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New FIB design combines extremely high beam currents with nanometer precision possibilities

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For more than thirty years FIB technology has revolutionized nanotechnological applications [1]. With the unique ability to combine both high-resolution imaging and flexible micromachining in one single platform, FIB opened completely new fields in science research as well as technological applications.

Due to the upcoming demand of larger material removal rates, new technologies have been developed which allow massive ablation, like a FIB based on plasma sources [2]. With the microscale virtual size of these sources, the application is however limited to rather coarse milling tasks and with that high resolution imaging or patterning processes are not possible. By using a Ga FIB machine combined with a microfocused pulsed laser it is possible to overcome this application gap and use the whole range from massive ablation until highest resolution [3], [4]. Nevertheless, the overall speed of the workflow using a combined laser and Ga FIB tool may be limited due to the maximum available ion current.

Up to now, commercially available Ga FIBs offer currents up to 50 nA at the most. For reaching higher current values without losing the resolution in the low current region beyond 1 pA it is indispensable to overcome several challenges in the electron-optical design. Working with low currents especially at low energies requires a minimal chromatic aberration of the lenses, yet the spherical aberration has to be minimized in order to achieve good beam profiles in the high-current region. Besides the aberrations of the lenses, also the ion interactions of the beam itself has to be considered [5] while optimizing the column design. To minimize these Coulomb effects it is necessary to optimize the aperture placements inside the column as well as the operating conditions.

In this work we present a new Ga FIB column with optimized design concerning all mentioned issues, which allows the full range of currents up to 100 nA and beam densities in excess of 70 nA/cm². Fig. 1 shows the calculated beam performance of the new column. The high-resolution performance is excellent and the smallest probe size could be experimentally measured to be 2.2 nm at 1 pA using a statistically averaged edge measurement [6].

The new column design provides six orders of magnitude of possible Ga currents and with this the full range of applications is covered (see Fig. 2). With the 100 nA option the process time of large material removals will be reduced by a factor of two compared to conventional Ga FIBs. The ultimate precision at the nanometer scale of the low currents is also available.

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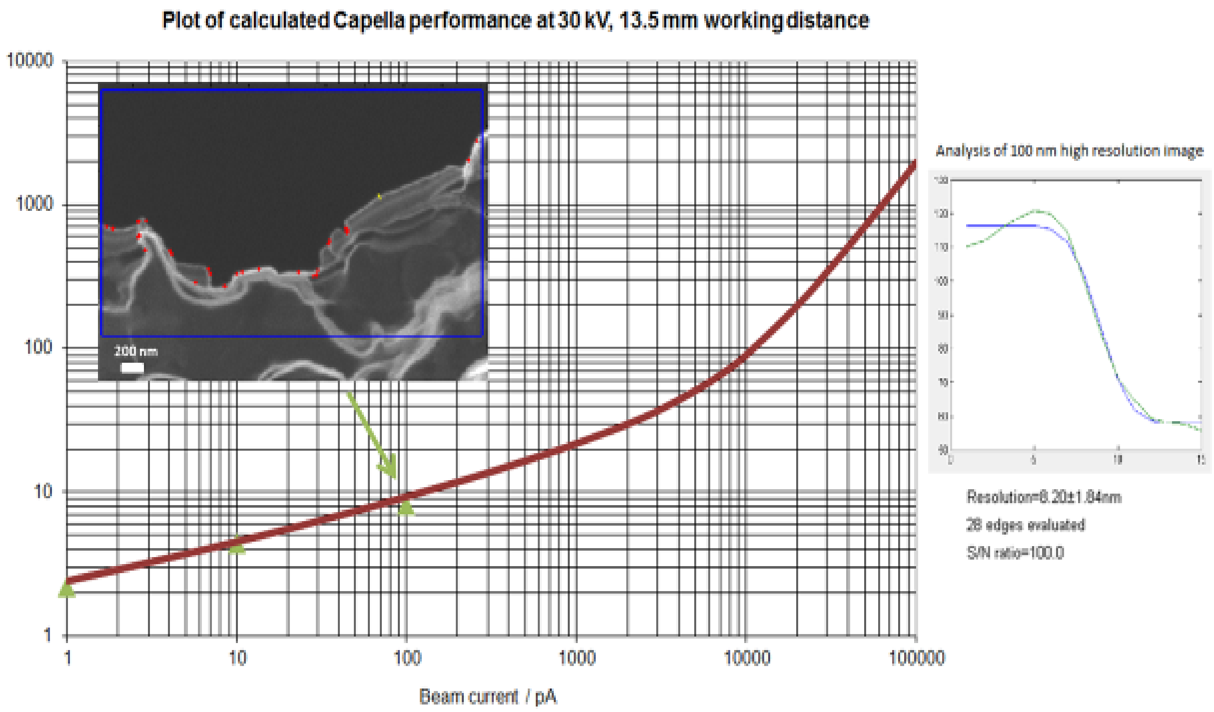

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Figure 1. The calculated probe size (r50) at a working distance of 13.5 mm and an ion energy of 30 kV is shown as the red curve. Measured resolution values are shown as green data points. The insert displays the measurement at 100 pA: The statistically averaged edge method [6] results in an r50 value of less than 8.2 nm.

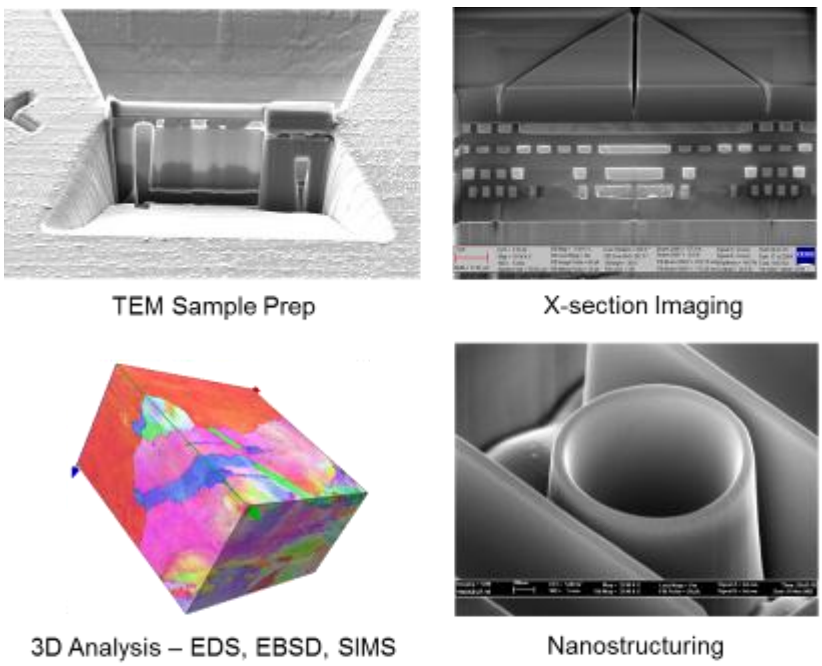

Figure 2. Applications such as (a) TEM sample preparation (b) preparation of cross-sections and (c) 3D analysis will greatly benefit from the increased current that is maximally available. At the same time no precision is lost and even delicate nanopatterning tasks may be performed (d).