Imaging, Modification, and Analysis of Nanostructures with the Helium Ion Microscope

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The Helium Ion Microscope (HIM) is a scanning microscope that utilizes a focused beam of helium ions to image and modify materials with high spatial resolution and chemical sensitivity [1]. A HIM can be envisioned as a scanning electron microscope (SEM) with a helium ion beam. The helium ion beam can be focused into a smaller diameter than an electron beam, and the HIM is thus capable to resolve features down to 0.25 nm. Helium ions are also more surface sensitive than electrons and they interact more strongly with matter. HIM images thus show much stronger chemical and topographical contrasts than SEM images. The HIM is further capable to image not only conductive, but also insulating samples without special treatment. This allows the investigation of unstained biomaterials and cell surfaces. When applying higher ion currents, the HIM can be also used for the modification and the milling of materials.

The presentation will contain various examples of HIM imaging and lithography. A particular focus is laid on 2D materials. 1 nm thick carbon nanomembranes (CNMs) are engineered with a controlled thickness, elasticity, conductivity and porosity [2]. HIM images provide valuable information to understand the structure of CNMs and their formation process [3]. The capability of the HIM for nanolithography of 2D materials will be shown by examples of milling CNMs and graphene, where nanopores with diameters down to 1.3 nm were fabricated [4]. HIM imaging of different carbon materials as well as of biological cells [5] will also be discussed.

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[3] A. Beyer, H. Vieker, R. Klett, H. Meyer zu Theenhausen, P. Angelova and A. Gölzhäuser: *Imaging of carbon nanomembranes with helium ion microscopy*, Beilstein J. of Nanotechnol. **6**, 1712 (2015).
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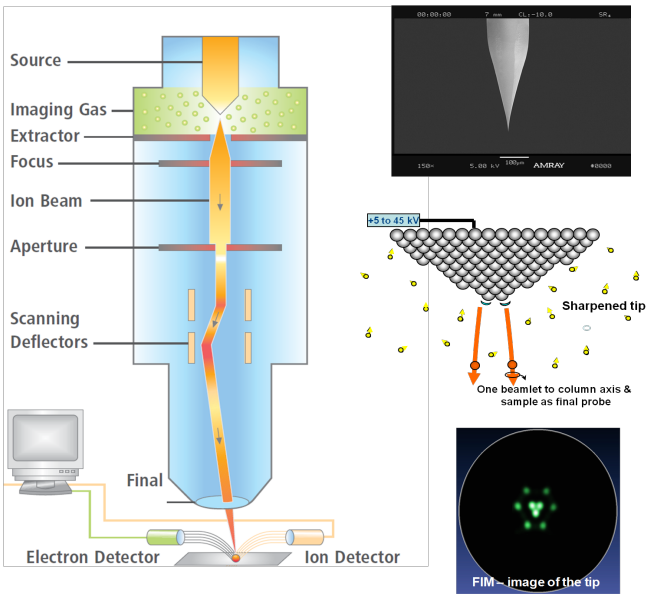

Fig. 1: Schematic of a Helium Ion Microscope (HIM): The He^+ ion source, realized by a metal tip sharpened in a field ion microscope to form an atomic trimer at the tip apex (Fig. from Carl Zeiss).

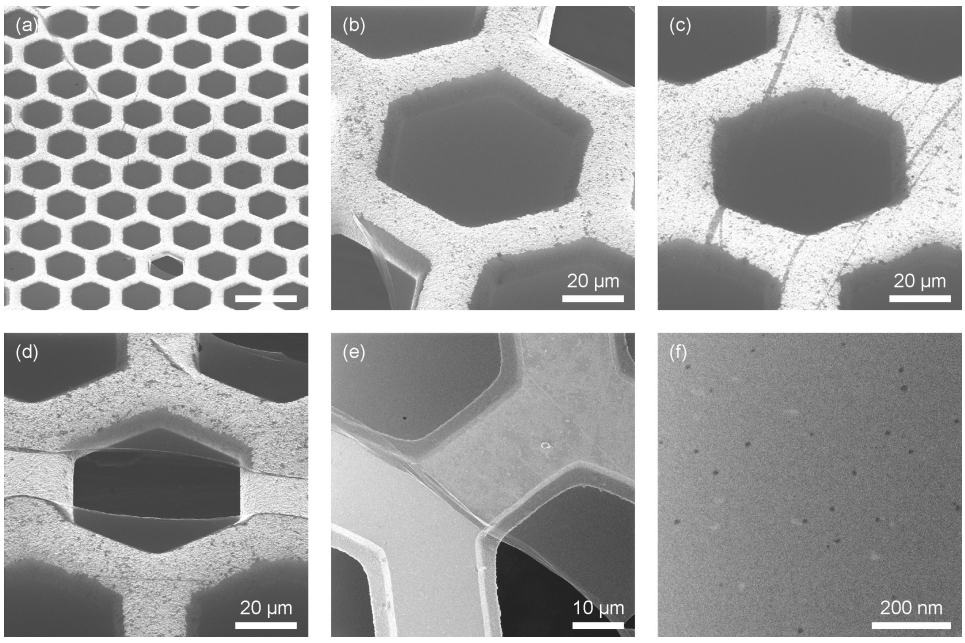

Fig 2: HIM images of 1 nm thick carbon nanomembranes (CNMs) supported by TEM grids. (a) Large area of intact membranes. Only one ruptured membrane is seen at the bottom. Scale bar is 100 µm. (b) Intact membrane. (c) Intact membrane with foldings. (d) Ruptured membrane. (e) Improved contrast with charge compensation. (f) Nanopores in large free-standing CNMs imaged with charge compensation. The nanopores appear as dark spots in the CNM.