Artificial van der Waals multiferroics with twisted two-dimensional materials

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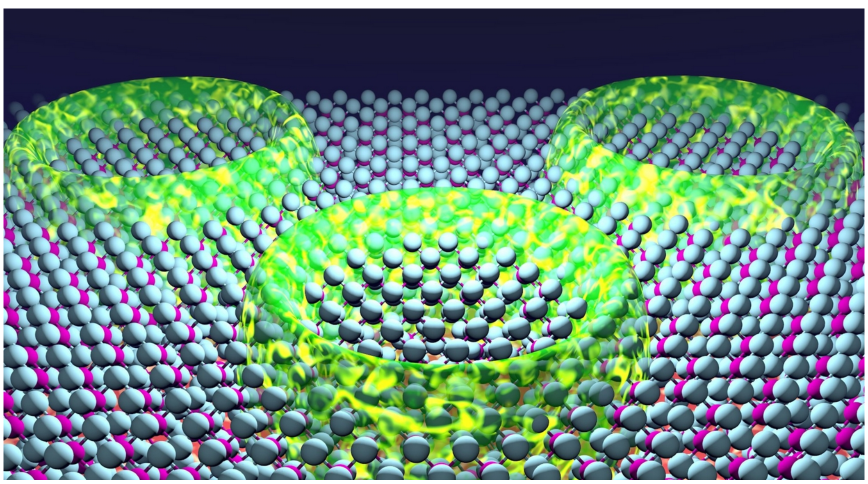
Twisted van der Waals materials have risen as a powerful platform to engineer artificial quantum matter. Artificial moire heterostructures, in general, display two length scales, the original lattice constant and the emergent moire length. Here we reveal a microscopic mechanism to engineer van der Waals multiferroics from the interplay of non-collinear magnetism and spin–orbit coupling, both in van der Waals monolayers [1] and twisted multilayers [2]. First, focusing on the recently isolated NiI2 multiferroic monolayer, we reveal the origin of the helimagnetic order, and the critical role of halide spin-orbit coupling in driving a ferroelectric distortion. We demonstrate that the electronic reconstruction accounting for the ferroelectric order emerges from the interplay of such a non-collinear magnetism and spin-orbit coupling. Second, we show the emergence of multiferroic order in twisted chromium trihalide bilayers, an order fully driven by the moiré pattern and absent in aligned multilayers. We show that a spin texture is generated in the moiré supercell of the twisted system as a consequence of the competition between stacking-dependent interlayer magnetic exchange and magnetic anisotropy. An electric polarization arises associated with such a non-collinear magnetic state due to the spin-orbit coupling, leading to the emergence of a local ferroelectric order following the moiré. Among the stochiometric trihalides, our results show that twisted CrBr3 bilayers give rise to the strongest multiferroic order. We further show the emergence of a strong magnetoelectric coupling, which allows the electric generation and control of magnetic skyrmions. Our results put forward van der Waals materials as a powerful platform to engineer artificial multiferroic order and electrically control exotic magnetic textures.



[1] Adolfo O Fumega and Jose L Lado 2022 2D Materials. 9 025010 (2022)
[2] Adolfo O. Fumega, Jose L. Lado, 2D Matererials 10 025026 (2023)