Engineering van der Waals Heterostructures: the importance of strain and superlattice effects

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The active 2D vdW's material, be it graphene (G) or a TMDC, must be encapsulated to achieve stable transport with high mobility. Hence there are at least two interfaces, for example hBN-G and G-hBN in encapsulated graphene, where the relative lattice alignment may play a role. It has been widely observed that the lattice of hBN imprints a potential to graphene, leading to a new bandstructure, the so-called superlattice (SL), where secondary Dirac points (sDP) can emerge. This can strongly effect the electrical properties, such as the electrical resistance and the supercurrent in Josephson junctions made form encapsulated graphene. We have found an excess edge current at gate voltages where van Hove singularities (vHS) appear in the SL bandstructure. We argue that the effective transport time in the bulk increases at the vHSs due to the suppression of the Fermi velocity.

SL effects can be engineered if lattices are intentionally aligned or stacked together with a well-defined rotation angle adjusted to within a fraction of a degree. Until now, only a single SL has been discussed in the literature. However, it is possible that two SLs with two different periods may emerge, since G is in contact with an upper and a lower hBN layer. These new SLs may themselves form a next generation of "2^{nd} order" superlattice (2SL) with an even larger periodicity. We have found evidence for 2SLs in stacks of encapsulated graphene.

Regarding strain, we first show that clean suspended graphene at high tension mechanically resonate with a fundamental mode larger than 1GHz due to the large (uniaxial) tension, corresponding to strain values exceeding 1%. It has been predicted that non-uniform strain can generate a pseudo-magnetic field in graphene which acts on the two different valleys with opposite signs. We strain encapsulated graphene, fabricated on a flexible substrate, by bending the substrate. Compared to suspended graphene, a significant advantage of substrate clamped devices is that the gate capacitance is not affected by bending, which is crucial for high-resolution transport measurements. We have also engineered strain gradients by shaping the graphene stacks in a trapezoid instead a rectangle. First electrical measurements show effects that can be assigned to both a strain-induced scalar and pseudo-magnetic potential.

Acknowledgment: This work has been done by the following list of contributors in alphabetic order: G. Abulizi, A. Baumgartner, M. Calame, A. Eichler, R. Delagrange, J. H. Garcia, D. I. Indolese, M. Jung, M. Kedves, P. Karnatak, A. Kononov, D. Mandrus, M.H. Liu, P. Makk, J. Overbeck, K. Qu, P. Rickhaus, T. Taniguchi, J. Wallbanks, L. Wang, K. Watanabe, J.-Q. Yan, and S. Zihlmann. I am very grateful to them! The work has financially been supported by the Swiss NSF, graphene flagship, H2020-ERC Adv, SNF-QSIT, SNI and further organizations.