The structure of the carbon atom and graphene originated from the strict solutions of the wave equation

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The general wave equation

$$\Delta\hat{\Psi} - \frac{1}{c^2}\frac{\partial^2\hat{\Psi}}{\partial t^2} = 0$$

contains information about the structure of matter and many regularities in nature. Analyzing its particular solutions, we have found features relating to the structure of atoms unknown earlier [1]. Here they are.

- Atoms have a quasi-spherical shell-nodal structure identical to the nodal structure of standing waves formed in a three-dimensional wave space, and are in essence neutron molecules.
- Potential polar-azimuthal nodes of spherical shells in stable atoms (nucleon molecules) contain by two coupled nucleons.
- Polar potential-kinetic nodes (not filled with nucleons in the most abundant and stable atoms) are ordered along the z axis of symmetry (in spherical coordinate system) of the atoms.
- Exchange (interaction) between completed nodes inside (strong) and outside (electromagnetic) of the atoms is realized by exchange charges of nucleon and electron on the fundamental frequency,

$$\omega_e = 1.869162559 \times 10^{18}\, s^{-1}$$

The obtained solutions were verified by different ways. All they completely confirmed correctness and validity of the solutions. The shell-nodal structure of the carbon atom is shown in Fig. 1.

Graphene, one-atom-thick layers of graphite, having a two dimensional hexagonal lattice, gives us a new unique possibility for the direct verification of some predictions, originated from the solutions. One of the latter is in the following.

According to modern notions, a two dimensional hexagonal lattice of graphene is regarded as having crystallographic symmetry of a six order. Hence, electrical conductivity of graphene in a hexagonal plane perpendicular to this axis must be isotropic, in full agreement with the basic symmetry theory [2] as having more than two-fold symmetry. This is why an examination of feasible conductivity anisotropy in pristine unstrained graphene has never been undertaken till now, and a question about such studies has never been raised among researchers. For this reason, a talk about an existence of natural conductivity anisotropy in graphene seemed nonsensical.

However, according to the shell-nodal structure of the carbon atom originated from said solutions, graphene has two-fold axis of symmetry [3]. Accordingly, it makes sense to undertake efforts to verify that. The tests are not so complicated, but obtained result can change many things in physics.

Polar potential-kinetic nodes along the z axis (empty and, therefore, undetected in structural analysis) form together an empty channel allowing the ballistic motion of electric charges in graphene (Fig. 2). They divide the hexagonal cell of potential nodes filled with coupled nucleons (detectable in structural analysis) onto two symmetrical halves. The fact that we do not see empty polar nodes forming the ballistic channel does not quite mean that these nodes do not exist. Modern technological means are too imperfect at present to observe all peculiarities of the structure of matter at the atomic level.

The following natural idea has arisen to verify aforesaid theoretical findings. The conductivity along the ballistic channel must differ from conductivity in other directions. Prior laboratory tests conducted quite recently, have confirmed an existence of conductivity anisotropy, *i.e*., the validity of theoretical solutions and predictions, and, hence, the truthfulness of the shell-nodal structure of the atoms, including carbon atoms and their specific ordering in the hexagonal lattice of graphene.

A polar diagram of conductivity anisotropy of graphene has a characteristic elliptical form. Along the major axis of anisotropy, coincident with the ballistic channel, graphene has the highest conductivity and behaves like a metal; in a direction perpendicular to the major axis (along the minor axis) graphene has the lowest conductivity and exhibits semiconducting properties.

Thus, in the framework of the shell-nodal atomic model, specific features of graphene find a natural explanation, including an “unusual” fact noted in [4] that “*graphene is...an interesting mix of a semiconductor...and a metal*...”; and so on.

Graphene anisotropy explains also the fact that graphene nanotubes, rolled-up form of graphene, have either conductivity, metallic or semiconducting. The rolling-up of graphene is realized mainly along two crystallographic directions [5]: along the major axis (we called it the Z-axis) and in perpendicular to it

direction. Nanotubes obtained have the minimal energy of state in these crystallographic directions. The rolling-up of graphene sheets runs spontaneously at the high temperature conditions; it is not yet controlled process. The rolling-up in other directions is thermodynamically unfavourable unstable process and, therefore, is not going on spontaneously.

Thus, these are new and important facts about the properties of graphene, and they should be taken into account in research and applications of this material.

References

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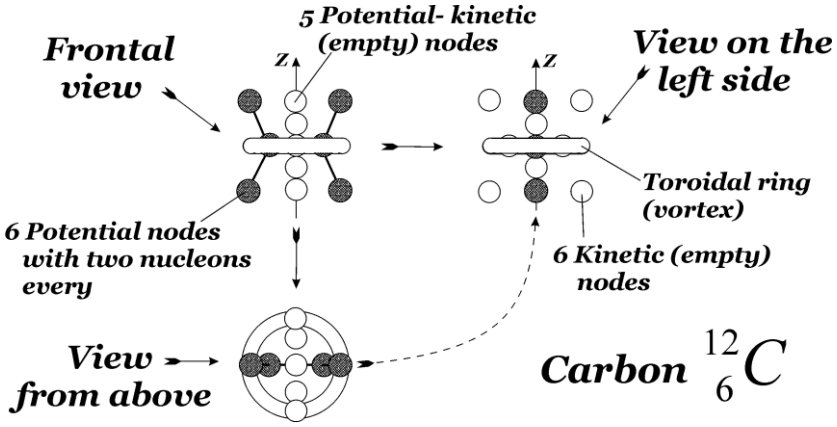

Fig. 1. The structure of a nucleon molecule (“atom”) of carbon-12 originated from particular solutions of the wave equation.

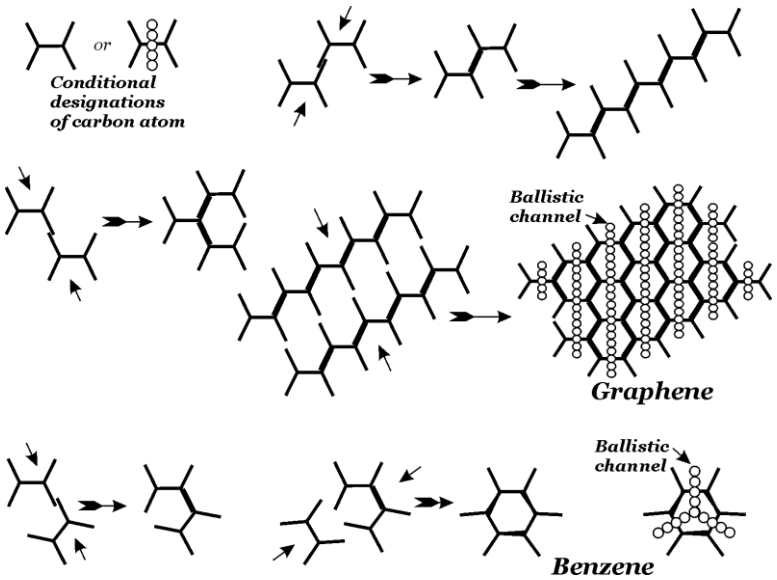

Fig. 2. A conditional designation of the carbon atom, a schematic representation of self-building (assembling) of two-dimensional carbon compounds, and the shell-nodal structure of graphene and benzene. The formation of molecules is realized along strong internodal bonds of contacting atoms (nucleon molecules) by overlapping nucleon nodes with nucleons in them.