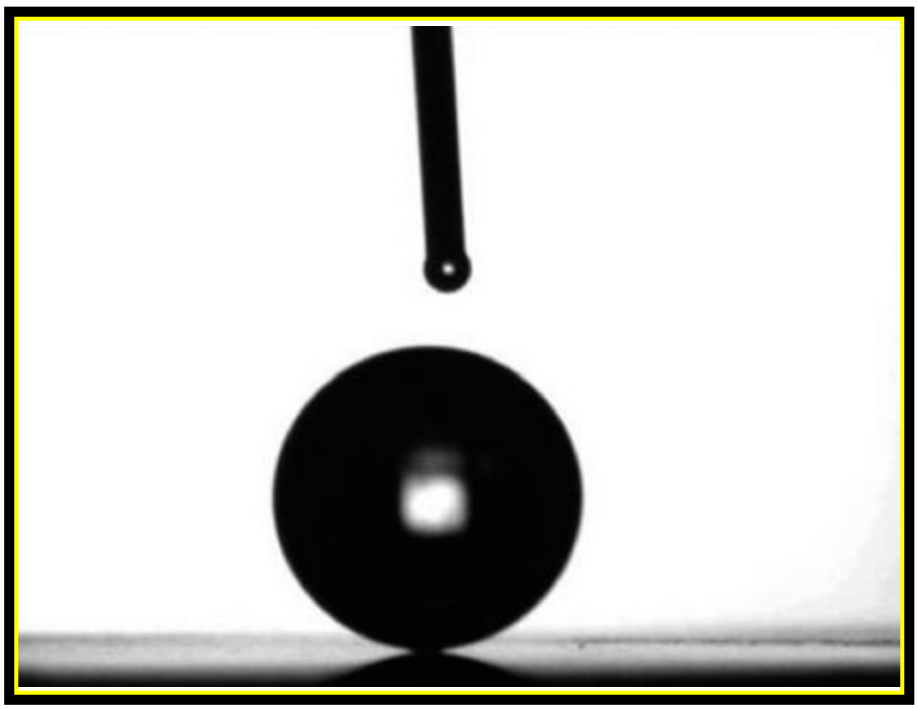
# NEATEC Learning Module

## Northeast Advanced Technological Education Center

# Simple Fabrication of a Super-Hydrophobic Surface

**Secondary Level - Grades 10th-12th – Assessment**



(Image credit: Larmour, I. et. Al., Angew. Chem. Int. Ed. 2007, 46, 1710-1712)

## Northeast Technological Education Center (NEATEC)
## Hudson Valley Community College
## STEM Introduction Topic

# Simple Fabrication of a Super-Hydrophobic Surface

### Secondary Level - Grades 10th-12th – Assessment

**NEATEC Mission Statement:**

"The Northeast Advanced Technological Education Center (NEATEC) is a Regional Center for Semiconductor and Nanotechnology Education funded by the National Science Foundation (NSF DUE #1003574) to serve as a critical, sustainable resource to create and maintain a skilled technical workforce for the semiconductor and nanotechnology industries in New York State and Western New England. Through an extensive network of community college, university, and industry partners, NEATEC will identify the essential technician competencies and skills required by such a workforce. NEATEC will develop curricular components and delivery methods to impart those skills to students. NEATEC will also create and disseminate educational materials to support curricula implementation at its community college and high school partners and provide professional development activities for K-12 schools and community college faculty. Lastly, through partner internships, co-ops, shadowing opportunities and outreach activities, NEATEC will educate current and future students regarding technological career pathways and expand the pipeline of K-12 students interested in semiconductor and nanotechnology career options."

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## What is STEM?

With all the acronyms that determine hundreds of different areas of education, it is easy to confuse them all. Since 2001, the letters STEM have been a normal part of educational vocabulary.

The acronym STEM stands for Science, Technology, Engineering, and Mathematics. This program was started by Judith A. Ramaley, the former director of the National Science Foundation's education and human-resources division. This approach to education is designed to revolutionize the teaching of subject areas such as mathematics and science by incorporating technology and engineering into regular curriculum by creating a "meta-discipline."

There is more; STEM Education attempts to transform the typical teacher-centered classroom by encouraging a curriculum that is driven by problem-solving, discovery, exploratory learning, and requires students to actively engage a situation in order to find its solution.

Science, technology, engineering and mathematics (STEM) education often has been called a meta-discipline, the "creation of a discipline based on the integration of other disciplinary knowledge into a new 'whole'. This interdisciplinary bridging among discrete disciplines is now treated as an entity, known as STEM (Morrison, 2006). " STEM education offers students one of the best opportunities to make sense of the world holistically, rather than in bits and pieces. STEM education removes the traditional barriers erected between the four disciplines, by integrating them into one cohesive teaching and learning paradigm. Morrison and others have referred to STEM as being an interdisciplinary approach. "STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy (Tsupros, 2009)."

## What is a NEATEC Learning Module (NLM)?

A NEATEC Learning Module (NLM) is self-contained unit that can be incorporated into existing science, math, and technology classes to supplement and enhance the content and the laboratory activities of the class. Each module includes all or some of the following sections:

- Background information about the topic of the unit
- A teacher's guide
- A student's guide
- List of lab materials for laboratory activities
- A list of teacher's and student's resources
- Power Point slides

The set of modules offered by NEATEC are divided into five categories based on the level of understanding of the participants:

1. NLM K-2: These are units suitable for students in grades Kindergarten to 2$^{nd}$ grades.
2. NLM 3-5. These are units suitable for students in grades 3$^{rd}$ to 5$^{th}$ grades.
3. NLM 6-8. These are units suitable for students in grades 6$^{th}$ to 8$^{th}$ grades.
4. NLM 9-12. These are units suitable for students in grades 9$^{rd}$ to 12$^{th}$ grades.
5. NLM for Community Colleges.
6. NEATEC Learning Modules include topics on Nanotechnology, Semiconductors, Photovoltaic, Alternate Energy, Mathematics, General Science and Technology.

# Simple Fabrication of a Super-Hydrophobic Surface

## Table of Contents

**Grade Level** High School Level - Grades 10-12

## Essential Questions

1. How does heptadecafluoro-1-decanethiol (HDFT) form a self-assembled monolayer on metal surfaces?
2. How does a self-assembled monolayer make a surface hydrophobic?
3. What are some uses of super-hydrophobic surfaces?

## Objectives

1. Fabricate a simple super-hydrophobic surface on a copper sheet by chemical modification.
2. Explore properties of super-hydrophobic surfaces.

## New York State Common Core Learning Standards *(**to be updated**)*

### Mathematics Standards:

- HSN-Q.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays
- HSN-Q.2 Define appropriate quantities for the purpose of descriptive modeling.
- HSN-Q.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities

### English Language Arts Standards:

- RST.11-.12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- RST.11-.12.2 Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
- RST.11-.12.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
- RST.11-.12.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 11–12 texts and topics*.
- RST.11-.12.5 Analyze how the text structures information or ideas into categories or hierarchies, demonstrating understanding of the information or ideas.
- RST.11-.12.6 Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, identifying important issues that remain unresolved.
- RST.11-.12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
- RST.11-.12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

- RST.11-.12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.
- RST.11-.12.10 By the end of grade 12, read and comprehend science/technical texts in the grades 11–CCR text complexity band independently and proficiently.

Learning Standard 1: Analysis, Inquiry and Design. Students will use mathematical analysis, scientific inquiry, and engineering design, as appropriate to pose questions, seek answers, and develop solutions.

- Scientific Inquiry Key Idea 1: The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing, creative process.
    - S1.1 Elaborate on basic scientific and personal explanations of natural phenomena, and develop extended visual models and mathematical formulations to represent thinking.
- Scientific Inquiry Key Idea 2: Beyond the use of reasoning and consensus, scientific inquiry involves the testing of proposed explanations involving the use of conventional techniques and procedures and usually requiring considerable ingenuity.
    - S2.1 Devise ways of making observations to test proposed explanations.
    - S2.3 Develop and present proposals including formal hypotheses to test explanations, i.e.; they predict what should be observed under specific conditions if their explanation is true.
    - S2.4 Carry out a research plan for testing explanations, including selecting and developing techniques, acquiring and building apparatus, and recording observations as necessary.
- Scientific Inquiry Key Idea 3: The observations made while testing proposed explanations, when analyzed using conventional and invented methods, provide new insights into phenomena.
    - S3.1 Use various means of representing and organizing observations (e.g., diagrams, tables, charts, graphs, equations, and matrices) and insightfully interpret the organized data.
    - S3.3 Assess correspondence between the predicted result contained in the hypothesis and the actual result, and reach a conclusion as to whether or not the explanation on which the prediction is supported.

Learning Standard 4: The Physical Setting. Students will understand and apply scientific concepts, principles, and theories pertaining to the physical setting and living environment and recognize the historical development of ideas in science.

- Key Idea 3: Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.
    - 3.1 Explain the properties of materials in terms of the arrangement and properties of the atoms that compose them.
        - xix Distinguish among ionic, molecular, and metallic sub-stances, given their properties
        - xxiv Describe the processes and uses of filtration, distillation, and chromatography in the separation of a mixture
        - xxix calculate solution concentration in molarity (M), percent mass, and parts per million (ppm)
        - Performance indicators 3.1 q, s, dd, ff, nn
    - 3.3 Apply the principle of conservation of mass to chemical reactions.
        - i balance equations, given the formulas for reactants and products
        - viii calculate the formula mass and gram-formula mass
        - Performance indicators 3.3 c
- Key Idea 5: Energy and matter interact through forces that result in changes in motion.
    - 5.2 Students will explain chemical bonding in terms of the behavior of electrons.

- ii  compare the physical properties of substances based on chemical bonds and intermolecular forces, e.g., conductivity, malleability, solubility, hardness, melting point, and boiling point
- Performance indicators 5.2 a, e, g, m, n

# Teacher Materials

This experiment was taken from UVA's Hands-on Introduction to Nanoscience:
http://www.virlab.virginia.edu/nanoscience_class/labs/materials/UVA_super_hydrophobicity_lab_manual.pdf

## Overview

This lab is taken from the work done by lain A. Larmour et al. on fabricating super-hydrophobic surfaces. Research on hydrophobic materials has been motivated by the water-repelling and self-cleaning nature of the lotus leaf. Scientists have shown that the hydrophobicity of the lotus leaf comes from the micro and nano roughness on its surface. Researchers have published countless recipes for emulating this super-hydrophobic behavior. Some of the artificial surfaces are made from polymers, carbon nanotubes, and metals. Possible applications include non-stick surfaces for cooking, low water resistance surfaces for speedboats, and self-cleaning windows.

## Chemicals and Materials Used in This Experiment

- Copper sheet – 0.016" x 12" x 12" (McMaster Carr P/N 8963K31)
- 500 grit 6" cushioned sanding disc (McMaster Carr P/N 4521A163)
- 800 grit 6" cushioned sanding disc (McMaster Carr P/N 4521A163)
- 1200 grit 6" cushioned sanding disc (McMaster Carr P/N 4521A163)
- 1500 grit 6" cushioned sanding disc (McMaster Carr P/N 4521A163)
- 2000 grit 6" cushioned sanding disc (McMaster Carr P/N 4521A163)
- Heptadecafluoro-1-decanethiol (HDFT) (Sigma Aldrich P/N 08686-1G-F)
- 0.01 M silver nitrate (Sigma Aldrich P/N 34294-1L-R)
- Dichloromethane (Sigma Aldrich P/N 270997-1L)
- Tweezers - General Precision; Antimagnetic stainless steel; Tapered tips w/flat round points (Fisher Scientific Catalog No.: 17-467-127)

**Included in the Kit (for 33 students, 9 groups of 3-4 students):**

- (9) ~ 2 x 5 cm copper sheet pieces
- (15) Sanding discs, 3 per grit (500, 800, 1200, 1500 and 2000)
- (36) 50 mL beakers
- (9) Tweezers
- (9) Disposable pipettes
- (1) 5-50 μL range micropipette
- (1) Vial of heptadecafluoro-1-decanethiol (HDFT)
- (1) Bottle of 0.01 M silver nitrate ($AgNO_3$), ~0.5 L
- (1) Bottle of dichloromethane ($CH_2Cl_2$), ~1 L
- 1 Pliers
- Squirt bottle

**Not Included in the Kit:**

- DI water
- Safety glasses/goggles
- Timers
- ***Fume hood required***

## Experiment Preparation

Prior to the experiment, read and prepare the following:

1. Prepare polishing stations.

2. For each group of students prepare (4 beakers labeled 1-4 per group):
    a. 40 mL of silver nitrate ($AgNO_3$) in Beaker 1:
    b. 40 mL of DI water in Beaker 2
    c. 40 mL of dichloromethane ($CH_2Cl_2$) to Beaker 3
    d. 40 mL of dichloromethane ($CH_2Cl_2$) to Beaker 4

***Keep these beakers in a fume hood and perform all wet chemistry in a fume hood.***

## Resource Information for Instructor Proficiency

Original documentation from UVA's Hands-on Introduction to Nanoscience

- http://www.virlab.virginia.edu/nanoscience_class/labs/materials/UVA_super_hydrophobicity_lab_manual.pdf

References

- http://www.virlab.virginia.edu/nanoscience_class/labs/Nanoscience%20Super%20Hydrophobicity%20Lab.htm
- http://en.wikipedia.org/wiki/Superhydrophobe
- http://en.wikipedia.org/wiki/Self-assembled_monolayer
- http://www.rolith.com/applications/self-cleaning
- http://www.theultimatefinish.co.uk/car-care-blog/car-care/nanotechnology-and-its-role-in-automotive-care/

## Special Education Accommodations & Modifications

- Experiments can be done as a whole group exploration rather than as individual small groups.

## Assessment:

Student completion of worksheet.

Ability to answer both pre-lab and post-lab questions at the conclusion of the module.

# Student Materials

# Simple Fabrication of a Super-Hydrophobic Surface

## Purpose

1. Fabricate a super-hydrophobic surface on copper sheet using simple chemical modification
2. Explore properties of super-hydrophobic surface

## Introduction

This lab is taken from the work done by lain A. Larmour et al.[1] on fabricating super-hydrophobic surfaces. Research on hydrophobic materials has been motivated by the water-repelling and self-cleaning nature of the lotus leaf. Scientists have shown that the hydrophobicity of the lotus leaf comes from the micro and nano roughness on its surface. Researchers have published countless recipes for emulating this super-hydrophobic behavior. Some of the artificial surfaces are made from polymers, carbon nanotubes, and metals. Possible applications include non-stick surfaces for cooking, low water resistance surfaces for speedboats, and self-cleaning windows.

In this lab, you will fabricate a simple super-hydrophobic surface on a copper sheet, using chemicals purchased from Sigma Aldrich. This process is very fast and straightforward composed of two main steps.

**Step 1: Producing a nano-roughened silver surface**

This step involves a simple reaction between copper and silver nitrate, producing nano-roughened silver surface on copper. The following equation explains this reaction:

$$Cu^0 + 2AgNO_{3(aq)} \rightleftharpoons Cu(NO_3)_{2(aq)} + 2Ag^0$$

In this reaction, the silver ion ($Ag^+$) in silver nitrate becomes reduced by the copper surface, forming silver metal.

**Step 2: HDFT monolayer self-assembly**

In the second step, the silver-coated copper is dipped in a 1 mM heptadecafluoro-1-decanethiol (HDFT) solution.

The purpose of this step is to leave a self-assembled monolayer with non-polar (and thus hydrophobic) molecular segments at the upper surface.

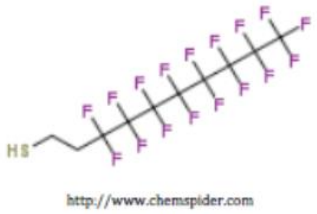


*Figure 1: Chemical structure of HDFT*

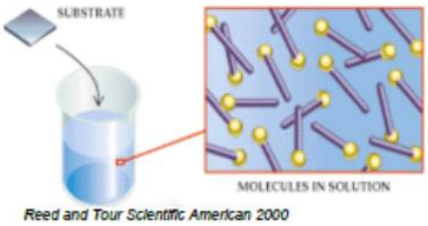


*Figure 2: Substrate immersed in HDFT solution*

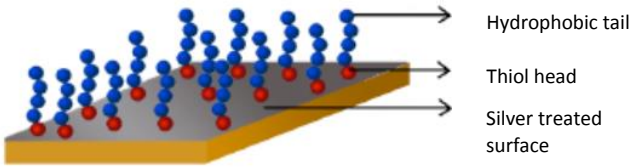


*Figure 3: Self-assembled monolayer made of HDFT*

## KEYWORDS

***Hydrophilic surface***
Surface "loves" water droplets. The surface maximizes its contact with water, leading to a contact angle of less than 90°.

***Hydrophobic surface***
Surface "fears" water droplets. The surface minimizes its contact with water, leading to a contact angle of greater than 90°.

***Super-hydrophobic surface***
Surface has nano-scale roughness, leading to contact angle of greater than 150°.

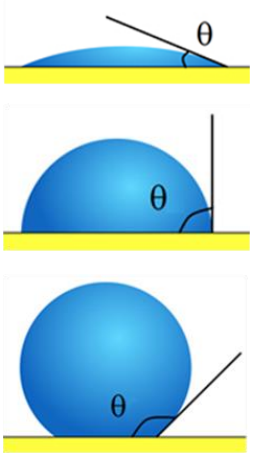


*Image credit: http://www.theultimatefinish.co.uk/car-care-bloa/car-care/nanotechnoloav-and-its-role-in-automotive-care/*

***Self-assembly***
It is a bottom-up approach for coating surfaces. In this process, the individual molecules template themselves on the surface and form a dense monolayer. Self-assembled monolayers can "functionalize" a surface to make it hydrophobic or hydrophilic.

During the second step of this lab, thiol head groups of the heptadecafluoro-1-decanthiol (HDFT) molecules form chemical bonds with silver nanoparticle surface, which holds the molecules on the substrate. The backbone of the molecule is the hydrophobic tail, which changes the functionality of the surface making it hydrophobic.

1. Larmour, I. et. Al., Angew. Chem. Int. Ed. 2007, 46, 1710-1712.

## Materials

Each group of students will need:

- 1 ~2 x 5 cm copper sheet
- Beaker 1: 40 mL of silver nitrate
- Beaker 2: 40 mL of DI water
- Beaker 3: 40 mL of dichloromethane
- Beaker 4: 40 mL of dichloromethane
- DI water
- 1 Tweezer
- Safety glasses/googles
- Gloves
- Timer
- 1 disposable pipette

To be shared by the class:

- Sanding discs (500, 800, 1200, 1500 and 2000 grit)
- Micropipette (5-50 μL range)
- Heptadecafluoro-1-decanethiol (HDFT)
- Pliers
- Squirt bottle

## Pre-Lab Questions

1. For the monolayer self-assembly step of this lab, you will need to prepare 40 mL of 1 mM HDFT solution in $CH_2Cl_2$.
   a. Calculate the molecular weight of HDFT ($CF_3(CF_2)_7CH_2CH_2SH$).

   b. Calculate the volume of HDFT to be added to 40 mL of $CH_2Cl_2$ to obtain a final concentration of 1 mM (density = 1.678 g/ml).

2. How does heptadecafluoro-1-decanethiol (HDFT) form a self-assembled monolayer on metal surfaces?

## Experimental Procedure & Results

<u>Step 1: Polish one side of a copper sample (1 per group)</u>

- Have the "designated polisher" put on gloves
- Go to the "500 grit polishing station"
- Put the best face of the copper down on the pad. Place your fingers on top of the copper and polish it by moving in a circular (or figure eight) pattern of motion.
  - *If the copper won't stay under your fingers, try first lifting up the pad and rubbing it against the copper held in your hand. Once you remove the bigger bumps or ridges, you should be able to put the pad back down and resume polishing with the copper under your fingers.*
- Check the polishing side of your copper. You may need to shift the position of your fingers to polish the entire copper surface.
- Polishing is complete when surface has an absolutely uniform appearance.
- Wife off copper surface with a fresh tissue or wipe (to remove any abrasive).
- REPEAT for 800, 1200, 1500 and 2000 grit pads (in that order).

**Notes/Observations:**

Step 2: Use pliers to bend up one corner of sample toward polished surface (~5 mm)

- This will mark the polished side and facilitate capture by tweezers.

**MOVING TO THE FUME HOOD:**

Step 3: Make 40 mL of 1 mM HDFT solution. Adjust the micropipette to the amount calculated in your pre-lab assignment (see pre-lab section below) and add HDFT to Beaker.

- Use the micropipette to lightly stir for several seconds. Make sure you only use the disposable tip part of the micropipette, and the micropipette body is not in the solution.

**Amount of HDFT added:**

**Notes/Observations:**

Step 4: Create the super-hydrophobic surface – deposit silver on the copper plate

- Set the timer to 2 minutes.
- Using tweezers, place the copper plate in silver nitrate (Beaker 1) for 2 minutes with the polished side facing up.
    - *The surface should now have a black tint.*
- Remove copper plate from silver nitrate and rinse in DI water (Beaker 2) for 20 seconds.
    - *Be careful when handling the copper plate with the tweezers in order to have minimal scratching on the silver surface.*
- Dry by shaking as much as possible. The back can be dried by placing the plate on a kimwipe, but do not touch the top surface. If you have access to a nitrogen gun, blow on it to dry.

**What is the black tint on the surface? Explain.**

**Notes/Observations (include a drawing):**

Step 5: Create the super-hydrophobic surface – form HDFT self-assembeled monolayer on nano-textured silver on copper plate

- Set the timer to 5 minutes.
- Place the dark side of the copper plate facing up in the bottom of Beaker 3 and let soak in HDFT for 5 minutes.
- Remove the plate from Beaker 3 and place it in dichoromethane (Beaker 4), while agitating for 20 seconds.

    - Dichloromethane is an organic solvent that is commonly used in chemistry.
- Rinse using DI water in a squirt bottle, and dry as much as possible. . The back can be dried by placing the plate on a kimwipe, but do not touch the top surface. Use nitrogen gun if available.

**Explain what happened on the surface during this step. Include a drawing.**

**Notes/Observations:**

Step 6: Test the super-hydrophobic surface with water (a.k.a PLAY!)

- **Water droplet pool/billiards**
    - Place the copper plate on a folded Kim-wipe with the super-hydrophobic surface facing up and spray with DI water.
    - Repeat the process with the other side of the plate and note the difference.
    - Put two or three prepared copper surfaces in a line
        - Can you get droplets to bounce off the surfaces one after another?

**Observations (provide a scientific explanation and include a drawing where appropriate):**

- **Super-sized water drops**
    - Put the tip of the water squeeze bottle almost touching the copper. Slowly squeeze out some water, using the tip to hold the growing drop in one place.

**Observations (provide a scientific explanation and include a drawing where appropriate):**

- **An instant mirror**
  - If you drop your copper end first into a full beaker of water, what will happen to its water-hating surface?
  - Now take a look at your copper from the side. Can you figure out what is going on?

**Observations (provide a scientific explanation and include a drawing where appropriate):**

- **A boat without a hull**
  - Instead gently set your copper down flat on the surface of a larger water-filled container
    - What happens?
    - Try forcing the copper down into the water.
    - If you do get it to sink, try raising one end back above the water to see what happens.

**Observations (provide a scientific explanation and include a drawing where appropriate):**

- **Plumbing without pipes (basis for a possible "lab on a chip")**
    - Do these experiments last as they will damage your copper sample.
    - With your tweezers, gently make a small scratch in the center of your copper. Do water droplets notice what you have done?
    - With your tweezers, gently scratch a wiggly line down the length of your sample.
    - Slightly raise one end of your sample (by resting one end on something)
    - Put a water droplet as the high end of your line. Can you get the droplet to run down the path? Can you see how printing patterns in hydrophobic (or hydrophilic) inks might be used to replace pipes (and make miniature chemistry labs)?

**Observations (provide a scientific explanation and include a drawing where appropriate):**

- Exam surface under SEM
    - With the TA's assistance, inspect the surface's microscopic texture with the Scanning Electron Microscope. Here we will compare the surface of an untreated copper with your treated sample.
    - Note your observation. Estimate the diameter of the smallest particles.

**Observations (provide a scientific explanation and include a drawing where appropriate):**

## Vovabulary & Post-Lab Questions

**Define each of the terms below in your own words:**

Think about what you learned by doing the experiment, and if you are still unsure, do some research to find out!

*Microscale*

*Nanoscale*

*Hydrophilic*

*Hydrophobic*

*Hydrophilic surface*

*Hydrophobic surface*

*Super-hydrophobic surface*

*Self-assembled monolayer*

1. Did you succeed in making a super-hydrophobic surface? Why or why not?

2. Suggest some ways to improve the fabrication process.

3. Explain how a self-assembled monolayer makes a surface hydrophobic.

4. What are some uses of super-hydrophobic surfaces (find examples other than ones given in the background above)? Explain how the super-hydrophobic surface will help the product.

# Answer Key

# *Answer Key*

## Pre-Lab Questions – ANSWER KEY

1. For the monolayer self-assembly step of this lab, you will need to prepare 40 mL of 1 mM HDFT solution in $CH_2Cl_2$.
   a. Calculate the molecular weight of HDFT ($CF_3(CF_2)_7CH_2CH_2SH$).

      *C: 12.01 g/mol, H: 1.008 g/mol, F: 18.998 g/mol, S:32.06 g/mol*

      *10 x 12.011 g/mol + 17 x 18.998 g/mol + 5 x 1.008 g/mol + 32.06 g/mol =* ***480.18 g/mol***

   b. Calculate the volume of HDFT to be added to 40 mL of $CH_2Cl_2$ to obtain a final concentration of 1 mM (density = 1.678 g/ml).

$$\frac{1\ mmol}{L} \cdot 0.040\ L \cdot \frac{480.18\ g}{mol} \cdot \frac{ml}{1.678\ g} = 0.0114\ ml = \mathbf{11.4\ \mu l}$$

2. How does heptadecafluoro-1-decanethiol (HDFT) form a self-assembled monolayer on metal surfaces?

   *The thiol head group of the molecule forms chemical bonds with the silver nanoparticles on the surface. This anchors the molecule on the substrate with the hydrophobic tail hanging off of the surface, forming a monolayer of molecules on substrate.*

## Vocabulary & Post-Lab Questions – ANSWER KEY

**Define each of the terms below in your own words:**

Think about what you learned by doing the experiment, and if you are still unsure, do some research to find out!

*Microscale* - *Relating to or occurring on a 1-100 μm scale (such as bacteria and virus)*

*Nanoscale* - *Relating to or occurring on a 1-100 nm scale*

*Hydrophilic* - *Water loving*

*Hydrophobic* - *Water fearing*

*Hydrophilic surface* - *Surface loves water, and the surface maximizes its contact with water, leading to a contact angle of less than 90°.*

*Hydrophobic surface* - *Surface fears water, and the surface minimizes its contact with water, leading to a contact angle of greater than 90°.*

*Superhydrophobic surface* - *Surface has nanoscale roughness, leading to contact angle of greater than 150°.*

*Self-assembled monolayer* – *Bottom-up approach for coating surfaces. The individual molecules template themselves on the surface and form a dense monolayer. Self-assembled monolayers can "functionalize" a surface and make it hydrophobic or hydrophilic.*

*Post-lab questions:*

1. Did you succeed in making a superhydrophobic surface? Why or why not?

   *Answers will vary depending on results, but in general, yes, if the surface repelled water strongly and stayed completely dry. No, if the surface was wettable.*

2. Can you suggest some ways to improve the superhydrophobic surface? Are there some changes you can make to the fabrication process?

   *Answers will vary depending on results. Answers may include suggestions such as improve the sanding process by using more grits, more sanding, experimenting with HDFT concentration to get a better self-assembled monolayer, etc.*

3. Explain how a self-assembled monolayer can make a surface hydrophobic.

   *Self-assembled monolayers can change properties of a surface by molecules of the layer attaching to the surface with one end while the "tail" end points away from the surface, allowing the molecules to pack and form a monolayer. If a molecule with a hydrophobic tail is used, the surface of the self-assembled monolayer will be hydrophobic making the surface hydrophobic.*

5. What are some uses of super-hydrophobic surfaces (find examples other than ones given in the background above)? Explain how the super-hydrophobic surface will help the product.

   *Answers will vary. Examples include self-cleaning vehicles and windshields, water-proof materials, lab-on-chip, medical equipment, etc.*

## Summary

In this activity your students will fabricate a super-hydrophobic surface by simple chemical modification. Molecules with a thiol and hydrophobic tail will be used to form a self-assembled monolayer on a silver-coated copper plate to make a super-hydrophobic surface. Students will then explore properties of a super-hydrophobic surface.

## Disclaimer



## Activity Evaluation

The Northeast Advanced Technological Education Center (NEATEC) would like your feedback on this activity. Your feedback allows NEATEC to maintain the quality and relevance of this activity.

To provided feedback, please email E.Crimmel@hvcc.edu

Your feedback is greatly appreciated.

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*This module was adapted from an experiment designed by Kian Keyvanfar David Backer from UVA's Hands-on Introduction to Nanoscience.*

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