



HAL
open science

Rapid, semi-quantitative elemental depth profiling using plasma profiling time-of-flight mass spectrometry

Jean-Paul Barnes, Yann Mazel, Emmanuel Nolot, Sébastien Legendre, Agnès Tempez

► **To cite this version:**

Jean-Paul Barnes, Yann Mazel, Emmanuel Nolot, Sébastien Legendre, Agnès Tempez. Rapid, semi-quantitative elemental depth profiling using plasma profiling time-of-flight mass spectrometry. FCMN 2022 - International Conference on Frontiers of Characterization and Metrology for Nanoelectronics, Mar 2022, Monterey (CA), United States. cea-04282621

HAL Id: cea-04282621

<https://cea.hal.science/cea-04282621>

Submitted on 13 Nov 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Jean-Paul Barnes¹, Yann Mazel¹, Agnès Tempez², Sébastien Legendre², Emmanuel Nolot¹

¹Univ. Grenoble Alpes, CEA, Leti, F-38000 Grenoble, France

²HORIBA France SAS, Palaiseau, France



RAPID, SEMI-QUANTITATIVE ELEMENTAL DEPTH PROFILING USING PLASMA TIME-OF-FLIGHT MASS SPECTROMETRY

Introduction

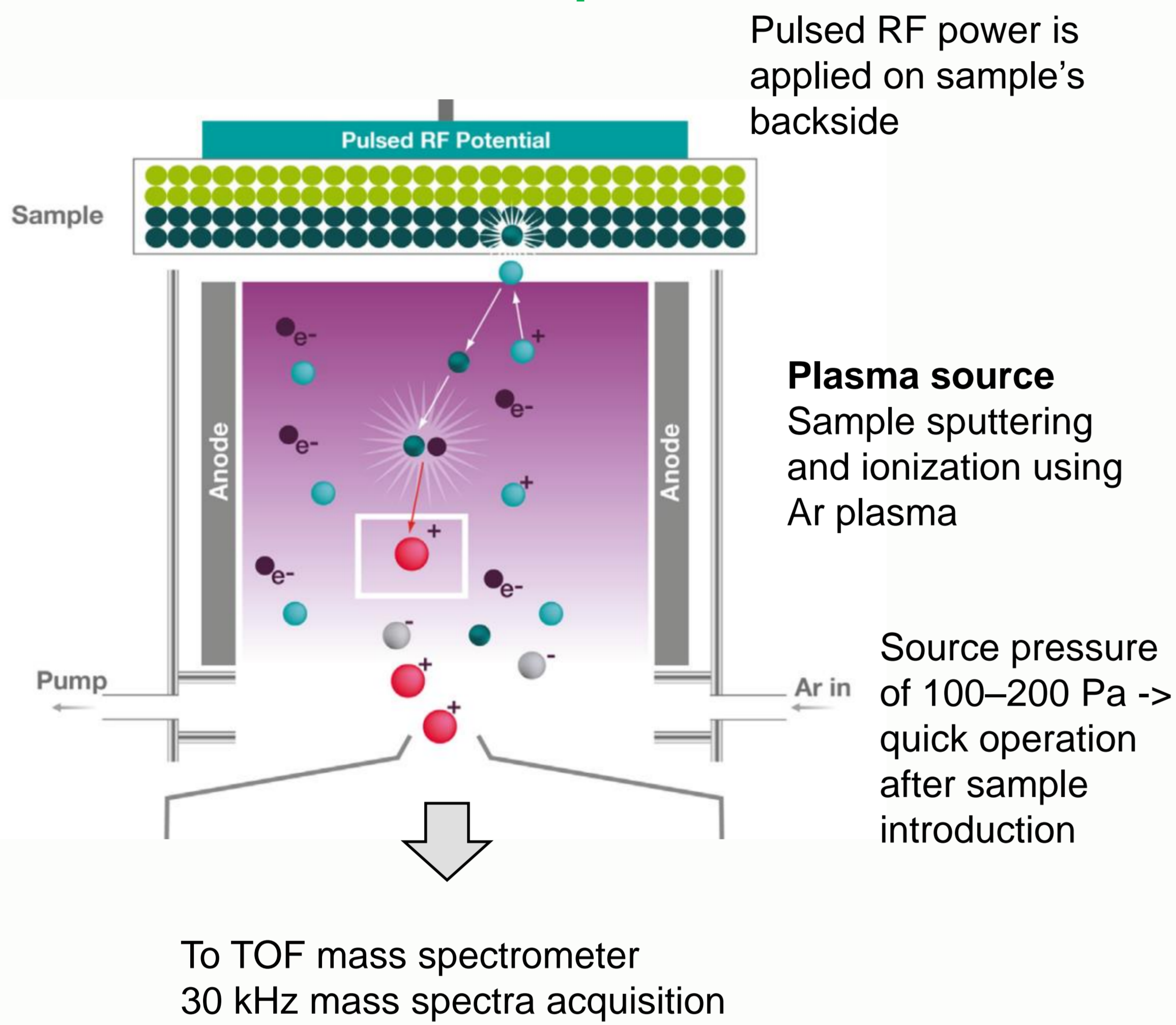
Plasma Profiling Time-Of-Flight Mass Spectrometry (PP-TOFMS) is a novel elemental depth profiling technique developed by Horiba Scientific. It couples an argon plasma source for sample sputtering and ionization with an orthogonal time-of-flight mass spectrometer. The technique delivers **nanometer-scale depth profiles with high sensitivity** and is capable of providing **calibration-free semi-quantitative results**. Moreover, the operation of the instrument is **simpler and faster compared to typical SIMS instruments** requiring only a few minutes including sample introduction and pumping.

CONTACT :

Yann Mazel

yann.mazel@cea.fr

The PP-TOF-MS technique

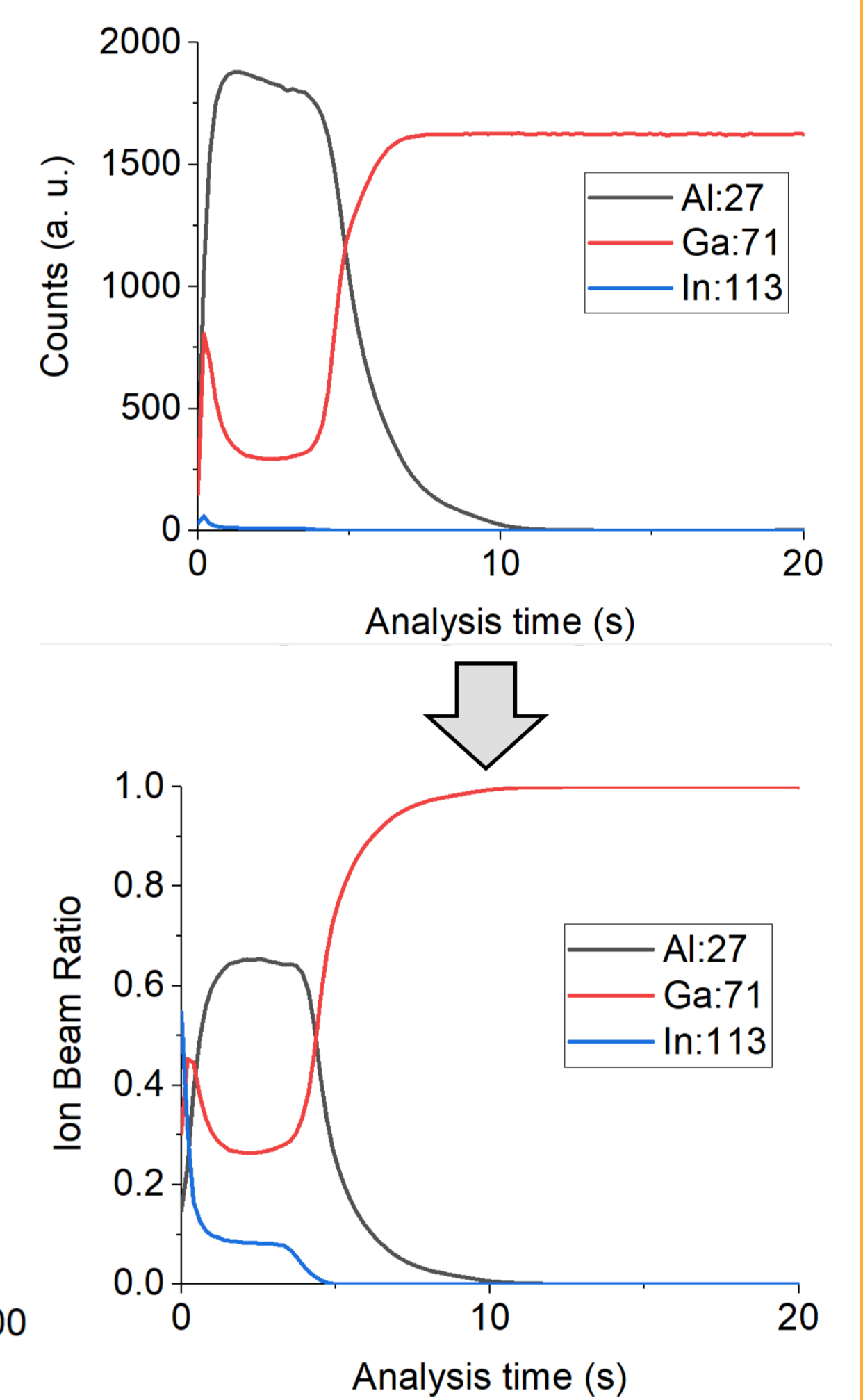
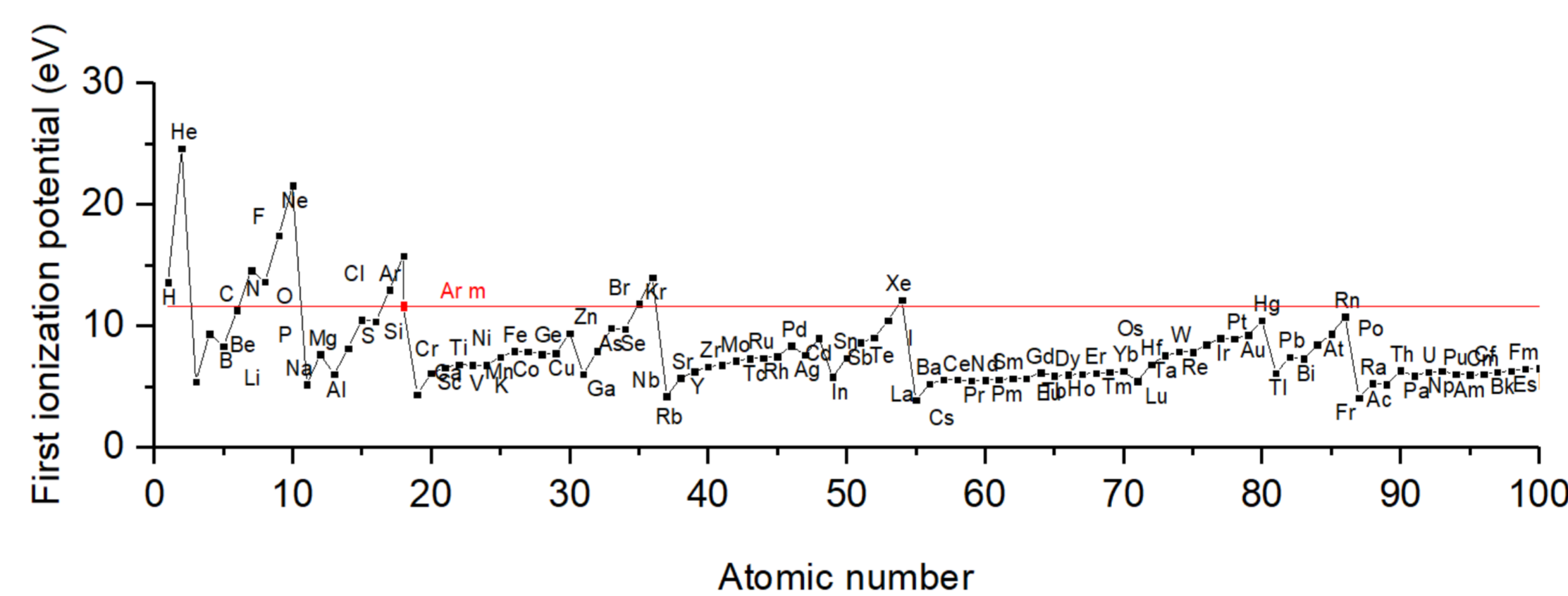


The Ion Beam Ratio method

Semi-quantification is obtained from the ratio of ion signals corrected for isotopic abundance^[1].

$$IBR_{ion}(t) = \frac{I_{ion}(t)}{ab_{ion}} / \sum_{ions} \frac{I_{ion}(t)'}{ab_{ion}} \quad \sum_{ions} IBR_{ion}(t) = 1$$

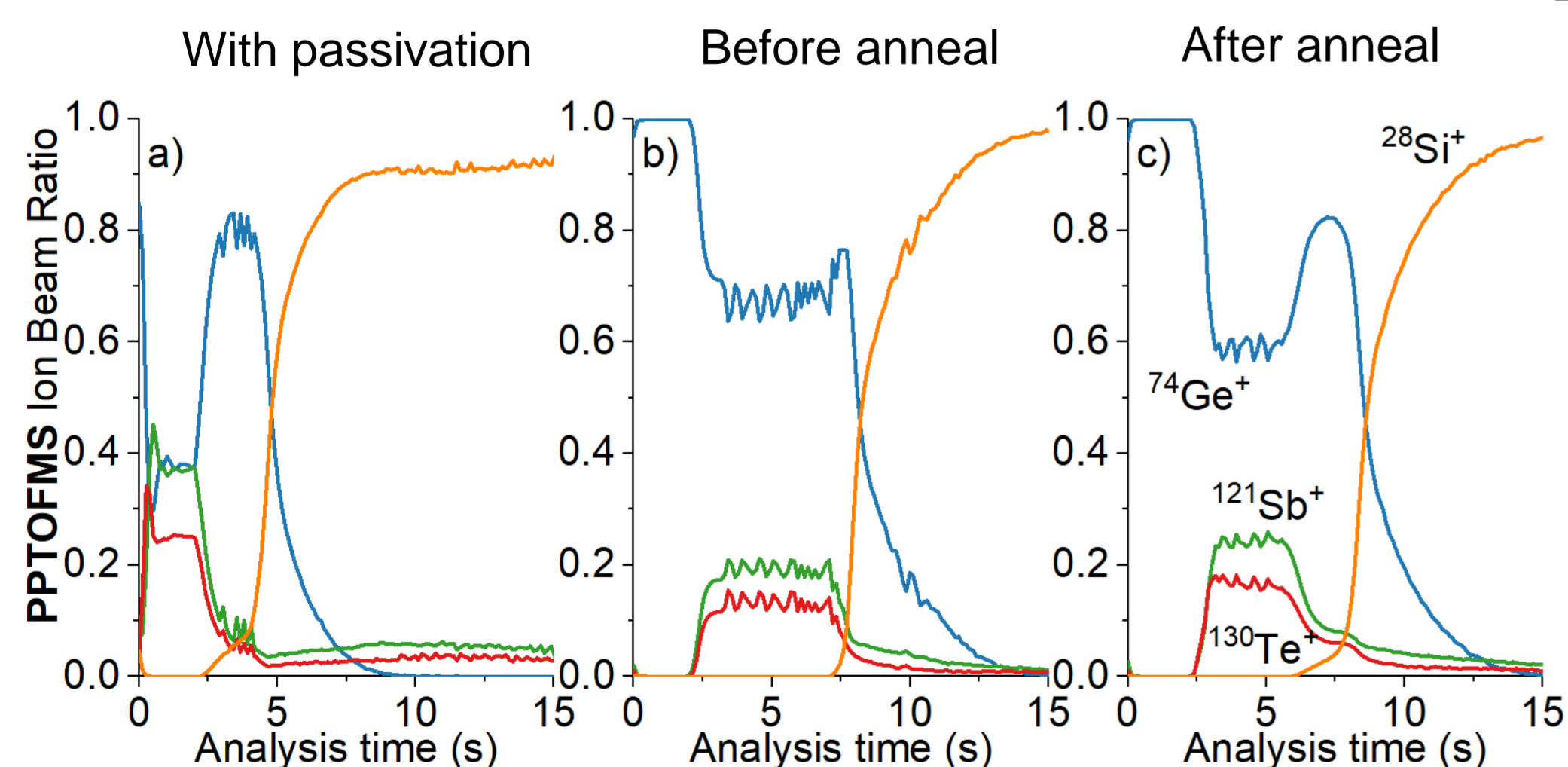
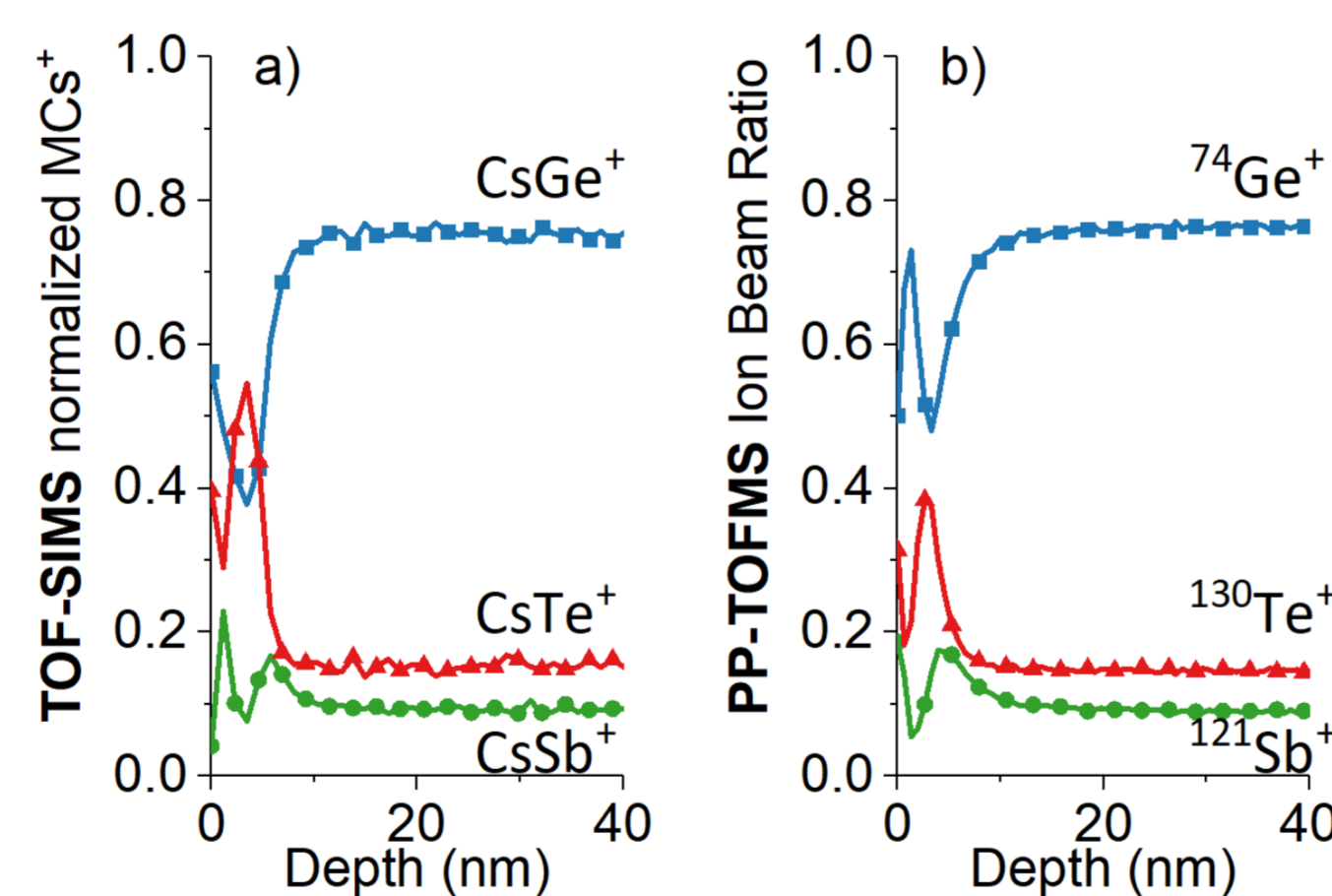
Works well with elements with 1st ionization energy inferior to 11.5 eV.



Applications

GeSbTe for memory applications

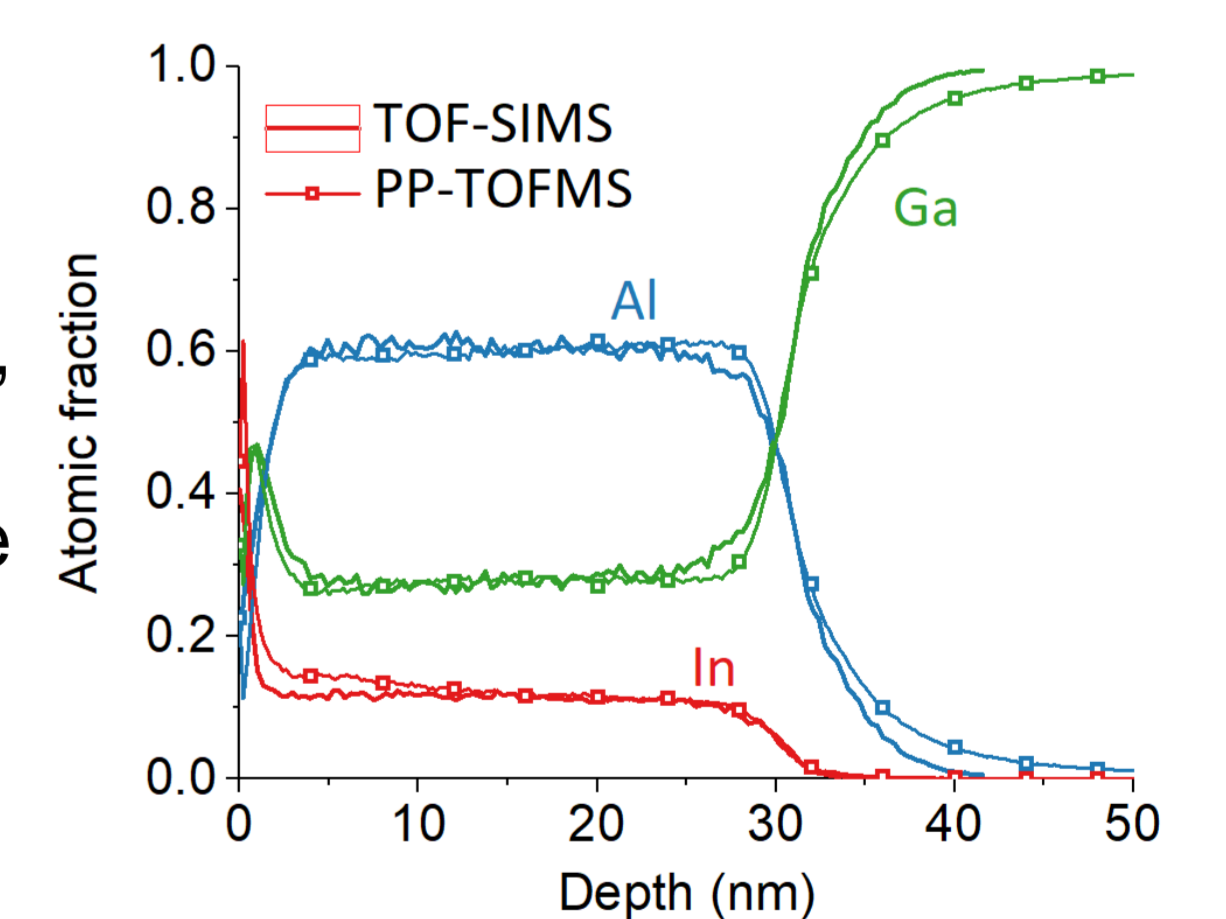
PP-TOF-MS IBR method has shown very good agreement with calibrated TOF-SIMS measurements while being much faster (3 mins/sample including introduction and pumping). The technique achieves nm scale depth resolution.



The technique was extensively used to support the material development^[2], in particular to study the effect of passivation layers to maintain a Ge-rich composition after annealing. PP-TOF-MS depth profiles of GeSbTe thin layers: after annealing without passivation layer (a), with the passivation layer before (b) and after (c) annealing.

InAlN barrier layers engineering for power applications

Due to their outstanding properties, III-nitride materials based on GaN, AlN, InN and their compounds are increasingly being used in the manufacture of high-power and optoelectronics components.



IBR and calibrated TOF-SIMS measurements show very good agreement^[3]. The technique proved to be very useful in the development of high quality ternary and quaternary alloys. PP-TOF-MS fast turnaround time was helpful as many process parameters need to be optimized. An example where PP-TOF-MS enabled the rapid optimisation of showerhead reactor conditions to minimize Ga content in InAlN films was published recently [4, 5].

References

- [1] F. L. King, J. Teng, and R. E. Steiner, *J. Mass Spectrom.* **30**, 1061 (1995)
- [2] E. Nolot et al., *Surf. Interface Anal.*, 1-5 (2020)
- [3] Y. Mazel et al., *J. Vac. Sci. Technol. B* **36**, 03F119-1-03F119-5 (2018)
- [4] M. Mrad et al. *J. Cryst. Growth* **507**, 139-142 (2019)
- [5] M. Mrad et al., *Appl. Phys. Express* **12**, 045504 (2019)

