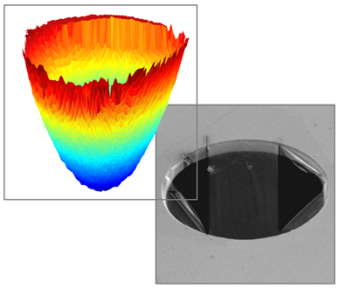
New measurement technique quantitatively determines the effect of wrinkles on the stiffness of graphene



Interferometric profilometry data under electrostatic actuation for a circular membrane, and image of a membrane modified by FIB cutting.

Scientific Achievement

A new interferometry technique was used to determine that the softening of graphene grown by chemical vapor deposition (CVD) is dominated by static wrinkles rather than flexural phonons.

Significance and Impact

Two-dimensional (2D) materials are promising for applications as oscillators, resonators, and other nanomechanical devices. This study suggests a path towards 2D materials with tunable mechanical properties via shape engineering.

Research Details

- The deflection of fully clamped, circular single layer graphene membranes was measured for a range of temperatures, geometries and defect concentrations
- Thermal crumpling is probed by varying temperature whilst static wrinkling is studied in devices with different shapes created by focused ion beam (FIB) cutting

Work was performed as User Project at the Center for Nanophase Materials Sciences, and at Vanderbilt University

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Narrative Highlight Text: Although graphene is one of the stiffest materials ever discovered, it is inevitably undulated due to atomistic, meso-scale and microscale phenomena. It has been hypothesized that topographic undulations of a 2D material cause a strong renormalization of the effective elastic constants. The in-plane stiffness of graphene is reduced by up to 10 times due to crumpling from wrinkles and thermal oscillations.

By using a novel technique to measure the mechanical response of graphene membranes with optical interferometry under electrostatic actuation, we implemented delicate mechanical probing that reveals differences in graphene elasticity due to crumpling. Through mechanics measurements as a function of membrane shape and temperature, we have learned that softening of CVD grown graphene is dominated by static wrinkles rather than flexural phonons.
This work highlights an advancement in the understanding of the mechanics of atomically thin materials and, in particular, offers new insight on the operation of graphene-based nanoelectromechanical (NEMS) devices such as switches, resonators and sensors.

Reference

"The effect of intrinsic crumpling on the mechanics of free-standing graphene."

Ryan J.T. Nicholl[1], Hiram J. Conley[1], Nickolay V. Lavrik[2], Ivan Vlassiouk[3], Yevgeniy S. Puzyrev[1], Vijayashree Parsi Sreenivas[1], Sokrates T. Pantelides[1] & Kirill I. Bolotin[1,4]

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