Imaging and Modification of 2D Materials: How Helium Ion Microscopy helps to fabricate novel filters and capacitors

Armin Gölzhäuser
Physics of Supramolecular Systems and Surfaces,
Bielefeld University, Universitätsstr. 25, 33615 Bielefeld, Germany
ag@uni-bielefeld.de

The Helium Ion Microscope (HIM) utilizes a focused beam of helium ions to image and modify materials with high spatial resolution and chemical sensitivity [1]. A helium ion beam can be focused into diameters down to 0.25 nm and helium ions are very surface sensitive and interact strongly with matter. HIM images thus show stronger chemical and topographical contrasts than, for example, SEM images. The HIM is further capable to image not only conductive, but also insulating samples without special treatment and when applying higher ion currents, the HIM can be also used for the modification and the milling of materials.
My presentation is a progress report on HIM imaging and lithography with two-dimensional (2D) materials, with a particular focus on the integration of 1 nm thick carbon nanomembranes (CNMs) engineered with a controlled thickness, conductivity and porosity [2], in functional devices. HIM images provide valuable information to understand the structure of CNMs and their formation process [3]. While HIM imaging with secondary electrons (SE) is well established, the ion transmission signal attracts growing attention as it provides information on thin materials and membranes [4]. Dark field transmission at different acceptance angles is compared to simulations and the membrane thickness is determined for different energies and thicknesses. The capability of the HIM for nanolithography of 2D materials will be shown [5]. Recent data on molecular transport through artificial nm- and natural sub-nm pores in novel 2D filtration devices [6] and the implementation of 2D materials in nanocapacitors [7] will be presented. It will be shown that HIM is a valuable tool in fabricating and analyzing these nanodevices.

[1] G. Hlawacek and A. Gölzhäuser (Ed.): *Helium Ion Microscopy*, Springer-International (2016).
[2] A. Turchanin and A. Gölzhäuser, Adv. Mater. **28**, 6075 (2016).
[3] A. Beyer, H. Vieker, R. Klett, H. Meyer zu Theenhausen, P. Angelova and A. Gölzhäuser, Beilstein J. of Nanotechnol. **6**, 1712 (2015).
[4] A. R. Hall, Microsc Microanal **19**, 740 (2013).
[5] D. Emmrich, A. Beyer, A. Nadzeyka, S. Bauerdick, J. C. Meyer, J. Kotakoski and A. Gölzhäuser, Appl. Phys. Lett. **108**, 16310 (2016).
[6] Y. Yang, P. Dementyev, N. Biere, D. Emmrich, P. Stohmann, R. Korzetz, X. Zhang, A. Beyer, S. Koch, D. Anselmetti, A. Gölzhäuser, *ACS Nano*, **12**, 4695 (2018).
[7] X. Zhang, E. Marschewski, P. Penner, T. Weimann, P. Hinze, A. Beyer, and A. Gölzhäuser, ACS Nano **12**, 10301 (2018).