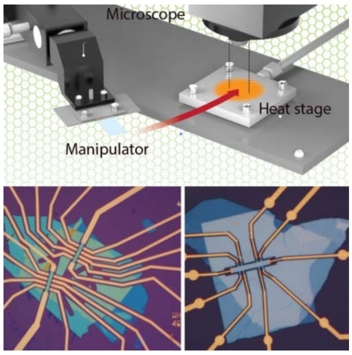
Center for Nanostructured Graphene - Highlights in 2016

Atomic scale assembly of 2D materials with atomically precise interfaces

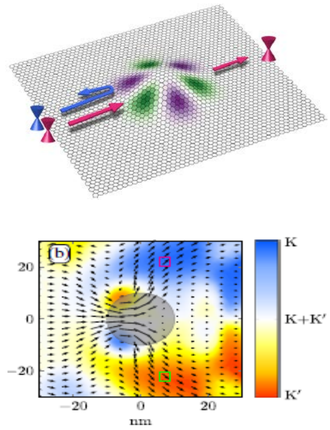
The assembly of two-dimensional, atomically thin materials in arbitrary three-dimensional stacks, held together by the universal van der Waals forces, is one of the most important recent developments in materials science. Controlling material composition and position in the atomic scale has become possible with unprecedented freedom by simple manual assembly, and provides a huge opportunity for electronics and optoelectronics, which already in their current commercial incarnations rely on the precise engineering of layered structures. To obtain atomically clean surfaces is, however, a great challenge. In collaboration with researchers from Columbia University, CNG researchers have developed the "hot-pickup" assembly method, where active control of the temperature is used to control both the all-important adhesion forces in the manipulation process, and to allow atomic-scale cleaning of the 2D crystal interfaces. This was demonstrated by a single batch of 23 high quality devices, with graphene being encapsulated inside hexagonal boron nitride (acting as a gate insulator and passivation layer) and contacted by one-dimensional edge contacts. The work was published in Nature Communications, and has been viewed more than 7000 times, helping researchers all around the world to achieve devices with atomically perfect 2D interfaces and junctions. A tutorial video has been recorded and will be launched in 2017.



F. Pizzocchero, L. Gammelgaard, B.S. Jessen, J. M. Caridad, L. Wang, J. Hone, P. Bøggild, T. J. Booth, "The hot pick-up technique for batch assembly of van der Waals heterostructures", Nature Communications **7**, 11894 (2016)

Valley filters in deformed graphene

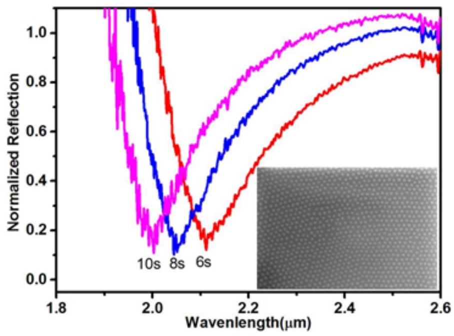
The low-energy part of graphene's energy band structure consists of two inequivalent but degenerate valleys in momentum space (schematically indicated by blue and red in the adjacent figure). The possibility to manipulate the valley degree of freedom defines the field of valleytronics, the valley analogue of spintronics. One can think of electrons in one of the valleys (say, the blue electrons) to correspond to a state "1", and the electrons (the red ones) in the other valley to correspond to the state "0", thereby forming the basic building block for digital electronics. Even more interestingly, an electron can be in both states at the same time, thereby opening a way to quantum mechanical qubits. A key requirement for valleytronic devices is the ability to break the valley degeneracy by filtering and spatially splitting valleys to generate valley polarized currents. We suggest a novel way to obtain valley polarization using strain-induced inhomogeneous pseudomagnetic fields which act differently on the two valleys. Notably, the suggested method does not involve external magnetic fields, or magnetic materials, as previous proposals. In our proposal the strain is due to experimentally feasible nanobubbles (but any local deformation would do): the associated pseudomagnetic fields lead to different real space trajectories for the electrons in the two valleys, thus allowing the two valleys to be addressed individually. In this way, graphene nanobubbles can be exploited in both valley filtering and valley splitting devices, and our simulations reveal that a number of different functionalities are possible depending on the deformation field.



M. Settnes, S. R. Power, M. Brandbyge, and A. P. Jauho, "Graphene nanobubbles as valley filters and beam splitters", Phys. Rev. Lett. **117**, 276801 (2016)

Graphene plasmons

Graphene plasmons, collective oscillations of electrons in graphene, have been widely explored in the mid-infrared and terahertz frequencies because of the tight mode confinements and long propagation distances. Graphene offers the additional advantage of being highly tunable. Graphene plasmons offer a new platform for strong light-matter interactions, thus paving a promising way for cavity quantum electrodynamics, molecular sensing, and active optoelectronics devices. However, the big challenge is to push graphene plasmons to shorter wavelengths (or higher frequencies) which would allow the integration of graphene plasmon concepts with existing mature technologies in the near infrared region. Our team used the block copolymer self-assembly method to realize wafer-scale graphene nanodisks arrays where the physical diameter of the nanodisks is shrunk down to 18 nm. We investigated the localized graphene plasmons supported by the nanodisks and experimentally demonstrate graphene plasmons working at 2 μm. To the best of our knowledge, this is the shortest wavelength ever reported for the localized graphene plasmon resonance. The results obtained here will facilitate graphene plasmons both for fundamental studies and for potential applications in the telecommunication window.



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