As small as small can be – Structuring 2D materials on the nanoscale

K Höflich
Ferdinand-Braun-Institut (FBH), D-12489 Berlin, Germany
katja.hoeflich@fbh-berlin.de

Future breakthroughs in nanotechnology will depend on the ability to produce materials and devices by design, i.e. to tailor both the material properties and the device geometries according to a sophisticated blueprint. Two-dimensional materials are particularly interesting candidates for designer materials, as novel functions can be realized by simply stacking different atomically thin crystals to tailor the coupling of their material excitations. Since the response to external stimuli, the coupling strengths and the corresponding figures of merit are determined by the device geometry, ultimate control of nanostructuring down to the single-digit nanometer range is in high demand.

Of particular interest here are direct writing techniques that combine great flexibility and simple implementation with the highest possible spatial resolution. Processing with focused ion beams enables the rapid prototyping of novel components in a maskless process, whereby focused He ion beams achieve a spatial resolution of less than 5 nm [1]. Patterning with charged particle beams is based on a digital process in which the beam dwells in one position for a certain time and is then moved to the next position to dwell there. The sum of these beam positions forms the beam path, and depending on the mass of the primary particles, either the substrate material is sputtered and/or modified, or new material is deposited. While this concept is very simple, the physical and chemical processes that take place locally are very complex [2].

In my presentation, I will give an overview of the fundamentals and various possibilities of direct structuring with ion beams, especially with focused He ions for the processing of suspended 2D materials. Using examples such as the automated patterning of phononic crystals in graphene [3] and the minimization of damage in the patterning of TMDCs [4] I will then explain the specific advantages and disadvantages of this technique in more detail.

[1] V. Deinhart et al., Beilstein J. Nanotechnol. **12**, 304 (2021).
[2] K. Höflich et al., Appl. Phys. Rev. **10**, 041311 (2023).
[3] J. N. Kirchhof et al., Nano Lett. **21**, 2174 (2021).
[4] H. C. Nerl et al., Comm. Phys. **7**, 388 (2024).