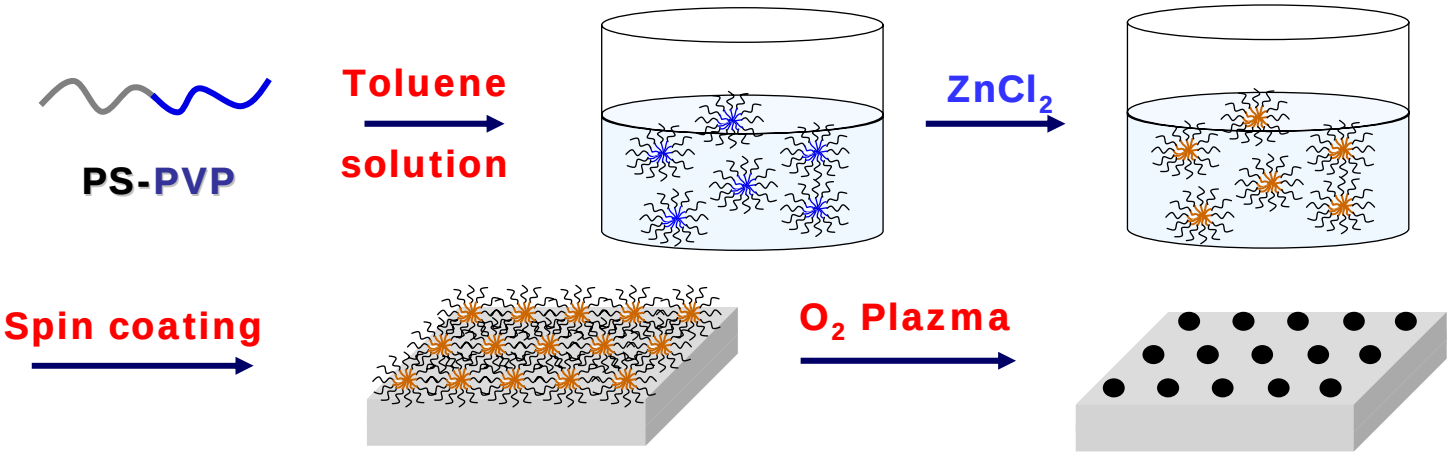


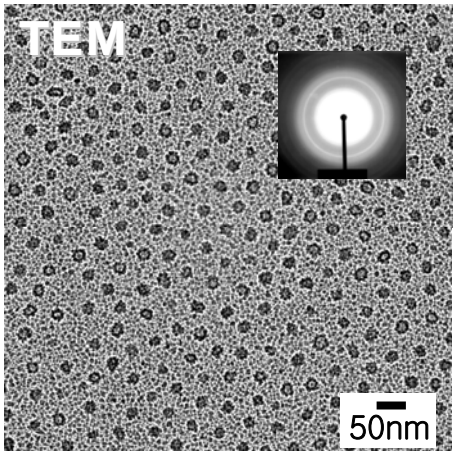


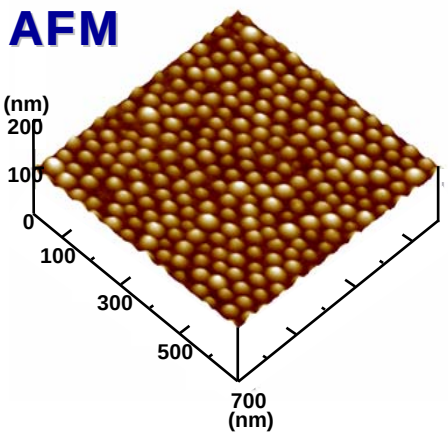
Higher volume % of A

Spherical (A) **Cylinderical (A)** **Lamellar** **Cylinderical (B)** **Spherical (B)**

Block copolymer technique : Reduction or decomposition within block copolymers domains

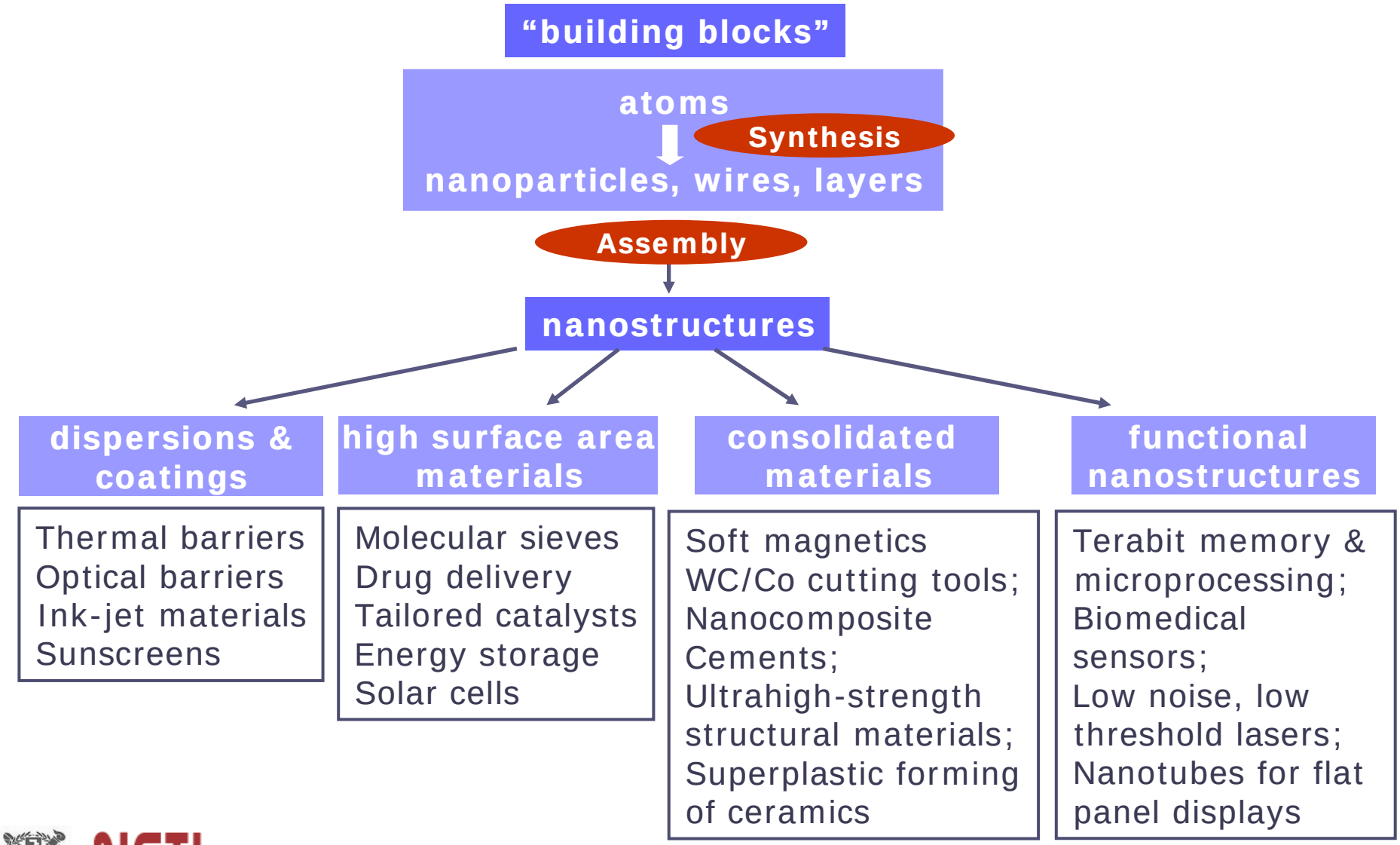






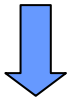
B. H. Sohn *et al.*
J. Am. Chem. Soc, **2001**, *123*, 12734.

Bottom – Up Approaches



Challenges of bottom-up fabrication

- ***Getting the structures to grow exactly how and where you want***
- ***Making complicated patterns***
- ***Fabricating robust structures***



Some common strategies

- ***Use catalysts, stress fields, diffraction gratings to achieve selective growth in specific locations***
- ***Use top-down processes in conjunction with bottom-up processes, and build on silicon substrates***