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Electrons trip on tiny semiconductor steps

Increasingly, engineers refer to the heads that read computer hard disks as "spintronics devices." That's because these sensors use the orientations of electrons' magnetic fields, or spins, to read the ones and zeros of digital information.

If scientists could extend spintronics to semiconductor chips, faster, cooler-running, lower-power devices might result. However, efforts to make spintronic components have stalled because electrons injected into semiconductors often don't maintain their up or down spin orientations.

In the May 25 SCIENCE, a team at the University of Arkansas in Fayetteville reveals a surface feature of semiconductors that appears responsible for flipping those electronic spins. Using a scanning tunneling microscope (STM) to probe gallium arsenide, Vincent P. LaBella and his colleagues have found that a surface step only two dozen atoms high can disrupt the spin orientation of more than 80 percent of the electrons injected there.

"This is the first time, I believe, that people have observed on the nanometer scale the disruption of spin injection," LaBella says.

To determine the fate of electrons' spins, the Arkansas researchers scanned the semiconductor surface while injecting electrons into it. To acquire information about the electrons, they simultaneously measured light rays emitted from the material. Melding those approaches "is really quite a beautiful idea," comments David D. Awschalom of the University of California, Santa Barbara.

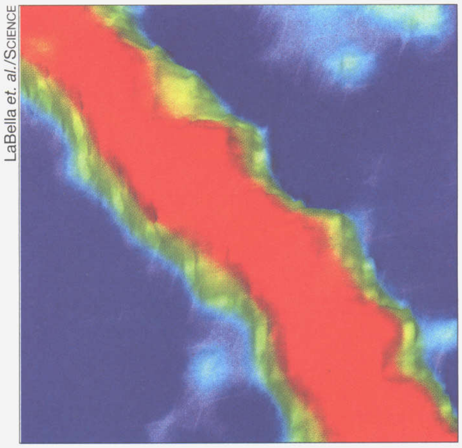
In STM scans, electrons leap from an ultrasharp tip through a vacuum into a surface (SN: 10/24/98, p. 268). By moving the tip up and down to maintain a constant current, the STM can sketch an atomically detailed topographic map.

In the recent experiment, electron-hungry atoms in the semiconductor absorbed some of the STM-supplied electrons and then emitted light. The light's orientation, or polarization, revealed the spin directions of absorbed electrons, LaBella says.

Within 5 nanometers of a sharp step in the sample, most of the electrons' spins flipped. On smoother portions of the surface, the spins remained unchanged.

Laurens W. Molenkamp of the University of Würzburg in Germany, cautions that the STM tip itself rather than a change in spin might alter the polarization.

If confirmed, the Arkansas researchers' find could be more than academic. Their method provides a way to identify steps and other spin-flipping structures that



LaBella et. al./SCIENCE

Electrons' spins flip least often (blue) on flat semiconductor surface and most often (red) in a 10-nanometer-wide swath near a 5-nm-tall step (not visible).

should be avoided in spintronic devices, says Hideo Ohno of Tohoku University in Sendai, Japan. Awschalom's group has observed electrons retaining their spin orientations in multilayered structures with well-matched interfaces (SN: 3/4/00, p. 155).

Observations like these may usher in more-extensive spintronic technology, including information-processing circuits that would depend on quantum properties of particles (SN: 4/3/99, p. 220), Awschalom notes. —P. Weiss