Advanced Focused Ion Beam Lithography for photonic, nanobio and graphene applications

Sven Bauerdick, Achim Nadzeyka, Andreas Remscheid

Raith GmbH, Konrad-Adenauer-Allee 8, 44263 Dortmund, Germany

bauerdick@raith.de

Focused ion beam (FIB) systems and combined FIB-SEM microscopes are widely used for sample preparation and various analytical tasks. Moreover, focused Ion Beam Lithography (IBL) can have significant advantages over electron beam lithography (EBL), like direct, resistless, and three-dimensional patterning, while at the same time delivering the *in-situ* process control by cross-sectioning and inspection that a FIB instrument typically affords. A dedicated IBL tool will overcome nanofabrication specific limitations of an analytical platform by employing true lithography architecture and an ion column and source optimized for high resolution and large area nano patterning. This includes in particular a laser interferometer stage, long-term beam to sample position stability, as well as enhanced beam current stability and true automation capabilities. These system features enable high resolution, large area patterning over long times for IBL applications such as X-ray zone plates [1], various photonic and plasmonic structures, large area gratings [2], and wafer-level nanopore devices (see Figure 1). As a result IBL is as powerful as, complementary to, and compatible with (mix & match) the other lithography techniques commonly found in nanoscale research and development facilities.

Membrane based solid state nanopore devices for DNA sequencing, molecule analysis or biological filtering are both from a scientific and an increasingly commercial point of view a high interest topic [3,4]. Desirable nanopores must be <20 nm to permit single molecule transit, they must be round, have high aspect ratio, and minimal damage or implantation of contaminants around them. A large number of nanopore devices are spent for research and in particular for commercial screening applications, which requires small batch wafer scale production with additional stability and reproducibility constrains on the process and instrumentation. We have automatically fabricated 20 nm pores in 100 nm thick Si_3N_4 membranes on a 4 inch wafer (see Figure 1). In particular the reproducibility has been investigated by wafer-scale scanning electron microscope metrology capabilities of an EBL system.

Graphene synthesis, fabrication and patterning have been approached with various techniques, whereas the focused ion beam has been used for direct milling of suspended flakes [5]. Moreover we have developed a novel graphene nanoribbon nanofabrication process [6] employing specific ion implantation for reducing the graphitization temperature of SiC bulk substrates (see Figure 2). We will report on these and other applications showing the benefits of ion beam patterning and especially the added capabilities of IBL. Results of sub 10 nm feature sizes, on highly topographic samples, of three-dimensional structures and of long-term processes are presented.

References

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[3] J. Edel, T. Albrecht, Nanopores for Bioanalytical Applications: Proceedings of the First International Conference (ROYAL SOC OF CHEMISTRY, 2012).
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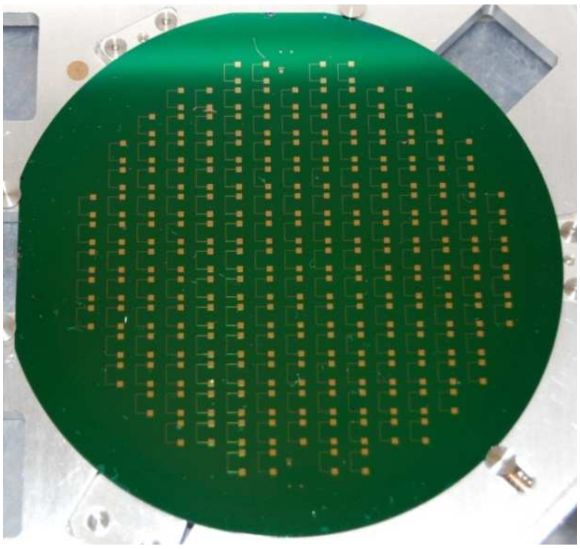
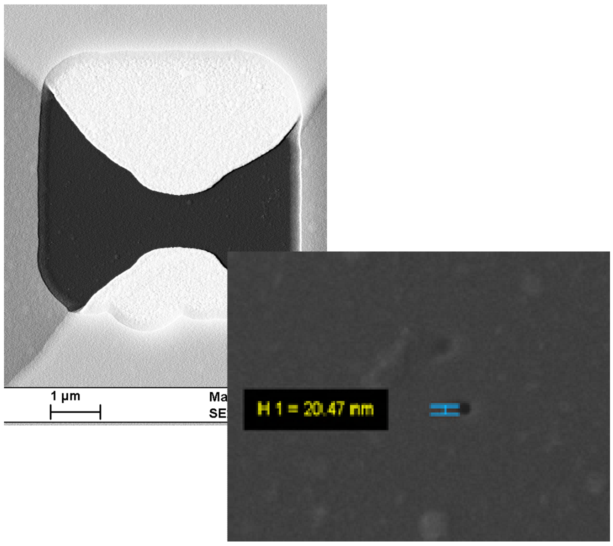
Figures

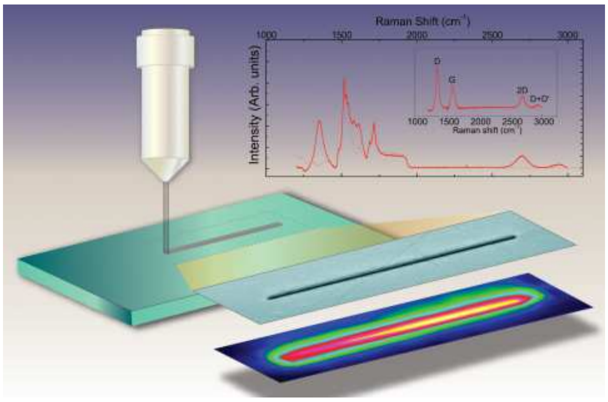


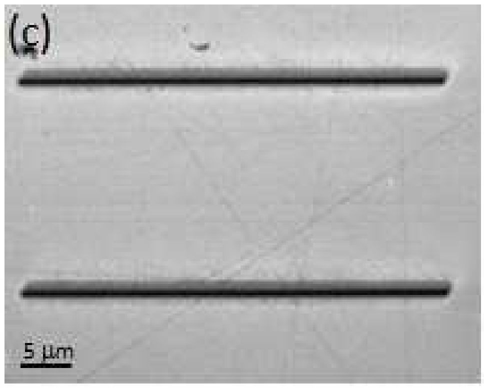


4 inch wafer of 175 nanopore devices with connection pads and read-out electrodes.

Read-out electrodes within window for 20 nm nanopore in 100 nm thick Si_3N_4 membrane.

Figure 1. Reproducible fabrication of nanobio devices with nanometer precision at wafer-scale.





Schematics of the technique employing specific ion implantation into SiC for ‘patterned synthesis’ of graphene [6].

Graphene nanoribbons directly patterned by IBL and thermal annealing [6].

Figure 2. Novel fabrication process for graphene nanoribbons.