On-Surface Synthesis and Characterization of Gulf-Edged Chiral Graphene Nanoribbons

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On-surface synthesis enables the fabrication of graphene nanoribbons (GNRs) with atomic precision, allowing tunability of their electronic, optical, and magnetic properties by engineering their edge structure and width [1]. However, progress on on-surface synthesized chiral GNRs (chGNRs) remains limited due to the lack of suitable precursors [2]. Here, we report a new synthesis motif of a gulf-edged (4,2,5)-chiral GNR ((4,2,5)-gchGNR) via on-surface synthesis in ultra-high vacuum conditions. The rationally designed precursor facilitates the fabrication of chGNR with an odd-number width. Growth steps are monitored using scanning probe microscopy, and the atomic structure is confirmed by non-contact atomic force microscopy. Combining scanning tunneling spectroscopy with theoretical simulations, we identify (4,2,5)-gchGNR as a closed-shell semiconductor with a bandgap of 1.8 eV. Raman spectroscopy further reveals its vibrational properties, including a distinctive mode at 1210 cm^{-1} that can be associated with C-H bond bending at the gulf-edge. Raman analysis also uncovers ambient instability, despite the large bandgap and non-spin-polarized edges—consistent with prior reports linking GNR stability to zigzag edge features, present in the gulf-edge (Figure 1). In summary, this study introduces a rationally designed chGNR synthesis motif and characterizes its properties correlatively, offering valuable guidelines for future chGNR synthesis strategies.

References

[1] Houtsma, R.K., De La Rie, J., Stöhr, M., Chemical Society Reviews, 11 (2021) 6541–6568.
[2] Deniz, O., Sánchez-Sánchez, C., Chen, Q. et al., Carbon, (2025) 120610.

Figures

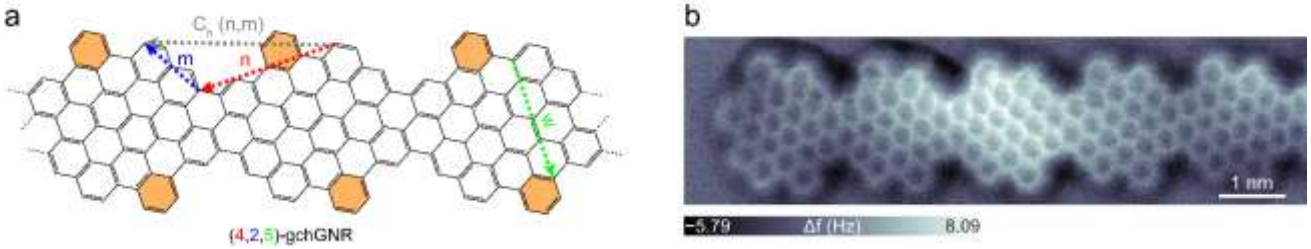

Figure 1: (a) The structure of (4,2,5)-gchGNR. The chiral vector C_h (n,m) and the width w are indicated with arrows. The benzene ring responsible for forming the gulf edge is highlighted with color. (b) High-resolution non-contact atomic force microscopy frequency shift image of (4,2,5)-gchGNR using a CO-functionalized tip with oscillation amplitude of 100 pm.