Towards Strongly Coupled van der Waals Heterostructures Using Layer-by-layer Transfer

Kyounghwan Kim,[1] G. Will Burg,[1] Babak Fallahazad, Stefano Larentis,[1] Hema C. P. Movva,[1] Emanuel Tutuc,[1]

[1] The University of Texas, Dept. of Electrical and Computer Engineering, Microelectronics Research Center, 10100 Burnet Rd, Bldg 160, Austin, TX 78758

Layered crystals such as graphite, hexagonal boron nitride (hBN), or transition metal dichalcogenides (TMDs) can be mechanically exfoliated down to a monolayer, thereby providing a large set of two-dimensional (2D) materials with metallic, semiconducting or insulating properties. Combining such 2D materials into layered, van der Waals (vdW) heterostructures using a layer-by-layer transfer approach opens the door to realizing heterostructures with novel functionalities, which may otherwise not be possible using thin film growth techniques.

We review here key techniques and vdW heterostructures realized using layer-by-layer transfer. We demonstrate the realization of vdW heterostructures with high accuracy rotational alignment between different layers [1], which enables the realization of moiré crystals (Fig. 1) in twisted bilayer graphene [2], and gate-tunable resonant tunneling in heterostructures consisting of graphene double layers separated by hBN [1, 3].

A key parameter controlling the functionality of vdW heterostructures is the interlayer coupling in the stacking direction. Measuring such interlayer coupling, and demonstrating heterostructures with strong coupling are key issues relevant to device applications. We discuss recent results in double bilayer graphene heterostructures separated by WSe_2 (Fig. 2) which show gate-tunable resonant tunneling with large current densities [4], comparable or better than values measured in epitaxial heterostructures.

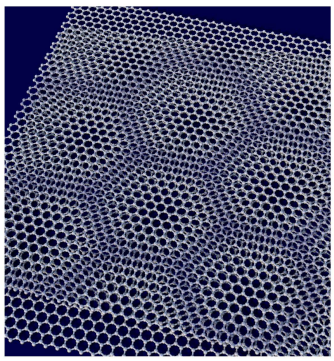

Figure 1. Schematic of a moiré crystal in twisted bilayer graphene.

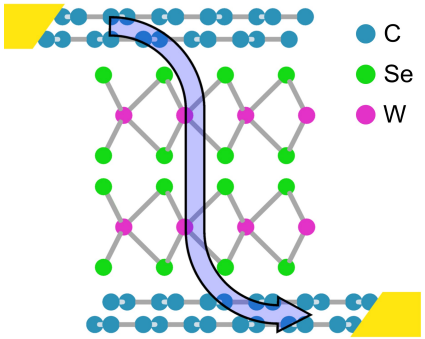

Figure 2: Schematic of a double bilayer graphene separated by WSe_2 vdW heterostructure.

[1] K. Kim, *et al.,* Nano Lett. **16**, 1989 (2016); [2] K. Kim, *et al.*, Proc. Natl. Acad. Sci. USA **114**, 3364 (2017); [3] B. Fallahazad, *et al.*, Nano Lett. **15**, 428 (2015); [4] G. W. Burg, *et al.*, Nano Lett. **17**, 3919 (2017).

[+] Author for correspondence: E. Tutuc (etutuc@mer.utexas.edu)