Ion Column and Source technology employing Gallium and New Ion Species for Advanced FIB Nanofabrication

V. Morin, S. Bauerdick, P. Mazarov, L. Bruchhaus, R. Jede

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

vincent.morin@raith.de

An increasing number of applications use focused ion beam (FIB) systems for nanofabrication and rapid prototyping tasks. FIB nanofabrication is a good partner to other lithography techniques providing complementary strengths like direct, resistless, and three-dimensional patterning.
Although a FIB process can in many cases be slower than a resist-accelerated process, the relative simplification of the overall nanofabrication approach, especially for the direct processing of novel materials, helps to achieve scientific results faster. We report on our continuous effort to advance FIB technology along with an instrumentation platform dedicated to nanofabrication requirements.

The nanofabrication requirements for FIB technology are specific and more demanding in terms of stability, resolution, and the support of new processing techniques. To advance nanofabrication applications, we have improved gallium-based liquid metal ion source (LMIS) with a stable gun emission design enabling long-term stability without the need for frequent heating, and producing low drifts in probe current (Figure 1) and beam position. Moreover, we report a FIB spot allowing excellent patterning resolution with low collateral damage. This spot is usually not a pure Gaussian distribution, instead exhibiting significant beam tails, which have to be as small as possible for high resolution nanofabrication. In order to measure the beam current distribution we employed a method based on the amorphization of single crystal silicon by Gallium ions.
Compared with conventional LMIS FIB, the results here show a very narrow and large central Gaussian part and very low tails. As the most relevant part for milling is in the dose range of 1 to 10^{-3}, this technology offers superior performance especially for nanofabrication. Combining this FIB technology with an instrumentation platform optimized for nanometer scale patterning over large areas and extended periods of time applications such as X-ray zone plates [1], large area gratings [2], plasmonic arrays, and wafer-scale nanopore devices become possible.

Moreover the type of ion defines the nature of the interaction mechanism with the sample and thus has significant consequences on the resulting nanostructures. Therefore, we have extended the technology towards the stable delivery of multiple ion species selectable into a nanometer-scale focused ion beam by employing a liquid metal alloy ion source (LMAIS). A mass separation filter is incorporated into the column to allow for fast and easy switching between different ions or clusters within less than a minute [3,4,5]. This provides single and multiple charged species of different mass (Figure 2), e.g. Be, Si, Ge or Au, resulting in significantly different interaction mechanisms. We present and discuss the capabilities of the instrument for sub-20 nm to sub-10 nm nanofabrication (Figure 3) as well as potential applications. Using a Si ion beam for high resolution low contamination milling or a Au ion beam for surface functionalization will be given as examples for a full range of techniques yet to be explored.

[1] A. Nadzeyka et al., Microelectr. Engineering 98 (2012), 198-201.
[2] S. K. Tripathi et al., J. Micromech. Microeng. 22 (2012) 055005.
[3] B. R. Appleton et al., Nucl. Instrum. Methods B 272, 153 (2012).
[4] S. Tongay et al., Appl. Phys. Lett. 100, 073501 (2012).
[5] S. Bauerdick et al., JVST B 31 (2013) 06F404.

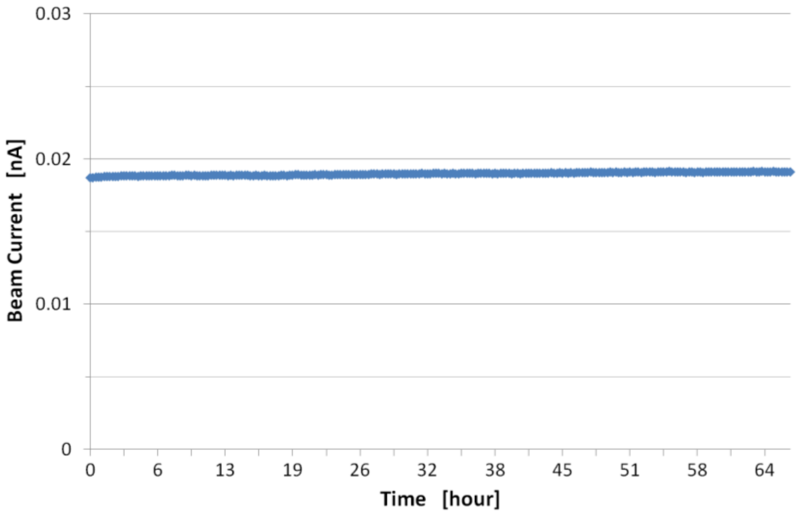

Figure 1: Probe current measurement of a Ga ion source over 67 hours

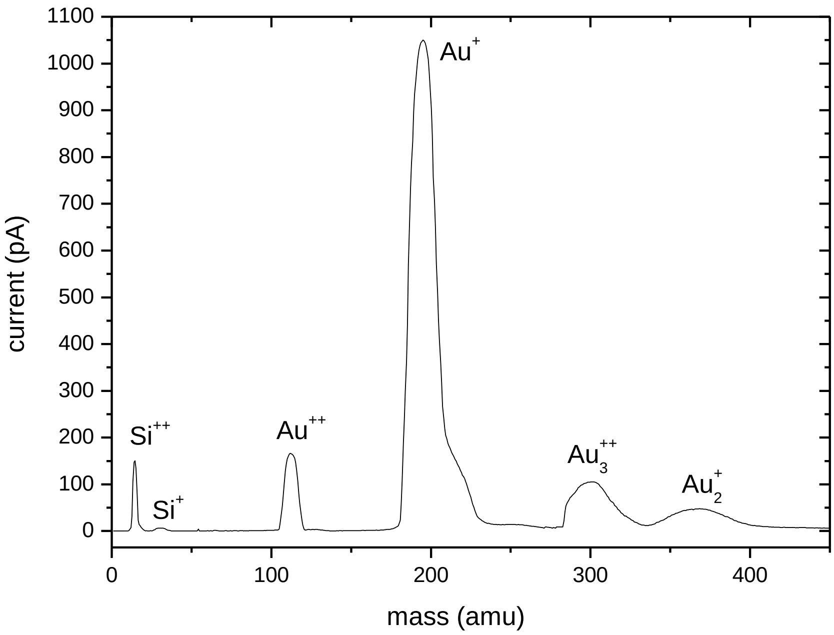

Figure 2: Mass spectrum of a AuSi ion source with various ion species.

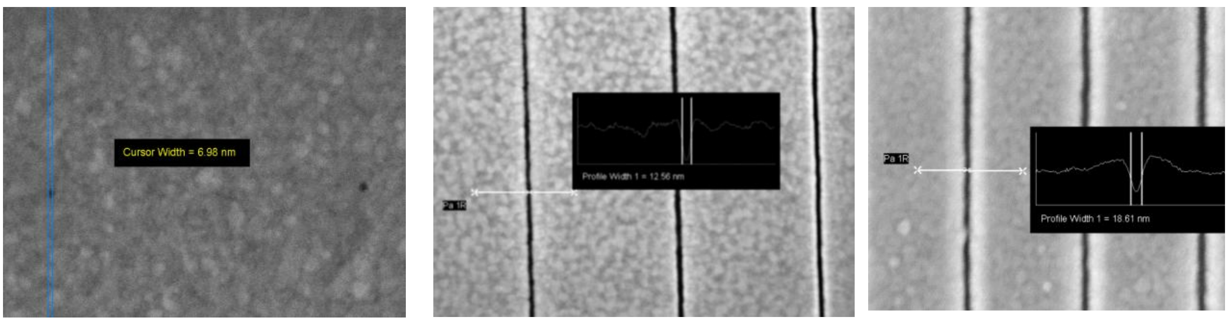

Figure 3: Results for milling of a 40 nm gold layer on a bulk sample: 7 nm to 19 nm features obtained with a Be, Si and Au ion beam (from left to right) [5].