



GENETICALLY ENGINEERED MATERIALS SCIENCE & ENGINEERING CENTER

NSF-MRSEC at the University of Washington

Teacher's Preparatory Guide

Self Assembly of Polystyrene Hexagons

Purpose

- Introduce students to the concept of self assembly
- Demonstrate effect of different variables applied to a self assembling system in the macro scale and their correlations to nanoscale phenomena
- Simulate hydrophilic and hydrophobic regions in a particle using magnetic forces
- Creation of complex structure through the simple repeated programming of subunits

Subject area(s),

Materials Science, Chemistry, Biology

Time required

3 hours

Target Grade Level

High School; 10 – 12 grade

Advance Preparation

Materials:

- Flat sheet of Styrofoam, ~0.25" (figs. 4,5)
- Small polar neodymium rare earth magnets (figs. 2,3)
- Glass pan or tray with a flat, clear bottom approximately 15 cm diameter and a few inches high (figs. 8,9)
- Cutting template (fig. 1)
- Water
- Scissors
- Razor blades (fig. 1)
- Blank white paper
- Ruler, protractor



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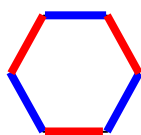
Safety Information

Use extreme caution when cutting with a razor blade. Always hold blade opposite the sharp edge.

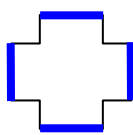
Teacher Preparation

The following steps are performed by the instructor as a preparation prior to the activity for classroom demonstration. This demonstration is meant to be performed by the teacher in preparation for the student lab to follow.

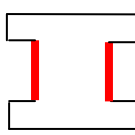
1..Using a razor blade and a pattern for the shape being made, cut out 35 uniform pieces of Styrofoam. Styrofoam shapes can be made from a variety of patterns, but should be relatively small (few cm's in size) and incorporate symmetry and be uniform in dimension. Some examples of shapes that could be used are given below, magnet polarity is designated as either blue or red faces:



A



B



C



D

Shapes B and C can function as a “lock and key” mechanism where the one face of “B” fits into the one of the two sites of “C”. In order for this to happen, the right side of “B” and the left side of “C” should have magnetic material that causes an attraction between these two sides. The same thing would need to happen for the left side of “B” and the right side of “C”. Shape D can be made in excess to form linear structures when magnets are placed in the recess as well as the head of the A-form.

2. Using the small rare earth magnets (figs. 2,3), place magnets at recessed locations from the face that will be a certain polarity (fig. 7).
3. Place Styrofoam pieces – with embedded magnets – into a pan filled with water to a depth equal to the thickness of each Styrofoam piece.



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4. Gently move the pan back and forth to cause Styrofoam objects to move in the water.
5. Re-adjust magnet positions to get an effective ordered arrangement.

Teaching Strategies

After the overhead demonstration and student introduction to the topic, students are to break up into groups to experiment on their own with the concepts. The student activity can range from a simple hour long laboratory to a 'final project' of sorts depending on the teacher's needs (like Rube Goldberg or Straw Tower).

For the graded portion of the lab, students are encouraged to test their creativity rather than just perform a simple experiment like in the demonstration. Thus, thought process and ingenuity should be stressed over the actual fabrication and demonstrations. Standards for grading may include the student's ability to create the most complex structure out of the fewest subunits.

Lab Questions:

1. What is meant by hydrophilic? What is meant by hydrophobic?
2. How can magnets be used to illustrate regions of hydrophilicity and hydrophobicity in larger structures that are being used to simulate nanoscale elements?
3. What are the advantages of self-assembled systems? Why are they necessary?
4. What types of movement may encourage a group of similar shaped Styrofoam pieces to form into an ordered arrangement?
5. What other basic shapes might be most suitable to use to form more elaborate ordered arrangements such as letter forms?
6. How well do the final ordered arrangements formed in this activity illustrate nanoscale phenomena?



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Assessment

- Lab Notebook Entry – sketches, drawings, ordered arrangement of paper shapes used to illustrate formation of letter.
- Typed Lab Abstract: Purpose, materials and procedures, results, and conclusions.

Teacher Background

1. Hydrogen bonding forms between water molecules due to the higher electronegativity of Oxygen over Hydrogen. Oxygen pulls electrons towards itself and away from Hydrogen leaving a slight positive charge near the Hydrogen and a slight negative charge near the Oxygen. This polar effect tends to draw water molecules toward each other – Hydrogen to Oxygen – and away from other substances that do not exhibit this kind of nonsymmetrical distribution of electron charge. Substances that have similar polar interactions as water are said to be hydrophilic – “water loving”, and substances that do not have a polar character – have a more equal distribution of electron effect – are said to be hydrophobic – “water fearing”. Hydrophobic elements group together in the presence of hydrophilic elements in order to minimize the surface area exposed to the hydrophilic regions.
2. Magnets can be used to show attractive forces like the ones described in #1 above – especially when the objects being moved are of significant mass as in this activity. It is important to locate magnets on the objects in such a way as to create a linear attractive force between N and S poles of separate magnets on different objects. This is one of the struggles with this activity – finding a small magnet that has a well defined N and S pole.
3. Movement can be characterized as back and forth along a line or rotational. Some shapes may form easier with a back and forth motion and some may form easier with a rotational motion. Hexagonal shapes tend to form “doughnut” or circular arrangements with a rotational motion instead of using a linear back and forth motion. Also, the strength of the force applied effects the overall outcome as well. Strong vigorous motions may only cause the individual shapes to completely rotate in the pan of water. A gently movement back and forth or rotationally seems to maximize the ordered arrangement of shapes. Finally, have a depth of water equal to, but not exceeding the thickness of the Styrofoam shapes



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- decreases the likelihood of shapes twisting up and down in the pan instead of just rotating or moving left and right.
4. Basic shapes should take into consideration the overall final letter shape and the potential attachment point for magnets. Letter shapes that have more than two lines of symmetry such as the letter O will more likely be constructed through an ordered arrangement of small pieces that also have more than two lines of symmetry – like a hexagon. Letters that have only one or two lines of symmetry, like a T, may order themselves more easily with small shapes that also have only one or two lines of symmetry.
 5. How well final arrangements mimic actual letters will be a function of shape size, force applied to the water in the pan as well as depth of water in the pan. Ultimately it will be helpful to point out that any final arrangement may mimic the reality that even in the natural world, there are defects in the final product.

General Nanotechnology Background

Why study Nanotechnology approaches to natural phenomena?

Ultimately the formation of materials occurs on the scale of interactions between atoms and molecules. Nanotechnology is the science of investigating, measuring, manipulating and modeling these interactions on the order of 1 – 100 nanometers. The more we know about how atoms and molecules interact – especially on a very small scale, the better prepared we will be to develop materials that fit a desired application.

Importance of Self-Assembly

As the scale of fabrication becomes smaller and smaller, it becomes very difficult to physically manipulate parts in order to produce a product. As a result it is a benefit to the manufacturer of small items on the order of nanoscale to have a mechanism for allowing the product to assemble itself. Ultimately it would be perfect to toss a collection of materials in a beaker, wait a relatively short period of time and have the finished product be produced. You could imagine tossing a collection of substances into a beaker and minutes later a coffee cup is formed that can be slid out of the beaker. Biological systems are excellent examples of self assembly. Proteins, lipids, carbohydrates, nucleic acids are all self assembled in living organisms. Learning from biological systems the elements of



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self assembly will one day lead to the development of materials and products that have advantages over those currently in use.

Reference:

1. N. Bowden, A. Terfort, J. Carbeck, G.. M. Whitesides, "Self-Assembly of Mesoscale Objects into Ordered Two-Dimensional Arrays", *Science*, New Series, Vol 276, pp. 233-235.
2. G.. M. Whitesides, M. Boncheva, "Beyond Molecules: Self-Assembly of Mesoscopic and Macroscopic Components", *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 99, No. 8, pp. 4769-4774.



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Resources for teachers:

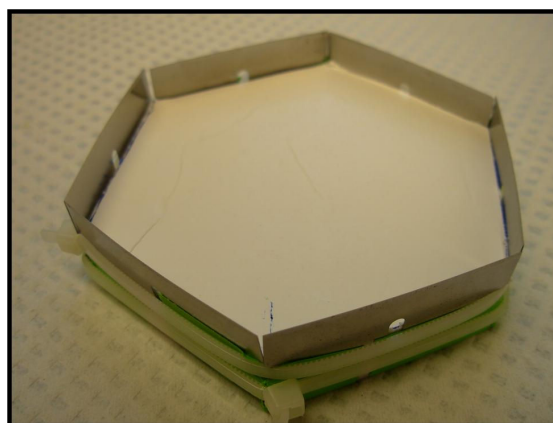


Fig. 1 - Hexagonal razor blade cutter



Fig. 2 - Polar neodymium magnets



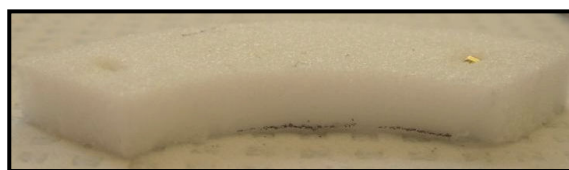
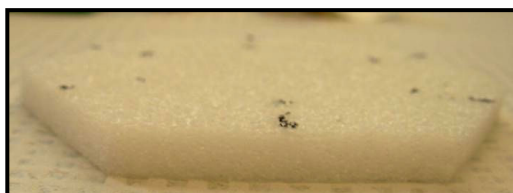
Fig. 3 - Relative size of magnets



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Figs. 4,5 - Foam subunit thicknesses

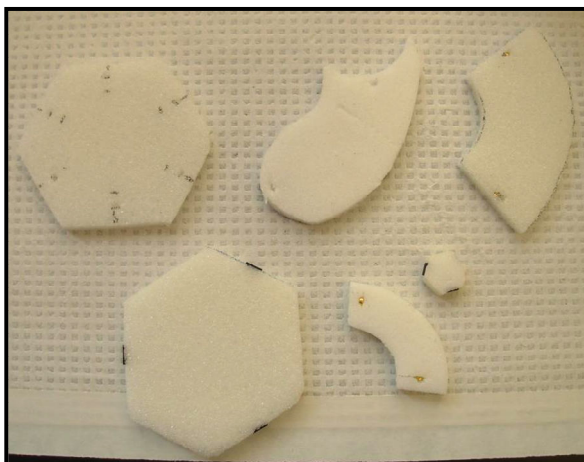


Fig. 6 - Foam subunit shapes

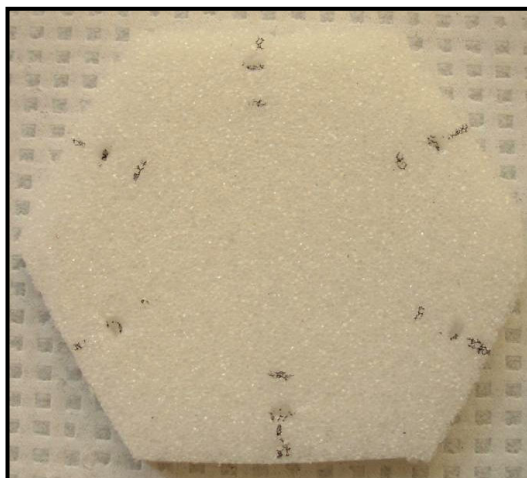


Fig. 7 - Recessed magnet positions



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Fig. 8 - Subunits and glass beaker for overhead demonstration

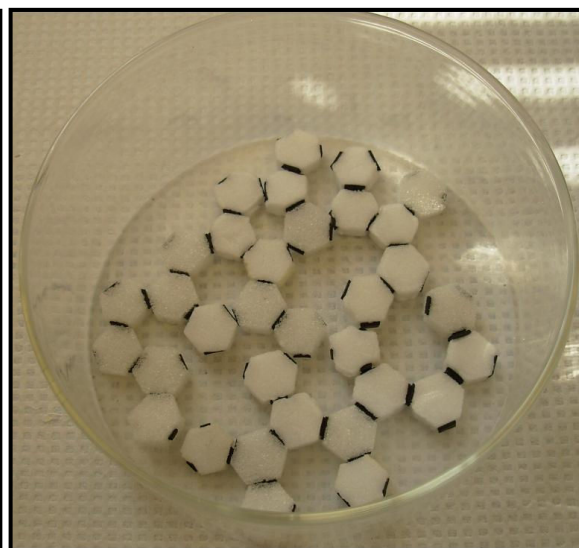


Fig. 9 - Assembled structure after agitation

The following people at the University of Washington in Seattle, WA are great resources for information on nanotechnology: Dr. Ethan Allen, Education & Outreach Manager, Center for Nanotechnology; Dr. Mehmet Sarikaya, Director of GEMSEC at the University of Washington; Christopher So, graduate student in Materials Science at the University of Washington