New Materials for Making 'Spintronic' Devices

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L to R: Alexei Tsvelik, Dmitri Kharzeev, Igor Zaliznyak.

An interdisciplinary group of scientists at the U.S. Department of Energy's Brookhaven National Laboratory has devised methods to make a new class of electronic devices based on a property of electrons known as "spin," rather than merely their electric charge. This approach, dubbed spintronics, could open the way to increasing dramatically the productivity of electronic devices operating at the nanoscale.

The Brookhaven scientists have filed a U.S. provisional patent application for their invention, which is now available for licensing.

"This development can open the way for the use of spintronics in practical room temperature devices, an exciting prospect," said DOE

Under Secretary for Science Raymond L. Orbach. "The interplay between outstanding facilities and laboratory researchers is a root cause for this achievement, and a direct consequence of the collaborative transformational research that takes place in our DOE laboratories."

In the field of electronics, devices based on manipulating electronic charges have been rapidly shrinking and, therefore, getting more efficient, ever since they were first developed in the middle of the last century. "But progress in miniaturization and increasing efficiency is approaching a fundamental technological limit imposed by the atomic structure of matter," said physicist Igor Zaliznyak, lead author on the Brookhaven Lab patent application. Once you've made circuits that approach the size of a few atoms or a single atom, you simply cannot make them any smaller.

To move beyond this limit, Zaliznyak's team has been exploring ways to take advantage of an electron's "quantum spin" in addition to its electric charge.

You can think of spin as somewhat analogous to the spin of a toy top, where the axis of rotation can point in any direction. But unlike a top, which can be slowed down, the "spinning" electron's rotation is a quantum property — that is, a set amount that cannot change. By aligning the spins of multiple electrons so they all point the same way — known as polarization — scientists aim to create a current of spins in addition to a current of charges.

The Brookhaven group uses magnetism to manipulate spin in graphene, a material consisting of flat sheets of carbon atoms arranged in a hexagonal pattern. They've proposed ways to make materials consisting of layers of graphene mated to magnetic and nonmagnetic layers.

These "graphene-magnet multilayers" (GMMs) are expected to retain

their properties at room temperature, an important practical requirement for spintronic devices. By properly arranging the magnetization of the magnetic layer(s), they can be used to create a full spectrum of spintronic devices, including (re-)writable microchips, transistors, logic gates, and more. Using magnetism for spin manipulation also opens exciting possibilities for creating active, re-writable and re-configurable devices whose function changes depending on the magnetization pattern written on the magnetic medium.

"Graphene is quite unique," Zaliznyak says, "in that an ideally balanced sheet is neither a conductor nor an insulator. Related to this is the fact that electrons in graphene behave in such a way that their mass effectively vanishes!" In other words, he explains, they move without inertia, like rays of light or particles accelerated to relativistic speeds — that is, close to the speed of light.

Such relativistic particles are studied at Brookhaven at the Relativistic Heavy Ion Collider (RHIC), a nuclear physics facility where scientists are trying to understand the fundamental properties and forces of matter. RHIC theoretical physicist Dmitri Kharzeev and condensed matter physicist Alexei Tsvelik have collaborated with Zaliznyak to gain a better understanding of the physics of magnetized graphene.

"Unifying the pool of knowledge and ideas of two fields is a great advantage for building the theoretical foundation for future devices," Zaliznyak said. The patent application filed by the Brookhaven scientists, which puts graphene-magnet multilayers to work, leverages the large amount of scientific knowledge accumulated in both fields into developing a novel technology. Plus, the opportunity to study relativistic particles in two dimensions — on flat sheets of graphene — was an unexpected and useful arena for Brookhaven's nuclear physicists trying to understand the properties of the matter produced at RHIC.

The patent application covers the methods for making the graphene-magnet multilayers, methods of using the GMMs, methods of magnetizing the GMMs, methods for measuring spintronic "current" in GMMs, and the spintronic devices made from GMMs.

Source: Brookhaven National Laboratory