Hydrophobic Surfaces: Deposition and Analysis

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Subject: Chemistry

Grade Level: High School

Standards: *Next Generation Science Standards*

NGSS HS-ETS1-3

Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

NGSS HS-PS1-2

Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.

NGSS HS-PS1-3

Plan and conduct an investigation to gather evidence and compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

Schedule:

2 x 45 minute periods

- 1 period for film application and condition modification
- 1 period for analysis

CCMR Lending Library Connected Activities:

- *Nano What?*
  - Nano Activities, Activity #4
- Chemical Reactions

Objectives:	**Vocabulary:**
Students will use both physical and chemical methods to coat surfaces with thin films. Quantitative and qualitative methods will be used to analyze hydrophobic and surface characteristics of coatings.	thin film coating hydrophobic/hydrophilic contact angle Redox reaction metal activity series stoichiometric conversion
Students Will: ● Apply thin coatings to multiple surface types using a variety of techniques ● Analyze and explain hydrophobic surface properties both qualitatively and quantitatively	**Materials:** ● glass slides ● candle + matches ● Clear Coat spray ● Deodorant spray ● copper sheets cut into ~ 4x4cm squares ● $AgNO_3$ solution (0.01, 0.02, 0.03, and 0.04M made from 0.1M) ● Sandpaper ● Forceps

Safety

- Students must wear safety goggles for the duration of the lab
- Teacher should use discretion with regards to letting students light candles
- Clear Coat + Deodorant application should be done next to open window
- Refer to MSDS for precautions and proper disposal of AgNO3 solution and silver coated copper

Science Content for the Teacher:

I. Refer to the MIT News article below for information on ***hydrophobic surfaces*** *and their applications:*
   - Explained: Hydrophobic and Hydrophilic

II. Refer to the "Lesson Background and Concepts for Teachers" section in the article below for information on ***water droplet shape analysis*** and ***measuring contact angle:***
   - Wetting and Contact Angle

III. Refer to the article from *Chinese Science Bulletin* for information on the chemistry underlying silver coating on a copper substrate:
   - Feng XJ, Shi YL, Wang YS, Yue GR, Yang W. Preparation of superhydrophobic silver nano coatings with feather-like structures by electroless galvanic deposition. Chinese Science Bulletin, 2013, 58: 1887-1891

Classroom Procedure:

Part I: Surface Deposition

I. Silver on Copper sheets
   a. Each group will receive 5 copper squares: one as a control and the other 4 to be plated using different concentrations of silver.
   b. Students will use sandpaper to "rough up" ONE side of each copper square. They should fold up one of the edges so that they know which side has been sandpapered after the plating is done.
   c. Students will then record the mass of each copper square in the table provided.
   d. Students will get about 100ml of 0.01M $AgNO_3$ solution from the teacher.

***NOTE to teacher:** To avoid all groups using the same concentration, stagger the concentrations that each group will start with.

   e. Using forceps or tweezers, students will place one of the copper sheets into the beaker and allow the reaction to take place for 120 seconds (2 minutes). BE SURE to record the concentration with the corresponding copper square.

***NOTE to teacher:** Depending on group size, 1 or 2 students can monitor the first reaction while the 1 or 2 other group members get the next concentration and start the reaction.

   f. After 120 seconds, students will use forceps to remove the silver plated copper from the solution and set it to dry on a paper towel.
   g. Repeat the above procedure for the 0.02M, 0.03M, and 0.04M $AgNO_3$. Make sure students label their copper squares.

II. Clear Coat + Deodorant Waterproofing
   a. Make sure this is done in a well-ventilated area (near an open window) and that groups are far apart.
   b. 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
   c. 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.
   d. 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.
   e. Place the slide on a fresh paper towel and allow to dry for at least several hours (one full day is best)


III. Carbon Coating
   a. Light a candle and allow it to burn for a minute or two.
   b. 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.
   c. 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)
   d. Carefully place the coated slide on a paper towel where the surface will not be disturbed.

Part II: Hydrophobicity (Waterproofing ability) Analysis

The analysis will focus on the measuring the contact angle between a drop of water and the film surfaces. The procedure found in the activity sheet is simple:

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.


Assessment:

Students will be asked to perform the following assessment tasks during both data collection and analysis/discussion.

- Measure and organize contact angle data
- State trends observed within data sets
- Describe challenges faced when designing and depositing thin surface films
- Explain why companies would require hydrophobic surfaces on materials
- Describe the ideal properties of a hydrophobic film for a phone LCD screen
- Explain how the intermolecular forces between the chemical components of a hydrophobic film compare to those of liquid water

The following rubric can be used to assess student work:

	1	2	3	4
Data	Data is either incoherent or missing many items and no units are present	Data is missing 3 or 4 items and units are inconsistent	Data is organized with 1 or 2 missing items and/or units	Data is thorough and well organized with correct units
Analysis and Discussion	Stated trends are incorrect or incoherent. No attempt is made to connect lab work to concepts and real-world issues, or response is incoherent.	Trends are stated but not explained using data. Responses barely connect lab work, concepts, and real-world issues, or connections are inaccurate.	Trends are clearly stated and mostly explained with data. Responses attempt to connect lab work, concepts, and real-world issues with reasonable success	Trends are clearly stated and explained with real data. Responses make clear connections between lab work, scientific concepts, and real-world issues


Resources:

See the **Science Content for the Teacher** *section above for links to relevant background resources.*

Extra Activities:

Challenges are marked as "➢ **Extension**" within the *Student Activity Sheet* and include the following:

- Use stoichiometric principles to calculate the extent to which each copper square reacted.
- Use a spreadsheet program to create a graph of **Average Contact Angle vs. [$AgNO_3$]**
- Collect contact angle data for other film coated materials around the room. Think about table surfaces, LCD screens, or even human skin!!!
- 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.
- 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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