Education and Outreach: Nanotechnology Activity Guides

Nanoelectronics: Giant Magnetoresistance (GMR) and Computer Hard Drives

Audience: Middle school class
Time Needed: 45 minutes

Objectives:

- Be introduced to nanotechnology and GMR, a phenomenon based on nanotechnology
- Review basic concepts of electricity and magnetism
- Participate in an interactive, hands-on activity that relates current computer technology to their lives.

Related Wisconsin Model Academic Science Standards:

- *A.4.1* When conducting science investigations, ask and answer questions that will help decide the general areas of science being addressed
- *A.4.2* When faced with a science-related problem, decide what evidence, models, or explanations previously studied can be used to better understand what is happening now
- *A.4.4* When studying science-related problems, decide which of the science themes are important
- *A.8.7* Design real or thought investigations to test the usefulness and limitations of a model
- *B.12.4* Show how basic research and applied research contribute to new discoveries, inventions, and applications
- *C.4.2* Use the science content being learned to ask questions, plan investigations, make observations, make predictions, and offer explanations
- *C.4.5* Use data they have collected to develop explanations and answer questions generated by investigations
- *C.4.8* Ask additional questions that might help focus or further an investigation
- *C.8.4* Use inferences to help decide possible results of their investigations, use observations to check their inferences
- *C.8.5* Use accepted scientific knowledge, models, and theories to explain their results and to raise further questions about their investigations
- *C.8.11* Raise further questions which still need to be answered
- *D.8.8* Describe and investigate the properties of light, heat, gravity, radio waves, magnetic fields, electrical fields, and sound waves as they interact with material objects in common situations

Activity Materials:

- Slides or overhead transparencies (pdf)
- Hard drives

- Screwdrivers (Philips and Torx)
- Poster paper
- Tape Markers
- Simple circuit demo (metal scraps, pieces of other materials, batteries, battery snaps, wire, LEDs)
- Magnetism demo (cow magnets, metal scraps, pieces of other materials)
- Coil LED demo (cow magnets, tube (rolled-up transparency) with copper coil attached to LED)
- Worksheets

Activity Instructions:

See the 'notes' section of the Powerpoint slides for instructions on how to combine the activities and the slides.

Introduction to Nano

Ask the students to get into groups of three to four. Explain that 'nano' means 10-9 or one billionth of something and that dividing by 1000 can help us understand how small nano is. Use a meter stick to show that a meter is divided into 1000 mm. Explain that if you divide 1 mm by 1000, you get 1 micrometer (something that we can't see), and if you divide the micrometer into another 1000 equal spaces, each one of those would be 1 nanometer.

Break down the word Giant Magnetoresistance

Ask each group to brainstorm definitions or explanations of one of the three following words: giant, magneto, resistance. After a couple minutes, ask a representative of each group to share his/her group's definition of the word.

Summarize by emphasizing that giant means the effect is very large, that the effect has something to do with magnetism, and that the resistance is related to how much electricity/current can flow through the material. GMR materials are found in read heads of computer hard drives and control the flow of current through a circuit that reads the magnetic data on the hard disk.

Electricity

Describe the three parts of an atom (electrons - negative charge, protons - positive charge, neutrons - neutral). Explain that moving electrons create an electric current. Explain that some materials are conductors and are good carriers of electric current, and that some materials are insulators and are not good carriers of electric current.

Ask the groups to answer the electricity question shown in the Powerpoint slide. In order to do so, each group will need to test various materials in a simple circuit for conductivity.

Magnetism

Explain how to identify magnetic and non-magnetic materials. Ask the groups to answer the magnetism question in the Powerpoint slide. In order to do so, each group will need to test various materials with a cow magnet for magnetism.

Electricity/Magnetism Relationship

Explain that current induces a magnetic field, and a that magnetic field induces an electric current. Ask the groups to answer the electricity/magnetism question in the Powerpoint slide. In order to do so, each group will need to experiment with the cow magnet and the coil/LED demo.

Giant Magnetoresistance and the Read/Write Head

Explain GMR materials and what happens when a magnetic current is introduced. Explain how information is stored on the platters. (Ask GMR group for explanation.) Ask the groups to answer the GMR question. Then students can try to find the read/write head by dissecting a hard drive with a screwdriver. Show the read/write head and explain basic function in computer hard drive (Ask GMR group for explanation.)

Discuss other applications for GMR Materials (bike shocks, GM runner boards on cars, traffic light sensors; see "Background" for further examples.).

Required Background Information:

In addition to the familiar properties of electrons (as negatively charged particles with a very small mass and the ability to carry current through a metal wire), electrons have the property of spin. When a charged electron spins, it creates a magnetic field in the opposite direction of the spin of the electron. Objects become magnetic when the electrons within them spin in the same direction, so as not to cancel out the magnetic fields.

Scientists found that when they alternated magnetic and non-magnetic layers, each a few atomic layers thick, the resistance in the materials changed dramatically when a magnetic field was introduced. When electrons in different magnetic layers spin in opposite directions, the resistance is high, as in Figure 1a; when the electrons spin in the same direction the resistance is low, as in Figure 1b. If a magnetic field were introduced to a material where the electrons were spinning in different directions, the spins would change to be all the same direction, thus causing a drop in resistance. These layered materials are called Giant Magnetoresistance (GMR) materials. The read heads of most modern hard drives are made of an engineered nanomaterial that exhibits GMR. GMR also is/can be used for motion detectors, automotive antilock breaks, current transformers, and many other things. What makes GMR materials new and different from materials that are used in these products already is the fact that they are smaller and more sensitive than their predecessors.

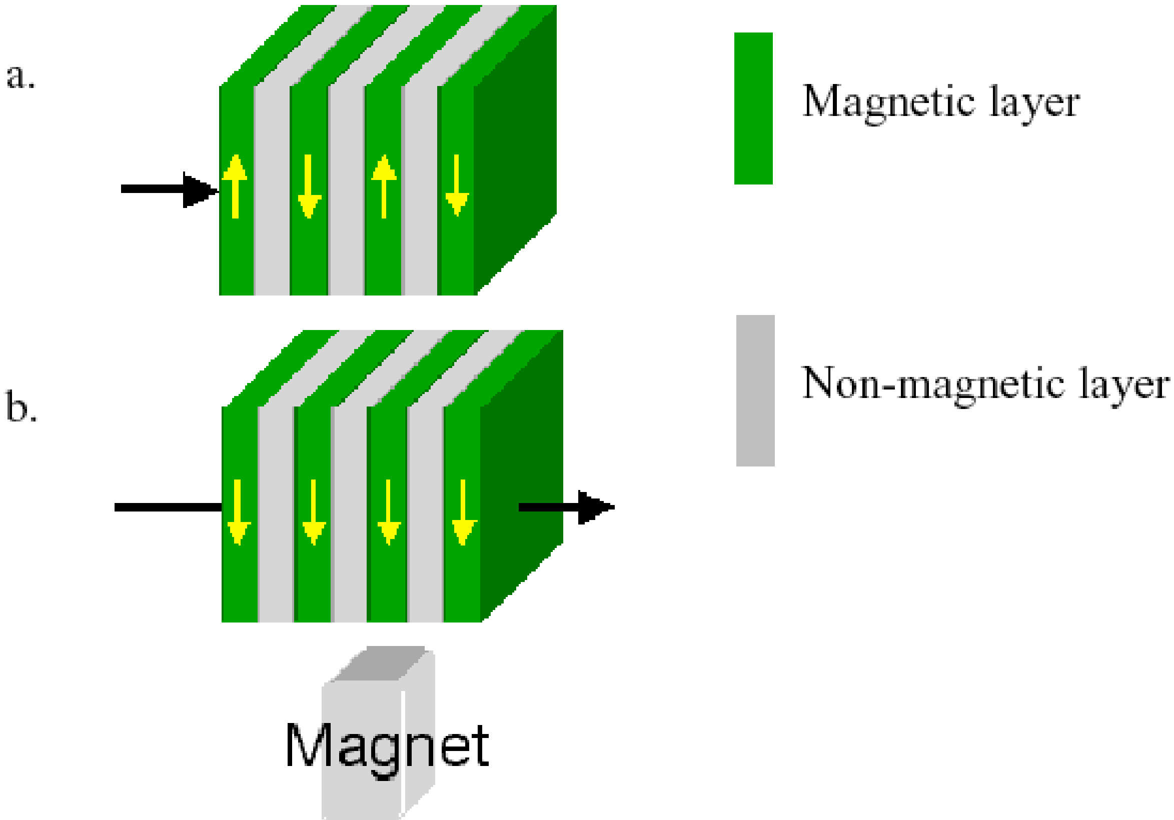

Figure 1: GMR materials are made from alternating layers of magnetic and non-magnetic metals that are nanometers in thickness.

Supplemental Materials:

- Slides: GMR Presentation (pdf)
- Movie: Giant Magnetoresistance
- Background Information: Giant Magnetoresistance

References:

IPSE website: http://mrsec.wisc.edu/edetc/IPSE/

GMR websites:

- Giant Magnetoresistance - http://www.stoner.leeds.ac.uk/research/gmr.htm
- Giant Magnetoresistance in Layered Magnetic Materials - http://www.ornl.gov/ORNLReview/v30n3-4/giant.htm
- The Giant Magnetoresistive Head: A giant leap for IBM Research - http://www.research.ibm.com/research/gmr.html

Computer hard drive websites:

- Hard Disk Drives - http://www.pcguide.com/ref/hdd/
- How Hard Disks Work - http://www.howstuffworks.com/hard-disk.htm
- Inside a Computer Hard Disc Drive: A Macro' and Microscopic Tour - http://www.microscopy-uk.org.uk/mag/art98/hdrive.html
- What's Inside a Hard Drive? - http://www.webopedia.com/DidYouKnow/Hardware_Software/2002/InsideHardDrive.asp

Electricity and magnetism websites:

- Good Conductors - http://www.st-andrews.ac.uk/~www_pa/Scots_Guide/info/comp/conduct/conduct/conduct.htm

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