Transport (electronic) properties of AB -bilayer graphene in the external magnetic and electric fields with general gap energy

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The results of a theoretical study of an influence of different kinds of the ground state energy gaps at the Dirac K and K' points in the quasiparticle spectrum on longitidunal and Hall optical conductivities of graphene AB-bilayer [1] on the base of Quantum Field Theory (being by the Quantum Electrodynamics) in (2+1)-dimensional space-time are presented. The exact analytical expressions for optical conductivities in electric (determining the gap of the order 5-20 meV) and magnetic fields (3-10 Tesla) are derived with the use of the 4-band microscopic Hamiltonian [2] but with general ground energy gap, depending on valley (ξ=+1,-1) and spin (s=h/2, -h/2) discrete variables. A U(1) -gauge-invariant Dirac-type Hamiltonian is linear with respect to covariant derivatives which include magnetic field potential perpendicular to bilayer sheets is suggested. To obtain the conductivities an exact Green function for the Schrödinger equation is derived as a matrix sum with respect to the Landau energy levels obtained with neglecting of trigonal warping of the carriers spectrum corresponding to hopping parameter γ_3= 0,315 eV. The current-current correlation tensor function is constructed on the base of this Green function. The resulting conductivities (in the microwave and infrared optical regions) are derived using the Kubo formula and take into account the dependence on temperature and chemical potential. They being in an analitical form provide the basic optical transitions between the Landau levels with the selection rule, Δn=1, while neglecting trigonal warping. The latter peculiarity is effectively taken into account as the perturbation with respect to hopping parameter γ_1= 0,4 eV in rather strong magnetic field [3]..

The limiting cases for the direct current conductivities are analyzed and the relations among the Hall conductivities and Faraday and Kerr angles, when the radiation transmits through the bilayer samples on Si and Si/SiO_2substrates in the electric and magnetic fields, are derived in the form being consistent with experimental data in dependence of general energy gap realization. The results predicted some regimes (quantum valley Hall state, layer antiferromagnet state, quantum anomalous Hall state, quantum spin Hall state) of ground states realization under external fields control being useful for nano and microoptoelectronic devices on a base of graphene developing results of ref. [4] for low-energy 3-band model in [5, [6].

The influence of deformation process in strained graphene both on the changing of the optical conductivities (determining the differential Ohm law) and on the heat transport properties for bilayer on substrate presents the nearest research program with use of mechanical computational technique.

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