Atomically precise graphene nanoribbons for quantum electronics

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Atomically precise graphene nanoribbons (GNRs) have attracted much interest from researchers worldwide, as they constitute an emerging class of quantum-designed materials tailored by controlling their width and edge structure during chemical synthesis [1-3]. The major challenges toward their exploitation in electronic applications include reliable contacting, complicated by their nanometer size, and the preservation of their intrinsic physical properties upon device integration [4]. Here, we report on the device integration of armchair GNRs into various device architectures with different electrode materials [5]. First, we demonstrate an improved tunability of GNRs quantum dot (QD) behavior thanks to multiple nanometer-sized gates [6]. Second, beyond graphene-based contacts, we demonstrate the successful contacting and characterization of individual GNRs using single-walled carbon nanotubes (SWNT) electrodes and multiple gates. We observe well-defined quantum transport phenomena, including Coulomb blockade, excited states, and Franck-Condon blockade, indicating that a single GNR was contacted [7]. In addition, we demonstrate the encapsulation of GNRs in hexagonal boron-nitride and the contacting using metallic side contacts. These experimental realizations of advanced contracting and gating pave the way for the integration of GNRs in quantum devices to exploit their topologically trivial and non-trivial nature.

References

[1] P. Ruffieux *et al.*, On-surface Synthesis of Graphene Nanoribbons with Zigzag Edge Topology. *Nature* 531, 489 (2016).
[2] J. Cai *et al.*, Atomically precise bottom-up fabrication of graphene nanoribbons. *Nature* 466, 470-473 (2010).
[3] Z. Chen *et al.*, Graphene Nanoribbons: On-surface Synthesis and Integration into Electronic Devices. *Adv. Mater.* 32, 2001893 (2020).
[4] H. Wang *et al.*, Graphene nanoribbons for quantum electronics. *Nat. Rev. Phys.* 3, 791-802 (2021);
[5] J. Zhang *et al.*, Contacting atomically precise graphene nanoribbons for next-generation quantum electronics. *Matter* 3, 2397 (2022).
[6] J. Zhang *et al.*, Tunable quantum dots from atomically precise graphene nanoribbons using a multi-gate architecture. *Adv. Electron. Mater,* 2201204 (2023);
[7] J. Zhang et al., Ultimately-scaled electrodes for contacting individual atomically-precise graphene nanoribbons. arXiv:2209.04353.

Figures

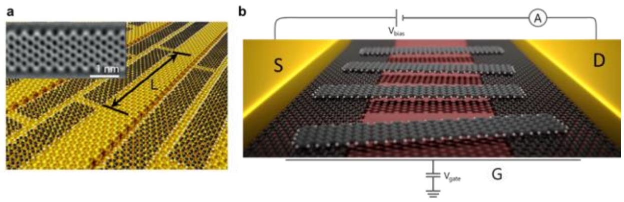

Figure 1: Atomically precise GNRs and their device integration. (a) Atomically precise GNRs illustrated by a sketch and a scanning tunneling microscopy image (inset). (b) Integration of GNRs into devices for transport measurements.