Properties of Intrinsic Ripples on Suspended/Free-Standing Graphene

Graphene-based Energy Harvesting
SURP 2021

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Date : 28-06-2021

Causes of Ripples

- Mermin-Wagner Theorem
- Stretching (in-plane displacement) and Bending (out of plane displacement)
- Dynamic flexing due to acoustic phonons
- Static Corrugation due to configuration energy
- Asymmetric Distribution of single/double bonds at room temperature

Causes of Ripples

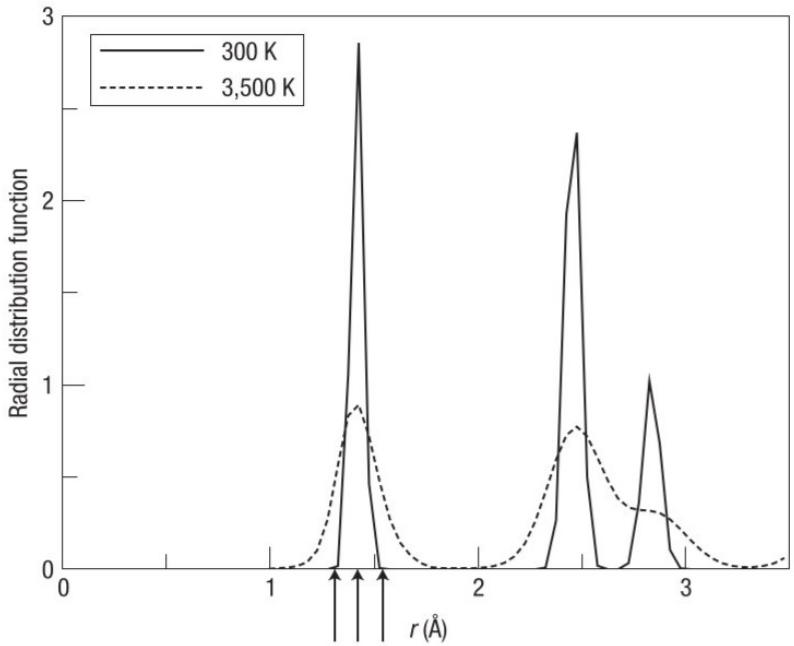

Figure 4 Radial distribution function for the $N = 8{,}640$ sample at $T = 300$ K and $T = 3{,}500$ K as a function of interatomic distance. The arrows indicate the length of double ($r = 1.31$ Å), conjugated ($r = 1.42$ Å) and single ($r = 1.54$ Å) bonds.

Simulation

- *ab-initio* DFT-based simulation was considered prohibitive due to length scale
- Monte-Carlo based atomistic simulation with LCBOPII Bond-Order Potential

Ripple Properties

- $\vec{u}$ (in-plane) ; h (out of plane)
- Case where bending and stretching are decoupled (under Harmonic Approximation) :

$$\langle h^2 \rangle \alpha \frac{T}{\kappa} L^2$$

- κ : Bending Rigidity (1.44 eV)
  T : Temperature
  L : Linear Sample Size
- Tension dictates Shape and Rate of Curvature Inversion

From the Patent

- Membrane with supports:
  - STM Tip forming a Capacitive Region
  - Voltage Source for a set-point current
- Graphene Membrane with a Metal contact in the substrate
- Fixed Charges added to an insulating layer (membrane) and another capacitor plate
- 1 pW/ripple (*approx* 1000 atoms)

From Other Papers

- Bending Rigidity (1.44 eV) calculated using DFT and configuration energy of the membrane determined by Helfrich Hamiltonian

$$E = \int_S [\gamma + 2B_M(C_M - C_0/2)^2 + B_G C_G] dS$$

- γ : Energy of Flat Surface
  B_M : Bending Rigidity
  C_x : Curvature Properties