Lecture 2. Methods and Techniques for Self-assembly

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Lecture 2: Methods and Techniques for Self-assembly

- Principle: forces/interactions

Various forces

- Covalent bond (chemical bonding)
- Van der Waals
- Electrostatic
- Hydrogen Bonding
- Hydrophobic
- Hydration (structural)
- Steric/polymers

Self-assembly and Nanotechnology
Dielectrophoretic Assembly of Nanowires

Sequential images of 3 µm-long NWs lining up between triangular-shaped electrodes (angle: 30°). AC field of 5 MHz (0.5V/µm) is applied between electrodes (gap size: 24 µm). (a) t = 0 s; (b) t = 0.5 s; (c) t = 1.0 s.


Dielectrophoresis (or DEP) is a phenomenon in which a force is exerted on a dielectric particle when it is subjected to a non-uniform electric field. This force does not require the particle to be charged. All particles exhibit dielectrophoretic activity in the presence of electric fields. However, the strength of the force depends strongly on the medium and particles' electrical properties, on the particles' shape and size, as well as on the frequency of the electric field.
Lecture 2: Techniques for Self-assembly-Examples

Molecular Linker: Biotin-Avidin

(A) Light and (B) fluorescence microscope images of Au/Pt/Au nanowires functionalized with BIC, biotin-terminated thiol, and exposed to NATR. (C) Light and (D) fluorescence microscope images of a self-assembled cluster of Au/Pt/Au nanowires with 500 nm gold segments. (E) Light and (F) fluorescence microscope images of Au/Pt/Au nanowires with 10 nm gold segments.


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Case Study I: Hydrophobic Force

Lipid bilayer

Self-assembly

Surfactant

Minimize $\Delta G$

Gold-Polypyrrole nanowires

Park, Lim, Chung, Mirkin, Science 2004, 303, 348

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Case Study I: Hydrophobic Force

Self-assembled monolayers (SAMs) on metal surface

- SH group only bonds to Au surface
- SH doesn’t bond Ni well since Ni is easily oxidized (NiO)

Contact angle measurements on metal thin films
- Au treated with SAM solution: 104 ± 3 ° (> 90 °)
- Ni treated with SAM solution: 43 ± 10 ° (< 90 °)

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Case Study I: Hydrophobic Force

Polymerization

Monomer + cross-linker

Polymerized Adhesive

- Benzoin isobutyl ether
- Or Benzoyl peroxide

Lauryl methacrylate

1,6-Hexanediol diacrylate

Add hydrophobic monomer + cross-linker + polymerization initiator

Add water

Nanowires self-assemble in water (Agitate)

Polymerize adhesive

HDT treated Nanowires in ethanol

Nanowires + adhesive in ethanol

UV Light

Heat

- Polymer monomers help reduce the nanowire surface roughness - "lubricant"
- Cured polymers can permanently bond the self-assembled structures formed - "adhesive"
Case Study I: Hydrophobic Force

Au nanowires

3D Bundles

Not assembled nanowires

2D self-assembled structures

Case Study I: Hydrophobic Force

Magnetic Self-Assembly

Stable configuration of a bar magnet

Assembled magnets

http://www.nanonet.go.jp/english/kids/k-make/organization.html
Case Study II: Magnetic Force

Fig. 1. (a) Schematic diagram of the strategy used to fabricate nanowires using electrodeposition in a nanoporous membrane. Scanning electron microscope (SEM) images of: (b) 200-nm and (c) 50-nm diameter Au-Ni-Au wires fabricated in nanoporous membranes. (The back scatter contrast is brightest for metals with higher atomic numbers; Au ends appears brighter than Ni.)
Case Study II: Magnetic Force

Fig. 4. Typical nanowire resistance curves. (a) A wire on top of contact pads before reflow with a high contact resistance, (b) a wire on top of contact pads after reflow with a small contact resistance, and (c) a wire underneath the contact pads with minimal contact resistance.

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*Proc. 5th IEEE Conf. Nanotech. 2005, 715-718*

Case Study III: Electrical Force

FIG. 1. Reversible Ag nanowire network formation from a suspension in water, with DEP at 0.2 V and 100 kHz (Ref. 21). The frames are labeled with the time (mins) after the first frame. The first frame is taken just before initiation of DEP, and the third frame is taken just before ending DEP. The scale bar corresponds to 30 μm.

FIG. 2. Examples of nanowire structures formed by dielectrophoresis of nanowires in liquid suspension. (a) Dense, overlapped network (Ref. 21). (b) Sparse, branching network. (c) End-to-end joined, predominately un-branched network. The scale bars correspond to 30 μm.
FIG. 3. (Color online) (a) Schematic of induced dipoles in nanowires. (b) Schematic of the circular flow pattern generated at the edges of the electrodes. (c) 50 nm diameter nanowires aligned at the edge of the pointed electrode, a few hundred microns from the point, with 100 kHz E-fields; then standing vertically on top of it with 10 kHz E-fields (the dots are the nanowires seen end on). (d) 200 nm diameter nanowires standing on top of the electrode, a few hundred microns from the point. (e) Vertical nanowires pushed towards the center of the electrode by flow. The scale bars correspond to 30 μm.


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Dielectrophoretic Assembly of Nanowires

Live example I: Reversible and Irreversible Metal Nanowire Networks and Vertically-Aligned Arrays


http://netserver.aip.org/cgi-bin/epaps?ID=E-APPLAB-88-202623

*Self-assembly and Nanotechnology*
Case Study III: Electrical Force


Self-assembly and Nanotechnology
Case Study III: Electrical Force

SEM images of nanowires assembled on the electrode substrate using DEP method. (a) non-optimized setting; (b) optimized setting; (c) dense; (d) dilute.