

## Focused ion beam using a rubidium cold-atom ion source

**Citation for published version (APA):**

Xu, S., Li, Y., Mutsaers, P. H. A., & Vredenburg, E. J. D. (2020). *Focused ion beam using a rubidium cold-atom ion source*. Poster session presented at CMD 2020 GEFES División de Física de la Materia Condensada.

**Document status and date:**

Published: 31/08/2020

**Document Version:**

Author's version before peer-review

**Please check the document version of this publication:**

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

**General rights**

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

[www.tue.nl/taverne](http://www.tue.nl/taverne)

**Take down policy**

If you believe that this document breaches copyright please contact us at:

[openaccess@tue.nl](mailto:openaccess@tue.nl)

providing details and we will investigate your claim.

## Focused Focused ion beam using a rubidium cold-atom ion source ion beam using a rubidium cold-atom ion source

Sheng Xu, Yang Li, Peter Mutsaers, and Edgar Vredenburgt

Department of Applied Physics, Eindhoven University of Technology,  
P.O. Box 513, 5600 MB Eindhoven, the Netherlands  
[e.j.d.vredenburgt@tue.nl](mailto:e.j.d.vredenburgt@tue.nl)

Focused Ion Beams are important tools for the semiconductor industry. Essential applications are editing circuits and repairing masks in the development phase, and failure analysis during wafer processing. As a result of the reduction of feature sizes in semiconductor circuits, FIBs also face higher demands in terms of resolution and reduced damage. Here a FIB instrument that may overcome these limitations is presented.

The essential innovation is the use of a cold-atom ion source<sup>1</sup> based on photoionization of a laser-intensified and cooled atomic rubidium beam. The beam is produced by a high-flux Knudsen cell followed by laser-intensification stage consisting of a magneto-optical compressor followed by a polarization-gradient molasses<sup>2</sup>. The resulting high-brightness rubidium atomic beam passes into a dedicated two-stage electrostatic accelerator with integrated optical build-up cavity for efficient photoionization.

The performance of the source was characterized by studying deliverable current, brightness and energy spread. The intensified atomic beam source has an equivalent ion brightness of at least  $6 \times 10^6$  A/m<sup>2</sup> sr eV, six times higher than that of the Ga-LMIS. Around 75% of the atomic beam can be photoionized, producing ion currents of up to 600 pA<sup>3</sup>. The energy spread of the ion beam can be as low as 0.21 eV FWHM<sup>4</sup>, beating the Ga-LMIS by a factor of 18.

The source was then mounted on a commercial FIB system and first ion microscopy and milling experiments were performed. For the measured brightness and energy spread of the ion source, realistic ion-optical simulations show that a probe resolution of order 1 nm is possible for currents of a few pA. In preliminary experiments, a 50% probe diameter of 3.5 nm was found for a current of 1.5 pA and a beam energy of 8 keV.

The current focus is on studying the interaction of rubidium ions with typical materials to investigate the essential suitability of a Rb<sup>+</sup> FIB for real-world.

### References

- [1] J.J. McClelland et al, Appl. Phys. Rev. 3, 011302 (2016)
- [2] G. ten Haaf et al, Phys. Rev. Appl. 7, 054013 (2017)
- [3] G. ten Haaf et al, Phys. Rev. A 96, 053412 (2017)
- [4] G. ten Haaf et al, Ultramicroscopy 190, 12 (2018)

**Online Conference CMD-2020-GEFES  
31-8-2020 – 4-9-2020)**