Layer Dependant Mechanical Properties of Graphene

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The impressive mechanical properties, including the elastic modulus, toughness, and lubrication properties of graphene has resulted in a significant interest in understanding their origins and limitations. For example, graphene has been shown to be one of the stiffest materials known, having an in-plane stiffness of 1 TPa [1]. Several studies have shown that many of these properties are dependent on the substrate supporting graphene and/or how many layers of graphene cover the substrate. For example, the friction properties have been observed to be layer dependent, with the mechanism of layer dependent friction being attributed to variations in the out-of-plane bending stiffness of graphene varying with its thickness [2-4]. While this friction mechanism has been often used, there have been little experimental work supporting the theoretical claims of layer-dependent out-of-plane stiffness. Here we conduct a rigorous set of experiments using ultra-high vacuum atomic force microscopy (AFM) to investigate these layer-dependent mechanical properties of graphene. Specifically, contact resonance AFM was conducted with Si tip on graphene of varying layers supported by a silicon substrate. Variations in the obtained contact resonance indicate changes in the elastic modulus in out-of-plane bending that shows a linear decrease in the elastic modulus with the number of layers of graphene. More specifically, an elastic modulus of 0.97 ± 0.001 TPa was measured for one layer graphene and observed decrease of 4.95% is observed with each additional layer of graphene up to 4 layers. These findings provide a substantial evidence for the frictional behaviour of graphene as well as enriching the knowledge about its layer dependant stiffness on top of simulation studies.

REFERENCES

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FIGURES

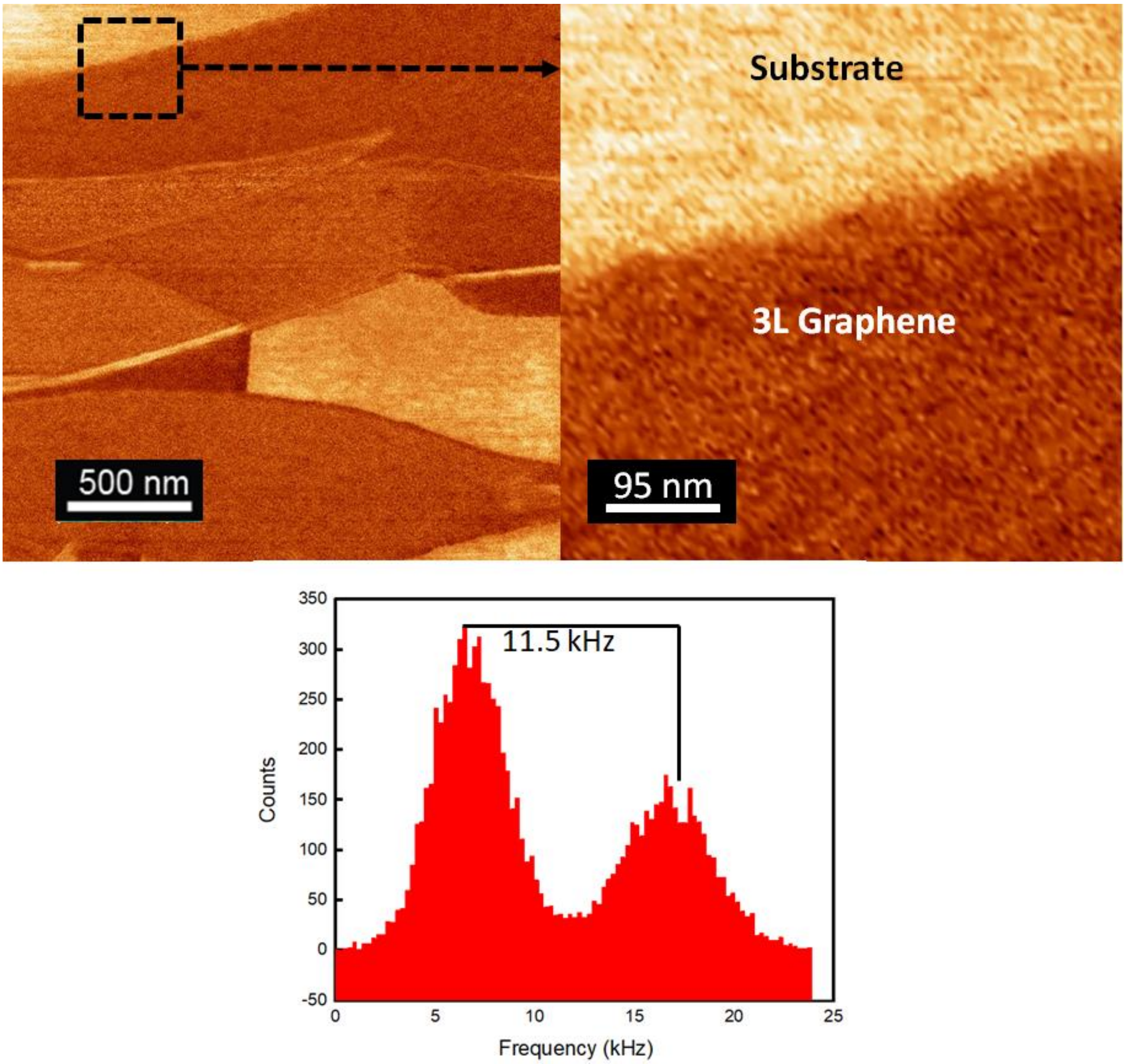

Figure 1: The histogram of the contact resonance frequency indicates a variation of about 12 kHz with addition of three layers graphene.

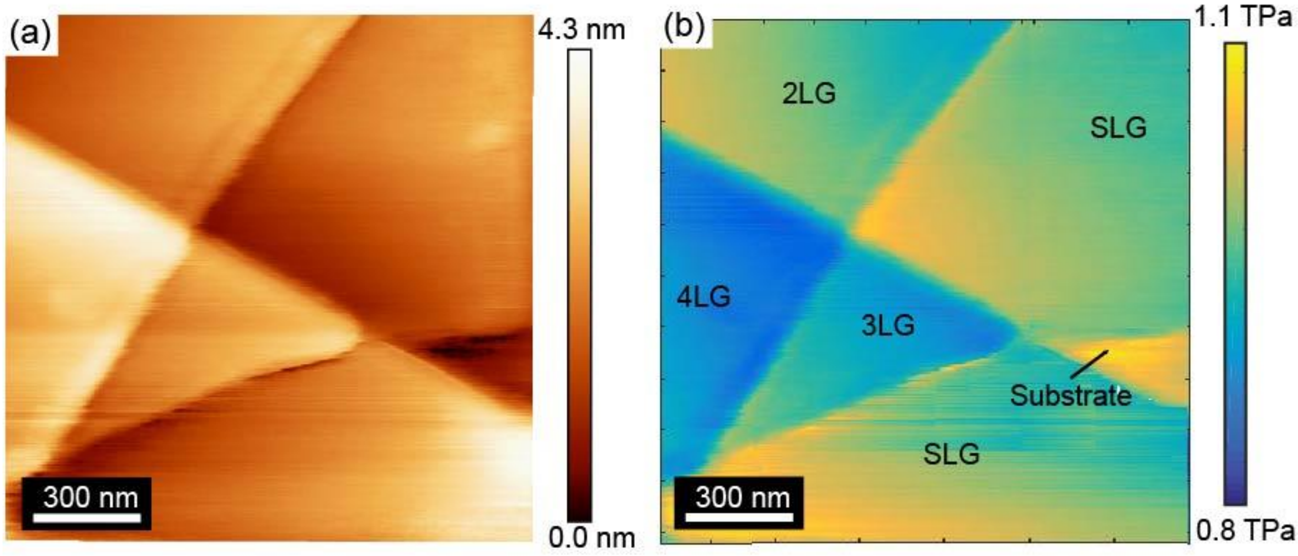

Figure 2: Topography of graphene area contains different graphene layers obtained byNC-cantilever. (b) Calculated elastic map through the CR experiments data.