A NOVEL METHOD TO MEASURE THE MECHANICAL PROPERTIES OF GRAPHENE

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Graphene as a thinnest two-dimensional material has attracted remarkable considerations since it was first isolated in 2004 [1]. An application of graphene is cantilever formation. Knowledge of mechanical properties of the graphene cantilever can help in the progress of nanoresonator technology. Using nano-indentation in the previous reports some mechanical constants such as the Youngs modulus for the graphene sheet were identified [2, 3]. Due to tip effects on the graphene sheet, this method hasnt enough accuracy in force measurement. In this paper, we report a novel method to measure the mechanical properties of graphene from non-contact atomic force microscopy (NAFM). We prepared the graphite oxide samples by natural graphite powder (Merk) using the modified Hummers and Offeman oxidation method [4, 5]. To obtain the graphene sheets we exposed graphene oxide (GO) samples to Hydrazine vapor. The prepared sheets dispersed on polished SiO_2 (100) substrates to be characterized by X-ray photoelectron spectroscopy (XPS) and atomic force microscopy (AFM) techniques. By using NAFM method the amplitude-displacement (A-D) curves were measured on various points of the graphene nano-sheets.

Figure 1(a) shows an XPS spectrum data from the prepared samples , which is corresponded to the C(1s) core level [6, 7]. Five peaks are related to C-O, C=O, C-N, C(O)O, C-H and C-C. Figure 4(b) shows the C(1s) peak after chemical reduction that confirm majority reduction of GO sheets. This is in agreement with the previous reports [7].

To measure the mechanical properties of the graphene sheet we used non-contact mode spectroscopy. In the A-D measurements, the sample is moved up and down by applying a voltage to the piezoelectric translator, onto which the sample is mounted, while measuring the amplitude of sinusoidal driving cantilever. To measure a proper curve from graphene we look through the sheets which the oscillating tip can detach it from the substrate. Figure 4 presents A-D curves from different point on the graphene surface. We can model these sheets near the resonating point in figure 3 by harmonic oscillator. For a sinusoidal driving force oscillator we can write:

$$\frac{d^2y}{dt^2} + 2\varsigma\omega_0\frac{dy}{dt} + \omega_0^2 y = \frac{1}{m}[F_0 sin(\omega t) - F_L] \tag{1}$$

where F_0, ω, ς and F_L are the driving amplitude, the driving frequency for a sinusoidal driving mechanism, damping ratio and a constant force between substrate and graphene. In equation

1 ω_0 is:

$$\omega_0^2 y = \frac{\int T dS \sin\Theta}{m} \approx \frac{T \int dS \tan\Theta}{m} = \frac{T(2\pi a a_0)y}{ma} = \frac{2Ta_0 y}{a^2\rho} \tag{2}$$

Neglecting F_L, the steady-state solution is:

$$y(t) = \frac{F_0}{mZ_m\omega}\sin(\omega t + \varphi) \tag{3}$$

where:

$$Z_m = \sqrt{(2\omega_0\varsigma)^2 + \frac{1}{\omega^2}(\omega_0^2 - \omega^2)^2} \tag{4}$$

According to our data when the oscillating cantilever goes away from the sheet, the acting force changes due to sheet separation from the substrate. According to this model and tip properties we can calculate the acting tension (T) from equation (2) at the resonance point. Our calculation by averaging over different points gave the T as 1763 Nm^{-2}. From oscillator amplitude, which is width of the resonance peak in figure 3(a), and by according a cap model similar to figure 2(c) we calculated strain. Results give a value about 2×10^{-9} which gives Young modulus as 0.9±0.1 TPa.

References

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