# Nano Waterproofing



## Lesson Focus

This lesson focuses on how nanotechnology has impacted the design and engineering of many everyday items, from paint to fabrics. Students learn about the hydrophobic effect and how similar properties can be introduced by reengineering products at the nano level. Students work in teams to develop a waterproof material and compare their results with nano waterproof materials developed recently by engineers and scientists.

## Lesson Synopsis

The "Nano Waterproofing" lesson explores how materials can be modified at the nano scale to provide features such as waterproofing and stain resistance. Student "engineering" teams develop their own waterproofing technique for a cotton fabric and test their design against a fabric that has been altered through nanotechnology applications.

## Age Levels

8-18.

## Objectives

- Learn about nanotechnology.
- Learn about the hydrophobic effect.
- Learn about surface area.
- Learn about teamwork and working in groups.

## Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- nanostructures
- surface area
- problem solving
- teamwork

## Lesson Activities

Students learn about how nanotechnology has impacted manufacture and use of fabrics. Students then work in a team to develop a waterproofing plan for a piece of cotton fabric, they execute their plan, test the fabric, and examine samples of fabrics that have had their surface altered through nanotechnology.

## Resources/Materials

- Teacher Resource Documents (attached)
- Student Worksheets (attached)
- Student Resource Sheets (attached)

## Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

## Internet Connections

- TryEngineering (www.tryengineering.org)
- TryNano (www.trynano.org)
- Nano-Tex (www.nano-tex.com)

## Recommended Reading

- Nanotechnology For Dummies (ISBN: 978-0470891919)
- Nanotechnology: Understanding Small Systems (ISBN: 978-1138072688)

## Optional Writing Activity

- Write an essay or a paragraph about potential benefits of applying nanotechnology to fabrics, surfaces, or materials used in hospitals or nursing homes?

## Extension Idea

- Have older students attempt to remove the waterproofing feature of nano fabrics in any way they can think of. For example, they might scrub the surface, dye it, boil it, wash it, freeze it, or iron it.

## For Teachers:
## Teacher Resource

### Lesson Goal
Lesson focuses on how nanotechnology has impacted the design and engineering of many everyday items, from paint to fabrics. Students learn about the hydrophobic effect and how similar properties can be introduced by reengineering products at the nano level. Students work in teams to develop a waterproof material and compare their results with nano waterproof materials developed recently by engineers and scientists.

### Lesson Objectives
- Learn about nanotechnology.
- Learn about the hydrophobic effect.
- Learn about surface area.
- Learn about teamwork and working in groups.

### Materials
- Student Resource Sheet
- Student Worksheets
- Microscope or camera scope (optional activity); sink or bucket to test fabrics
- One set of materials for each group of students:
  - Four 4" x 4" pieces of plain white cotton fabric
  - One 4" x 4" piece of fabric that has been adjusted at the nano level (suggestion -- purchase one white shirt made of nano fabric and cut up for distribution to the class. These can be purchased at many stores or online -- a sample list is at www.nano-tex.com/company/brand_partners.html.)
  - "waterproofing" materials: wax, crayons, flax seed, lanolin, clay, glue, spoons or sticks for smoothing -- or other items suggested by the students

### Procedure

1. Show students the various Student Reference Sheets. These may be read in class, or provided as reading material for the prior night's homework.

2. Divide students into groups of 2-3 students, providing a set of materials per group.

3. Explain that students must devise a way to "waterproof" a piece of fabric that ultimately would be made into a shirt. In this case, "waterproof" means that water should not be absorbed by the fabric, but will bead up on the fabric instead.

4. Students meet and develop a written plan for three different approaches: Fabric A, Fabric B, and Fabric C. (the fourth fabric piece is provided in case of errors)

5. Students next "manufacture" their three fabric pieces.

## *For Teachers: Teacher Resource*

### Procedure (continued)

6. As an extension, students could examine their "waterproof" fabrics using a microscope to see how the surface changed with each "waterproofing" system. Provide a sample of material altered at the nano level for them to examine as well. While students will not be able to see the changes using a regular classroom microscope, the lack of visible difference between unaltered cotton and nano-treated cotton will serve to show the power of different types of microscopes.

7. Student teams next test out their fabrics using a basin of water or a sink, complete an evaluation/reflection worksheet, and present their findings to the class. You may consider using colored water or fruit juice to test for staining too.

### Time Needed

Two to three 45 minute sessions.

### Optional Modelmaking Extension

Have students build a model representing the Hydrophobic effect. This could be done with a foam ball with straws or toothpicks attached to simulate the tiny hairlike projections that keep water off the direct surface of some leaves. This will also help visually illustrate how waterproofing works at the nano scale.

## *For Students:*
## *What is Nanotechnology?*

Imagine being able to observe the motion of a red blood cell as it moves through your vein. What would it be like to observe the sodium and chlorine atoms as they get close enough to actually transfer electrons and form a salt crystal or observe the vibration of molecules as the temperature rises in a pan of water? Because of tools or 'scopes' that have been developed and improved over the last few decades we can observe situations like many of the examples at the start of this paragraph. This ability to observe, measure and even manipulate materials at the molecular or atomic scale is called nanotechnology or nanoscience. If we have a nano "something" we have one billionth of that something. Scientists and engineers apply the nano prefix to many "somethings" including meters (length), seconds (time), liters (volume) and grams (mass) to represent what is understandably a very small quantity. Most often nano is applied to the length scale and we measure and talk about nanometers (nm). Individual atoms are smaller than 1 nm in diameter, with it taking about 10 hydrogen atoms in a row to create a line 1 nm in length. Other atoms are larger than hydrogen but still have diameters less than a nanometer. A typical virus is about 100 nm in diameter and a bacterium is about 1000 nm head to tail. The tools that have allowed us to observe the previously invisible world of the nanoscale are the Atomic Force Microscope and the Scanning Electron Microscope.

### ◆ How Big is Small?

It can be hard to visualize how small things are at the nanoscale. The following exercise can help you visualize how big small can be! Consider a bowling ball, a billiard ball, a tennis ball, a golf ball, a marble, and a pea. Think about the relative size of these items.

### ◆ Scanning Electron Microscope

The scanning electron microscope is a special type of electron microscope that creates images of a sample surface by scanning it with a high-energy beam of electrons in a raster scan pattern. In a raster scan, an image is cut up into a sequence of (usually horizontal) strips known as "scan lines." The electrons interact with the atoms that make up the sample and produce signals that provide data about the surface's shape, composition, and even whether it can conduct electricity. Many images taken with scanning electron microscopes maybe viewed at www.dartmouth.edu/~emlab/gallery.

## For Students:
## What is The Hydrophobic Effect?

Hydrophobic comes from the word hydro (water) and phobos (fear). It can be demonstrated by trying to mix oil and water. And, also is evident if you look at some leaves and flower petals that repel water in droplets after a rain storm. For the leaves, the water repellant can sometimes be a waxy coating on the leaves, or can be the existance of tiny hairlike projections off the surface of the leaf which causes a buffer of air between the hairs -- the air keeps the water away.

### ◆ Superhydrophobic Surfaces

Superhydrophobic surfaces such as the leaves of the lotus plant have surfaces that are highly hydrophobic, or very difficult to wet. The contact angles of a water droplet exceeds 150° and the roll-off angle is less than 10°. This is referred to as the Lotus effect and the image to the right illustrates this concept.

### ◆ Fabric Applications?

Scientists and engineers who were aware of the hydrophobic effect decided to apply nanotechnology to the surfaces of fabrics to make them water proof too! The waterproof feature often also helps protect fabrics from staining because liquid cannot easily soak into the fabric fibers. A good example is the work done by a company called Nano-Tex. The company adds nano "whiskers" to cotton fibers in the same way that some leaves have little "hairs" on their surface. Creating the effect for fabric is a little tricky -- a cotton fiber is shaped like a round cylinder, and Nano-Tex adds tiny nano "whiskers" all around the cylinder so it has a fuzzy surface. The fabric doesn't appear any different or feel any different, but it does repel liquids. And, because liquids do not soak into the fabric, the process also helps the fabric resist staining too. Nano-Tex utilizes nanotechnology to: 1) design molecules with specific performance attributes; 2) engineer the molecules to assemble on the surface of textile fibers with extreme precision, and 3) ensure that they permanently attach to the fibers through patented binding technology. If the molecules were not permanently attached then the fabric might lose its ability to push water away after several machine washings. Over 80 textile mills worldwide are using Nano-Tex treatments in products sold by more than 100 apparel and commercial interior brands. This is just one example of an industry applying nanotechnology to solve problems.

## *Student Activity: Waterproofing Challenge*

You are part of a team of engineers who have been given the challenge to develop a new process for waterproofing clothing. You have been provided with several pieces of cotton along with many possible materials you might decide to use for your waterproofing technique. For the purposes of your challenge, "waterproof" means that water should not be absorbed by the fabric, but will bead up on the fabric instead. You may try two or three different solutions and see which works best!

◆ **Planning Stage**

Meet as a team and discuss the problem you need to solve. Use the box below to describe your solution and list the materials you think you'll need to meet the challenge. Explain why you think your solution will solve the problem!

| |
|---|
| **Fabric A**<br>Your plan and hypothesis:<br><br>Materials Needed: |
| **Fabric B**<br>Your plan and hypothesis:<br><br>Materials Needed: |
| **Fabric C**<br>Your plan and hypothesis:<br><br>Materials Needed: |

## *Student Activity: Waterproofing Challenge (Continued)*

### ◆ Execution Stage

Execute each of your plans (be sure to mark each piece of fabric, so you know what process you applied to it).

### ◆ Investigation Stage

If you have access to a microscope, examine each of your pieces of fabric and in the box below describe what you see, noting both what you see and how they differ from the other fabric samples.  You'll have a chance to examine a sample of fabric that has been altered at the nano level too! Consider whether the fabric surfaces appear smooth, bumpy, convex, concave, or have other characteristics.

| **Surface Observations** | | | |
|---|---|---|---|
| Fabric A | Fabric B | Fabric C | Nano Fabric |
| | | | |

### ◆ Testing Stage

Over a wash basin or sink pour water over your fabric and see if it beads up or is absorbed.  If your teacher agrees, you may wish to use a colored water or juice to more easily see if the water is absorbed at all.  Mark your observations below.

| **Water Test Observations** | | | |
|---|---|---|---|
| Fabric A | Fabric B | Fabric C | Nano Fabric |
| | | | |

## *Student Activity: Waterproofing Challenge (Continued)*

◆ **Evaluation Phase**
Complete the following questions as a group:

1. Did any of your fabrics prove to be waterproof?

If yes, which procedure do you think was the best, and why?
If no, why do you think your procedures did not work?

2. What solution of another team do you think worked best? Why?

3. What do you think would happen if you washed and dried your fabric? Would it retain the waterproofing?

4. What was the most surprising observation during the microscope comparison (if you completed that part of the activitiy)?

5. How did the nano treated fabric compare to your most successful fabric in the water test?

6. How did the nano treated fabric compare to your most successful fabric under the microscope?

## *Student Activity: Waterproofing Challenge (Continued)*

7. If you had to do it all over again, how would your team have approached this challenge differently? Why?

8. Do you think that materials engineers have to adapt their original ideas during product testing? Why might they?

9. Did you find that there were many different solutions in your classroom that met the project goal? What does this tell you about how engineering teams solve problems in the real world?

10. Do you think you would have been able to complete this project easier if you were working alone? Explain…

11. What other applications can you think of where a surface might be changed at the nano scale to improve function or performance? One idea is coating windshields so water flows off faster…..what can you think of?

## *For Teachers:*
## *Alignment to Curriculum Frameworks*

Note: All lesson plans in this series are aligned to the National Science Education Standards which were produced by the National Research Council and endorsed by the National Science Teachers Association, and if applicable, also to the International Technology Education Association's Standards for Technological Literacy or the National Council of Teachers of Mathematics' Principles and Standards for School Mathematics.

- **National Science Education Standards Grades K-4 (ages 4 - 9)**

**CONTENT STANDARD A: Science as Inquiry**
As a result of activities, all students should develop
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

**CONTENT STANDARD B: Physical Science**
As a result of the activities, all students should develop an understanding of
- Properties of objects and materials

**CONTENT STANDARD E: Science and Technology**
As a result of activities, all students should develop
- Abilities of technological design
- Abilities to distinguish between natural objects and objects made by humans

**CONTENT STANDARD F: Science in Personal and Social Perspectives**
As a result of activities, all students should develop understanding of
- Science and technology in local challenges

- **National Science Education Standards Grades 5-8 (ages 10 - 14)**

**CONTENT STANDARD A: Science as Inquiry**
As a result of activities, all students should develop
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

**CONTENT STANDARD B: Physical Science**
As a result of their activities, all students should develop an understanding of
- Properties and changes of properties in matter

**CONTENT STANDARD E: Science and Technology**
As a result of activities in grades 5-8, all students should develop
- Abilities of technological design
- Understandings about science and technology

**CONTENT STANDARD F: Science in Personal and Social Perspectives**
As a result of activities, all students should develop understanding of
- Science and technology in society

## *For Teachers:*
## *Alignment to Curriculum Frameworks*

◆ **National Science Education Standards Grades 9-12 (ages 14 - 18)**

**CONTENT STANDARD A: Science as Inquiry**
As a result of activities, all students should develop
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

**CONTENT STANDARD B: Physical Science**
As a result of their activities, all students should develop understanding of
- Structure of atoms
- Structure and properties of matter

**CONTENT STANDARD E: Science and Technology**
As a result of activities, all students should develop
- Abilities of technological design
- Understandings about science and technology

**CONTENT STANDARD F: Science in Personal and Social Perspectives**
As a result of activities, all students should develop understanding of
- Science and technology in local, national, and global challenges

◆ **Standards for Technological Literacy - All Ages**

**The Nature of Technology**
- Standard 1: Students will develop an understanding of the characteristics and scope of technology.
- Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

**Design**
- Standard 9: Students will develop an understanding of engineering design.
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

**Abilities for a Technological World**
- Standard 11: Students will develop abilities to apply the design process.
- Standard 13: Students will develop abilities to assess the impact of products and systems.

**The Designed World**
- Standard 19: Students will develop an understanding of and be able to select and use manufacturing technologies.