Physics of graphene nano-ribbons

Sandler, N[1]

[1] *Nanoscale and Quantum Phenomena Institute - Ohio University*

Graphene, the single layer form of crystalline carbon, has been the focus of tremendous scientific activity since its isolation in 2004. Besides its remarkable properties of good conductivity and structural flexibility, the low-temperature/energy properties can be obtained by modeling the material with Dirac-type Hamiltonians, opening the possibility of studying QED phenomena in a condensed matter system. Numerical models based on tight-binding calculations for semi-infinite geometries revealed the relevance of edge termination on graphene properties: armchair edges produce either metallic or insulating ribbons while zigzag only produce metallic ones. Furthermore, zigzag ribbons are expected to exhibit a new insulating phase of matter, the Quantum Spin Hall (QSH) phase, when intrinsic-spin orbit (I-SO) interactions are considered[2]. The QSH phase is characterized by the presence of chiral edge states, with electron momentum coupled to its spin. Although much theoretical work has been carried out on graphene, questions on the role of enhanced Coulomb interactions resulting from confined geometries remain opened. The aim of this talk is to provide insight into these issues by studying tight-binding and Dirac-type model Hamiltonians that include the I-SO and unscreened Coulomb interactions for ribbons with both edge terminations. Our results indicate that metallic armchair ribbons, with no Coulomb interaction, retain their conducting properties in the presence of the I-SO interaction regardless the strength of the coupling. In the presence of an unscreened Coulomb interaction, the small-momentum electron-electron scattering opens a width (W)-dependent charge gap in the spectrum of half-filled (neutral) ribbons that vanishes in the limit of infinite width as 1/W, in agreement with recent experimental observations. The gap survives in the presence of realistic I-SO interactions. Calculated correlation functions, reveal an incipient magnetic order along the edges analogous to the one predicted in the QSH phase for zigzag ribbons. In zigzag ribbons, the character of localized edge wavefunctions for non-interacting electrons changes from a strong localization to a damped oscillatory behavior as the I-SO coupling is changed. Unscreened Coulomb interactions open a charge gap and destroy the chiral property of the edge states, thus rendering the QSH phase instable. A numerical analysis of the width-dependent gap suggests an exponential vanishing with W in contrast with results for armchair ribbons.