MRSEC Education and Outreach

Refrigerator Magnet Activity Guide

Quick Reference Activity Guide

Activity Materials

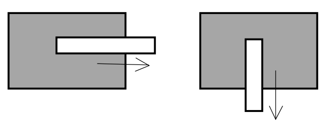
Refrigerator magnet with removable probe strip
Magnetic field diagrams

Starting Points

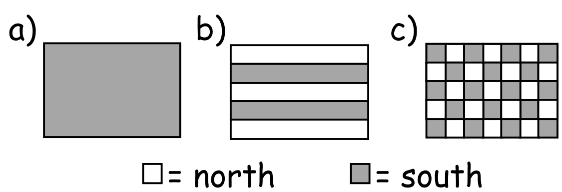
One of the great breakthroughs in the field of nanotechnology was the ability to image individual atoms. We "see" the individual atoms that make up the nanoworld using instruments called scanning probe microscopes (SPMs). These instruments use a probe tip that terminates in a single atom. When the probe strip is scanned across a surface in atom-sized movements, differences in force can be felt by the probe tip as it is closer or farther away from the surface atoms. Researchers use this method to image the pattern of atoms on the surface.

Demonstration Procedures

To demonstrate how atoms are “seen”, remove the labeled "probe strip" from your refrigerator magnet by tearing it along the perforation. Now, drag the probe strip along the dark unprinted side of the magnet in the two perpendicular directions, as shown below.



Based on what you feel, which of these three diagrams best represents how the magnetic field is arranged? Does it feel like choice A – a completely uniform arrangement, does it feel like choice B – alternating stripes, or does it feel more like choice C – alternating in both directions like a checkerboard? How many say A, B, C?



If you said choice B, you are correct!

The way a scanning probe microscope works is very similar to the experiment we just did. If the probe strip was sharpened to a single atom and you could move it atom by atom across the surface and feel the differences in forces, then you would have an SPM!

Fact Sheet

Scanning probe microscopy (SPM) refers to a class of microscopes that use a probe to collect data about a sample's surface. Scanning tunneling microscopes (STM), atomic force microscopes (AFM), magnetic force microscopes (MFM), and electrostatic force microscopes (EFM) are all examples of SPMs.

Swiss scientists Dr. Gerd Binnig and Dr. Heinrich Rohrer are acknowledged to be the founders of SPM. They invented the first scanning tunneling microscope (STM) in the 1981 while working at IBM's Zurich Research Center.

- **1981:** Dr. Binnig and Dr. Rohrer invent the scanning tunneling microscope (STM).
- **1982:** Dr. Binnig and Dr. Rohrer are the first people to see atoms when they use an STM to view a silicon sample.
- **1985:** Dr. Binnig, Dr. Christoph Gerber (IBM Zurich Research Center), and Dr. C. F. Quate (Stanford University) develop the atomic force microscope (AFM).
- **1986**: Dr. Binnig and Dr. Rohrer are awarded the Nobel Prize in physics for the invention of the STM.
- **1987:** Tom Albrecht of Stanford University is the first person to use an AFM to see atoms.
- **1988:** AFM becomes available commercially.

References

National Science Foundation Materials Research Science and Engineering Centers
http://www.nsf.gov/mps/dmr/mrsec.htm

UW-Madison Materials Research Science and Engineering Center
http:// mrsec.wisc.edu/edetc/

IN-VSEE
http://invsee.asu.edu/

Museum of Scanning Probe Microscopy and Nanotechnology
http://www.nanoworld.org/english/museum.htm

Nanoscience Instruments
SPM Chronology - http://www.nanoscience.com/education/chronology.html
SPM Introduction - http://www.nanoscience.com/education/tech-overview.html

San Jose State University Materials Engineering
http://www.engr.sjsu.edu/WofMatE/Mat'sChar2.htm

Scanning Probe Microscopy at Bristol: Introduction to Scanning Force Microscopy
http://spm.phy.bris.ac.uk/techniques/

SII Technology: SPM and its History
http://www.sii.co.jp/info/eg/nano_spm_sub02.html

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Background and Supporting Information

The first person to really study the microscopic world was a man by the name of Antoni van Leeuwenhoek. He built his own microscopes using lenses the size of a head of a pin. A world that no one had ever seen before came to life under his microscopes – a world teeming with creatures he called "animalcules", or little animals. He made detailed drawings and wrote careful descriptions of each of the little animals. Today, we know that Leeuwenhoek's animalcules were really protists, simple single-celled organisms, and bacteria. Other scientists followed in Leeuwenhoek's footsteps and developed the modern light microscope in the middle of the 19^{th} century.

Scientists soon discovered that light microscopes had a limit to what they could see. If they looked at an object smaller than 0.275 micrometers wide, it became blurred and distorted. In order for scientists to see smaller things, a new kind of microscope would need to be invented.

The electron microscope was invented in 1931 by two German scientists, Max Knott and Ernst Ruska. In an electron microscope, beams of fast-moving electrons are focused on a sample. When the electrons hit the sample, they scatter. The scattering of the electrons is what allows us to see small objects. An electron microscope can magnify objects over 500,000 times, allowing scientists to see and study viruses, DNA, and build tiny circuits on computer chips. Electron microscopes cannot see objects smaller than 200 nanometers across, a restriction imposed by the wavelength of light. An electron microscope cannot be used to see individual atoms.

Gerd Binnig and Heinrich Rohrer developed scanning probe microscopy in the 1980s so scientists could see individual atoms. Scanning probe microscopes have a very sharp tip – so sharp that it's only one atom thick. By dragging this tip around on different surfaces and recording the bumps and grooves, scientists are able to piece together what each surface looks like at the atomic level.

The invention of scanning probe microscopy was a great breakthrough in the field of nanotechnology. Now that scientists could see individual atoms, they could begin to manipulate these atoms to build different structures and study what happens.

By the end of the 5th grade, students should know that*

- Materials may be composed of parts that are too small to be seen without magnification.

By the end of the 8th grade, students should know that

- All matter is made up of atoms, which are far too small to see directly through a[n optical] microscope. The atoms of any element are alike but are different from atoms of other elements. Atoms may stick together in well-defined molecules or may be packed together in large arrays. Different arrangements of atoms into groups compose all substances.

By the end of the 12th grade, students should know that

- Atoms are made of a positive nucleus surrounded by negative electrons. An atom's electron configuration, particularly the outermost electrons, determines how the atom can interact with other atoms. Atoms form bonds to other atoms by transferring or sharing electrons.
- The nucleus, a tiny fraction of the volume of an atom, is composed of protons and neutrons, each almost two thousand times heavier than an electron. The number of positive protons in the nucleus determines what an atom's electron configuration can be and so defines the element. In a neutral atom, the number of electrons equals the number of protons. But an atom may acquire an unbalanced charge by gaining or losing electrons.
- Atoms often join with one another in various combinations in distinct molecules or in repeating three-dimensional crystal patterns. An enormous variety of biological, chemical, and physical phenomena can be explained by changes in the arrangement and motion of atoms and molecules.
- The configuration of atoms in a molecule determines the molecule's properties. Shapes are particularly important in how large molecules interact with others.

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* (Taken from "Benchmarks for Science Literacy," Project 2061, American Association for the Advancement of Science, 1993.)

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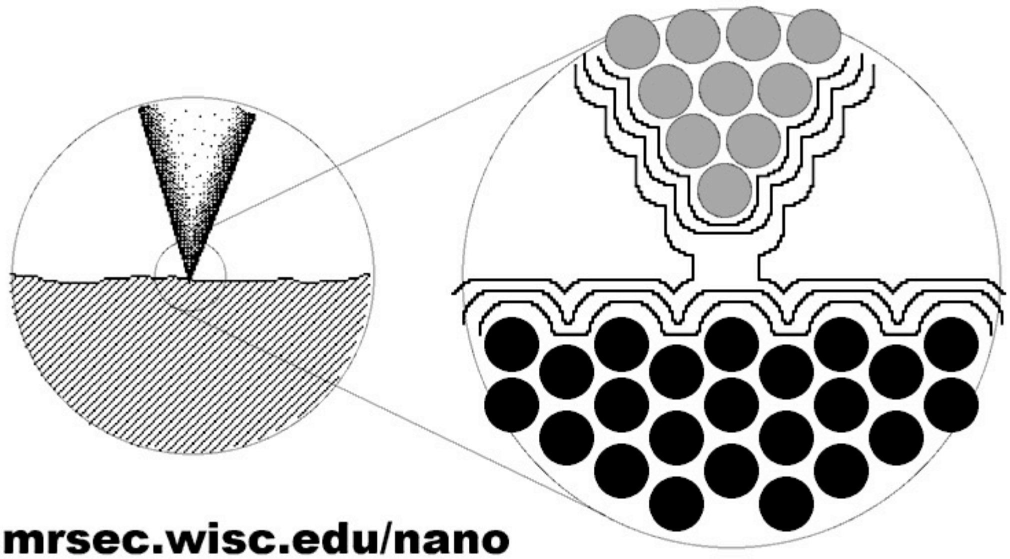
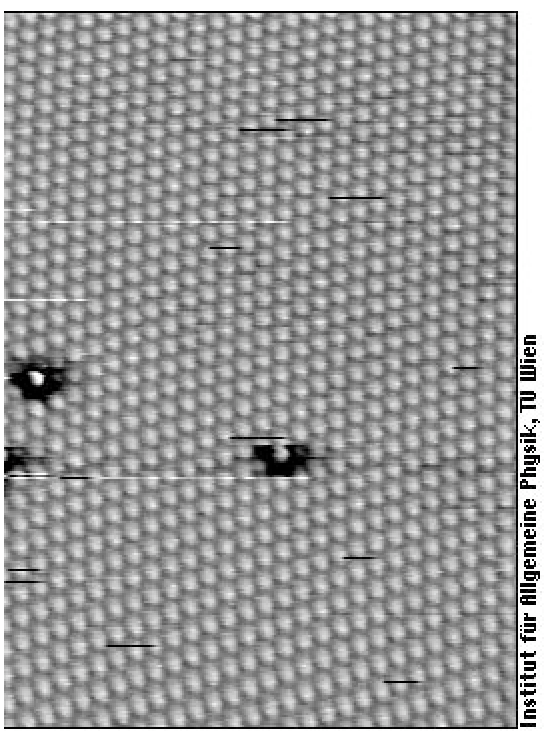
Exploring the NANOWORLD

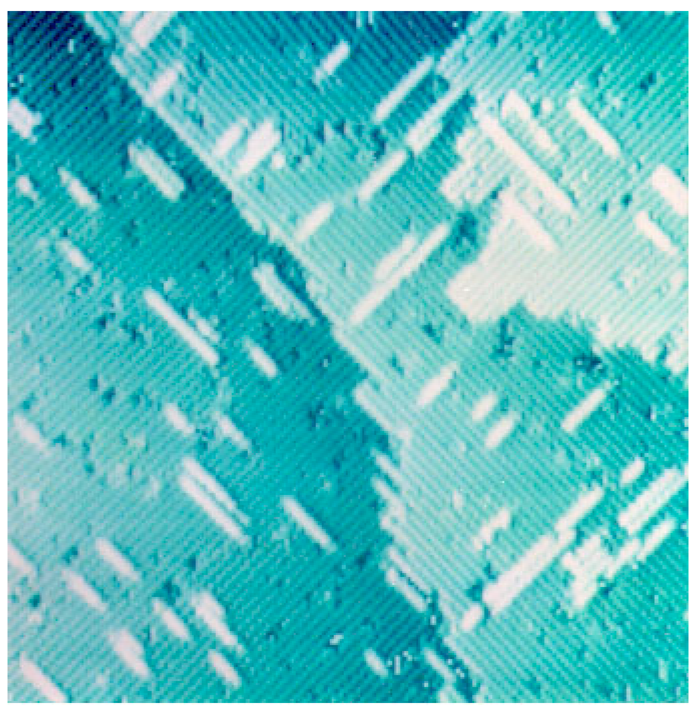


www.mrsec.wisc.edu/nano

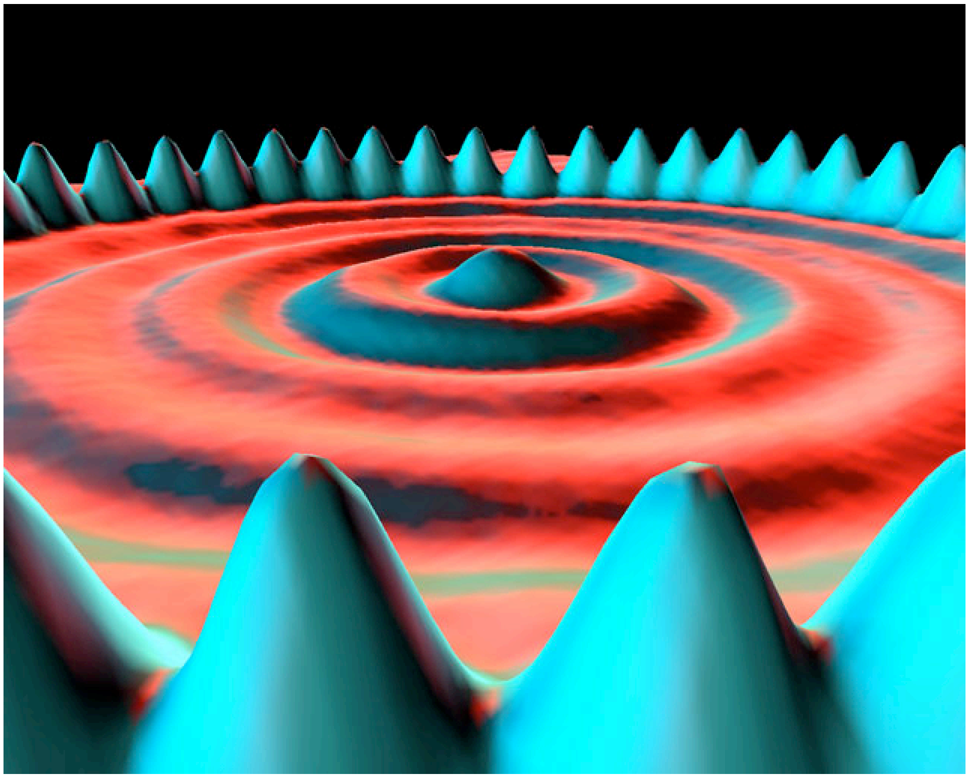
probe strip



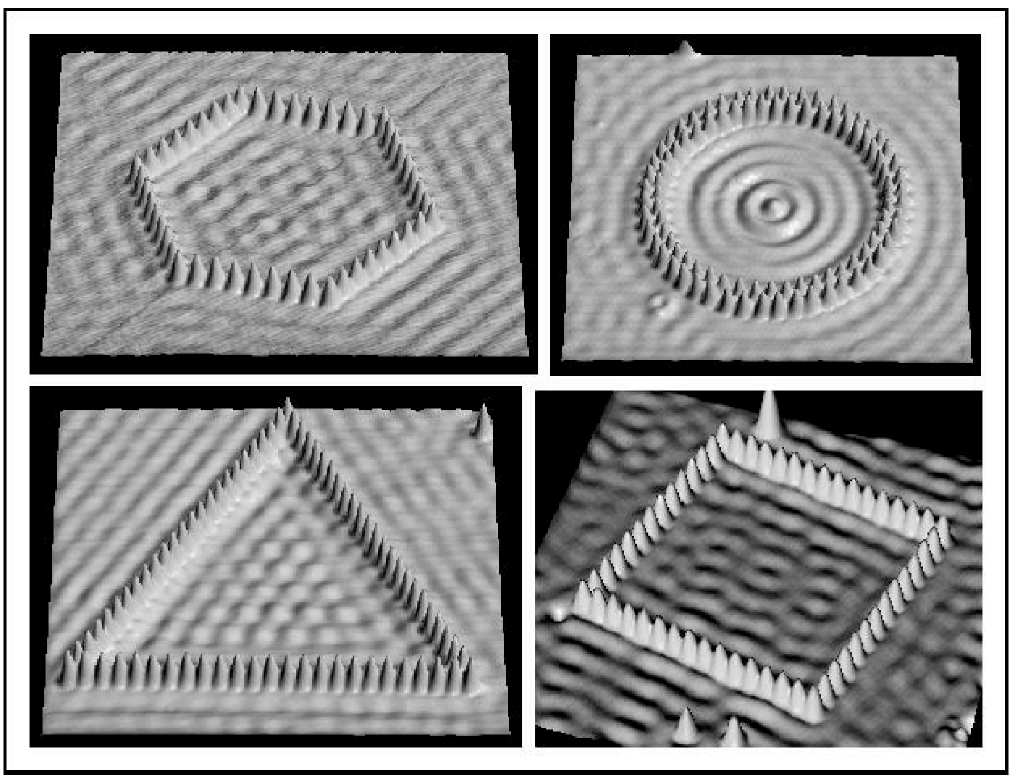
Lead Atoms on a Copper Surface



Silicon



Quantum Corral



More Quantum Corrals

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