QUANTUM TRANSPORT IN MOLECULARLY DOPED DIRAC MATERIALS

Tuning the charge carrier density of two-dimensional (2D) materials by incorporating dopants into the crystal lattice is a challenging task as it tends to damage the delicate crystal lattice. An attractive alternative for doping 2D crystals is the surface transfer doping by adsorption of molecules on 2D crystals, which can lead to ordered molecular arrays. However, such systems, demonstrated in ultra-high vacuum conditions (UHV), are often unstable in ambient conditions.

We have recently shown (1) that air-stable doping of epitaxial graphene on SiC—achieved by spin-coating deposition of 2,3,5,6-tetrafluoro-tetracyano-quino-dimethane (F4TCNQ) incorporated in poly(methyl-methacrylate)—proceeds via the spontaneous accumulation of dopants at the graphene-polymer interface and by the formation of a charge-transfer complex that yields low-disorder, charge-neutral, large-area graphene with carrier mobilities ~70 000 cm2 V^{-1} s^{-1} at cryogenic temperatures. The assembly of dopants on 2D materials assisted by a polymer matrix, demonstrated by spincoating wafer-scale substrates in ambient conditions, opens up a scalable technological route toward expanding the functionality of 2D materials.

During this project you will explore a process for molecular doping of Dirac Materials, with different molecular dopants aiming at tuning the electronic properties of graphene looking for magnetism or enhanced optical absorbtion. The properties of Dirac crystals after doping will be assessed through electrical measurements. Along the project, you will go through the entire microfabrication process in order to make micro/nanodevices: 1) CAD design, 2) E-beam lithography, 3) Thin-film deposition and lift-off. The device will be tested by electrical measurements at room and cryogenic temperatures, under strong magnetic field and under light irradiation.

By the end of the project, you will have acquired/developed at least the following:

- General cleanroom experience
- Micro/nanofabrication skills using photo/electon beam lithography
- Knowledge of electrical measurements for low resistive devices
- Computer controlled of instruments using standard software MatLab/LabView.

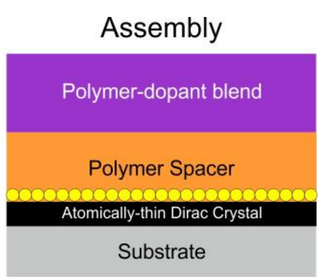

Figure 1. Spontaneous assembly of molecular dopants (yellow circles) on Dirac crystals via diffusion through polymers (1). After deposition of polymers by spin-coating, the diffusion of dopants in the polymer dopant-blend can be controlled and fine-tuned by thermal annealing, with temperature T of the order of the glass transition temperature Tg of the polymer spacer, and for a time t to be determined experimentally. When the temperature is lowered below Tg, dopants remain assembled on the surface of the Dirac crystal. Polymers serve also the purpose of encapsulation layer, protecting fragile or unstable crystals from ambient.

Reference

1. H. He, K. H. Kim, A. Danilov, D. Montemurro, L. Yu, Y. W. Park, F. Lombardi, T. Bauch, K. Moth-Poulsen, T. Iakimov, R. Yakimova, P. Malmberg, C. Müller, S. Kubatkin, S. Lara-Avila, Uniform doping of graphene close to the charge neutrality point by polymer-assisted spontaneous assembly of molecular dopants. Nat. Commun. 9, 3956 (2018).

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