Expo Station

Laser-focused on Chemistry

Build a model of an Atomic Force Microscope (AFM) out of Legos® and a few additional items. Participants make a tapping motion to illustrate the tapping motion of an AFM probe as they slowly push the AFM across a custom-built Lego sample.

Ages

12-18

Activity Time

Preparation: 30 minutes
Activity: 5-8 minutes

Group Size

Number of participants:
1 person per Lego station

Ratio of facilitators to participants:
1 facilitator for each participant

Concepts to Explore

- Scientists and engineers invent and use tools to observe things beyond what our senses can see, hear, and feel.
- Atomic Force Microscopy allows chemists to visualize the arrangement of atoms and molecules on the surface of a sample by drawing a 3-D model that they can see.
- Atomic Force Microscopy detects changes in the electron cloud of the single atom at the tip of the probe. The probe does not physical touch the sample.
- Atomic Force Microscopy (SPM) allows scientists to observe the arrangement of atoms at the surface of a solid at the nanoscale level.

Safety Requirements & Other Considerations

- Safety glasses are appropriate for this activity.
- Place the model AFM in a cardboard box to prevent the focused light from shining in the eyes of participants and facilitators. The box also makes the graph easier to see.
- Seat facilitators next to participants along one side of the table.
- Do not point the laser or any other bright light into the eyes of a person or animal or toward a moving vehicle.

Question to Investigate
How can scientists visualize the arrangement of atoms and molecules?

Materials Required
Per station

- 1 square Lego® base, 25.5 cm or 10 inches
- 1 AFM Lego kit
  - 4 wheels
  - 4 flat 2x2 bricks
  - 4 flat 4x6 bricks
  - 5 flat 6x8 bricks
  - 10 regular 2x6 bricks
  - 26 regular 2x4 bricks
  - Container or bag to hold AFM Legos
- Assorted Lego bricks to make the “sample”
- 1 photon microlight, purple or white
- Cardboard strips, 1 x 12 inches
- Scissors
- Tape, 2 pieces
- 2 glue dots or 1 rubber band
- Phosphorescent vinyl sheet, 12 x 12 inches
- Double-sided tape
- Cardboard box, 12 x 12 x 12 inches
- 1 plastic ruler, 30 cm or 12 inch
- 2 binder clips
- 1 tall plastic or metal straw
- 2 donut magnets

Preparation Prior to Activity

Prepare Materials

- Use a container or bag to make one AFM Lego kit for each station. You may choose to include the microlight, binder clips, and glue dots or rubber band in the kit.

On-Site

- Refer to the print instructions in the bin with the supplies for this activity to build the Lego AFM. Assembling the Lego AFM will take approximately 15 minutes. You will need another 15 minutes to complete the assembly of the sample and screen as well as make, test, and adjust the probe.
- Arrange three stations across the front and sides of a 6- or 8-foot rectangular table.
- Place 2 chairs in front of each cardboard box.

Instructions & Talking Points

<table>
<tr><th colspan="3">Facilitate the activity</th></tr>
<tr><th>Step</th><th>Instructions</th><th>Talking Points</th></tr>
<tr><td>Introduce a key challenge in studying atoms and molecules</td><td>Show a graphic of ocean waves around a boat and a chain.
Tell participants:
Microscopes use light. The waves in the picture are like visible light. Microscopes can help us see things that are very tiny yet still big enough to block the waves of visible light.
Chemists have a challenge. How can you study things that are smaller than the wavelengths of visible light?
This is a model of an Atomic Force Microscope (ATM) that chemists use to “feel” atoms at the surface of a sample.</td><td>What are ways you can see very small things:
Like an ant?
Baby snails in their transparent egg sacs?
An amoeba made up of just one cell?</td></tr>
<tr><td>Point out the parts of the model and what they represent</td><td>Tell participants:
Each Lego on the baseplate represents one atom.
The tip of the probe is so sharp that its tip is made up of only one atom.
The movements of the probe are going to move the light, which will show up for a short time on the screen.</td><td></td></tr>
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Show participants how to tap the probe while rolling the probe assembly	• Model how to tap and roll the probe so that it touches the tops of the Legos in the sample.	• What do you notice about the shape of the light on the screen?
Give participants time to tap and roll as they investigate the arrangement of Legos on the surface	• Turn on micro light and give participants a chance to tap and roll. • Point out how the shape of the curve goes up when the Legos are taller and down when they are smaller.	• Based on what you have done with the model, how do you think the probe of a real ATM might move?
Hold the straw with the two donut magnets stacked so that they repel each other	Direct participants to: • Push down on the top magnet. • Push the bottom magnet up? • Explain that atoms repel each other when they first get close to one another. • This means that the sample will not get damaged when someone examines it with an ATM.	• What happens when the probe of an ATM gets close to an atom at the surface of a sample? *The probe never actually touches the surface of the sample because when the atom on the tip of the probe gets close it is repelled by atoms on the surface.*
Show examples of images made with a real ATM	• The first ATM was made to etch small bits of silicon metal for possible use in electronics. It worked! This is how we can have a device that fits in a pocket that you can use to take pictures, watch internet videos, text, and talk to a friend. Scientists and engineers are working now on using the arrangement of atoms for data storage.	• Which electronic devices do you enjoy that either didn't exist or were a lot bigger when your parents were kids? Cameras, video recorders, computers… TVs are flat screened, and the screen is likely bigger than the TVs that parents had when they were kids.

Clean Up

- Turn off the photon microlight between users.
- You may need to adjust the probe from time to time or replace it with a new piece of cardboard. There are extra cardboard pieces, scissors, glue dots, and tape in the bin so that you can make another probe.
- At the end of the session:
    - Remove the cardboard probe from the ruler
    - Take the probe assembly apart.
    - Place 49 bricks, 4 wheels, 2 binder clips, and 1 microlight in each white paper container.
    - Carefully stack all of the donut magnets and place them all on one plastic straw.
    - Remove the phosphorescent vinyl from the back of the cardboard box.
    - Remove the tape from the box and fold the box so that it is flat. We will ship these boxes back to ACS to reuse them, so please stack all 6 together.
    - Place everything else neatly inside the bin.

Explore the Chemistry

Atomic force microscopy (AFM) is a technique used to investigate the surface features of some materials by "feeling" or "touching" the surface with an extremely small probe. This provides a sort of topographical map of the molecules on the surface. This map gives us information regarding the roughness of the surface, the spacing of atoms, and the properties of the surface. In this activity, participants test a model of an AFM.

A real AFM uses an extremely small probe with a point so sharp there is only one single atom at its tip. This atom is either repelled or attracted to the atoms and molecules at the surface of the sample. This attraction or repulsion is recorded through the deflection of a laser.

In our model, the light is near the probe and shines directly on a screen made of phosphorescent vinyl. Legos arranged at varying heights represent the atoms and molecules on a surface. When the probe is tapped, the tip lands on the Lego structure. As it is pushed across, the light is recorded temporarily on the screen to help participants imagine how chemists can infer how the atoms are arranged based on the curve of a graph.

The arrangement of atoms within a material affects that material's properties, such as hardness, thermal and electrical conductivity, and opaqueness. Understanding how the atoms are arranged, especially on a material's surface is vital to learning why a material exhibits certain properties.

This is no small task however, as atoms are incredibly tiny. So, how do we actually "see" them? An AFM can be used to "feel" the arrangement of items on a material's surface on a molecular level. An AFM has a cantilever with a very tiny needle attached at the end. The needle is dragged across the surface of a material, and when the needle comes into contact with an atom, it causes the cantilever to bend upwards. A laser is used to determine how much the cantilever has bent, how much the laser light is deflected is indicative of the height of the atom. The resulting image is a height map of the material's surface, similar to a topographical map.

This is how scientists and engineers can visualize how atoms within molecules or ionic compounds are arranged at the surface of a sample. AFMs allow scientists and engineers to etch silicon to make our electronics increasingly smaller. They are also used as scientists and engineers investigate ways to make data storage even more efficient.

References

- ACS Kids & Chemistry

- Dr. Ashley Bylstone, member of the American Chemical Society's Committee on Community Activities and the *Photography and Imaging: Picture Perfect Chemistry* Theme Team contributed the original activity that this one is derived from. Dr. Blystone is a professor of chemistry at the University of Illinois at Urbana Champaign.

- Build an Atomic Force Microscope Model from Home! https://www.youtube.com/watch?v=l62_Ib-rjU0

- Cresswell, Z.; Kawasaki, J. Seeing Atoms with an Atomic Force Microscope. https://drive.google.com/file/d/1UqGvgq0H8EUj6IVNMxt2ltB3TxEGQuL5/view

- Planinšič, G.; Kovač, J. Nano Goes to School: A Teaching Model of the Atomic Force Microscope. Physics Education 2007, 43 (1), 37–45. https://doi.org/10.1088/0031-9120/43/01/002