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Student Worksheet

The Water Race: Hydrophobic & Hydrophilic Surfaces

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.

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.

Hydrophobic interaction plays 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.

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. One of the many ways to form SAMs on different solid substrates is to use thiol-containing organic molecules to form a packed SAM on coinage metals such as gold, silver, copper. 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.

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 $C_{18}H_{38}$- 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.

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Materials

- Copper Dual-sided PC Board 114 x 161 mm

- PCB Etchant Solution
- 1-Hexadecanethiol
- 16-mercaptohexadecanoic acid
- 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.

Experimental Procedure (see Figure below)

1. Put on gloves, goggles and lab aprons.

2. Clean copper PC board first with acetone and then with ethanol at Station 1 and dry with air at Station 2.

3. Using a wash bottle or micropipette, place a drop of distilled water on the surface of the copper to test the surface properties of the copper. (Water will stick to the surface when the surface is tilted on a hydrophilic surface and will run off of a hydrophobic surface.) Record your observations in your lab notebook.

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4. At Station 3, place copper PC board so that one half the board is in the Ferric Chloride solution for 30 seconds. This will etch the surface to remove the copper oxide.

5. At Station 4, rinse the ferric chloride off the copper in distilled water.

6. Air dry at Station 2.

7. At Station 5, place copper board so the etched surface is in the $–CH_3$ solution for 5 minutes. Then take out the board and wash with ethanol at Station 1.

8. Air dry at Station 2.

9. At your lab table, add one drop of distilled water using a micropipette (or wash bottle) to the untreated copper half and one drop of distilled water to the side treated with $–CH_3$.

10. Tilt the surface of the copper board to determine if the water sticks to the surface (hydrophilic) or runs off the surface (hydrophobic).

11. Record your observations in your lab notebook.

12. Clean a second copper PC board with acetone and ethanol at Station 1 and air dry at Station 2.

13. At Station 3, place copper PC board so that one half the board is in the Ferric Chloride solution for 30 seconds. This will etch the surface.

14. At Station 4, rinse the ferric chloride off the copper in distilled water.

15. Air dry at Station 2.

16. At Station 6, place copper board so the etched surface is in the –COOH solution for 5 minutes and then wash with ethanol.

17. Air dry at Station 2.

18. At your lab table, add one drop of distilled water using a micropipette (or wash bottle) to the untreated copper half and one drop of distilled water to the side treated with –COOH.

19. Tilt the surface of the copper board to determine if the water sticks to the surface (hydrophilic) or runs off the surface (hydrophobic).

20. Record your observations in your lab notebook.

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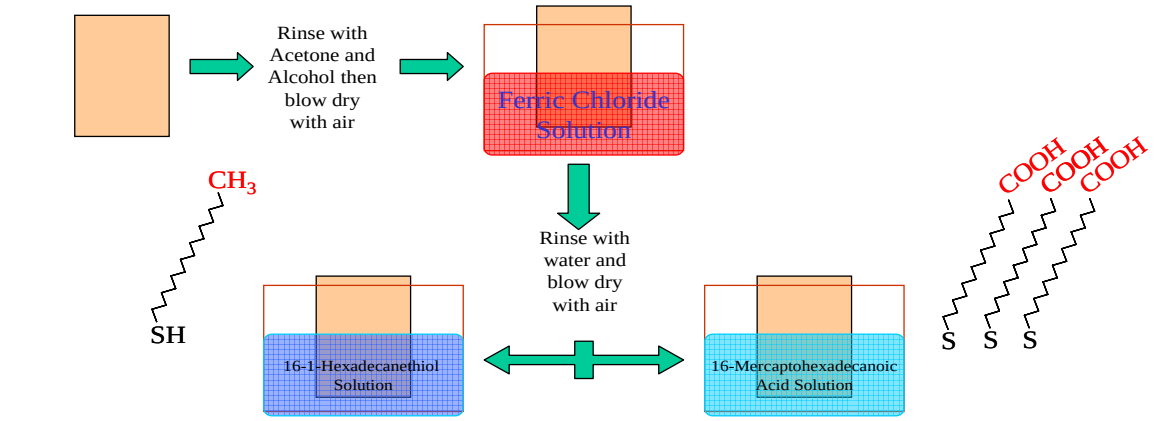
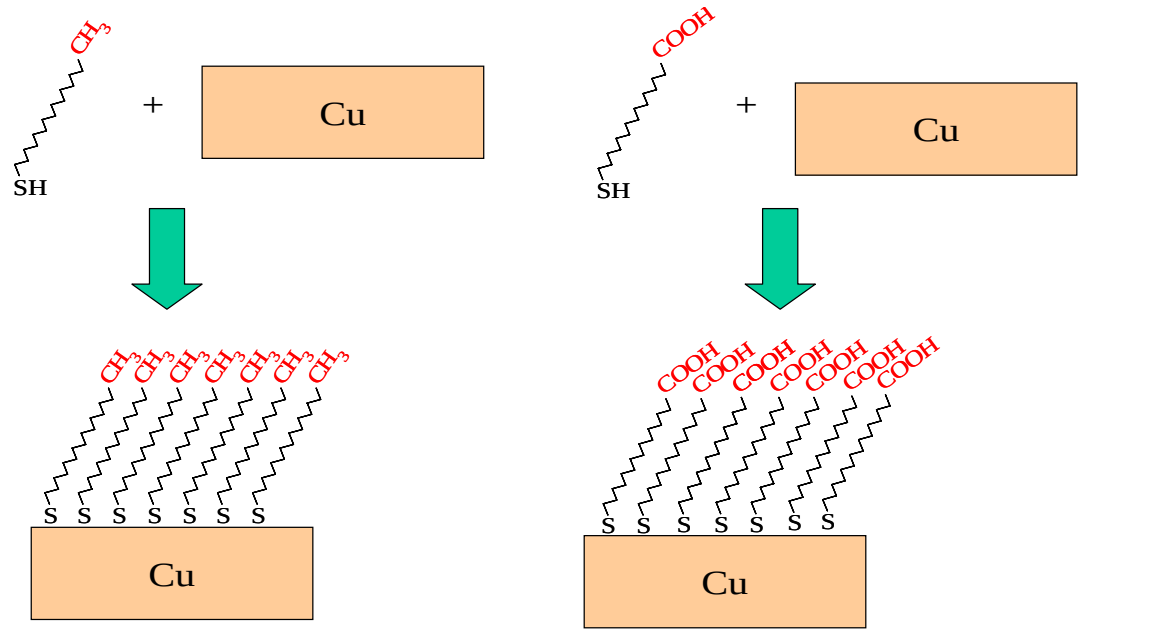
Experimental Procedure for Forming SAMs on Copper Board





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Data and Observation:

Substance	Observations	Hydrophobic or hydrophilic
Clean copper PC board		
1-hexadecanethiol solution ($-CH_3$)		
16-mercaptohexadecanoic acid (-COOH)		

Conclusion: Write a paragraph to describe the results of the experiment and your reflections on your experiences during this lab.

Summary Questions:

1. Can the properties of a surface be changed? What is your evidence?
2. What happens to water on a hydrophobic surface?
3. What happens to water on a hydrophilic surface?