Indirect interaction research of the double layer impurity graphene in the framework of s-d model

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Recently the big attention of researchers is concentrated on calculations of electronic, magnetic, conductive changes and other properties of graphene, caused by introduction of single atomic impurity on its surface [1 - 4]. From the data received at the analysis of substances properties with collectivized electrons, it is known, that at impurity introduction with *d*- or *f*- electrons strong updating of electronic or magnetic properties is possible. The most known fact is, apparently, Kondo effect is the change of conductive properties at impurity introduction with temperature change.

Therefore research of the collective effects connected with interaction of the impurity with a crystal lattice of graphene, i.e. RKKY (Ruderman-Kittel-Kasuya-Yosida) interaction [5 - 7] is very interesting.

In the given work in the framework of s-d model features of RKKY-interaction in double-layer impurity graphene have been calculated. Atomic hydrogen was considered as an impurity. Calculations have shown, that on small distances antiferromagnetic ordering of the impurity spins is preferable, and with distance increasing the ordering becomes ferromagnetic. Dependences of exchange interaction factor on parameters are shown.

Dispersion relation for the impurity graphene was obtained analitically by using the mathematical formalism of Green's functions. Then, using the Frohlich's method of calculating indirect interaction expression for the indirect coupling constant depending on the distance between the impurities was obtained. The dependence of the indirect interaction for different values of the external electrostatic potential is shown in Figure 1.

The increase of electric field intensity leads to the strongly oscillating dependence of indirect interaction of the impurity spins on the distance between impurities that can be connected with resonant transitions of the electrons between the split levels.

The increase of an external magnetic field also leads to non-uniform distribution of the impurity spins, formation of domain structures, alternation of areas of ferromagnetic and antiferromagnetic orderliness is actually observed.

Thus, it is quite probable, that graphene sheets, processed by hydrogen plasma, are useful for creation of spintronics devices, changing magnetic properties of a material by variation of external parameters.

The feature of the RKKY-interaction of adsorbed atoms on the surface of double-layer graphene, made in this paper is that it considered the exchange interaction on the basis of the total (including short-wave part) electron spectrum of the crystal lattice. The dispersion relation includes electrons pulses in the whole Brillouin zone.

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References:

[1] D. Henwood, J. David Carey, Phys. Rev. B. **75** (2007), 245413.
[2] Alejandro Lugo-Solis and Igor Vasiliev, Phys. Rev. B. **76** (2007), 235431.
[3] Rudro R. Biswas and Subir Sachdev.Phys. Rev. B. **76** (2007), 205122.
[4] M I. Katsnelson, Phys. Rev. B **74** (2006), 201401 (R).
[5] Annica M. Black-Schaffer. Phys. Rev. B **82,** (2010), 073409
[6] V. K. Dugaev, V. I. Litvinov, J. Barnas. Phys. Rev. B **74,** (2006), 224438.
[7] T. Stauber, N. M. R. Peres, F. Guinea, A. H. Castro Neto, Phys. Rev. B. **75** (2007), 115425.

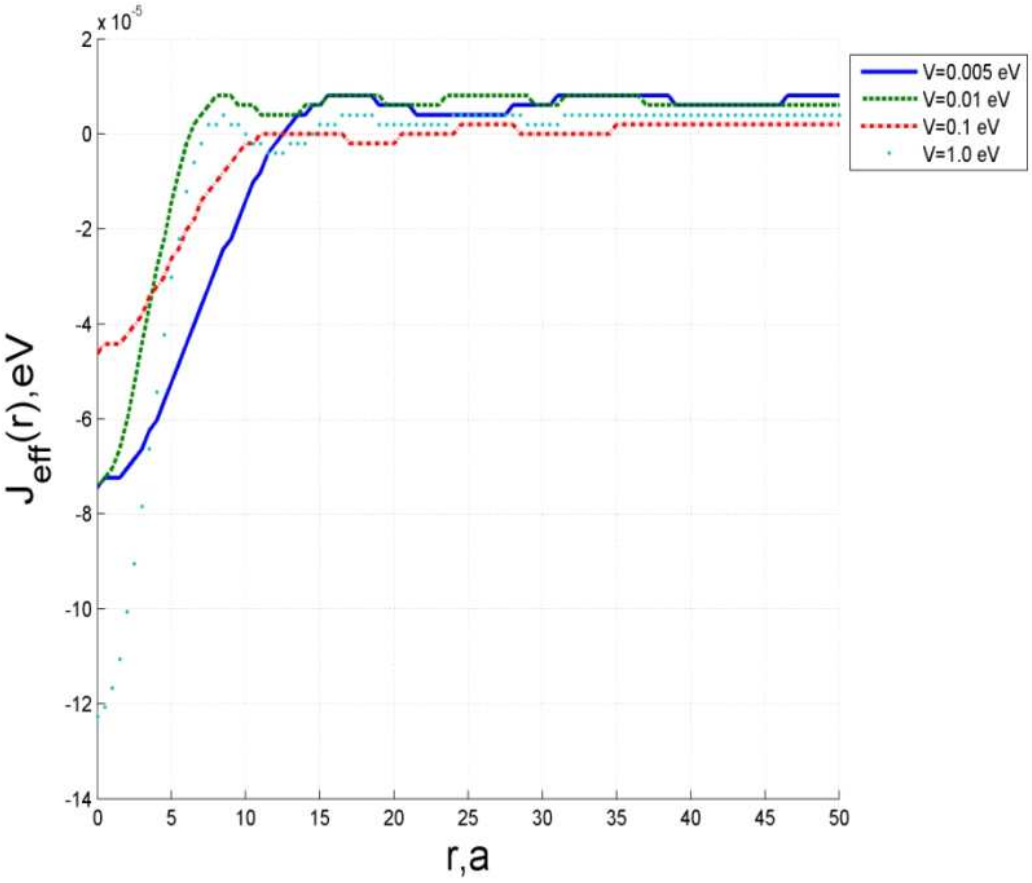

Figure 1. The d*ependence of exchange interaction distribution on the distance for various values of electrostatic potential. The distance is expressed in terms of a constant lattice, a=2.49 Å.*