

Atomic-resolution visualization of non-planar graphene nanoribbon by using transmission electron microscopy

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Keywords: Graphene nanoribbon; Transmission electron microscopy

Synthesis of atomically precise graphene nanostructures was achieved by the development of the “bottom-up” method and revealed the unique chemical properties depending on their structures.¹ While these structures were mostly planar, the non-planar graphene nanoribbon (GNR) has attracted much attention because they are expected to have unprecedented chiroptic, mechanical, and electromagnetic properties. However, their structural characterization is very challenging. Scanning probe microscopy can visualize the planar structure at atomic resolution, but the high resolution cannot be achieved for non-planar structure.

Here we report the observation of fjord-GNR,² non-planar GNR with helically twisted structure, by using transmission electron microscopy (TEM). The isolation of a single GNR was achieved by covalent anchoring to an amino group introduced on the tip of carbon nanohorn and washing out excess GNRs. Moreover, the edge-chlorination reaction assisted the structural analysis of GNR by increasing the contrast in TEM images (Figure 1a). The dotted contrast of Cl atoms in TEM image was well reproduced by simulation analysis (Figure 1b).

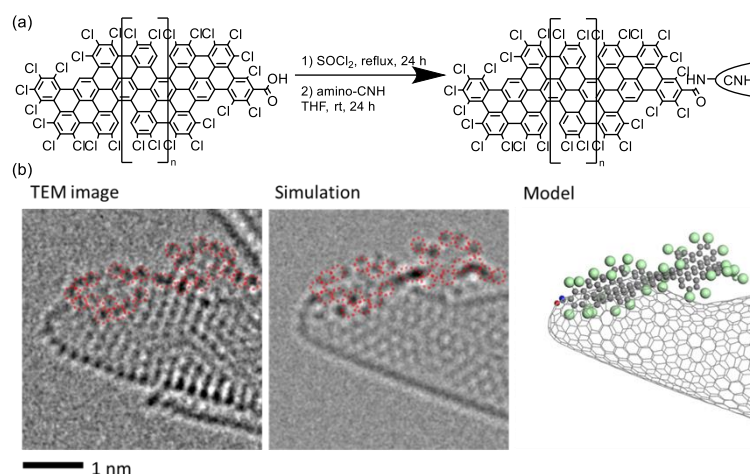


Figure 1. TEM observation of a non-planar graphene nanoribbon. (a) Molecular structure of chlorinated fjord-edged GNR (Cl-FGNR) and reaction with amino-functionalized carbon nanohorn. (b) TEM image, its simulation, and a corresponding molecular model of Cl-FGNR.
1) A. Narita, et al. *Chem. Sci.* **2019**, *10*, 964. 2) Yao, X. et al. *J. Am. Chem. Soc.* **2021**, *143*, 5654.