Teacher's Preparatory Guide

Semiconductors-Doping to create a semiconductor: changing conductive properties through diffusion

Purpose
In the semiconductor industry scientists take advantage of diffusion to "dope" or introduce atoms into a silicon wafer to change its conductive properties. The lesson simulates the diffusion of a gas phase substance (ammonia) into a solid substrate and compares the lab model of diffusion to the doping process of silicon wafers. Students will examine how diffusion occurs and explore how the electrical properties of semiconductors are developed.

Time required:
Fifty minute class time (prep time not included)

Level:
Upper middle school to high school

Teacher Background
Silicon is a very common element. It is the main element in sand and quartz. If you look "silicon" up in the periodic table, you will find that it sits next to aluminum, below carbon and above germanium.

Carbon, silicon and germanium have unique property in their electron structure. Each has four electrons in its outer orbital. This allows them to form nice crystals. The four electrons form perfect covalent bonds with four neighboring atoms, creating a lattice. In carbon, we know the crystalline form as diamond. In silicon, the crystalline form is a silvery, metallic-looking substance.

Metals tend to be good conductors of electricity because they usually have free electrons that can move easily between atoms, and electricity involves the flow of electrons. While silicon crystals look metallic, they are not. All of the outer electrons in a silicon crystal are involved in perfect covalent bonds so they can't move around. A pure silicon crystal is nearly an insulator-very little electricity will flow through it.

You can change the behavior of silicon and turn it into a conductor by doping it. In doping you mix a small amount of an impurity into the silicon crystal. This impurity can be introduced by diffusion.

In this lessons' simulation, ammonia vapor escapes from the concentrated solution and travels into the gelatin causing the phenolphthalein to change color. "Plumes" of color will be in evidence. They are due to the density gradients produced by dissolving ammonia.

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Materials

1. Petri dishes prepared with gelatin and water (Directions follow under advanced preparation)
2. Phenolphthalein solution
3. Clear plastic re-sealable bag
4. Dropper bottle of ammonia
5. Student work sheet
6. Background information material from Internet
7. Timers or stop watch
8. White sheets of paper
9. Metric rulers
10. Background information from Internet on making semiconductors.

Advance Preparation

Prep of Petri dishes:

1. Use Knox gelatin dissolved in warm water (follow box directions).
2. Mix in a few drops of phenolphthalein solution (0.05 g of solid phenolphthalein with 50 ml of ethanol and 50 mL of distilled water) as an indicator. This can be purchased already prepared.
3. Pour gelatin mixture into Petri dishes to a depth of about 15 mm and allow to set. (usually sets in about an hour).

Safety Information

Goggles are required. Ammonia is a strong base with an unpleasant smell. Care must be taken to protect skin and eyes. Vapor can be absorbed by contact lenses. Perform activity in a well-ventilated area.

Directions for the Activity

1. Before starting the lab, discuss the characteristics of how diffusion happens in the different states of matter. Gas atoms move freely, nothing impedes diffusion, rate is rapid. Liquids have more impedance but still fairly rapid diffusion in less viscous liquids. Solids have little movement of atoms and very slow diffusion.

2. Have students read the materials on how semiconductors work at either of these websites: HowStuffWorks at http://electronics.howstuffworks.com/diode.htm or Intel at http://www.intel.com/education/makingchips/preparation.htm

Procedure (from Student Activity Guide)

1. Place the uncovered Petri dish inside a re-sealable bag with the lid placed upside down next to it. (You will drop the ammonia droplets into the lid)

2. Place a few drops of ammonia (household ammonia will work). Seal the bag which now contains the Petri dish with indicator and the upside down lid containing a few drops of ammonia.

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Allow for diffusion to take place for three minutes or until you can no longer see changes in the gelatin.

3. Place the bag on a piece of white paper on the lab table and continue to make observations ever 3 minutes. Record on student instruction/worksheet.

4. Carefully remove the Petri dish and measure the depth of diffusion.

Cleanup:

1. Make sure that students are aware of where to dispose materials.
2. Materials may be flushed down the drain with water.

Worksheet (with answers)

Worksheet with answers follows below after National Science Education Standards

Assessment

Evaluate student's understanding by having them answer the following questions:

1. What substance in the activity diffused? (Ammonia)
2. How did you know that it had diffused? (Indicator turned pink)

Resources:

To learn more about electronics and nanotechnology, here are some web sites with educational resources:

http://www.intel.com/education
http://www.nano.gov
http://www.ieee.org/web/education/preuniversity/tispt/lessons.html
http://www.tryengineering.org/lesson.php

National Science Education Standards

Middle School Content Standard

- Standard A
  - Abilities necessary to do scientific inquiry
  - Understandings about scientific inquiry
- Standard B
  - Properties and changes of properties in matter
- Standard E
  - Abilities of technological design
  - Understanding about science and technology

High School Content Standards

- Standard A
  - Identify questions and concepts that guide scientific investigations
  - Understanding about scientific inquiry
- Standard B
  - Structure of atoms
  - Structure and properties of matter

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    - Chemical reaction
    - Motions and forces
    - Interactions of energy and matter
- Standard E
    - Abilities about technological design
    - Understanding about science and technology

Student Worksheet or Guide

Semiconductors-Doping to create a semiconductor

Make a Prediction

______Students are to predict whether ammonia will diffuse to the indicator/gelatin mixture.______________________________________

Conduct an Experiment

1. Place the uncovered Petri dish inside a re-sealable bag with the lid upside down next to it. (You will drop the ammonia droplets into the lid)

2. Place a few drops of ammonia on the lid. Seal the bag which now contains the Petri dish with indicator and the upside down lid containing a few drops of ammonia. Allow for diffusion to take place for three minutes or until you can no longer see changes in the gelatin.

3. Place the bag on a piece of white paper on the lab table and continue to make observations ever 3 minutes. Record on table below.

4. Carefully remove the Petri dish and measure the depth of diffusion. Record.

Record Your Observations

Time	Observations
3 minutes	
6 minutes	
9 minutes	
12 minutes	
depth	

Observations will vary from group to group. As time continues they should see more of the indicator/gelatin mixture turn pink.

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Analyze the Results

1. Did you observe what you predicted? Explain

   ____

   If not, how did your observation differ from your prediction?

   ____

   ____

   ____

2. Did you have a control group? If yes, what was it? If no, how would you make one?

   _________The instructions did not indicate that a control group was present.__

   ____

   ____

3. Do your observations leave you with any more questions? Do they enable you to make more predictions? If so, what are they?

   _________Why did the indicator turn pink? _________________________

   ____

   ____

   ___

4. What color does the phenolphthalein indicator turn from the ammonia mixing with the gelatin?

   _________The phenolphthalein indicator turns a pinkish color because of the increase of hydrogen from the ammonia mixing with the gelatin. Diffusion of the hydrogen going from higher concentration to a lower concentration.______

   ____

   ____

Draw Conclusions

5. Allow the Petri dish to set out in the open. What happens? Why do you think the color change disappears?

   ________As the Petri dish sets out the increased hydrogen diffuses into the air and the indicator returns to neutral.________________________________

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