Tailoring Mechanically Tunable Strain Fields in Graphene

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There are a number of theoretical proposals based on strain engineering of graphene and other two-dimensional materials, however purely mechanical control of strain fields in these systems has remained a major challenge. The two approaches mostly used so far either couple the electrical and mechanical properties of the system simultaneously or introduce some unwanted disturbances due to the substrate [1, 2]. Here, we report on silicon micromachined comb-drive actuators (see Figure 1) to controllably and reproducibly induce strain in a suspended graphene sheet in an entirely mechanical way (see Figure 2a) [3]. We use spatially resolved confocal Raman spectroscopy to quantify the induced strain, and we show that different strain fields and gradients can be obtained by engineering the clamping geometry (see Figure 2b). In particular we show mechanically tunable strain gradients of up to 1.4 %/µm (see Figure 2c). Our approach also allows for multiple axis straining (interesting for pseudo-magnetic fields) and is equally applicable to other two-dimensional materials, opening the door to investigating their mechanical and electromechanical properties. The presented approach thus provides a workhorse for developing new sensor and transducer concepts. Our measurements also clearly identify defects at the edges of a graphene sheet as being weak spots responsible for its mechanical failure.

References

[1] Bunch *et al.*, Science 315 (2007) 490
[2] Mohiuddin *et al.*, Phys. Rev. B. 79 (2009) 205433
[3] Goldsche *et al.*, Nano Lett. (2018) (arXiv: 1711.04505)

Figures

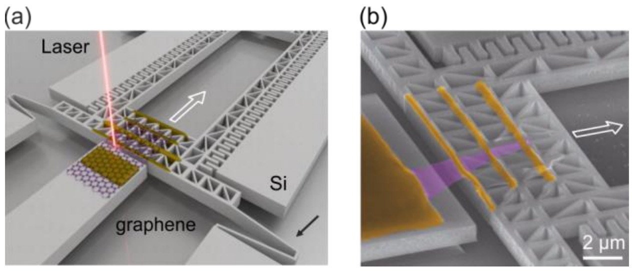

Figure 1: (a) Schematic illustration of a comb-drive actuator that applies uniaxial strain to the graphene flake by moving in the direction of the white arrow. The fixed part is resting on the substrate whereas the suspended part is freely hanging and is held by V-shaped springs (see black arrow). (b) False color scanning electron microscope (SEM) image of a measured device, in which the cross-linked PMMA clamping (yellow) of the graphene (pink) is highlighted.

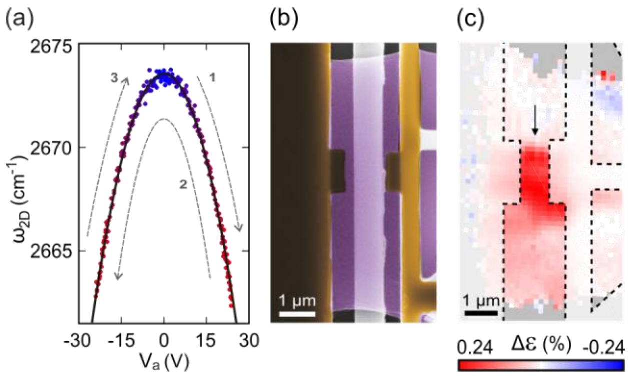

Figure 2: (a) ω_{2D} versus V_a shows parabolic behavior. The gray arrows 1 to 3 indicate the sweep direction of the potential V_a in the measurement. (b) False color SEM image (similar to Figure 1b) of a typical measured device where the PMMA-clamping contains two noses. (c) The spatially resolved induced strain $\Delta\epsilon$

shows a maximum gradient of 1.4 %/µm at the position of the black arrow.