Physicists trap, map tiny magnetic vortex

September 7 2006

In a research first that could lead to a new generation of hard drives capable of storing thousands of movies per square inch, physicists at Rice University have decoded the three-dimensional structure of a tornado-like magnetic vortex no larger than a red blood cell.

"Understanding the nuances and functions of magnetic vortices is likely going to be a key in creating next-generation magnetic storage devices," said lead researcher Carl Rau, professor of physics and astronomy. "It's widely believed this technology will support storage densities in the range of terabits per square inch, and our group is equally excited about the potential for magnetic processors and for high-speed magnetic RAM."

The findings are available online and due to appear in an upcoming issue of *Physical Review Letters*.

Rau and postdoctoral researcher Jian Li used a one-of-a-kind scanning ion microscope to first create and then measure ultra-thin circular disks of soft magnetic cobalt. Their goal was to trap and image a single magnetic vortex, a cone-like structure that's created in the magnetic field at the disk when all the magnetic moments of the atoms in the disk align into uniform concentric circles. However, towards the core of the disk, the magnetic moments point more and more out of the plane of the disk, like a swirling cone. If the vortex spins in a right-handed direction, the cone points up, and if the vortex spins left, the cone points down.

In searching for the right sized disk to create the phenomenon, Rau and

Li used thin films of cobalt --about the thickness of a cell membrane. They made disks with diameters as large as 38 microns – about half the width of a human hair – and as small as one micron – about the size of a bacterium. The single vortex was found on disks measuring six microns in diameter, slightly smaller than a red blood cell.

"Most people are familiar with the vortex: we see it in satellite photos of hurricanes, in whirlpools and in bathtub drains – even in Van Gogh's famous painting 'Starry Night,'" Rau said. "In nanomagnetism, however, vortices are quite hard to see experimentally. Most often, we must infer their existence from some other measurement.

"Our high-resolution spin microscope is the exception here," he said. "It allows us to map not just the overall vortex, but also the detailed location and orientation of millions of magnetic moments that combine physical forces to create the overall structure."

The instrument Rau and Li used in the study is a scanning ion microscope with polarization analysis, or SIMPA. The device consists of a highly-focused ion beam that fires gallium ions at surfaces of flat cobalt samples. The beam is first used to etch away the cobalt around each circular disk. Then, using a different setting, the gallium ions are fired at the cobalt surface in such a way as to induce the release of electrons. The electrons, which carry specific information about the magnetic state of the cobalt atoms that release them, are captured by a detector and analyzed.

Rau said better understanding of magnetic vortices could allow breakthroughs in the design of nanostructures for ultra-high-density hard disk media, non-volatile magnetic random access memory and novel magnetic logic gates that could replace volatile semiconductor logic. Compared to regular electronic devices, the magnetic devices would be faster, smaller, use less power, create less heat and they wouldn't lose information when power was turned off.

"Imagine if you never had to reboot your computer again," Rau said.

Source: Rice University