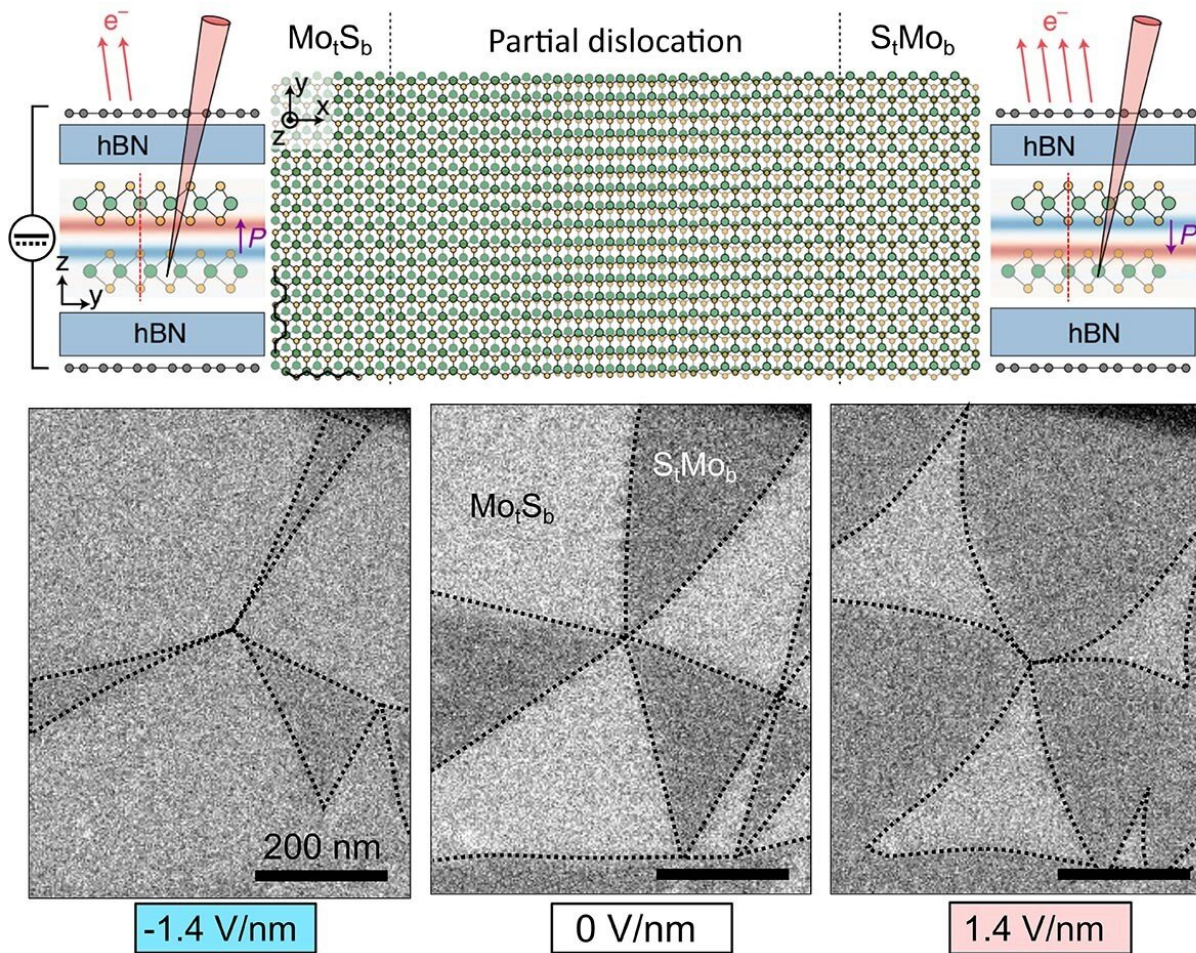


# Engineering 2D semiconductors with built-in memory functions

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Credit: University of Manchester

A team of researchers at The University of Manchester's National

Graphene Institute (NGI) and the National Physical Laboratory (NPL) has demonstrated that slightly twisted 2D transition metal dichalcogenides (TMDs) display room-temperature ferroelectricity.

This characteristic, combined with TMDs' outstanding optical properties, can be used to build multi-functional optoelectronic devices such as transistors and LEDs with built-in memory functions on nanometre length scale.

Ferroelectrics are materials with two or more electrically polarisable states that can be reversibly switched with the application of an external electric field. This material property is ideal for applications such as non-volatile memory, microwave devices, sensors and transistors. Until recently, out-of-plane switchable ferroelectricity at room temperature had been achieved only in films thicker than 3 nanometres.

## **2D heterostructures**

Since the isolation of graphene in 2004, researchers across academia have studied a variety of new 2D materials with a wide range of exciting properties. These atomically thin 2D crystals can be stacked on top of one another to create so-called heterostructures—artificial materials with tailored functions.

More recently, a team of researchers from NGI, in collaboration with NPL, demonstrated that below a twist angle of  $2^\circ$ , atomic lattices physically reconstruct to form regions (or domains) of perfectly stacked bilayers separated by boundaries of locally accumulated strain. For two monolayers stacked parallel to each other, a tessellated pattern of mirror-reflected triangular domains is created. Most importantly, the two neighboring domains have an asymmetric crystal symmetry, causing an asymmetry in their electronic properties.

## Ferroelectric switching at room temperature

In the work, published in *Nature Nanotechnology*, the team demonstrated that the [domain structure](#) created with low-angle twisting hosts interfacial ferroelectricity in bilayer TMDs. Kelvin probe force microscopy revealed that neighboring domains are oppositely polarized and electrical transport measurements demonstrated reliable ferroelectric switching at room temperature.

The team went on to develop a scanning electron microscope (SEM) technique with enhanced contrast, using signal from back-scattered electrons. This made it possible to apply an electric field in-situ while imaging changes to the domain structure in a non-invasive manner, providing essential information on how the [domain](#) switching mechanism works. The boundaries separating the oppositely polarized domains were found to expand and contract depending on the sign of the applied electric field and led to a significant redistribution of the polarized states.

This work clearly demonstrates that the twist degree of freedom can allow the creation of atomically thin optoelectronics with tailored and multi-functional properties.

## Wide scope for tailored 2D materials

Lead author Astrid Weston says that "it's very exciting that we can demonstrate that this simple tool of twisting can engineer new properties in 2D crystals. With the wide variety of 2D crystals to choose from, it provides us with almost unlimited scope to create perfectly tailored artificial materials."

Co-author Dr. Eli G Castanon added that "being able to observe the

pattern and behavior of ferroelectric domains in structures that have nanometre thickness with KPFM and SEM was very exciting. The advancement of characterisation techniques together with the extensive possibilities for the formation of novel heterostructures of 2D materials paves the way to achieve new capabilities at the nanoscale for many industries."

**More information:** Astrid Weston et al, Interfacial ferroelectricity in marginally twisted 2D semiconductors, *Nature Nanotechnology* (2022). [DOI: 10.1038/s41565-022-01072-w](https://doi.org/10.1038/s41565-022-01072-w)

Provided by University of Manchester

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