Liquid Metal Alloy Ion Sources (LMAIS) for FIB Applications to advance nano analytics and nanofabrication

Torsten Richter, Peter Gnauck, Alexander Ost, Frank Nouvertné
Raith Group, Konrad Adenauer Allee 8, 44263 Dortmund, Germany
torsten.richter@raith.com

Advanced ion source technologies, particularly focused ion beam (FIB) systems, are key enablers for breakthroughs in material characterization and nanofabrication. FIB systems play a critical role for analytical techniques such as Secondary Ion Mass Spectrometry (SIMS) [1], but also for precision applications like 3D structural analysis as well as nanofabrication and device trimming. The Liquid Metal Alloy Ion Source (LMAIS) represents a significant step forward, offering versatile, high-precision ion beams that cater to a range of advanced use cases. With its ability to emit multiple ion species simultaneously (e.g., Bi^+ or Au^+ and Li^+, or Si^{2+}), LMAIS facilitates quick switching between primary ions, enabling optimized performance for diverse applications [2].

For material characterization, LMAIS-powered FIB systems integrated with SIMS allow high-resolution chemical imaging in two and three dimensions [3]. By combining heavy ions (e.g., Bi^+ or Au^+) for controlled material delayering with lighter ions (e.g., Li^+ or Si^{2+}) for high-resolution imaging, these systems provide unmatched depth resolution and highest spatial precision. This capability is invaluable for analyzing complex materials such as CIGS (copper indium gallium selenide) solar cells, geological specimens, and microelectronics components, which require a lateral SIMS resolution below 20 nm (Figure 1).

In nanofabrication, the precise implantation of ions from LMAIS enable innovative device trimming methods. For example, silicon ion implantation can passively tune optical properties in silicon nitride photonic circuits, eliminating the need for energy consuming active elements like thermo-optic heaters [4]. This approach enhances the scalability and energy efficiency of photonic devices (Figure 2).

Through innovations in ion source technology and its integration into cutting-edge platforms, LMAIS is driving advancements in precision analytics and nanofabrication. These breakthroughs are paving the way for the next generation of high-performance devices and materials. In this contribution we will present use cases and workflows offering unparalleled capabilities for correlative nano-analysis and nanofabrication and taking advantage of a high-end laser interferometer sample stage with LMAIS FIB technology and a retractable magnetic sector SIMS.

[1] O. De Castro et al., Anal. Chem 94 10754 (2022)
[2] A. Nadzeyka et al., Journal of Vacuum Science & Technology B 41 (2023)
[3] A.D. Ost et al, Microscopy & Microanalysis 30 (Supplement 1) (2024)
[4] A. Varri et al, Adv. Mater. 2310596 (2023)

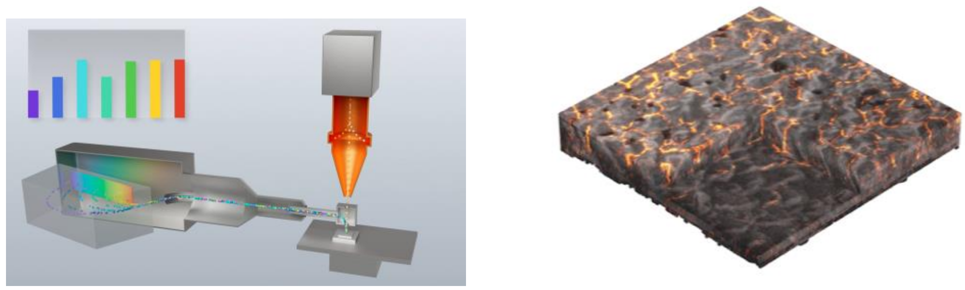

Figure 1:
Left: Schematic overview of the analytical SIMS platform, consisting of a vertical FIB column equipped with a LMAIS, laser interferometer stage and retractable SIMS unit. The SIMS unit features a magnetic sector for mass separation and continuous focal plane detector to detect all masses of the secondary ions in parallel.
Right: 3D volume SIMS reconstruction of a Rubidium enriched CIGS solar cell using 15 image planes. Rubidium (orange) is segregated in the grain boundaries within the indium phase (gray) (5µm x 5µm x 250nm).

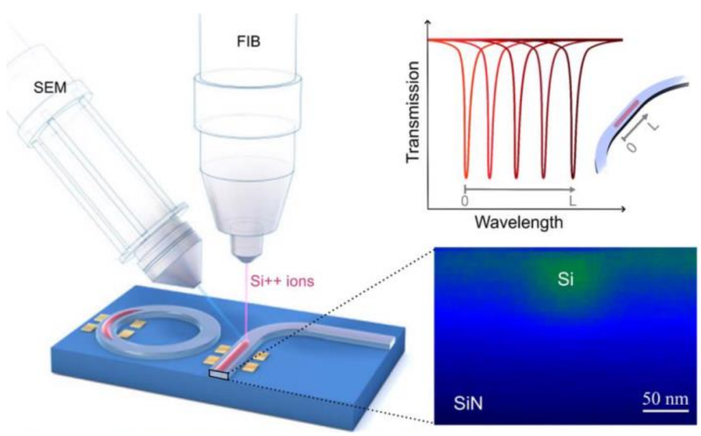

Figure 2:
Photonic device trimming by means of automated silicon implantation from LMAIS. The photonic circuits consist of silicon nitride ring resonators on top of the SiO2 substrate. The inset on the right displays the plasmon map reconstructed from low-loss energy spectrum. Optical response of the trimmed features: Significant redshifts in the transmission spectrum of ring resonators depending of the patterning lengths of the waveguide material.