

Beyond silicon: New semiconductor moves spintronics toward reality

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A new semiconductor compound is bringing fresh momentum to the field of spintronics, an emerging breed of computing device that may lead to smaller, faster, less power-hungry electronics.

Created from a unique low-symmetry [crystal structure](#), the compound is the first to build spintronic properties into a material that's stable at room temperature and easily tailored to a variety of applications. It could eventually be used as the base material for spintronic processors and other devices, much like silicon is the base for electronic computing devices.

Spintronics use both the "on" or "off" electrical charge and the "up" or "down" magnetic spin of electrons to store information, whereas today's electronics use only [electrical charge](#). Spin-based circuits can be smaller than charge-based circuits, enabling device makers to pack more of them onto a single processor. This is a key advantage, since traditional electronics are approaching their physical size limits.

"You can only make an electronic circuit so small before the charge of an electron becomes erratic," said Ferdinand Poudeu, assistant professor of materials science and engineering at the University of Michigan "But the spin of electrons remains stable at much smaller sizes, so spintronic devices open the door to a whole new generation of computing."

Spintronics can also retain data even after power is shut off, unlike today's microprocessors and computer memory. This may enable device makers to combine functions that require separate components in today's computing devices. For example, instead of using a processor to make calculations, RAM memory for primary storage and a hard drive for secondary storage, a single spintronic chip could handle all three functions, dramatically reducing the size and power consumption of computers.

But spintronic semiconductors require precise levels of both magnetism and conductivity. Researchers have struggled to create one that can be easily tuned to the levels required and that maintains its properties over a range of temperatures. Poudeu said that the root of the problem lies in the crystalline structure that makes up semiconductors.

"Today's semiconductors are made of crystals with simple, symmetrical patterns, like a microscopic lattice that repeats over and over," he said. "We control the properties of those semiconductors by adding atoms of different elements to the holes in that lattice. For example, we can add bismuth to increase conductivity, or iron to increase magnetism."

"To make spintronic [semiconductors](#), we need to add atoms of different sizes, and we need flexibility in where we place those atoms. But in most commonly used crystals, the holes are all similarly sized and regularly spaced. That gives us a very limited amount of control."

Researchers have been working for years to solve this problem by finding new ways to add atoms to commonly used crystalline structures. But Poudeu's team took a different approach, creating an entirely new crystal structure. They used a mixture of iron, bismuth and selenium to create a complex crystal that offers much greater flexibility. Their low-symmetry crystal has holes of varying size placed at varying distances in multiple, overlapping layers.

"Ordinarily, conductivity and magnetism are linked together, so you can't change one without affecting the other," said Juan Lopez, a doctoral student in [materials science](#) and engineering who worked on the project. "But this new compound changes that. It enables us to arrange atoms in a huge number of different combinations so that we can manipulate conductivity and magnetism independently. That level of control is going to open a whole new set of possibilities in [spintronics](#)."

Lopez said the project's cross-disciplinary team has brought a fresh perspective to the project, combining chemistry, crystallography and computer science to build a new solution to a problem that has vexed researchers for years.

"What I've really enjoyed about this project is that we've taken a clean-sheet approach," he said. "Our backgrounds have helped us think differently about spintronics and find a completely new solution to a relatively old problem. And we're gaining a better understanding of the fundamental science of crystallography as well."

So far, the team has only created and tested the new compound in powder form. The next step is to manufacture it in the thin film that would be required for a spintronic device. Lopez believes that this may be feasible within a year.

A paper on the work, "Coexistence of High-T Ferromagnetism and n-Type Electrical Conductivity in FeBi₂Se₄," is published online in the *Journal of the American Chemical Society*.

Provided by University of Michigan

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