Project Title: Enabling Deterministic Manufacturability of 2D Moiré Quantum Materials

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This project seeks to enable the high-throughput deterministic fabrication of arbitrary length scale and symmetry moiré quantum materials from van der Waals bonded 2D semiconductors. When bilayer 2D materials are constructed with a twist between layers, a moiré interference pattern is formed between layers with larger periodicity than any of the constituent layer unit cells. In these systems, a wealth of exotic phases appear that result from moiré pattern-dependent many-body electron correlation effects, with the pattern itself being tunable with twist. This tunability has been seen as the holy grail of the field of quantum materials, which seeks to fully realize and understand all the exotic behavior of electrons when considering interactions with other electrons in solid-state matter. Unfortunately, the process to fabricate these moiré quantum materials is difficult, with the leading fabrication technique being a manual tear-and-stack process with macroscale viscoelastic stamps. This difficulty is the critical key element preventing the large-scale discovery of new moiré quantum materials and achieving an understanding of all possible correlated electronic states that may arise in this class.

Our group has recently shown a new method to overcome these challenges, by generating moiré interference through the controlled application of layer-by-layer strain (heterostrain) on **non-twisted** 2D materials, where moiré interference results from strain-induced lattice mismatch without twisting or stacking. Our recent results indicate a potential throughput enhancement of moiré materials fabrication of >4 orders of magnitude, thus breaking the fabrication bottleneck in this class of materials. The next critical key step is the integration of such materials into electronic devices with high enough quality to demonstrate quantum materials properties. Within this project we aim to solve the remaining device-level challenges to enabling high-throughput manufacturing of 2D moiré quantum materials: materials uniformity, materials quality, contact metal integration, and dielectric integration. Our success will enable the design of new quantum materials, which would enable advances such as lossless electricity transmission, efficient magnetic levitation, implementing fault-tolerant topological quantum computing, and seeding the next generation of novel conventional electronic devices beyond the limitations of classical materials.