

Teacher's Preparatory Guide

The Water Race: Hydrophobic & Hydrophilic Surfaces

Purpose

- Introduce students to the engineering of an interfacial surface at the nanoscale.
- Demonstrate the concepts of hydrophobic and hydrophilic behavior.
- Create a hydrophilic or hydrophobic surface using a 2 nanometer thick self assembled monolayer (SAM).

Level

High School

Time required

50-minutes

Advance Preparation

Materials:

- Copper Dual-sided PC Board 114 x 161 mm (276-1499A Radio Shack)
- Chemicals
 - PCB Etchant Solution (276-1534 Radio Shack)
 - 1-Hexadecanethiol (448303-1G Sigma Aldrich Corporation)
 - 16-mercaptohexadecanoic acid (52270-100ml Sigma Aldrich Corporation)
 - Ethanol
 - Acetone
 - Distilled water
- 4 100 ml beakers
- 3 watch glasses
- timers
- hot plate
- air source (or hair dryer)
- micropipettes and tips
- wash bottles with distilled water for students

Safety equipment: gloves, aprons, goggles, Material Safety Data Sheets (MSDS) for all chemicals.

Teacher's Preparatory Guide

Teacher Preparation:

Clean and thoroughly dry 4 beakers.

Make solutions:

- 1 beaker of 1-hexadecanethiol solution (100 microliters in 40 ml ethanol) – Label -CH₃ and cover with a watch glass.
- 1 beaker of 16-mercaptohexadecanoic acid (10 millimoles [.114 grams] in 40 ml ethanol) – heat at 30 Celsius to dissolve. Label -COOH and cover with a watch glass.
- 1 beaker with 40 ml. PCB Etchant Solution. Label Ferric Chloride and cover with a watch glass.
- 1 beaker with distilled water for rinse.

Prepare one wash bottle with ethanol and one with acetone.

Set up beakers on a counter at 6 labeled stations for student teams to rotate.

Station 1: Copper pieces, acetone, ethanol

Station 2: Air source for drying

Station 3: Ferric Chloride, timer

Station 4: Distilled Water rinse

Station 5: -CH₃ solution, timer

Station 6: -COOH solution, timer

Cut copper into segments to fit into the beakers. Each lab group needs 2 pieces.

Review MSDS and all safety rules with students prior to the start of the experiment.

Safety Information

Safety equipment: gloves, aprons, goggles, Material Safety Data Sheets (MSDS) for all chemicals. Review MSDSs for all chemicals. Wear safety goggles and protective clothing.

Teaching Strategies

Lab Questions:

1. What do the terms hydrophobic and hydrophilic mean?

Teacher's Preparatory Guide

2. What is the definition of one nanometer?
3. What is a self assembled molecular (SAM) monolayer?
4. How does changing the surface of a substance affect its interaction with water?

Assessment:

- Lab Notebook Entry
- Typed Lab Abstract: Purpose, materials and procedures, results, and conclusions.

Teacher Background:

1. In the water molecule, the hydrogen atoms tend to have a slightly positive charge and the oxygen atoms a slightly negative charge. Water molecules cling to each other through the hydrogen bond. No polar molecules form hydrogen bonds, so in the presence of water, the nonpolar molecules associate with one another while excluding the water molecules. This minimizes the overall free energy of the system. Nonpolar molecules that repel the water molecules are said to be hydrophobic and polar molecules forming ionic or a hydrogen bond with the water molecule are said to be hydrophilic. This property of water was important for the evolution of life. Hydrophobic interaction plays the most critical roles in the formation of the lipid bilayer of the cell membrane and the folding of proteins and nucleic acids; therefore, hydrophobic interaction is the foundation for the existence of life.

2. A nanometer is one billionth of a meter. The field of nanotechnology works with materials and measurements 100 nanometers or smaller.

3. A self-assembled monolayer (SAM) is a layer of organic molecules formed spontaneously on a solid substrate. One end of the organic molecule binds to the solid surface via a covalent bond while the other end points outwards. There are many ways to form SAMs on different solid substrates. Two most commonly used methods are using thiol containing organic molecules to form a packed SAM on coinage metals such as gold, silver, copper, or using various silane molecules to form SAM on silicon or insulating glass surfaces. Because the exposed end of the SAM determines the surface properties of the SAM modified substrate, we can alter a hydrophobic surface (a surface that expels water) into a hydrophilic surface (a surface that attracts water) by carefully selecting the SAM forming molecules.

Teacher's Preparatory Guide

However, the application of SAM is not restricted to modification of surface properties.

For example, if an electrically conducting chemical group is added to the exposed end of SAM, a nano-conducting wire or sheet can be formed¹. In this experiment, we will focus on modifying the copper surface properties using SAM of 1-hexadecanethiol and 16-mercaptohexadecanoic acid. Both of these molecules contain a thiol group that forms a covalent bond to the copper surface. However, the exposed ends of these two molecules have completely different chemical properties. 1-hexadecanethiol has a highly hydrophobic C₁₈H₃₈- tail while 16-mercaptohexadecanoic acid has a hydrophilic carboxyl group pointing outwards. So you can imagine that grafting 1-hexadecanethiol SAM on the copper surface renders a more hydrophobic surface while formation of 16-mercaptohexadecanoic acid SAM on copper surface will make it more hydrophilic.

4. Water is repelled more by a surface when the hydrophobicity of the surface is increased. The contact angle of a water droplet is larger on a more hydrophobic surface.

General Nanotechnology Background:

What is Nanotechnology?

Nanotechnology is the precision placement, measurement, manipulation and modeling of individual or small groups of atoms or molecules. Typically, such activities in the size range of 1-100 nanometers are considered as nanotechnology.

Importance of Nanotechnology

Almost every industry will be affected by nanotechnology. Many are already using it. Many applications include the creation of unique materials with desirable properties not attainable through bulk material processing. Nanotechnology can enable cheaper production methods, greater data storage and retrieval, designed drug discovery and delivery, more economical production of semiconductors, and creation of highly efficient nanofilters among a myriad of other uses.

Introducing students to nanotechnology is possible through some lab activities. *Cutting it Down to Nano* and *NanoSolutions*, two very inexpensive activities that are on the University of Wisconsin website (<http://mrsec.wisc.edu/edetc/IPSE/educators/>) are good introductions.

Teacher's Preparatory Guide

Reference:

1. S. Hong, R. Reifenger, W. Tian, S. Datta, J. I. Henderson, and C. P. Kubiak, "Molecular conductance spectroscopy of conjugated, phenylbased molecules on Au(111): the effect of end groups on molecular conduction," *Superlattices Microstruct.*, Vol. **28**, pp. 289–303, 2000.

Resources for teachers

The following people at the University of Washington in Seattle, WA are great resources for information on nanotechnology: Dr. Ethan Allen, Education & Outreach Manager, Center for Nanotechnology; Amy Leslie, Lead Teacher, University of Washington Engineered Biomaterials; Dong Qin, Associate Director, Center for Nanotechnology.

To learn more about nanotechnology, here are a few great web sites:

<http://www.nano.gov> – This site gives information on the National Nanotechnology Initiative. There is a section for K-12 students and teacher resources.

www.howstuffworks.com/nanotechnology.htm – A great site for students to learn about nanotechnology as well as other devices.

<http://mrsec.wisc.edu/edetc/> - This site has great lab activities.

<http://www.tntg.org/id46.htm> - This site has links to other nanotech sites.

www.nano.washington.edu – This site gives information on the programs at the University of Washington in Seattle.

Alonda Droege is a high school science teacher at Highline High School, 225 S. 152nd Street, Burien, WA 98148, 206-433-2511; droega2@hsd401.org. **Dr. Jianchun Dong** is a Graduate Student in the Electrical Engineering Department of the University of Washington. **Dr. Babak Amir Parviz** is an Assistant Professor in the Electrical Engineering Department of the University of Washington.