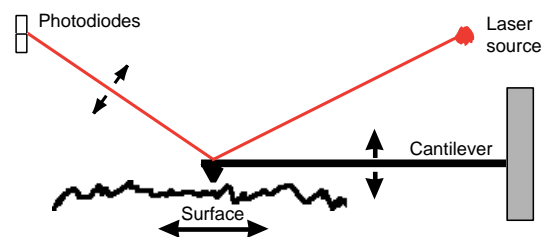


A Refrigerator Magnet Analog of Scanning-Probe Microscopy

by Julie K. Lorenz, Joel A. Olson, Dean J. Campbell, George C. Lisensky, and Arthur B. Ellis*

Background

Images of individual atoms can be obtained via scanning-probe microscopies. These experimental techniques are leading to breakthroughs in the development of new materials and are enhancing our understanding of atomic-scale phenomena. They all involve a probe tip terminated in one or just a few atoms. The interaction between the tip and a sample surface is measured as the tip moves (scans) relative to the surface. A property such as electric current or interatomic force is used to measure the strength of the tip-surface interaction. Examples include Scanning Tunneling Microscopy (STM) and Atomic Force Microscopy (AFM). The activity described on the Student Side of this insert uses the magnetic interactions between a flexible-sheet refrigerator magnet and a probe tip cut from the same magnet as a macroscopic analog of scanning probe microscopies.



Forces between the surface and the cantilever tip shift the position of a reflected laser beam in AFM.

About the Activity

A refrigerator magnet has many north and south poles, not just two as in a bar magnet. The magnetic poles are, to our knowledge, always arranged in stripes. A probe strip cut along the white line shown at the right will be deflected up and down when pulled across the magnet perpendicular to the stripes. Students are asked to cut strips from adjacent edges, find the one that has the correct orientation, and, by pulling it across the surface, deduce the relative arrangement of the magnetic poles.

The activity can be done in class or as a take-home experiment using most flexible-sheet refrigerator magnets. Large sheets can be cut to size and used (ref 1).

In this activity the magnetic force between the probe strip and the magnet depends on the distance between the two surfaces and the relative size and alignment of their magnetic fields. By scanning the surface with the probe, an entire surface image can be obtained. This activity is analogous to atomic force microscopy and is a macroscopic example of magnetic force microscopy (MFM) used for larger-scale imaging. By correctly answering the Questions section on the other side, students should recognize that an atomically small probe is needed for atomic-scale imaging and that their probe must be brought within atomic-scale distances of the surface. For more information see reference 2.

This activity can be used in the curriculum when atoms are introduced. It will help students understand how atomic-scale images are obtained. It could easily be adapted for group study and exploration.



■ North □ South

Back of a refrigerator magnet showing the magnetic poles.

More Information

1. Magnet sources: Edmund Scientific (101 East Gloucester Pike, Barrington, NJ 08007-1380; phone: 609/573-6250; www.edsci.com), NADA Scientific LTD. (PO Box 1336, Champlain, NY 12919-1336; phone: 800/799-6232; fax: 518/298-3063; www.nadasci.com), and Magnet Sales and Mfg. Co. (11248 Playa Ct., Culver City, CA 90230-6100; phone: 310/391-7213; fax: 310/390-4357; www.magnetsales.com).

2. Rapp, C. S. *J. Chem. Educ.* **1997**, *74*, 1087; McGhie, A. J.; Tang, S. L.; Li, S. F. Y. *Chemtech* **1995**, *25*, 20; Glausiusz, J.; *Discover* **1995**, *16*, 118.

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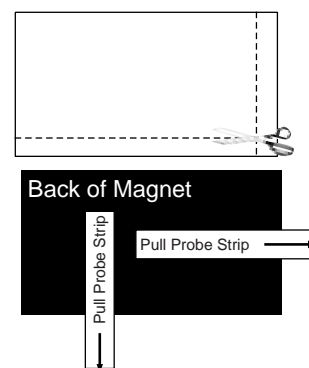
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A Refrigerator Magnet Analog of Scanning-Probe Microscopy

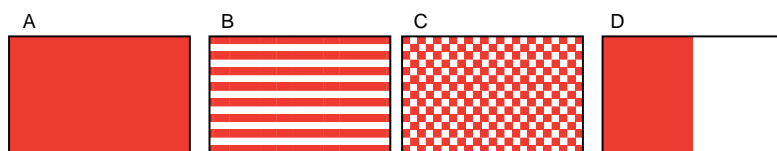
How are the north and south poles of a refrigerator magnet arranged? In this activity you will discover how to answer this question and will gain an understanding of a cutting-edge imaging technology.

Try This

1. Obtain a flexible-sheet refrigerator magnet.
2. Cut one 5-mm wide strip along each edge of the magnet, as shown at the right.
3. Place the unprinted side of one of the magnetic strips against the unprinted side of the magnet. Drag the strip across the back of the magnet in both directions, as shown in the picture at the right. Repeat with the second strip. The strip that is alternately attracted and repelled (bounces) should be used as the probe strip. Discard the other strip.
4. Experiment with the probe strip that you have retained by pulling it across the surface slowly, then quickly; close to the surface, then far away; at various angles, etc. Which of the arrangements of magnetic poles shown below is most consistent with your experiments?



Cutting and testing probe strips.



Some possible magnetic pole arrangements for a refrigerator magnet.

■ North □ South

Questions

Does the magnetic force between the probe strip and the back of the magnet depend on the distance between the two surfaces, i. e., can the probe map variations when it is far from the surface? Suppose the probe ends in a single magnetic pole. How would the probe respond for each of the patterns above? Would the size of the tip of the probe matter? If the poles are made very small, say nanometer scale, could their arrangement still be determined?

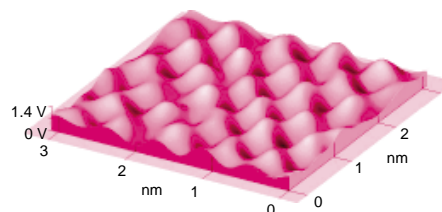
Atomic-scale images of a surface can be obtained by atomic force microscopy (AFM). To produce an image like the one shown below, a probe is moved relative to the surface and variations in force are recorded for a series of parallel passes. This force measurement, when plotted as a function of position, provides an image of the arrangement of atoms on a surface. How do your experiments relate to AFM? What other forces might be used to do atomic-scale imaging?

See Atomic-Scale Images on the WWW

http://www.iap.tuwien.ac.at/www/surface/STM_Gallery/index.html
http://www.asu.edu/clas/csss/SPM/IG_gifs/gallery.html
<http://www.almaden.ibm.com/vis/stm/gallery.html>
<http://mrgcvd.engr.wisc.edu/lagally/>
<http://www.chem.wisc.edu/~hamers/gallery/index.html>

For related activities see <http://mrsec.wisc.edu/EDETC/Edetc.html>

AFM image of oxygen atoms on a freshly cleaved surface of mica, a naturally occurring mineral. Image provided by Richard Piner and Chad Mirkin, Northwestern University.



This activity was part of the 1997 ACS Pimentel Award Address. See *J. Chem. Educ.* **1997**, *74*, 1033.

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