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Ground-state of Two-dimensional Graphene in the Presence of Random Charged Impurities[1]

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The low energy electronic excitations of graphene are described by a massless Dirac fermion model. In clean isolated graphene the Fermi energy lies exactly at the Dirac point where the linear chiral electron and hole bands cross each other. Close to the Dirac point the average carrier density vanishes and the density fluctuations are expected to dominate the physics of graphene. In current experiment the fluctuations are mostly due to quenched disorder. In this talk I present the Thomas-Fermi-Dirac (TFD) theory [1] to calculate the carrier density of graphene in presence of disorder. The TFD theory includes the effects of non-linear screening, exchange and correlation. The approach is independent of the disorder source and very efficient allowing the calculation of disorder-averaged quantities that can be directly compared with experiments. Recent transport results strongly suggest that in current graphene samples charge impurities are the main source of disorder. I then present the results of the TFD theory for this case. I show that close to the Dirac point the carrier density breaks-up in electron-hole puddles and is characterized by two types of inhomogeneities: wide regions of low density and sparse narrow regions of high density and a typical correlation length of 10 nm. I present detailed results that show how the disordered averaged quantities characterizing the carrier density profile depend on the experimental parameters. I show that at finite voltages the density probability distribution has a bimodal character providing direct evidence for the existence of puddles over a finite range of gate voltages. In graphene the exchange-correlation term increases with density contrary to parabolic-band electron liquids and because of this it tends to suppress density inhomogeneities. I show that this effect becomes very important close to the Dirac point, especially at low impurity densities.

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