Size matters in the giant magnetoresistance effect in semiconductors

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In a paper appearing in Nature's *Scientific Reports*, Dr. Ramesh Mani, professor of physics and astronomy at Georgia State University, reports that a giant magnetoresistance effect depends on the physical size of the device in the GaAs/AlGaAs semiconductor system.

Giant magnetoresistance indicates a large change in the electrical resistance with the application of a small magnetic field. This effect can be used to detect the presence of small magnetic fields. Magnetic sensors based on this concept are used to read out information stored in magnetic particles on rotating platters in computer hard disks. Other types of magnetic sensors are also used in brushless electric motors within cooling fans in computers, and as wheel speed sensors in some automobiles. Semiconductors are materials with electrical characteristics that fall between those of insulators and metals. Such materials are widely used, especially in electronics.

In research that is supported by grants from the U.S. Department of Energy and the U.S. Army Research Office, Mani studied the magnetoresistance in flat, very thin sheets of electrons in the ultra high quality GaAs/AlGaAs semiconductor with his colleagues Annika Kriisa from Emory University and Werner Wegscheider from the ETH-Zurich in Switzerland.

The researchers found that the change in the resistance or resistivity with the magnetic field depends on the size of the device. They demonstrated that, under the application of a magnetic field, wide devices develop a smaller and quicker change, while small devices develop a bigger but slower change in the resistivity. The resistance or resistivity of a material to the flow of electricity is a technologically important property, especially in semiconductors.

In a typical semiconductor, the disorder is so strong that electrons undergo many collisions over a short distance - distance much less than millimeters. Then, the edges or walls of the device have no influence on measured properties because the electrons lose memory of one edge or wall by the time they get to another.

The strong sensitivity of the magnetoresistance to the size of the device observed in this research indicates that scattering with the walls of the device might be making a substantial contribution to electron scattering. This result testifies to the high quality of the semiconductor used in this research, produced by Prof. Werner Wegscheider at ETH-Zurich in Switzerland.

This research team developed a model to understand the observations and deduced that when the semiconductor system becomes of even better quality, the change in the resistance under the application of a magnetic field will become even bigger. Indeed, the change might become so big that the resistance vanishes entirely in the small magnetic field.

Provided by Georgia State University

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