ENGINEERING

Sculpting Charge in Graphene Through Patterned Strain

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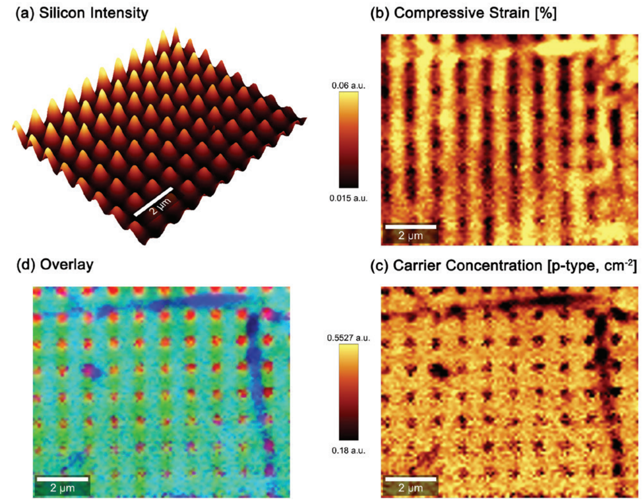
Graphene, an atomically thin carbon sheet, possesses differentiating optical and electrical properties that have led to worldwide exploration into its utility for applications ranging from quantum computing and sensing to optical devices. Regardless of application, sculpting the quantity and distribution of charge within graphene provides a path to enhanced performance. Here, this sculpting is accomplished by draping graphene over a topographically patterned substrate. Draping graphene over a "bumpy" substrate induces patterned strain. It also creates a distribution of touchpoints between graphene and the underlying substrate. Since mechanical strain affects the charge density in graphene as does its contact with another material, the cumulative effect of each induces patterned charge within the 2D material. Practically, this is shown by transferring monolayer graphene onto a silicon wafer, the face of which has been etched to produce pillars in a square lattice spaced at 1 μm. Strain and carrier concentration were then imaged by analyzing changes in the peak positions of graphene's Raman spectrum, as shown in the figure. Linear "strain stripes" were observed that run in one direction relative to the pillars. Carrier concentration varied only somewhat in response to these strain stripes. It was instead more strongly impacted by "spots"' correlated with contact of the graphene with the patterned substrate. Irrespective of cause, these results affirm that topographic patterning of graphene provides a path to spatially controlling charge, thereby opening alternative pathways for designing devices based upon this material.



(a) Silicon was etched to create pillars over which the 2D-solid graphene was draped. By placing graphene over the patterned substrate, the (b) strain and (c) carrier concentration could be spatially varied, although not in a (d) one-to-one fashion as evidenced by overlaying the results. In (d), red hues correspond to the silicon Raman intensity, while the blue and green correspond to the graphene strain and carrier concentration.

Research advisor Thomas Beechem writes: "Spatially patterning charge in graphene and other two-dimensional materials creates an entire palette to design optical and electronic devices having functionality not available in normal 'thick' materials. Dylan and Jenna's work explores a path of inducing this patterned charge by laying them over bumpy surfaces."

http://dx.doi.org/10.7771/2158-4052.1566