Master's project: Mechanics of atomically-thick graphene cantilevers

Project description:

Graphene, a single monolayer of carbon, possesses unique mechanical properties. In the simplest model, the bending rigidity of graphene is negligible, as expected of an atomically thick material. However, the out-of-plane phonons in graphene lead to its crumpling. That crumpling, in turn, is expected to greatly renormalize the bending rigidity of graphene and change its other mechanical properties. Indeed, we have recently shown that crumpling of graphene leads to its mechanical "softening" and emergence of the non-linear Hooke's law in its stress/strain response [1]. Nevertheless, there is still active debate regarding theoretical description of crumpled atomically-thick membrane that is graphene [2].

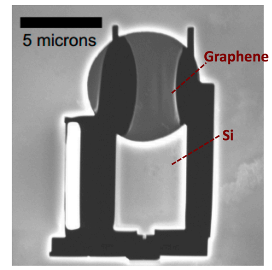

Figure 1: Singly clamped graphene cantilever

The aim of the project is two-fold. First, we will set up the experiment to definitively measure the bending rigidity of graphene and puzzle out the contribution due to crumpling. We will fabricating singly-suspended graphene cantilevers (Fig. 1) and measuring Brownian noise spectrum of light reflected off of the cantilevers [3]. Second, we will utilize these singly-suspended cantilevers as tunable and ultrasensitive sensors of mechanical forces. The extreme "floppiness" of graphene is expected make graphene cantilevers one of the most sensitive force-sensing devices ever made.

During the project the student will acquire the following skills:

- **Chemical vapor deposition of two-dimensional materials including graphene.** The student will develop, from scratch, a system to grow two-dimensional materials via chemical vapor deposition (CVD) approach. The student will learn to characterize various types CVD-grown two-dimensional materials using optical and Raman spectroscopies.
- **Nanofabrication.** The student will transfer graphene onto silicon nitride membranes and than patter graphene using focused job beam lithography (FIB) to create singly-clamped graphene cantilevers (Fig. 1).
- **Optomechanical measurements.** Working together with a PhD student, the student will participate in developing of a sensitive interferometer that is capable of detecting the Brownian motion of graphene [3].
- **Micromechanical modelling and statistical mechanics of membranes**
- **Data analysis, programming, preparing a scientific publication**

After the completion of the project, it will be possible to continue towards a PhD in the same research area in the Bolotin group under the European project "Strained2Dmaterials".

References

[1] Nicholl et al., Physical Review Letters 118, 266101 (2017)
[2] Katsnelson et al., arXiv:1302.1385 (2013)
[3] van der Zande et al., Nano Lett. 10, 4869 (2010)