Measurement of the Elastic Properties and Intrinsic Strength of Monolayer Graphene

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The elastic properties and intrinsic breaking strength of free-standing monolayer graphene membranes are measured. The free-standing films are suspended above circular wells in a silicon substrate and are fabricated by exfoliating single atomic layers of graphene from a graphite source. The mechanical properties of the graphene are characterized via nanoindentation with an atomic force microscope by measuring the force and displacement relationship upon indenting the graphene film in the center of the suspended film. The force-displacement behavior is interpreted within a framework of non-linear elastic stress-strain response, from which the second- and third-order elastic moduli are determined. In addition, we show that the breaking strength of the monolayer graphene represents the intrinsic strength of a defect free sheet. These experiments establish graphene as the strongest material ever measured, and show that atomically perfect nanoscale materials can be mechanically tested to deformations well beyond the linear regime.