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Water Surface Unlocks Chemo-Mechanical Properties of Graphene

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Abstract

The mechanics of graphene is commonly probed in tensile tests which inevitably perturb the thermally fluctuating membrane [1]. Compressive tests are expected to preserve the natural out-of-plane fluctuations in graphene, however only in experimental designs where the mechanics of the graphene and of underlying substrate are not intermixed [2]. Water offers numerous advantages to conduct graphene compression experiments: i) The surface of water is strictly planar and serves as an appropriate mattress for the two-dimensional graphene. ii) The adhesion energy between hydrophobic graphene and water is lower than graphene on typical substrates which guarantees a negligible graphene/substrate interaction. In addition, iii) graphene can smoothly slide on the surface of water (no dry friction) which allows free deformation upon compressive buckling. Here, we compress graphene floating on water in a Langmuir-Blodgett trough. Remarkably, the Young's modulus respects a scaling law [3] and falls two orders of magnitude below the previous reports. The chemical functionalization/modification of the graphene lattice affect the mechanics of graphene; particularly we explored the effect of the sp^3 hybridization and crystalline voids. Compression of graphene beyond the elastic limit yields wrinkles, the evolution of which, in a progressive compression, gives rise to internal friction, i.e. viscoelasticity, observed for the first time in graphene.

References

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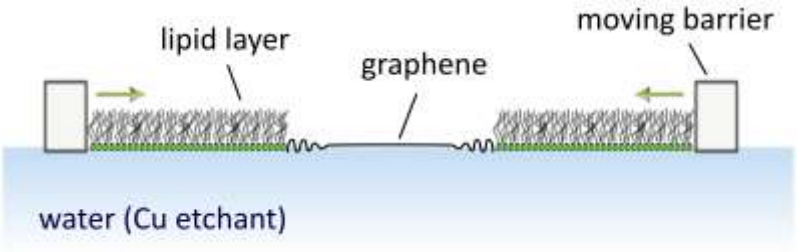
[2] O. Frank, et. al., Compression behavior of single-layer graphenes, ACS Nano. 4 (2010) 3131–3138.
[3] J.H. Los, A. Fasolino, M.I. Katsnelson, Scaling behavior and strain dependence of in-plane elastic properties of graphene, Phys. Rev. Lett. 116 (2016) 015901.

Figures



Graphene (pristine or chemically functionalized) floating on the surface of water is subject to the external compression from a lipid layer in a Langmuir-Blodgett trough