Nanocomposites and nanomaterials

Supercritical instability in graphene with two charged impurities

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Motivated by a recent observation of atomic collapse in clusters of charged Ca impurities in graphene[1], we study using the continuum model the supercritical instability in the simplest cluster of charged impurities in graphene formed by two similar impurities whose charges are subcritical like in the experiment. On the other hand, we assume that the total charge of two impurities $\zeta = 2Z\alpha$ exceeds the critical one $\zeta_c = 1/2$ if these impurities are placed together. Therefore, at fixed ζ the supercritical regime sets in for a certain critical distance R_{cr} between the impurities. The critical distance R_{cr} in the system of two charged centers is defined as that at which the electron bound state with the lowest energy reaches the boundary of the lower continuum.

A variational calculation of the critical distance R_{cr} is carried out[2,3]. The energy and width of a quasistationary state as functions of the distance between two impurities are derived in the quasiclassical approximation[2].

The critical distance $R_{cr} \to 0$ as $\zeta \to 1/2$ and $R_{cr} \to \infty$ as $\zeta \to 1$ (in the last case each charge tends to the critical one). Our results show that at fixed ζ the critical distance tends to infinity when the effective mass of quasiparticle $m \to 0$. This means that in the considered model, as soon as the total charge of two impurities exceeds the critical one $\zeta_c = 1/2$, the system is in the supercritical regime for any distance between the impurities[2,3].

In the real specimen, there is always a remnant density of charge carriers that screens the Coulomb potential. This may make difficult to observe experimentally these resonances beyond a certain distance between the impurities.

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2. *Sobol, O.O., Gorbar, E.V., and Gusynin, V.P.*, Supercritical Instability in Graphene with Two Charged Impurities // Phys.Rev. B.-2013.-**88**,.-P.205116.
3. *Sobol, O.O.*, Variational method for the calculation of critical distance between two Coulomb centers in graphene // Ukr.J.Phys.-2014.-**59**, N 5.-P. 531-540.