Graphene nanostructures

The year 2019 marks the 15th anniversary of the discovery of graphene by Andre Geim and Kostya Novoselov together with their colleagues (for graphene prehistory see reviews [1–3]). Graphene, a one-atom-thick layer of carbon atoms packed in the honeycomb lattice, is the first really two-dimensional material with many remarkable physical properties, some of them are a consequence of its band structure whose the valence and conduction bands touch at the so-called Dirac points. Theoretically, it was shown a long time ago that quasiparticle excitations in graphene have a linear dispersion near Dirac points and are described by the massless Dirac equation in two space dimensions. The observation of anomalous integer quantum Hall effect in graphene is in perfect agreement with the theoretical predictions and became a direct experimental proof of the existence of gapless Dirac quasiparticles in graphene. Besides many possible practical applications, graphene can be used as a bench-top particle-physics laboratory allowing to investigate the fundamental interactions of matter [4]. In fact, it provides a condensed-matter analog of quantum electrodynamics and some QED-like effects such as the Klein tunneling and supercritical atomic collapse were recently observed in graphene experimentally.

The discovery of graphene has led to an explosion of experimental and theoretical works in the study of materials with the relativistic-like spectrum of quasiparticles whose dynamics are governed by the Dirac or Weyl equation, such as topological insulators [5] and three-dimensional Dirac and Weyl semimetals [6]. Moreover, since the properties and energy dispersion of the electron states in condensed matter systems are constrained by the crystal space group rather than the Poincare group, this gives rise to the possibility of fermionic excitations with no analogs in high-energy physics [7]. Indeed, some materials host fermionic excitations with three-fold degeneracies near nodal points (the so-called pseudospin-1 fermions) and provide an interesting platform for studying exotic physical properties such as the Fermi arcs, transport anomalies, topological Lifshitz transitions, the dispersionless (flat) bands which may lead to the realization of many very interesting strongly correlated states.

The issue contains works on two-dimensional systems related to graphene and its cousins. The review paper by M.V. Strikha *et al.* is focused on recent predictions of nontrivial physical phenomena taking place in the nanostructure single-layer graphene on ferroelectric substrate, which are related with magnetic field. The integer quantum Hall effect in a graphene channel with a *p-n* junction at domain wall in a strained ferroelectric film is considered. The ferromagnetic dielectric–grapheme–ferroelectric substrate system is presented as a promising non-volatile device for modern spintronics. It is demonstrated, that if the Fermi level in the graphene channel belongs to energy intervals where the graphene band spectrum, modified by EuO, becomes sharply spin-asymmetric, such a device can be an ideal nonvolatile spin filter.

Absorption of atomic and molecular species in carbon cellular structures is the subject of a brief review by N.V. Krainyukova *et al.* In the review paper by I.A. Gospodarev *et al.* the phonon density of states and thermodynamic properties of graphene-based nanostructures are calculated.

The paper by Yu.V. Skrypnyk and V.M. Loktev studies the electronic spectrum of graphene with a single point impurity. It is well known that a well-defined resonance state can arise in the electronic spectrum of graphene when there is a single impurity atom in the lattice, and its tight-binding potential is sufficiently large by absolute value. The authors show that, in the domain of the well-defined impurity resonance, the local density of states (LDOS) at the first-nearest neighbor of the impurity site can be obtained with sufficient accuracy by multiplying the magnitude of the LDOS at the impurity site with a certain factor, which is proportional to the squared impurity potential.

The paper by I.V. Sukhenko *et al.* studies differential entropy per particle in three-dimensional Dirac semimetals in the external magnetic field. This quantity can be measured in the experiment where modulation of the sample temperature changes the chemical potential leading to recharging current in the gated structure. The authors show that in the presence of a magnetic field the dependence of differential entropy per particle on the chemical potential near a charge-neutral point is quite different from the corresponding dependence in graphene due to different roles of zero Landau level in these materials.

In the paper by V.A. Lykah and E.S. Syrkin the adsorption of graphene and carbon nanotubes are considered using first principle charge transfer calculations. The paper by A.V. Rusakova *et al*. is devoted to the synthesis and micromechanical properties of nanocomposites based on graphene oxide. The measurement of the temperature dependence of electrical conductivity of reduced graphene oxide composite with single-walled nanotubes and reduced graphene oxide films is the subject of the paper by N.V. Kurnosov *et al*. The influence of pulsed high-frequency discharge on low-temperature sorption of hydrogen of graphene oxide was studied in the paper by A.V. Dolbin *et al*.

We hope the articles presented in the issue will be useful to readers of the journal and interesting to researchers working in the area of graphene and related materials.

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