

Nano-Structuring of 2D Materials using the Scanning Transmission Electron Microscope

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The ongoing miniaturization across a wide range of technological devices drives the need to push the boundaries of nanofabrication. The modification of two-dimensional materials is of significant importance in this context, where high-precision structuring tools, such as a focused electron beam, enable the structuring at the nanoscale, tailoring the shape and properties of the material.

Using automated beam control in a scanning transmission electron microscope (STEM), graphene was structured at the atomic scale. Contamination minimization is mediated by in situ heating of the sample via a MEMS chip. Following this methodology, it was possible to create carbon nanotubes and nanotube junctions from bilayer graphene [1] (Figure 1a). By cutting parallel lines into the bilayer structure, nanoribbons were created, which spontaneously unfolded into nanotubes with a hollow interior and round edges. This may open new routes for sculpting at the molecular scale and could be a valuable tool for nano-kirigami. Furthermore, it was possible to structure freestanding monolayer graphene with periodic patterns of holes with a hole diameter of 2-3 nm and a periodicity of 5-8 nm. Large area hole arrays (600x600 nm) with several thousand individual holes could be realized this way [2] (Figure 1c). As a result of quantum confinement effects, theoretical calculations estimate a band gap opening of the graphene of about 0.4-0.6 eV [3]. Building on this patterning capability, current work aims to establish a transistor geometry using electron beam induced deposition of platinum as electrical contacts and SiO₂ as dielectric to close the gap between modification and characterization.

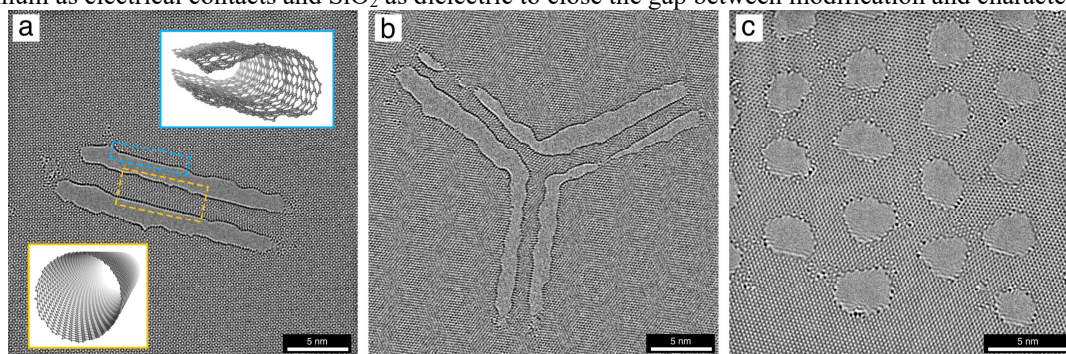


Figure 1. TEM of the fabricated structures. (a) Chiral nanotube fabricated by precisely cutting bilayer graphene. The insets show how the tube and bilayer edge look in theory. (b) Three nanotubes, merged into an interconnected junction. (c) Nanomesh of closely spaced holes patterned into monolayer graphene.

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References

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