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Theory of an inhomogeneous electron structure of graphene at its neutrality point

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Graphene is a surprisingly good conductor. Despite its direct exposure to various sources of disorder (charged impurities, non-uniformity of the substrate, etc.), graphene remains conductive even when the nominal concentration of both electron and hole carriers drops to zero - the neutrality point (NP). Theory of the minimal conductivity of graphene is an outstanding challenge because of the non-perturbative nature of disorder at the NP and the still unsettled question of which type of disorder is really dominant. Here, we report on our progress towards analytical solution of the model of graphene subject to the disorder in the form of in-plane charged impurities. Our approach is asymptotically exact for graphene in high dielectric-constant environment where Coulomb interactions of electrons with impurities and electrons with each other become weak. We show that screening of the impurity potential is nonlinear, producing a fractal structure of electron and hole puddles. Statistical properties of this density distribution as well as the charge compressibility of the system are calculated in the leading-log approximation. The minimal conductivity is shown to depend logarithmically on the dielectric constant. We compare our results with other theoretical works and current experiments. Our findings suggest that in real samples charged impurities are either not exactly coplanar with graphene, or are correlated, or are not the only source of disorder. This work is supported by the NSF.