Local Optical Probe for Motion and Strain Detection of Resonances in Graphene Membrane Drums

C. Schwarz, B. Pigeau, A. Kuhn, D. Kalita, Z. Han, L. Marty, O. Arcizet, N. Bendiab, V. Bouchiat

Univ. Grenoble Alpes, F-38000 Grenoble, FRANCE
CNRS, Inst Néel, F-38000 Grenoble, FRANCE
cornelia.schwarz@neel.cnrs.fr

Nanoelectromechanical systems (NEMSs) are emerging nanoscale elements at the crossroads between mechanics, optics and electronics, with significant potential for actuation and sensing applications. The reduction of dimensions compared to their micronic counterparts brings new effects including sensitivity to very low mass, resonant frequencies in the radiofrequency range, mechanical non-linearities and observation of quantum mechanical effects. An important issue of NEMS is the understanding of fundamental physical properties conditioning dissipation mechanisms, known to limit mechanical quality factors and to induce aging due to material degradation. There is a need for detection methods tailored for these systems which allow probing material parameters, motion and stress at the nanometer scale. Graphene, as a one-atom-thick layer, provides an ultimate membrane with a very low mass along with high Young modulus. Moreover its vibrational properties make it a new playground to probe strain in an actuated NEMS.

Here, we show a non-invasive local optical probe for the measurement of motion and stress within a monolayer graphene NEMS with a well-defined geometry provided by a combination of reflection measurements and Raman spectroscopy. The system studied consists of a monolayer graphene sheet grown by chemical vapour deposition (CVD) that is suspended over prepatterned holes in a silicon dioxide substrate. Thus the geometry of the resonators is well- controlled and diameters up to 10 µm are reached. The graphene membrane is actuated electrically by applying a voltage to the silicon backgate or mechanically with a piezo crystal. The actuation ranges from a quasi-static load up to the mechanical resonance at some MHz.

With reflection measurements of the actuated membrane the resonance frequencies of up to the first eight vibrational membrane modes can be determined. Furthermore mechanical non-linearities of the graphene are revealed by reflection measurements at high excitation powers. Raman measurements comparing the static and actuated state allow to determine the strain induced in the driven graphene membrane.

In summary, a geometrically well-defined monolayer graphene resonator is presented which allows to study graphene material properties by reflection measurements. The latter are complemented by Raman spectroscopy measurements which open the route towards the nanoscale spatial detection of strain induced in a mechanical resonance mode of the graphene. Such spectroscopic detection reveals the coupling between a strained nano-resonator and the energy of an inelastically scattered photon, and thus offers a new approach to optomechanics.

References

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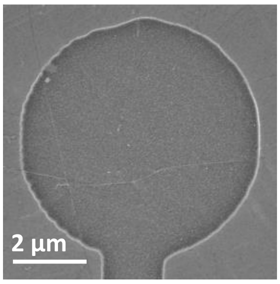

Figure 1: SEM micrograph of a suspended monolayer graphene drum

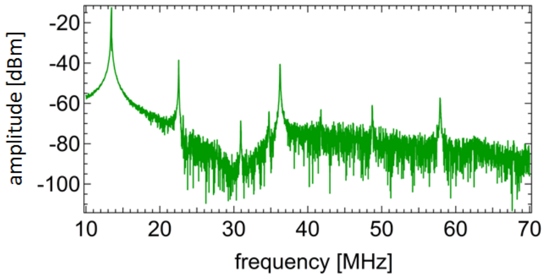

Figure 2: Mechanical resonance modes of suspended monolayer graphene drum