Graphene and graphene-based nanostructures

(Preface)

This issue of the journal «Fizika Nizkikh Temperatur» is dedicated to the discovery of graphene — a monolayer graphite — in 2004. First of all, graphene possesses extra-ordinary for condensed matter electronic properties due to specific form of its electronic spectrum. The low energy dispersion of charge carriers (electrons and holes) is described in graphene by massless two-dimensional Dirac Hamiltonian where the role of spin of relativistic fermions plays a pseudospin index connected with the internal two-sublattice structure of the honeycomb lattice of carbon atoms. The Dirac-like behavior of charge quasiparticle excitations in graphene results in many unusual for solid state physics electronic properties of this material such as anomalous («half-integer») quantum Hall effect (observed even at room temperatures) and the minimum conductivity of neutral, or undoped, graphene samples of the order of conductance quantum. Unique electronic properties and the scalability of graphene devices to nanoscale sizes make this — now in some sense prima material — a very promising component for a future nano- and even spin-electronics. On the other hand, recently, it was experimentally shown that mechanical properties of carbon monolayer (in particular, its second- and third-order elastic stiffness) are one of the best among strongest materials ever measured.

Another aspect of the current extra-ordinary interest to graphene is connected to true fundamental physics. Dirac electronic spectrum in pure graphene makes it possible to theoretically study and experimentally test unusual and still unobserved effects of relativistic physics, such as Zitterbewegung (jittery motion of the wave functions), Klein paradox, atomic collapse and others, in laboratory. Though, every researcher should have in mind that Dirac fermion speed in graphene is 300 times less than the speed of light. Besides, because of the quasiparticles in graphene exist in slightly curved plane space a large similarity with particle propagation in gravitational field is also appeared. It is also known that conducting electron system in metallic single wall carbon nanotubes is described by the theory of Luttinger liquid and the most significant prediction of this theory were observed in experiments with these remarkable nanoobjects. All above said sound that the scientific potentialities of graphene seem to be unlimited.

Graphene, being a novel isolated material, for many years was known as a principal building block of carbon-based structures («zero-dimensional» resonant valence bond molecules — benzene, fullerenes and metallofullerenes, «one-dimensional» carbon nanotubes and graphene stripes, «three-dimensional» graphite). For instance, last decade carbon nanotubes were one of the hottest topic of theoretical and experimental investigations in physics and chemistry. Therefore it is evident why Editorial Board of the journal came to the conclusion that the appearance of the special «graphene issue» should be important and interesting.

The papers published in this special issue of «Fizika Nizkikh Temperatur» are original investigations and short reviews where the recent progress in the physics of graphene, carbon nanotubes and semiconducting quantum wires is in detail discussed. We hope that our proceedings published on the top of interest to graphene will contribute to better understanding of the interplay of relativistic effects and crystal state properties of these remarkable one- and two-dimensional solid state systems.

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