Quantum Confinement in Aligned Zigzag "Pseudo-Ribbons" Embedded in Graphene on Ni(100)

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Lateral confinement is one of the prominent strategies for tailoring the electronic properties of graphene and other 2D materials. The most typical example of such 1D quantum confinement is the nanoribbon, where the nanometer width leads to the opening of an electronic bandgap. Nonetheless, it is still under debate whether properties induced by lateral quantum confinement of electrons can be obtained without creating physical edges as for nanoribbons, i.e. while preserving the integrity of targeted two-dimensional material. To address this question, we will demonstrate and discuss the formation of one-dimensional, ribbon-like structures with zigzag-edges embedded in a continuous single-layer graphene sheet grown on Ni(100).[1] We employ state-of-the-art Scanning Tunneling Microscopy and Spectroscopy, Low Energy Electron Microscopy, X-ray PhotoElectron Emission Microscopy and *ab-initio* calculations to prove that such graphene 'pseudo-ribbons' (GPRs) exhibit many of the properties found in zigzag-nanoribbons while avoiding the limitations that prevent their practical implementation in electronic devices, e.g. presence of atomic defects, cumbersome production of ribbons with suitable length and random alignment with the substrate. We find that the ribbon-like structures we produced are parallel, 1.4 nm wide, hundreds of nm long, and show one-dimensional states comparable to nanoribbons of similar size with physical zigzag edges. On the basis of theoretical calculations, we demonstrate that, apart from the lateral confinement effect, GPRs exhibit the same band structure and the same carrier mobility of freestanding graphene, even while embedded in a heavily-doped graphene sheet. Remarkably, we report, for the first time, direct measurements on how the electronic band structure of a two-dimensional material is affected by the induced one-dimensional lateral quantum confinement. The GPR alignment with the substrate is so precise that it allows for angle-resolved photoemission spectroscopy (ARPES) experiments spanning the whole First Brillouin Zone. The effect of one-dimensional confinement on ARPES will be carefully discussed and rationalized in terms of geometric blurring and effective band dispersion.

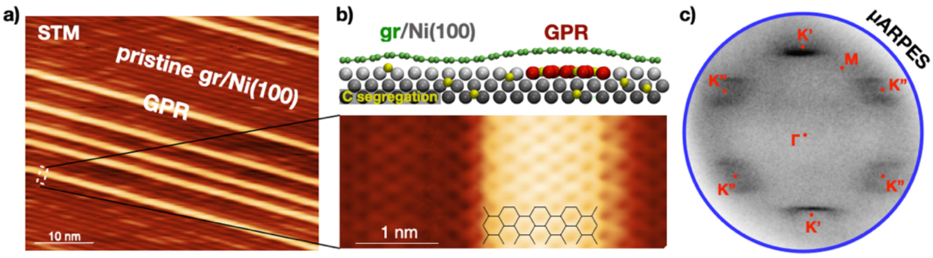

Fig. 1. a) STM image of graphene/Ni(100) presenting 1D moiré pattern in pristine and lifted "pseudo-ribbons" (GPR). b) hi-res STM image of a GPR and its model structure in side view. GPRs are produced by carbon segregation and formation of interfacial nickel carbide (in red). c) *k*-space mapping of photoemitted electrons. The graphene Dirac cones are distorted by the 1D character of GPRs.

[1] A. Sala *et al.,* Adv. Funct. Mater. **32**, 2105844 (2022)