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Exploring Collapsed Single-Walled Carbon Nanotubes as Quasi-1D Electronic Systems

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The collapse of large-diameter, chiral, single-walled carbon nanotubes (SWCNTs) can form bilayer-like ribbons, characterized by quasi-one-dimensional (1D) moiré superlattices and exotic electronic behavior. Using analytical treatments of diameter, chirality, and moiré twist angles, we demonstrate that the moiré wavelength approximates the width of the collapsed SWCNT, producing quasi-1D moiré potentials along its longitudinal axis when the chiral indices are fixed at (n, m=1). This geometry departs from standard two-dimensional twisted bilayer systems by confining the moiré pattern to one dimension. Changes in band structure upon collapse are explored via tight-binding Hamiltonians and Bloch wavefunctions, substantiating that numerical or iterative methods are required for precise predictions. However, by projecting the low-energy Dirac Hamiltonian near the graphene K-point onto the tube's longitudinal axis, we obtain a tractable quasi-1D Hamiltonian that yields approximate insight into the emergent bands when truncated and diagonalized. This projection is akin to slicing a 2D (planar) twisted bilayer graphene sheet into a strip only one moiré unit wide, yielding a quasi-1D ribbon. Toy model calculations employing this slicing approach were carried out to validate the method, successfully reproducing the band structures anticipated for monolayer nanoribbons. These findings establish a foundation for understanding moiré-induced electronic properties in quasi-1D systems, opening pathways for theoretical and experimental exploration of novel low-dimensional quantum phenomena.

Keyword-1

Moiré Superlattices

Keyword-2

Quasi-One-Dimensional

Keyword-3

Collapsed SWCNTs

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