Bottom-up Synthesis and Characterization of Nanoporous Graphene Structures with Graphene or Biphenylene-type Fusion

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The application of graphene derivatives in semiconductor devices such as field-effect transistors requires band gap tuning, which can be achieved, for instance, with the insertion of nanopores[1]. The bottom-up on-surface synthesis in ultra-high vacuum, using haloarene precursors on catalytic noble metal surfaces, allows for the synthesis of atomically well-defined nanoporous graphene (NPG) structures[2,3] suitable for such device applications.

Here we use a new approach to synthesize novel NPG structures. Firstly, we synthesize porous graphene nanoribbons (p-GNRs) on Au(111) and Au(788) using 7,10-dibromo-1,4-diphenyl-triphenylene (DBDT)[4,5]. LT-STM/STS, NC-AFM and ARPES measurements show that p-GNRs grow with low-number of defects and exhibit semiconducting character.

When the p-GNR coverage is high on Au(111), a subsequent thermal annealing to 500°C induces the formation of diverse NPG structures with either graphene-type or biphenylene-type fusion (see Figure 1). The structural and electronic properties of these intriguing NPG structures are characterized with LT-STM/STS, NC-AFM and supported with density functional theory (DFT) calculations. DFT shows that while graphene-type NPGs are direct bandgap semiconductors, biphenylene-type NPGs bear an indirect bandgap. In addition, the insertion of biphenylene into the NPG induces a reduction of the bandgap as compared to the purely graphene-type counterparts.

These interesting results add an additional control-knob towards engineering the electronic properties of NPGs suitable for prospective device applications.

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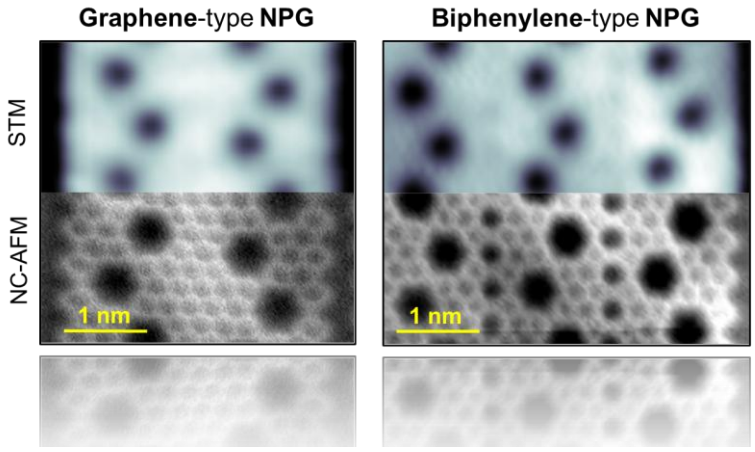

Figure 1: LT-STM and NC-AFM images of Graphene-type and Biphenylene-type NPG structures.