Relativistic Dispersion of Massive Electrons in Graphene Nanoribbons

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Quantum confinement of massless Dirac fermions in graphene nanoribbons (GNRs) leads to the opening of a gap and a non-zero effective mass of the charge carriers, an essential step for the integration of such materials as circuit elements. Previous determinations of the effective mass using experimental band dispersions have yielded surprisingly inconsistent results [1-3]. Here we show that the experimental dispersion relation of 6-aGNRs determined by Scanning Tunnelling Spectroscopy can be accurately described with a model that discretizes the full band dispersion of graphene. Our results demonstrate that the electrons in GNRs satisfy a hyperbolic relativistic dispersion relation for massive particles. A parabolic fit will therefore yield accurate values of the effective masses only for low electron momentum, so that the electron wavelength is much larger than the "Compton" wavelength of the relativistic electrons.

References:
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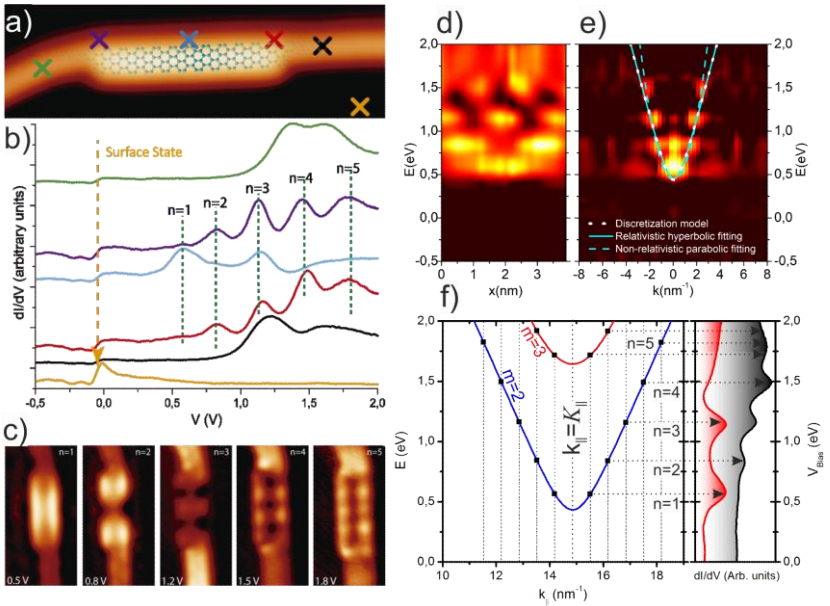

Fig 1. (a) 4,3 × 9,7 nm^2 STM topographic image of 6-aGNR linked to two polyphenylene wires with the chemical scheme superimposed. (It = 50 pA, Vb = -500 mV,). (b) STS spectra taken at different positions indicated in (a). (c) Differential conductance maps recorded at the energies of the confined states. (d) Stack of STS spectra recorded along the long axis of the 6-aGNR box. (e) Line-by-line FFT of a) showing the dispersion relation, E vs k. Dotted white line: dispersion calculated with our discretization model. Full blue line: relativistic hyperbola (maximum group velocity v = 8.1 × 105 m/s; effective mass 0.12me). Dashed blue line: non-relativistic parabola (bottom of the band +0:43 eV; effective mass 0.19me). (f) Left panel: Conduction subbands for 6 aGNR. Vertical dotted lines correspond to the discrete values of the parallel momentum and the corresponding discrete energy levels are highlighted with square symbols. The correspondence between these calculated energy levels and the peaks of the experimental dI/dV curves (right panel) is shown by horizontal arrows.