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## **AC 2011-454: EXCHANGE THE NNIN OUTREACH DEMONSTRATION GUIDE: A SET OF NANOTECHNOLOGY DEMONSTRATIONS FOR UPPER ELEMENTARY THROUGH HIGH SCHOOL.**

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Nancy Healy is the Education and Outreach Coordinator for the National Nanotechnology Infrastructure Network (NNIN). NNIN is an NSF-funded user support network of 14 universities which also provides nano-education outreach activities and programs. NNIN provides informal and formal activities to a K-gray age span. Her office is located at Georgia Institute of Technology, Nanotechnology Research Center. Prior to joining the NNIN in 2004, she was a program manager at the S.C. Commission on Higher Education. At SCCHE she was active in science and math K-12 issues, teacher education, and teacher professional development. She managed federal and state grant programs focused on teacher professional development. For ten years she served on the Board of Examiners for the National Council for the Accreditation of Teacher Education. She was also at the University of South Carolina for 17 years where she taught undergraduates, had an active research program in paleo-oceanography, and numerous graduate students. She has a B.S. in Zoology from the University of Rhode Island and an M.S. and Ph.D. in Geological Sciences from the University of South Carolina.

### **Joyce Palmer Allen, National Nanotechnology Infrastructure Network**

Joyce Palmer Allen is the Assistant Educational Coordinator for the National Nanotechnology Infrastructure Network (NNIN) and works at the Nanotechnology Research Center at Georgia Institute of Technology. Her job includes planning, developing and implementing educational outreach programs in nanotechnology and representing the NNIN Education and Outreach office at local and national conferences and meetings. She also helps to oversee programs such as the NNIN Research Experience for Teachers and Research Experience for Undergrads at Georgia Tech.

Before joining NNIN and Georgia Tech, Joyce was a National Board Certified Teacher who taught science in grades 9-12 for thirty years. During her years of teaching she served on many local and state committees and received numerous recognitions. She has a B.S., M.Ed and Ed.S in science education from Georgia Southern University.

## **Exchange – The NNIN Outreach Demonstration Guide: A set of nanotechnology demonstrations for upper elementary through high school.**

### **Introduction**

The National Nanotechnology Infrastructure Network is an integrated geographically-diverse partnership of 14 university-based laboratories supported by the National Science Foundation. Part of our mission is to provide education and outreach to a wide audience through a variety of methods. Our goal is to develop a nano-literate population which is ready for this new technology as consumers and as part of the workforce. Over the past several years, we have developed a set of demonstrations and hands-on activities that we use with school groups, open houses, and community programs. These materials come from a variety of sources including the NNIN and other nano-education groups such as Nanoscale Science and Engineering Centers and Materials Research Science and Engineering Centers. We have compiled a set of 15 of these demonstrations into a user-friendly *NNIN Outreach Demonstration Guide* ([http://www.nnin.org/nnin\\_k12teachers.html](http://www.nnin.org/nnin_k12teachers.html)).

The activities typically come from larger educational lessons designed for secondary science students. However, with large groups attending short duration events we wanted to use the excitement of these lessons in a demonstration or hands-on activity. Thus, we compiled our favorites into the *Guide* which span the breadth of nanoscale research and engineering, are easy to do, and require low-cost materials. The *Guide* provides helpful hints on doing these demonstrations, a list of materials needed, and the resource to find the full lesson that the demonstration is based on. These activities can be performed in a variety of settings including the K-12 classroom and many are tied to concepts taught in the science curriculum. Presented below are three of our 15 activities from the *NNIN Demonstration Guide*. The full *Guide* contains demonstrations on: hydrophobic properties, smart memory alloys, ferrofluids, size and scale, nanoproducts, liquid crystals, bunny suits, forces at the nanoscale, self assembly, encapsulation, edible chips, surface effects, allotropes of carbon, tools of nanoscale science and engineering, and thin films.

We have used these demonstrations with thousands of school-age children and adults. The typical setting for the demonstrations is with school groups who visit the research facilities for tours and an introduction to nanoscale science and engineering (NSE). For visiting school groups we do a variety of activities which includes three to four demonstrations. For these, we break the visiting group into a maximum of 12 students so that all can see and interact with the demo. We have performed several of these demos at the Materials Research Society's Nano Cafes and Education Outreach table top demonstrations. The largest group that we have worked with was the First Annual USA Science and Engineering Festival that occurred in Washington, DC October 23-24, 2010. Approximately 500,000 people participated in this event and we estimated that we had 7,000 visitors to our booth do interact with 6 of the NNIN demos.

Assessment of informal events is difficult to do with any real accuracy. Positive comments and the “wows” are always good indicators that the demonstration was enjoyed. We use questioning of students during the demonstrations to gauge understanding of the science behind them. For school groups, we perform a pre and post survey (based on the introductory

talk and the activities) to determine if they learned such things as the size of a nanometer, what are some current nanoproducts, what products contain nanoparticles, what is hydrophobic and hydrophilic, what is a smart memory alloy, among others. We only use the results to provide feedback to the program and make changes where needed.

### **Demonstration 1. Ferrofluid – Nanotechnology and Magnetism**

The NNIN lesson *What does Nanotechnology have to do with Magnetism?*- A *Ferrofluid Activity* will give you the background information for the full lesson. It can be found at [http://www.nnin.org/nnin\\_k12magnetism.html](http://www.nnin.org/nnin_k12magnetism.html). It also provides resources for buying ferrofluid or Google ferrofluid to locate sources to purchase. You may make your own as several methods are available on the Internet. Several questions are suggested below and your choices will depend on the age of your audience.



#### **Materials:**

Prepare ahead of time:

1. closed container of iron filings; label #1
2. closed container of iron filings and water; label #2
3. closed container of ferrofluid; label #3
4. closed container of ferrofluid and a penny; label #4
5. several pairs of latex/nitrile gloves
6. several small magnets
7. Parafilm® to help seal containers and prevent leakage

#### **To do the demo:**

##### **Part 1:**

Begin demo by asking students what they think is in container #1. Follow-up questions may include: Why do you think it is? Do you think this substance is a solid or a liquid? How do you know? What makes a solid a solid? What makes a solid a solid at the atomic level? *Before you leave this part of demo tell them that the container contains iron filings* and ask if they think the iron filings are magnetic.

Next have student(s) place a magnet on top of container #1, turn container over, and then set the container in the upright position. Ask students what happens to the iron filings. Follow-up

questions may include: Why are the iron filings attracted to the magnet? Are the iron filings a permanent magnet? How do they know? What do we call something that is magnetic only when it is in the magnetic field of another magnet?

*Discuss the movement of electrons in a non-magnetic substance and how the movement is aligned in a domain of a magnetic substance.*

### **Part 2:**

Have students look at container #2. Ask what is in the container? Then ask students if they think a liquid can be a magnet? Follow-up questions may include: What makes a liquid a liquid? What makes a liquid a liquid at the atomic level? What do you think will happen if you put the magnet on top of the container and flip it over like you did with container #1?

Tell them to put magnet on top of the container, flip it over and then set it upright like they did for container #1. Ask them what happened. Why do you think that the iron filings stayed at the top and not the water?

*Tell students to think about how atoms behave differently in liquids and solids.*

### **Part 3:**

We recommend that the students wear gloves when they handle containers of ferrofluid.

Have students look at container #3. Ask what they think is in the container?

*Tell them that the container contains ferrofluid which is a colloidal mixture of nanosized particles of a paramagnetic material. Tell them that this means that there are solid particles suspended in a liquid. (The supplier of our ferrofluid states that the particles are around 10 nm.)* You may want to ask students some of the following questions: What is a colloid? If the container has a solid and a liquid in it like container #2, why doesn't the solid settle to the bottom of the container like in #2? *Discuss with students that at the nanoscale electrostatic forces are greater than gravity. So the particles' attraction for each other is greater than the pull of gravity that would pull them down.*

Tell students to place the magnet *under* container #3 and move it around. Ask them what is happening? Follow up questions may include: Why is the liquid and the solids following the magnet? Why are spikes forming where the magnet is at?

*Remind the students that the electrostatic attraction of the particles are so great that the paramagnetic particles are attracted to the magnet and the liquid particles are attracted to the paramagnetic particles so they move with the magnet also.*

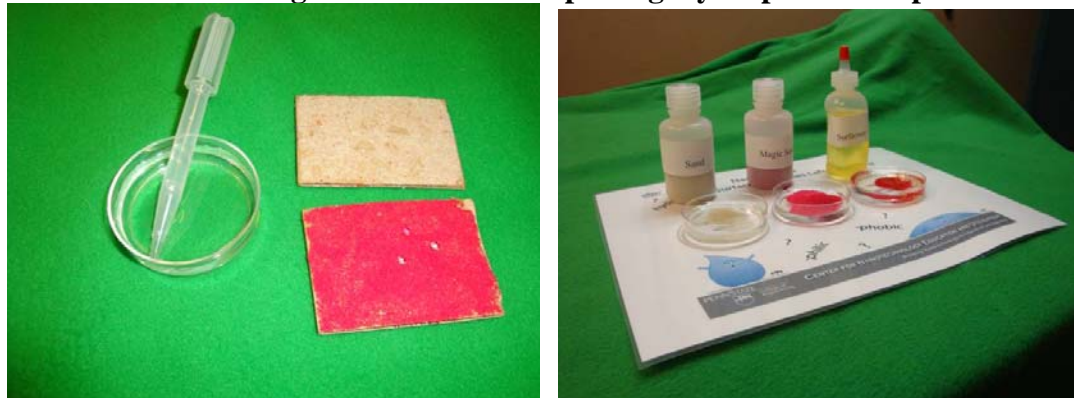
### **Part 4:**

Ask students to define density. Ask what determines when something floats? *Tell them that a unique feature of ferrofluid is that when it is in the magnetic field of another magnet its density changes.*

Tell them to look at container #4. Ask if they can see the penny that is in the container? *Explain that the penny is on the bottom of the container because its density is greater than the ferrofluids. Remind them that if materials are able to move they will layer themselves with the most dense at the bottom and the least dense at the top.*

Tell them to put the magnet *under* the container and move it around. Ask them what is happening and why. *They should see that the penny is now trying to get on top of the ferrofluid because the penny is now less dense than the ferrofluid.*

## Demonstration 2 Magic Sand Demo – Exploring Hydrophobic Properties



The NNIN lesson *Exploring Magic Sand* will give you the background information for the full lesson ([http://www.nnin.org/nnin\\_k12teachers.html](http://www.nnin.org/nnin_k12teachers.html)). It also has resources to buy the materials but you can Google “magic sand” and find other sources plus YouTube videos.

### Materials:

1. container of magic sand (small vials or bottles) plus a larger container with magic sand (we use the one pound container it is shipped in)
2. container of regular sand (small vials or bottles) plus a larger container of regular sand
3. 2-3 inch cardboard pieces to make sand demos (see picture above)
4. rubber cement
5. small petri dishes or small clear cups (2-3 depending on demo used) each filled  $\frac{1}{2}$  with water
6. water in squirt bottle or use beaker/cup with water and eye dropper
7. funnel and fast flow filter paper (or coffee filters)
8. beaker/cup to catch liquid from funnel
9. clear beaker or cup
10. water and stirring rod
11. small drop bottle of surfactant (if doing this part of demo) – dish soap or vegetable oil (you may add food color to this so it is easier to see)
12. paper towels
13. plastic table cloth (optional)
14. hand held scope (optional) (Radio Shack Illuminated Microscope Model MM-100 Catalog # 63-1313)

**To do a demo:**

Prepare demo pieces in advance of event:

1. Cut circles or squares from cardboard (minimum size 2”) – such as from a shipping box. We use a die cut machine to cut circles or squares. Alternatively use a small plastic spoon
2. Spread out a sheet of paper to work over.
3. Spread rubber cement over cardboard piece and sprinkle with magic sand (press as necessary to stick). Shake off excess sand and reuse or return to container. If using spoon, spray with adhesive and coat with magic sand.
4. Spread rubber cement over cardboard piece or spray spoon with adhesive and sprinkle with regular sand (press as necessary to stick). Shake off excess sand and reuse or return to container.

**Part 1:** Ask students what hydrophobic and hydrophilic mean. Ask what will happen when you pour sand into a Petri dish with water. Ask for volunteers to sprinkle sand in one of the Petri dishes of water. Ask another volunteer to sprinkle magic sand in another Petri dish. Explain what is occurring and why this is nanotechnology (see lesson). You can also demonstrate what happens when there is a surfactant by adding drops of vegetable oil into a Petri dish and sprinkle with magic sand.

**Part 2:** Hand students the two types of circles (spoons) and have them place drops of water on them using squirt bottles or eye droppers. Bring extra circles/spoons as we use 2-3 for each group and they also get wet and need to dry out. You may also let students use the handheld lens to look at the two sands to see if they can see differences. The Magic Sand is typically more rounded, less angular to allow for the monolayer to adhere.

**Part 3:** Have a clear container filled  $\frac{1}{2}$  -  $\frac{2}{3}$  with water. Pour a larger amount of magic sand into the container. Hand container to students and let them “play” with the magic sand by stirring it or lifting the sand up with the stirrer above the water’s surface (it will be dry). When all have seen this demo, pour water into filter paper and show how the sand is dry. You will need to discard the Petri dish with the magic sand and surfactant. You can reuse the magic sand from the other Petri dish by filtering it. We usually discard the contents of the dish of water with regular sand. Prepare for your next group or reuse the Petri dishes without doing the pouring of materials with the next group.

There is a good YouTube video demonstrating the properties of magic sand.

<http://www.youtube.com/watch?v=-1id-gHQjbs>

A variation of the demo can be found on NISE Net

<http://www.nisenet.org/catalog/programs/magic-sandnanosurfaces>

To extend this activity you can demonstrate with hydrophobic leaves (Lotus Effect) such as elephant ears, lotus plants, nasturtium, collards, cabbage, or mustard greens. If you use any of the greens **do not** use the prewashed packets only the non-washed whole-leaf varieties. There are good YouTube videos of the Lotus Effect. <http://www.youtube.com/watch?v=LJtQ6dvcbOg> and <http://www.youtube.com/watch?v=MFHcSrNRU5E>

To show how nature's hydrophobic properties are duplicated in consumer products use NanoTex™ fabric (samples available from the company; <http://www.nano-tex.com/>) or nanopants (Target Cherokee Stain Resistant) or stain resistant shirts (Dockers). Use water to demonstrate the hydrophobic properties of the material. Sto Corporation makes Lotusan™ a building wall covering but it takes 30 days to cure the materials so it may not be worthwhile to make your own demo pieces. However, they have a nice video showing the effect <http://www.stocorp.com/allweb.nsf/lotusanpage>. There is a poster on our web site of the Lotus Effect. <http://www.mirc.gatech.edu/education/documents/LotusEffectinfoforLotusan.pdf>

### **Demonstration 3. Creating Colors by Changing Scale**

Developed by NNIN Education Coordinator Ethan Allen at Center for Nanotechnology, University of Washington

This is a demonstration about thin films.



### **Materials**

1. Clear fingernail polish – any brand works fine.
2. Black Tyvek® or construction paper, cut into ~4”squares. Construction paper is OK, but absorbs water, drips out black dye, and takes quite a while to dry. Using Tyvek, as it is non-absorbent, avoids these issues, enables much more rapid drying of the films, and thus permits much shorter turn-around times for processing this demonstration/interactive.
3. Shallow plate or dish, with enough water to cover or submerge one of the black squares.
4. Paper towels to clean up excess water.

To do the demo:

1. Place a black square under water so that just its corners are exposed.
2. Pick up some clear nail polish from the bottle with the brush.

3. Drop ONE small bead of nail polish from the brush onto the water. (If needed, just touch the drop of polish to the surface of the water.)  
Watch the **colors appear** as the drop spreads out into a thin film!
4. Carefully lift the square to catch as much of the film as possible, draining off excess water. Do not let the film slide off the square.
5. Let the film and square dry.

### **What is going on?**

#### ***How can we see really tiny structures without using a microscope?***

Here we make a very thin film from a drop of clear fingernail polish. Flattening the droplet to a film of microscopic (a few thousand nanometers) thickness makes the material appear brightly colored.

#### ***Where else do we see colors that are based in the scale of the material?***

The sheen you see in soap bubbles and the ‘rainbow’ effect in some oil slicks are examples of this same thin film phenomenon. Closely related are the iridescent colors that appear on CDs and DVDs, and in some bird feathers, butterfly wings, and some beetles. These result from the material having a regular, repeated structural unit that is about the same size as the wavelength of light – a few hundred nanometers.

### **How does this work?**

#### ***Why does the clear liquid become a colorful film?***

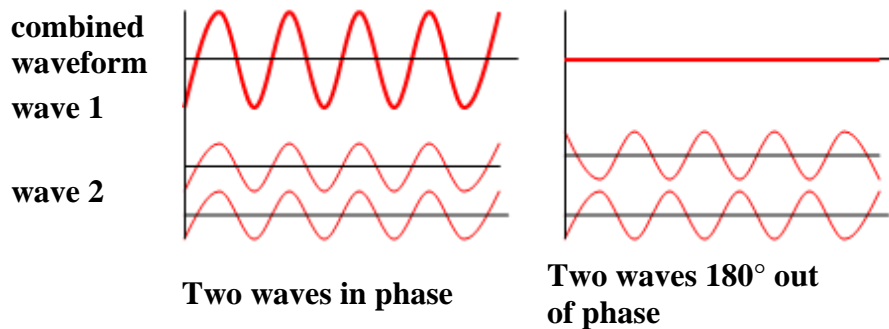
As the small drop of liquid spreads out on the water, its thickness decreases to a few microns. (A micron is one thousandth of a millimeter.) The bright iridescent colors in the film result from the interference of light reflecting back from the top and bottom of this thin film.

Most light passes through the clear film. But some of the light from above reflects back up off of the smooth top surface of the film; and some of the light passes into the film and then reflects back up off of the bottom surface of the film.

This light reflecting back up from the bottom surface of the film then emerges from the top surface but, because it has traveled very slightly further than the light reflecting from the top surface, is now out of phase with the light reflecting off the top surface. The two sources – reflections from the top and bottom surfaces of the thin film – interfere with one another; sometimes they reinforce each other, producing bright colors, and sometimes they cancel each other out, producing no color (see the diagram below).

The varying thickness of the film at its edges produces these bands of changing colors called ‘interference fringes.’ Much of the center of the film is more or less of uniform thickness and thus will tend to be of a single color.





[diagram from Wikipedia - [http://en.wikipedia.org/wiki/Interference\\_fringe](http://en.wikipedia.org/wiki/Interference_fringe) - on 1/5/10]

### Extension

Make several films and let them dry. Observe and compare them carefully to one another. What do you note about the progression of colored bands from the outermost edges toward the center? What does this indicate about the specific sequence of color bands that you see?

### Some Other Questions:

1. What happens if you use colored nail polish?
2. What happens if the nail polish is thicker (more viscous) or thinner (more watery)?
3. What happens if you use a bigger or smaller drop of nail polish?
4. What happens if you put one thin film on top of another?
5. How could you find out how thick the film is?
6. How do the colored bands around the edge of the film correspond to film thickness?
7. What happens if you view the film under different colored lights?

We use the following to place the paper containing the thin film in and provide information to participants

**Scientist/educator Ethan Allen developed this activity to help make nanoscale phenomena visible and accessible, with support from the:**

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