Ferroelectric Domains in marginally twisted 2D semiconductors characterized by Kelvin Probe Force Microscopy

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Stacking 2D materials to form vertical heterostructures can lead to emerging properties and, in particular, by changing the twist angle between stacked layers, one introduces a new degree of freedom used to further engineer the system. By twisting identical 2D layers or layers with slight lattice mismatch, a new periodic pattern emerges, called moiré pattern, which can become the dominant factor in determining the electronic band structure of the system. In the limit of very small angles, in addition to the moiré pattern, the atomic lattices locally relax into areas of favorable stacking creating a regime of triangular domains [1]. For twisted bilayer transition metal dichalcogenides (TMDs), the triangles have alternating stacking domains of metal atoms aligned over chalcogen (MX), and chalcogens aligned over metal atoms (XM). These domains have a net vertical polarization alternating between adjacent stacking [1,2] – resulting a new type of ferroelectricity.

We fabricate twisted TMD heterostructures by using the dry transfer and tear-and-stack techniques. We use Kelvin Probe Force Microscopy (KPFM) to characterize the properties of these ferroelectric domains at the nanoscale. By directly probing the local surface potential and the surface work function, using KPFM we seek to uncover quantitative insights into surface polarization, charge carrier densities and band alignment. In particular, we discuss how the polarization of the ferroelectric domains depends on their electrostatic environment.

References

[1] Laurent Molino, et al. Adv. Mater. 2023, 35, 2207816.

[2] Laurent Molino, et al. Nano Letters 2023 23 (24), 11778-11784