Monolayer-bilayer graphene quantum dots

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Abstract

Quantum dots (QDs) in monolayer and in bilayer graphene are the subject of a considerable number of both theoretical and experimental studies [1] with the hope of benefiting of the exceptional properties of graphene, such as high carrier mobility and long spin coherence time for electronic and particularly spintronic applications. QDs in monolayer graphene (MLG) are fabricated by direct etching of a pristine graphene sheet into the small flakes in which the shape and edges of the dot become very important [2]. Realistic few layer graphene samples extracted from graphite often contain patches of both MLG and BLG. Electronic transport measurements demonstrated the importance of monolayer-bilayer interface states in transport and electronic properties of quantum structures fabricated based on such samples [3, 4]. The monolayer-bilayer interface states were theoretically investigated in a system of two semi-infinite MLG and BLG sheets with both zigzag- and armchair-terminated junctions in the absence [5] and presence [6] of an external magnetic field.

The existence of both monolayer and bilayer islands in exfoliated graphene samples, motivated us to propose different types of graphene QDs consisting of both MLG and BLG. Using tight-binding model, we study the confined states in two different hybrid monolayer - bilayer systems: (i) a hexagonal anti-dot in bilayer graphene under a perpendicularly applied electric field (Fig. 1(a)) and (ii) a hexagonal bilayer graphene dot surrounded by a hexagonal region of monolayer graphene (Fig. 1(b)). The behavior of the energy levels as a function of dot size (L) and in the presence of an external magnetic field is investigated. In the presence of electrostatic bias we find that the energy spectrum of the dots shows different type of states, i. e. dot-localized states, edge states and hybridized dot-edge states. For the dots with armchair edges the energy spectrum only exhibits dot-localized states. We demonstrate that these dot-localized energy levels inside the gap formed by the potential bias decrease as expected as the dot size increases, while edge and hybridized states exhibit an opposite behavior. In the presence of both magnetic and electric fields for a zigzag dot we observe states presenting character of chiral states inside the gap and the convergence of the energy spectra to the Landau levels in all system configurations.

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Figures

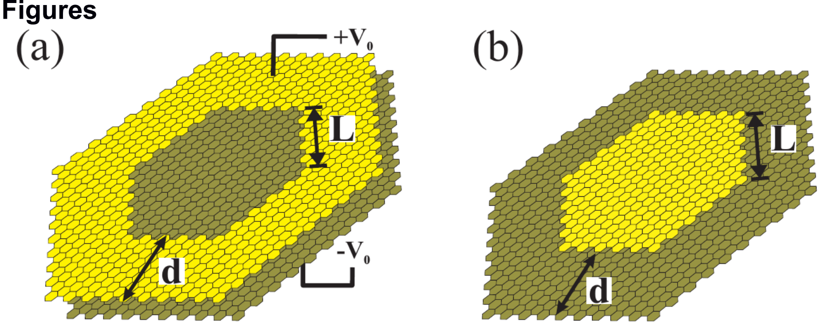

Fig. 1: Schematic illustration of two different systems of hybrid monolayer-bilayer graphene QDs.