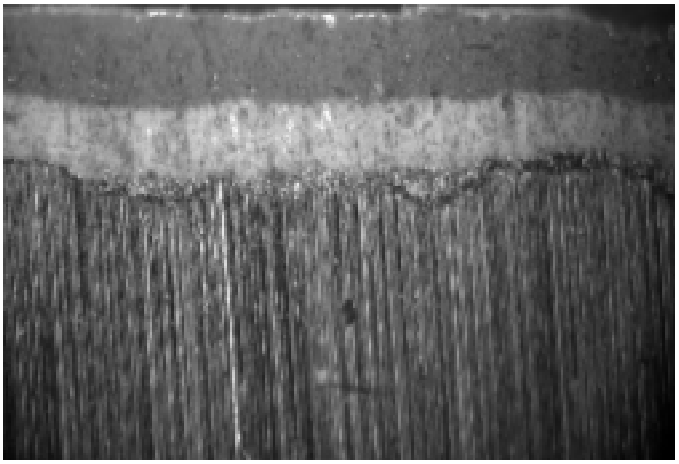
Name: ___________________________ Date: ________________

Hydrophobic Surfaces

Deposition and Analysis

Take a look at all the materials around you; and think about all the things you interact with on a daily basis. There's a good chance that many of these materials are not just one specific substance, but they have had some kind of thin coating (or film) applied in order to upgrade the aesthetic, structural, chemical, or electrical properties of the underlying material. A very simple example can be seen below. The image shows a cross section of a wood surface (vertical grains on the bottom half) that has been painted (the double layer on top):



(Image JS Ultrasonics)

➔ In the space below, make a list of familiar materials that have been coated with a thin film:
Ex: wooden wall + painted surface

In this activity, we are going to coat some common materials with films that exhibit **hydrophobic** properties.

➔ Perhaps you are already familiar with the term *hydrophobic*. But if you're not, you can make an educated inference by breaking the word down into its component parts. In the space below, write down what it means for a substance to be *hydrophobic:*

The activity will take place in two parts:

- In Part I, we will coat Copper and Glass with hydrophobic films using simple **deposition** techniques
- In Part II, we will analyze the hydrophobic properties of our new materials.

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Part I: Hydrophobic Surface Deposition

The process of coating a surface with a thin film is often referred to as **deposition** from the verb "to deposit."

A. Silver film on copper

We will take employ a redox reaction and metal activity in order to perform a chemical deposition of silver on a copper sheet.

★ ALWAYS wear your SAFETY GOGGLES throughout the process.

1. Your group will receive 5 Copper squares. One will be used as a control, and the 4 will be reacted with different concentrations of silver nitrate, $AgNO_3$ (0.01, 0.02, 0.03, and 0.04M)
2. Use sandpaper to "rough up" only ONE side of each copper square. Fold up a small part of the corner of each square to indicate the sandpapered side.
3. Measure and record the initial mass of each copper square in the table below. Place each square on an individual paper towel numbered 1-5.
4. Take one of your beakers and obtain about 100 ml of 0.01M $AgNO_3$ from your teacher. Record this concentration for copper square #2.
5. We will carry out the reaction for **120 seconds,** or 2 minutes. Using forceps or tweezers, place the copper in the solution and begin timing. At the 120 second mark, use forceps to remove the copper/silver square and place it back on the paper towel to dry.
6. Repeat steps 4-6 for the remaining concentrations of $AgNO_3$.
7. Carry out parts **B** and **C** below so the Copper/Silver has sufficient time to dry. Measure and record the final masses before the period ends.

Copper square	#1	#2	#3	#4	#5
[$AgNO_3$] (M)	-				
Initial Mass (g)					
Final mass (g)					

B. Clear Coat + Deodorant on Glass

Here, we will carry out a simple physical deposition on a glass surface by spraying.

★ Make sure this is done in a well-ventilated area away from other groups

1. Place a glass slide on a good size area of paper towels (old newspaper or magazine pages work too) so that the sprays do not get directly on working surfaces
2. Shake the Clear Coat can for at least 30 seconds to a minute to mix it up. Hold the nozzle about 12 inches away (no less) from the glass slide. Spray only for 3-4 seconds so that the spray coats the slide evenly.
3. Immediately after applying the Clear Coat (we don't want it to dry), hold the deodorant can about 12 inches away and spray for 3-4 seconds to coat evenly.
4. Place the slide on a fresh paper towel and allow to dry for at least several hours (one full day is best)

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C. Carbon film on Glass

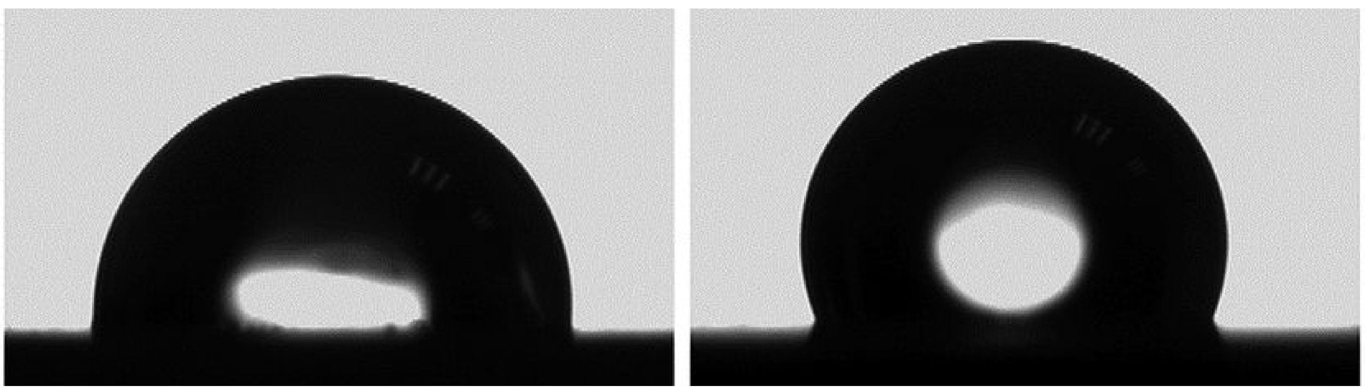
This final deposition will have us use a combustion reaction to physically deposit carbon (soot) on a glass surface.

1. Light a candle and allow it to burn for a minute or two.
2. Use forceps to hold a glass slide along either edge, and smoothly pass it back and forth directly over the flame. You should notice a black film (soot) being deposited on the surface of the glass.
3. The key is to coat the slide with a thin, even film of carbon that is not excessively heavy or light in any one area. You should not be able to see through any part of the glass (except where it was being held by the forceps).
4. Carefully place the coated slide on a paper towel where the surface will not be disturbed.

Part II: Hydrophobic Surface Analysis

Now we are ready to measure and analyze the **hydrophobicity** of our thin film surfaces. You can think of this as simply the "waterproofing ability" of the surface. Now, we could of course just drop some water on the surfaces and *qualitatively* say whether the surface is good at repelling water or not. But we want to be a bit more *quantitative.*

Materials scientists employ a technique called **drop shape analysis** in order to analyze how water interacts with a surface.



(Image Royal Society of Chemistry)

➔ Take a look at the images above. Which surface is more hydrophobic (more waterproof)? Explain your reasoning.

Ok, so we have some nice images. But how can we quantify what we are seeing?

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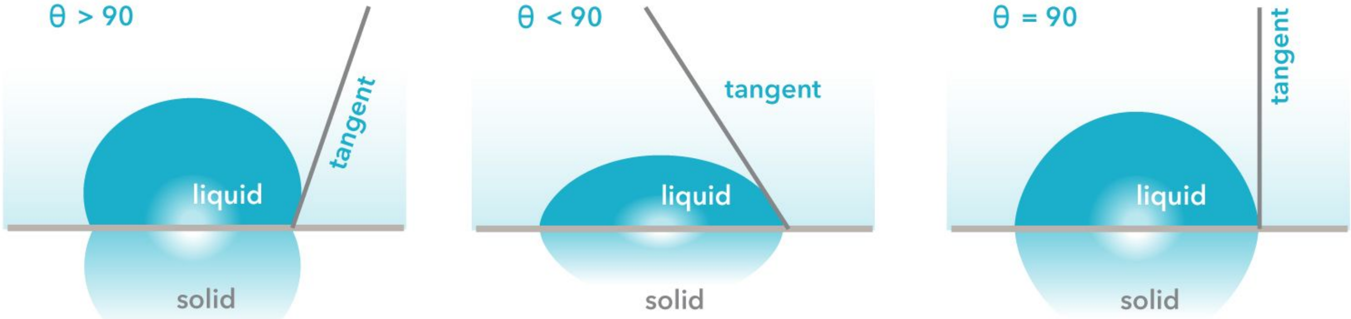
Contact angle is a measurement that tells us the "wettability" or waterproofing ability of a solid surface. Check out the image below (image Biolin Scientific)



- ➔ Measure the contact angles in the two images above (90° is already shown).
- ➔ Write a rule that relates **contact angle** to **hydrophobicity** (or waterproofing ability):

Research scientists in academia and industry use expensive instruments that place extremely small drops of water on surfaces in order to collect visual data and perform analyses. We are going to use the cameras on our phones to create images for analysis.

The simple procedure is as follow:

1. Fill a beaker with regular tap water. Use a plastic dropper to place one drop of water on the surface to be analyzed.
2. Use your camera to snap a side view photo of the drop similar to the images above. This will take some patience and practice. And some cameras will of course give better quality images than others.
3. Repeat the procedure at two other different spots on the same surface. This will enable us to obtain an average contact angle.
    - ★ For the Copper + Silver material, you will obtain images for BOTH sides (sandpaper and no sandpaper)
4. Upload your images to your Google Drive account (or email them to yourself) so that they can be printed and analyzed.
5. You will record your data in the table on the next page.

We will carry out the procedure above for all of our prepared surfaces. We'll do the same for other available materials if time permits.

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I. Silver film on Copper

First, let's take some time to analyze the chemistry that took place.

➔ Write a balanced equation for the reaction

➔ Why is this considered a **redox reaction?**

➔ Use the metal activity series (or standard reduction potential values) to *explain* why this reaction occurs without any input of energy.

➢ **Extension:** Use stoichiometric principles to calculate the extent to which each copper square reacted. Your teacher will help you get started.

Record your contact angle data in the table below.

★ NSP = Non-Sandpapered side, SP = Sandpapered side

	#1		#2		#3		#4		#5	
[$AgNO_3$]	-									
	NSP	SP	NSP	SP	NSP	SP	NSP	SP	NSP	SP
contact angle #1										
contact angle #2										
contact angle #3										
Average contact angle										

➢ **Extension**: Use a spreadsheet program to create a graph of **Average Contact Angle vs. [$AgNO_3$]**

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II. Clear Coat + Deodorant film on Glass

Here, we will use a plain glass slide as a control.

	Glass only	Clear Coat + Deodorant
contact angle #1		
contact angle #2		
contact angle #3		
Average contact angle		

III. Carbon film on Glass

The control here will be the "Glass only" data from the table above.

	Carbon film on Glass
contact angle #1	
contact angle #2	
contact angle #3	
Average contact angle	

➢ **Extensions**

IV. Collect contact angle data for other film coated materials around the room. Think about table surfaces, LCD screens, or even human skin!!!

V. Devise a test that will quantitatively determine how easily a drop of water slides off each surface. Think about creating inclined planes with each sample and making angle measurements between the table surface and the sample.

VI. Use a hot plate to heat the coated samples. Analyze hydrophobic properties as above to see if heat treatments affect the film.

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Data Analysis and Discussion

1. State the trend(s) in contact angle observed on the silver coated copper at the different concentrations of $AgNO_3$.

2. How did sandpapering one side of the copper alter the observed contact angles? How would you explain this? (Hint: Think about the texture of the surface).

3. Compare the contact angles observed on glass only, Clear Coat + deodorant on glass, and carbon on glass.

4. Describe the challenges that scientists and companies face when designing and depositing thin films on material surfaces.

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5. Why would it be in the best interest of a company to make the surface of a material hydrophobic? What types of materials should definitely have hydrophobic surfaces?

6. Describe the ideal properties of a hydrophobic film for the LCD screen on a phone.

7. Challenge: Think about the fact that water molecules interact with each other via **intermolecular forces** called *hydrogen bonds* (see image below). If a surface film is made to be **hydrophobic**, describe how the forces between the film's chemical components compare to those of water. Draw a diagram to supplement your response.