# Layer assembly technique for the realization of ultra-clean graphene van der Waals heterostructures

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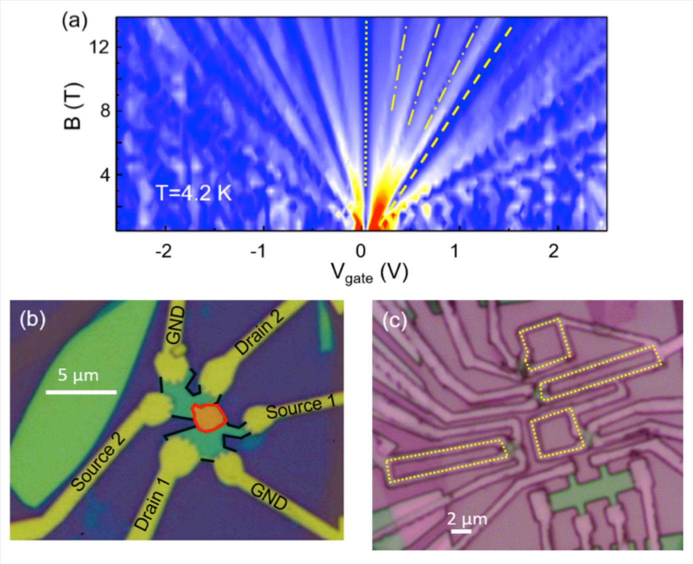
In order to access the very peculiar fundamental electronic properties of graphene, such as the *quantum Hall ferromagnetism* arising at large magnetic field due to the presence of both *spin* and *valley* symmetries [1], it is crucial to realize graphene samples of the highest quality. A major impedement comes from the contamination of the graphene surface during sample processing, *e.g.* by polymers used for electron beam lithography. To prevent this, and obtain the highest possible sample qualities, we have implemented in SPEC a *van der Waals* heterostructures assembly technique first developed in 2013 [2], where the graphene crystal is encapsulated between two atomically flat hexagonal boron nitride (h-BN) crystals. This encapsulation allows processing the samples (*e.g.* depositing metallic contacts connecting the edges of the graphene crystal [2]) without polluting the graphene surface, yielding ultra-high quality devices with record mobilities.



The assembly platform implemented in SPEC allows constructing clean, multilayer heterostructures, with micrometer alignement precision. In particular, we are able to realize state-of-the-art samples where few-nanometers-thick graphite flakes are incorporated in the heterostructure to be used as electrostatic gates, so as to tune the carrier density in graphene. Panel (a) of the above figure shows the low temperature transport characteristics of such a bilayer graphene device, where the derivative of the sample resistance with respect to back gate voltage $V_{gate}$ is plotted versus $V_{gate}$ and applied magnetic field. The yellow lines emphasize the quantum Hall effect states at filling factor 4 (dashed line), as well as the unusual, symmetry-broken filling factors 3, 2, 1 (dot-dashed lines), and the antiferrmoagnetic state at filling factor 0 (dotted line). Those four last states demonstrate the very high quality of the device. Using this platform, we are able to fabricate complex multiterminal devices (panel (b)), with various types of metallic electrodes, including superconductors. Panel (c) shows several multiterminal graphene devices (made from the same graphene flake) connected to Ta/Nb superconducting leads realizing flux loops (yellow dashed lines).

Unsing this state of the art fabrication technique, we will probe unexplored aspect o quantum transport in graphene, such as electron quantum optics, heat transport In the quantum Hall regime, and low temperature THz plasmonics.

[1] M. O. Goerbig, *Electronic properties of graphene in a strong magnetic field.* Rev. Mod. Phys. 83, 1193 (2011)
[2] L. Wang, et al. *One-Dimensional Electrical Contact to a Two-Dimensional Material.* Science 342, 614-617 (2013)

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