Breakthrough made in atomically thin magnets

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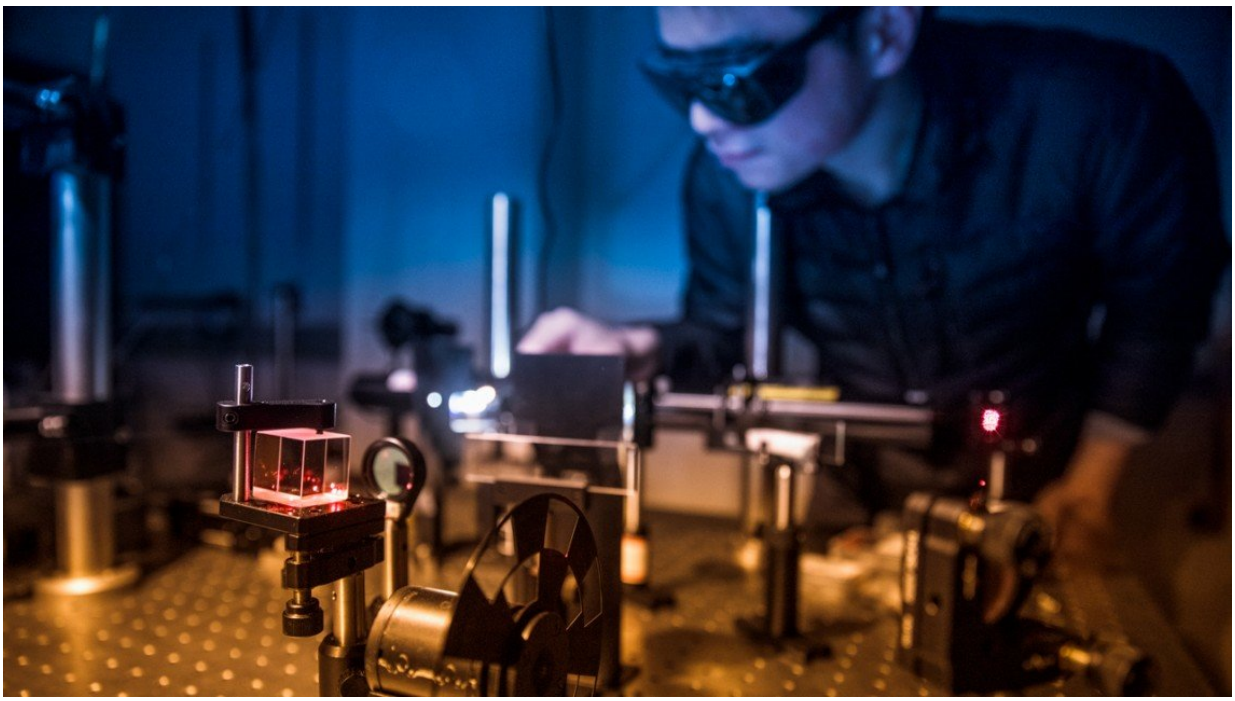

Shengwei Jiang, postdoctoral researcher, aligns an optical setup for magneto-optical Kerr rotation microscopy measurements on atomically thin magnets. Credit: Lindsay France

Cornell researchers have become the first to control atomically thin magnets with an electric field, a breakthrough that provides a blueprint for producing exceptionally powerful and efficient data storage in computer chips, among other applications.

The research is detailed in the paper, "Electric-field switching of two-dimensional van der Waals magnets," published in *Nature Materials* by Jie Shan, professor of applied and engineering physics; Kin Fai Mak, assistant professor of physics; and postdoctoral scholar Shengwei Jiang.

In 1966, Cornell physicist David Mermin and his postdoc Herbert Wagner theorized that 2-D magnets could not exist if the spins of their electrons could point in any direction. It wasn't until 2017 that some of the first 2-D materials with the proper alignment of spins were discovered, opening the door to an entirely new family of materials known as 2-D van der Waals magnets.

Shan and Mak, who specialize in researching atomically thin materials, jumped on the opportunity to research the new magnets and their unique characteristics.

"If it's a bulk material, you can't easily access the atoms inside," said Mak. "But if the magnet is just a monolayer, you can do a lot to it. You can apply an electric field to it, put extra electrons into it, and that can modulate the material properties."

Using a sample of chromium triiodide, the research team set out to do just that. Their goal was to apply a small amount of voltage to create an electric field and control the 2-D compound's magnetism, giving them the ability to switch it on and off.

To achieve this, they stacked two atomic layers of chromium triiodide with atomically thin gate dielectrics and electrodes. This created a field-effect device that could flip the electron-spin direction in the chromium triiodide layers using small gate voltages, activating the magnetic switching. The process is reversible and repeatable at temperatures under 57-degrees Kelvin.

The discovery is an important one for the future of electronics because "the majority of existing technology is based on magnetic switching, like in memory devices that record and store data," said Shan. However, magnets in most modern electronics don't respond to an electric field. Instead, a current is passed through a coil, creating a magnetic field that can be used to switch the magnet on and off. It's an inefficient method because the current creates heat and consumes electrical power.

Two-dimensional chromium-triiodide magnets have a unique advantage in that an electric field can be directly applied to activate the switching, and very little energy is required.

"The process is also very effective because if you have a nanometer thickness and you apply just one volt, the field is already 1 volt per nanometer. That's huge," said Shan.

The research team plans to continue exploring 2-D magnets and hopes to form new collaborations around campus, including with scientists and engineers who can help them find new 2-D magnetic materials that, unlike chromium triiodide, can work at room temperature.

"In a sense, what we have demonstrated here is more like a device concept," said Mak. "When we find the right kind of material that can operate at a higher temperature, we can immediately apply this idea to those materials. But it's not there yet."

More information: Shengwei Jiang et al, Electric-field switching of two-dimensional van der Waals magnets, *Nature Materials* (2018). DOI: 10.1038/s41563-018-0040-6

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