Sample Preparation Methods

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Focused Ion Beam nanofabrication employing multiple Ion Species from Liquid Metal Alloy Ion Sources

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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 other nanolithography techniques, like direct, resistless, and threedimensional patterning, while at the same time delivering the in-situ process control by cross sectioning and inspection that a FIB instrument typically affords. Since the type of ion has dramatic consequences on the nature of the interaction mechanism with the sample and thus the resulting nanostructures, we have extended the unique ion column and
Gallium source towards the long-term stable delivery of multiple species for a nanometer-scale focused ion beam employing a liquid metal alloy ion source (LMAIS). The column is equipped with an ExB filter capable of selecting from various ion species of one source [1, 2]. This provides single and multiple charged species of different mass (Figure 1) without changing the source, e.g. Si, Ge and Au, resulting in significantly different interaction volumes. We present the capabilities of the multiplespecies IBL instrument including excellent long-term current stability (Figure 1) and sub-20 nm beam resolution for various ions like Si (Figure 2) and Au. The characteristics and applications of different species will be discussed in terms of imaging, patterning and functionalization. From nanofabrication point of view – besides the lateral beam resolution – aspects like depth of interaction, sputter yield, available beam current and stability are equally or more important and depend on different application requirements. Advantages of the IBL setup in general for long-term and large area patterning will be shown by challenging nanofabrication examples like X-ray zone plates [3], large area gratings [4], and waferlevel nanopore devices for DNA sequencing [5, 6]. With the new ion species besides Gallium some of these applications can be further improved, e.g. less contamination in high resolution milling processes using Si, faster milling using Au or varying the implantation depth from Au double charged to Au clusters for optimizing functionalization or catalytic seeding. On-going investigations include photonics and plasmonics, nanopore membrane devices as well as selective growth of graphene [2, 7], whereas more fundamental studies of ion and matter interaction, directed self-assembly or growth of nano-scaled materials are possible as well.

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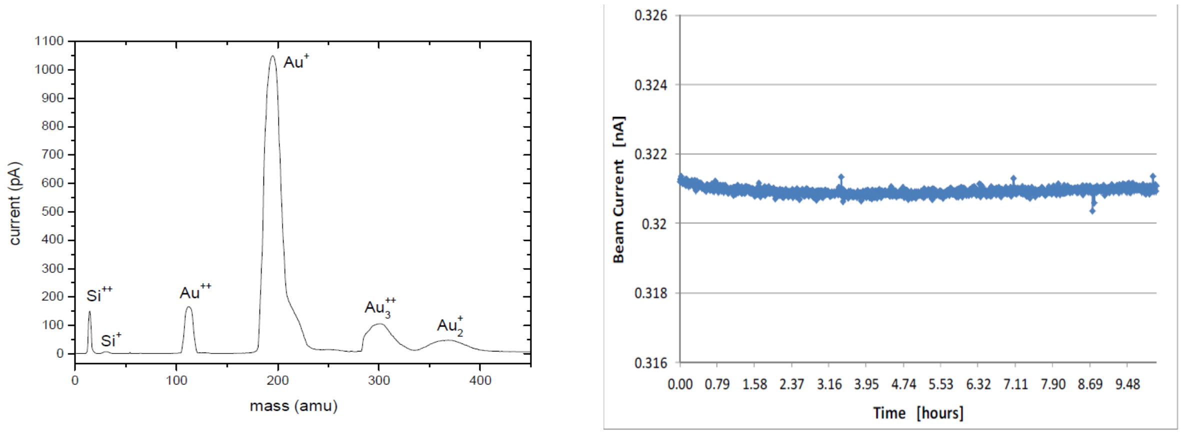

Figure 1. Mass spectrum (showing ions of different charge and mass) and stability measurement over 10 h of a AuSi Liquid Metal Alloy Ion Source (LMAIS).

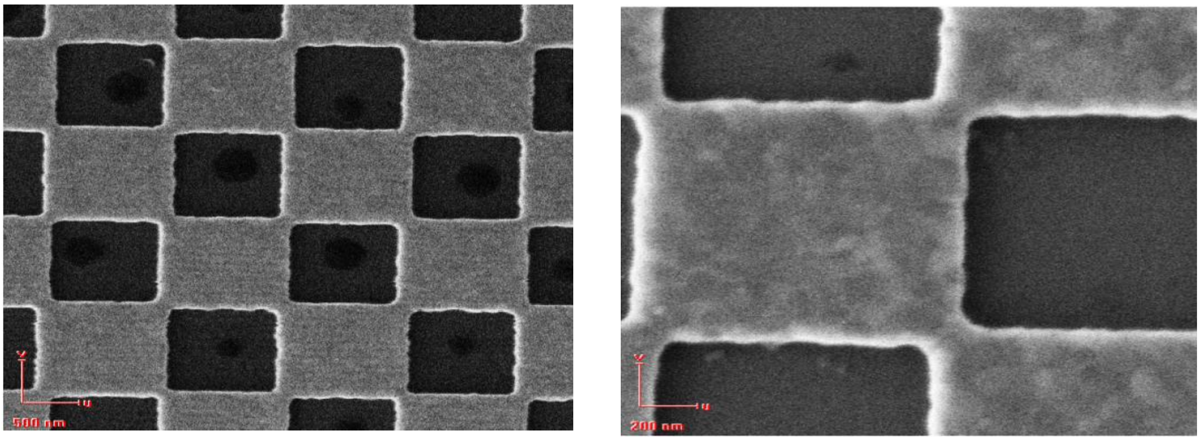

Figure 2. Secondary electron images obtained by scanning a focused Si^{++} ion beam over a sample of gold squares on silicon. The beam diameter is about 8 nm and can be applied to fabricate 10 – 15 nm features