# Novel FIB-nanofabrication strategies with Lithium and Bismuth ions from GaBiLi Liquid Metal Alloy Ion Sources

T. Richter, A. Nadzeyka, P. Mazarov, F. Meyer
*Raith GmbH, Konrad-Adenauer-Allee 8, 44263 Dortmund, Germany*
*torsten.richter@raith.de*

Applications in nanoscale science require high resolution fabrication techniques at high fidelity, accuracy, and reproducibility. Focused Ion Beam (FIB) nano-patterning has become established as a direct, versatile, and precise fabrication method of smallest features at the nanoscale [1].
However, high demands in terms of sputter yield, beam stability and patterning resolution are made on the ion beam that is used for direct FIB nano-patterning. Liquid Metal Alloy Ion Source (LMAIS) is an emerging FIB source technology that provides a versatile solution to deliver light and heavy ions from a single source for FIB nanofabrication [2]. In this contribution we present unique direct nano-patterning results and novel workflows using Focused Ion Beams containing Lithium and Bismuth from GaBiLi LMAIS. Lithium and Bismuth ions are emitted simultaneously with subsequent ion separation in an ExB filter.
Therefore rapid, easy, and reliable toggling between light Lithium ions and heavy Bismuth ions enables novel nanofabrication processes. This workflow allows taking advantage of the benefits of the different ion beams. A Lithium-ion beam has the smallest beam diameter and enables highest patterning resolution as well as imaging resolution of all ions available from LMAIS [3, 4] whereas Bismuth ion beam provides higher sputter yield at higher vertical resolution [5, 6]. Metallic nanogaps with gap size less than 10nm are a considerable challenge for various fabrication methods [7]. To overcome challenges, we present a 2-step process for bowtie nano-antennas. The approach takes advantage of large volume material milling with a Bi ion beam at high sputter yield to speed up the entire fabrication process and subsequent high lateral resolution fine shaping using a Lithium beam from the same ion source.

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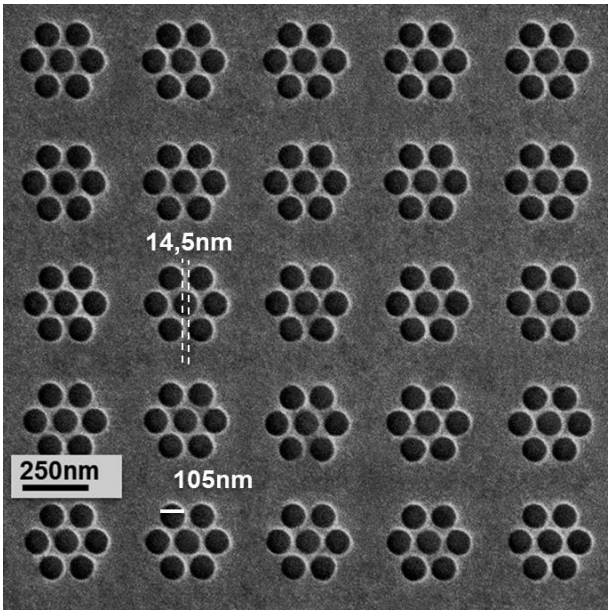
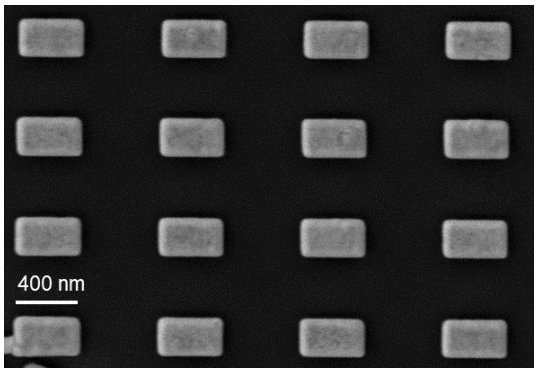
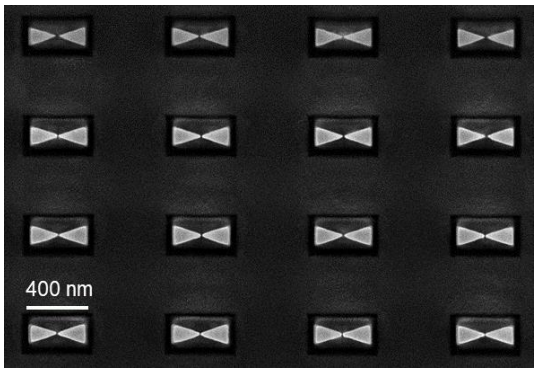



*Figure 1: Li FIB patterning of heptamer-arranged nanohole (HNH) arrays in 50nm Au film on $SiO_2$ and subsequent Li ion beam imaging*




Step 1: Bi FIB for large volume milling at high sputter yield to excavate rectangular boxes




Step 2: Li FIB for fine shaping of rectangular boxes to fabricate bowties structures at highest resolution.

*Figure 2: Stepwise fabrication of nano bowties in 50nm Au film on Si*