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Atomic-Scale Evidence for the Nucleation Sites of Multilayer Graphene and Its Dynamic Evolution to a Carbon Nanotube

Lili Zhang, 1 Maoshuai He, 2 Jakob B. Wagner 1
1Technical University of Denmark, Center for Electron Nanoscopy, Fysikvej 307, 2800 Kgs. Lyngby, Denmark
2Laboratoire d’Étude des Microstructures, ONERA-CNRS, BP 72, 92322 Châtillon CEDEX, France
Phone: +45-5269-6573
E-mail: lilizha@dtu.dk

In situ environmental transmission electron microscopy (ETEM) is of great importance to provide direct experimental evidence of structural dynamics of nanomaterials in a reactive gas at elevated temperature. 1,2 Here, the catalytic nucleation of carbon nanostructures from nanoparticles are recorded with aberration-corrected high-resolution TEM studies. Figure 1 shows the surface-bounded graphene on a certain facet of the particle stacks layer by layer, meanwhile, the disordered region inside the particle expands deeply along the interface of particle and support, suggesting a bulk diffusion path of carbon. However, the appearance of the gas-absorbed interface on the other facet of the particle allows assembling a graphene layer on its partial surface via surface diffusion. The evolution of the particle morphology then results in an increased number of layers and a tube-like structure. Overall, this work provides an improved understanding of nucleation mechanism of graphene and carbon nanotubes.


Figure 1. A series of high-resolution TEM images showing the nucleation processes of multilayer graphene. (a-c) A stack of graphene on one facet of the particle. (d) A graphene layer assembles on the other facet of the particle. Fast fourier transforms (FFTs) from the squares showing the expanded disordered region inside the particle.