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STABILITY OF GRAPHENE SURFACE AN APPLICATION OF CHIRAL MODEL

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ABSTRACT

A suspended sheet of pure graphene a layer of carbon atoms bonded together in a honeycomb lattice is the most two-dimensional system imaginable. Graphene sheet have for long been known to exist in disguised from graphite (stacked graphene layers) it was generally believed that an extended graphene sheet would not be stable against the effect of thermal and other fluctuations. Furthermore, it was believed that even if they were stable, it would be impossible to isolate them so that their properties could be studied systematically. Based on this the chiral model was suggested, the ideal graphene plane were determined by the kink-like solution. The corrugation of the graphene surface was described in the form of ripple and rings. Thus, our graphene plane reviles the tendency of bending.

Keywords: Graphene, Chiral Model, Ripple, Kink

INTRODUCTION

Graphene (fig.1) has attracted great interest in condensed matter physics since its discovery due to its novel electronic structures. It is fundamentally one single layer of graphite; a layer of sp2 bonded carbon atoms arranged in a honeycomb (hexagonal) lattice. As predicted by P.R.Wallace, 1947 a suspended sheet of pure graphene, a layer of carbon atoms bonded together in a honeycomb lattice is the most two-dimensional system imaginable. It was first described by P.R Wallace, before it was discovered in 2004 by K.S.Nevoselov and A.K.Geim(Novoselov, et al., 2004).

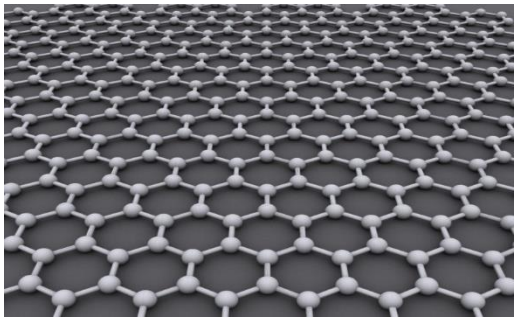

Figure 1: Graphene plane (Novoselov, 2005).

Since after the discovery that graphene could be reproducibly found on a silicon dioxide wafer, deluge of experiments immediately followed, and renewed interest has led to numerous of theoretical predictions and

exotic experiments utilizing graphene's unique properties.

The stability of two dimensional (2D) layers has been a subject of a long-standing theoretical debate. According to Mermin Wagner theorem, long wavelength fluctuations destroy the long-range order of two dimensional crystals (Mermin, 1968). However the discovery of graphene, the first truly 2D crystal (Novoselov, 2005) and recent experimental observation of ripples in suspended grapheme (Meyer, 2007) has raised the issues especially important.Understanding the mechanism of the stability of graphene is crucial for understanding the electronic transport in this material that is attracting much interest owing to its unusual Dirac spectrum and electronic properties.

Carbon atom possess 6 electrons; 2 in the inner shell and 4 in the outer shell, the 4 outer shell electrons in an individual carbon atom are available for chemical bonding, but in graphene, each atom is connected to 3 other carbon atom on the 2D plane, living 1 electron freely available in the third dimension for electronic conduction (Jean-Noel, *et al.,* 2008). These highly-mobile electrons are called the pi(π) electrons and are located above and below the graphene sheet. This pi orbital's overlap and help to enhance the carbon to carbon bonds in graphene. (Fasolino, et al., 2007)

In graphene three electrons participate in sp2 bonds. These three bonds are realized in a plane with regular 120 angles between them. Each bond is covalently shared with a neighboring atom in a σ bond, giving graphene its hexagonal structure and its robustness. In the hybridized sp-state the carbon atom possess four valence electron, one of them being "free" in graphene lattice and all others forming sp-bonds with the neighbors (YU.P.Rybakov, 2012).

In this phenomenological approach to the study of graphene stability, the chiral model was considered. It appears naturally to introduce scalar a_0 and 3-vector **a** fields corresponding to the s-orbital and the p-orbital states of the "free" electron respectively. These two fields can be combined into the unitary matrix $U \in SU(2)$ considered as the order parameter of the model adopted. In the first approximation we considered the static 1D configuration corresponding to the ideal graphene plane, the normal being oriented along the z-axis. The order parameter has the form:$U = \exp(i\psi\tau_3)$, $\psi = \psi(z)$.

MATERIALS AND METHOD

Lagrangian density of the Model

$$\mathcal{L} = -\frac{1}{2} I\psi'^2 - \frac{1}{2}\lambda^2 sin^2\psi \quad (1)$$

The Lagrangian in (1) corresponds to the sigma-model approach in the field theory with the mass term. We introduce the constant model parameters I *and* λ, if one compare the Lagrangian density with that of

the Landau-Lifshits theory corresponding to the quasi-classical long-wave approximation to the Heisenberg magnetic model (A.M.Kosevich, et al., 1988), (Jimenez, et al., 2001) one interpret the parameter I in (1) as the exchange energy per spacing.

The equation of motion from the Lagrangian in (1) yield:

$$2I\psi'' - \lambda^2 sin2\psi = 0 \tag{2}$$

The solution to equation (2) satisfying the boundary conditions

$$\psi(-\infty) = 0\,, \;\; \psi(+\infty) = \pi$$

This has the well-known kink-like form:

$$\psi_0(z) = 2\arctan\exp(z/\ell) \tag{3}$$

If we consider the case of small perturbation to the solution (3) in the vicinity of the ideal graphene plane, i.e. for small z.

One finds for the perturbations $\xi = \delta a_3 \; and \; a_\pm = a_1 \pm i a_2$ the following Lagrangian density holds:

$$\psi_0(0) = \pi/2,$$

$$\Delta\xi = 0, \quad \left(\Delta - \ell^{-2}\right)a_+ = 0$$

$$\mathcal{L} = \frac{1}{2}I\left(z^{-2}\partial_\mu\xi\partial^\mu\xi + \partial_\mu a_+\partial^\mu a_-\right) - \frac{1}{2}\lambda^2 a_+ a_- \tag{4}$$

The equations for static perturbations read:

$$z^2\partial_z\left(z^{-2}\partial_\mu\xi\right) + \Delta_\perp\xi = 0, \qquad (\Delta - \ell^{-2})a_+ = 0 \tag{5}$$

Where $\Delta_\perp = \partial_x^2 + \partial_y^2$. The Cartesian coordinates $x\,, y$ being the coordinates of the ideal monolayer graphene plane $z = 0$, one easily finds the excitations of the periodic form:

$$\xi = \xi_0 exp(-k^2z^2/2)coskx, \; a_+ = A_+e^{\bar{k}z}cosKx, \; K^2 = \bar{k}^2 - \lambda^2/I \tag{6}$$

Where $\bar{k}\ell > 1$.

RESULTS

By considering the exponential increase in z of the equation (6) signifies the instability of the ideal graphene plane initially mentioned by N.D.Mermin and H.Wagner for the case of mag netic (Wagner, 2012). To explore further, there exist also the ring excitations of the axially-symmetric form:

$$\xi = \xi_0 exp(-k^2 z^2/2) j_0(k\rho) \text{ ,, } a_+ = A_+ e^{im\varphi}, e^{\bar{k}z} j_m(k\rho) \quad (7)$$

Where j_m the Bessel is function of the $m-th$ order, $m = 0,1,2, \ldots..$ and ρ, φ are the polar coordinates in the graphene plane. Thus, our monolayer graphene plane reviles the tendency of bending.

DISCUSSION

The chiral model proposed permit one to describe the ripples structure of the real monolayer graphene surface. In view of equation (5) it should be understood that the dispersion curve reveals the anisotropic nature and has two branches. The first one concerns the transverse a_3- perturbations and has the photon like behavior. The second one concerns the longitudinal a_1- and a_2 perturbation and has the massive behavior as stated in equation (7) above illustrating the Mermin-Wagner instability of the 2-dimensional configuration

CONCLUSION

The hybridize sp-states of valence electrons in the carbon atom was described by SU (2) matrix considered as the order parameter. The chiral model of graphene base on this order parameter was suggested in the long-wave approximation, the proposed chiral model of graphene permits one to describe the ripple structure of the real graphene surface illustrating the Mermin-Wagner instability of the 2D configuration. Also, in view of equation (5) the dispersion curve reveals the anisotropic character of graphene and has to branches: The first one concerns the transverse a_3-perturbations and has the photon-like behavior. The second one concerns the longitudinal a_1, a_2-perturbations and has the "massive" behavior. Thus, our graphene plane reviles the tendency of bending.

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