We recently demonstrated a controllable and reproducible method to obtain suspended monolayer graphene nanoribbons with atomically defined edge shape [1]. Our method exploits the electron-beam of a Scanning Transmission Electron Microscope (accelerated at 300 kV) to create vacancies in the lattice by knock-on damage and pattern graphene in any designed shape.

The small beam spot size (0.1 nm) enables close-to-atomic cutting precision, while heating graphene at 600°C during the patterning process avoids formation of beam-induced Carbon deposition and allows self-repair of the graphene lattice. Self-repair mechanism is essential to obtain well-defined (zig-zag or armchair) edge shape and, if the electron beam dose is lowered, to perform non-destructive imaging of the graphene nanoribbons.

Drawing the electron-beam path with a software script, we were able to obtain reproducible graphene nanoribbons with a minimum width of 2 nm and defined edges (see Fig. 1 and 2). In order to unravel some of the predicted properties of these graphene nanoribbons, we are currently exploring their transport properties through in-situ electrical measurement inside a Transmission Electron Microscope.

Early results show that large-area suspended graphene is stable over gaps of ~1 μm size. Both CVD grown and exfoliated graphene have been used. Performing 2 wire measurements, we saw that contact resistance between graphene and gold contact pads has a non-neglectable influence on the measurements, although it can be greatly reduced with in-situ thermal annealing above 300°C.

References:

Acknowledgement: The research leading to these results has received funding from the European Research Council, ERC Project n. 267922

We thank Kavli NanoLab Delft for the support provided in the fabrication of our NEMS devices.
Fig. 1: Annular dark-field STEM image of a nanoribbon array, illustrating the reproducibility of the patterning. These four patterns were created using a script-controlled electron beam.

Fig. 2: HRTEM image of a nanoribbon in monolayer graphene sculpted at 300 kV and 600°C and imaged at 80 kV and 600°C. The yellow line indicates a zig-zag edge. An atom structure model for zig-zag edge is given as inset in the figure.