Strain and Friction in Few Layer 2D Crystals

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Abstract

Strain in 2D crystals can tune material properties [1], controllably breaking crystal symmetry [2], and inducing pseudo magnetic fields [3]. Friction plays a central role in these applications because of its effect on the strain field's engineering, orientation and magnitude. We have developed a simple experiment for generating known strain fields in 2D crystals to explore phonon response and friction.

We suspend a 2D crystal over a hole etched in a Si substrate creating a sealed micro-chamber. We place these chambers into a pressure vessel with an optical window for Raman measurements while simultaneously applying external pressure (figure 1). The external pressure deforms and slides the 2D material into the hole, and we measure the strained Raman spectra with high spatial resolution (figure 2). The friction force and phonon strain response are determined by fitting a global set of parameters to an extended continuum model that improves precision (figure 3).

Our method is applicable to a wide variety of 2D crystals and substrates. In previous work we studied graphene [4], and most recently we focused on hexagonal Boron Nitride (hBN). The coefficient of friction (COF) between hBN and SiO_2 is μ=0.37 ± 0.19, which is more than three times larger than trilayer graphene's COF, 0.11 ± 0.01. The Gruneisen parameter and shear deformation potential for the E_{2g} mode in hBN, a degenerate mode analogous to the G mode in graphene, are measured to be 1.84 ± 0.09 and 1.0 ± 4.6 respectively. Measurement of the shear deformation potential through analysis of polarized Raman spectra highlights the utility of our technique considering this parameter has eluded decades of experiments on bulk material.

Measurements of Molybdenum disulfide (MoS_2) and phosphorene are under way. We have also begun to alter the substrate chemically with silanization and replacing it with other materials such as hBN. The multitude of possibilities fosters an understanding of the structural, chemical and geometric aspects of tribology as has never been available before.

Figure 1: Micro-chamber and pressure vessel geometry (Argon Ion Laser: λ = 512nm, Beam Width = 0.75μm.)

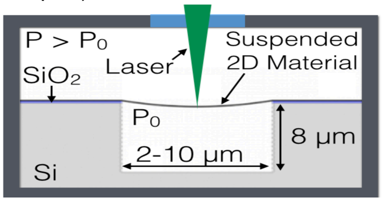


Figure 2: Strained Raman spectra of a 7 layer hBN flake over a 6μm hole.

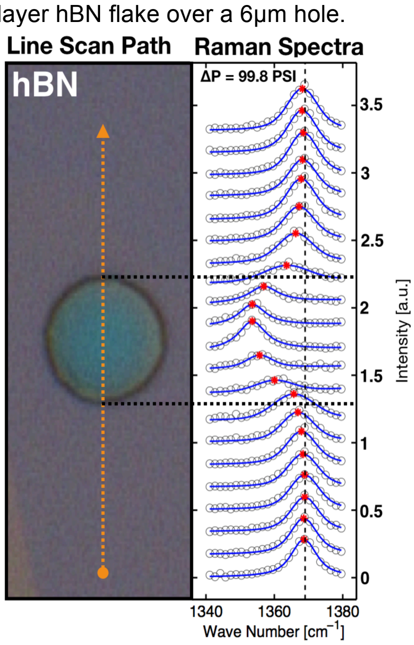
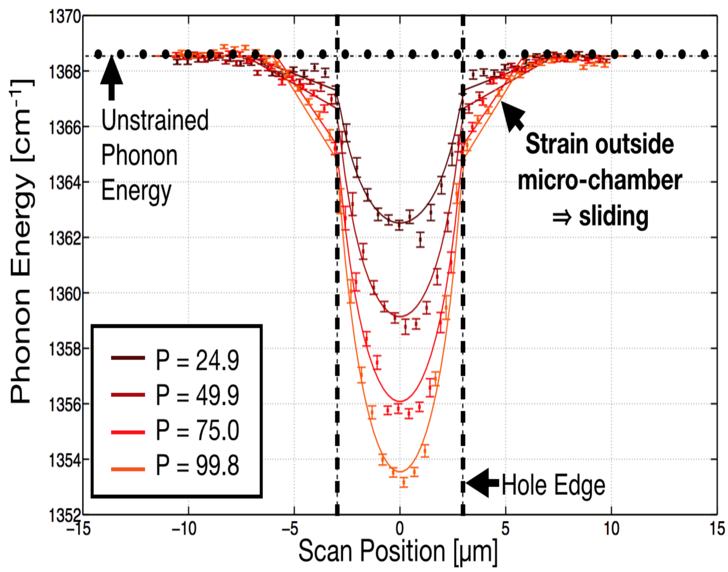


Figure 3: Phonon strain response global fitting over multiple pressures (Pressure is in PSI. Error bars represent one standard deviation, and the material is hBN.)



References

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