Van der Waals (VDW) material shows the right stuff at 200 nanometres

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Lan Wang leads FLEET's Enabling Technology B, which cuts across all three Research themes. Credit: FLEET

The unusual electronic and magnetic properties of van der Waals (vdW) materials, made up of many 'stacked' 2-D layers, offer potential for future electronics, including spintronics.

In a recent study, FLEET researchers at RMIT found that one promising candidate material, Fe_3GeTe_2 (FGT), fits the bill – provided it's created in layers only 200 millionths of a millimetre in thickness.

This pioneering work paves the way for a new research field, namely, vdW heterostructure based spintronics.

Two-dimensional vdW materials are potential building blocks for new, high-performance electronic, electro-optic, and photonic devices.

However, their application in spintronics has been limited because so few materials display the required magnetic properties.

For serious consideration in spintronics, a vdW ferromagnetic metal with hard magnetic properties and a near square-shaped hysteresis loop is indispensable. Perpendicular magnetic anisotropy is also favourable.

FLEET's RMIT researchers performed anomalous Hall effect measurements on single-crystal Fe_3GeTe_2 (FGT) nanoflakes, resolving the desired magnetic properties when thickness of the sample was reduced to less than 200 nm.

The researchers were motivated to investigate FGT's improved properties at atomically-thin thicknesses.

"FGT has long been considered a promising vdW ferromagnetic metal", explains lead author Cheng Tan. "But its ferromagnetic properties (a very small MR/MS ratio and coercivity at all temperatures) suggested limited potential as a building block for vdW magnetic heterostructures".

However, those properties strongly depend on thickness-dependent domain structure, and molecular beam epitaxy (MBE)-grown, wafer-scale FGT thin films have improved magnetic properties.

"So we reduced thickness and kept measuring," explains Tan.

Hall effect measurements on single-crystal FGT nanoflakes showed magnetic properties are highly dependent on thickness, and that by reducing the thickness to less than 200 nm, the required characteristics can be achieved, making vdW FGT a ferromagnetic metal suitable for vdW heterostructure-based spintronics.

Other researchers will build on the results.

To better identify other candidate materials, the researchers developed a model that can be generalised for vdW ferromagnetic thin films or nanoflakes, which will open new research paths for those studying the possible existence of magnetic coupling between vdW atomic layers.

"It is exciting, pioneering work," says research theme leader Lan Wang. "And it paves the way for a new research field: vdW heterostructures-based spintronics".

Stacked with other vdW nanoflakes, Fe_3GeTe_2 nanoflakes could be used in a variety of devices exhibiting giant magnetoresistance and tunnelling magnetoresistance. Spin orbit torque and spin field effect transistor devices are further possibilities.

The opportunity exists to design and fabricate many devices based on vdW magnets. For example, magnetising 2-D topological insulators, or stacking vdW ferromagnetic metals for spin–orbit torque devices.

The study Hard magnetic properties in nanoflake van der Waals Fe_3GeTe_2, published in *Nature Communications* in April, was showcased in April's *Nature Communications* Editors' condensed-matter physics Highlights, chosen by *Nature* editor Yu Gong (magnetic materials and spintronics).

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FLEET & nanofabrication

Wang, Tan and Albarakati are members of FLEET, an Australian government-funded research centre developing a new generation of ultra-low energy electronics.

FLEET's research sits at the very boundary of what is possible in condensed-matter physics. Nanofabrication of functioning devices will be key to the Centre's success, coordinated within FLEET via Enabling technology B, led by Lan Wang and linking each of the Centre's three research themes.

FLEET combines Australian strength in micro- and nanofabrication with world-leading expertise in van der Waals heterostructure fabrication to build the capacity for advanced atomically-thin device fabrication.

Wang's group at RMIT recently developed methods to build such nanoscale structures, required to achieve zero-dissipation electrical current, comprising two stacked, 2-D semiconductors.

Bound together by van der Waals (vdW) forces, and comprising twin, disparate, atomically-thin layers, such structures are known as van der Waals heterostructures.

These nanostructures are key to FLEET's Research theme 1 (topological materials) and Research theme 2 (exciton superfluids).

More information: Cheng Tan et al. Hard magnetic properties in nanoflake van der Waals Fe_3GeTe_2, *Nature Communications* (2018). DOI: 10.1038/s41467-018-04018-w

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