# Advancing Nanoscale Analytics: Compact Magnetic Sector Spectrometer and Continuous Focal Plane Detector for Hyperspectral SIMS Imaging

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The constant drive toward miniaturization in materials science, coupled with the need to resolve complex interfaces in environmental and energy systems, demands analytical tools that bridge the gap between nanometric spatial resolution and high chemical sensitivity. While Focused Ion Beam (FIB) platforms are traditionally recognized for microscopy and sample preparation, recent breakthroughs in ion source technology, most notably the Low-Temperature Ion Source (LoTIS) delivering high-brightness $Cs^+$ beams ($10^7$.$Acm^{-2}sr^{-1}$), have paved the way for SIMS integrated in FIB platform. This contribution highlights the major technological developments led by us to transform FIB(-SEM) instruments into advanced analytical workstations, centered on a custom compact magnetic sector mass spectrometer enabling elemental and isotopic mapping with a lateral resolution reaching 15 nm.

A second, and perhaps even more transformative, technological leap is the development of a continuous Focal Plane Detector (FPD). Unlike conventional magnetic sector instruments limited to monitoring a few pre-selected ions via discrete detectors, the FPD utilizes a long microchannel plate coupled with a delay-line readout system. This setup enables simultaneous detection of the full mass spectrum (up to 500 amu) at every pixel. This hyperspectral capability brings the "post-acquisition" flexibility available in Time-of-Flight SIMS to the superior dynamic range and signal-to-noise performance of magnetic sector SIMS [1, 2].

Beyond detection, the integration of this SIMS architecture within a FIB-SEM platform unlocks a broad set of complementary capabilities that extend the analytical scope of SIMS. High-precision micromachining enables immediate in situ analysis of cross-sections or lamellas without air exposure, while specialized cryo or electrochemical modules allow studies under specific operational conditions. By correlating SIMS with EBSD, BSE, and EDX signals routinely available on the platform, these instruments provide a unique multimodal environment for holistic material characterization [1].

The analytical power of this instrumentation is demonstrated across a broad range of applications: mapping of light elements (Li, H) for degradation studies in next-generation batteries and hydrogen embrittlement; high-resolution 3D chemical profiling of complex microelectronic architectures (FinFETs, stacked nanosheets) for dopant and interfacial diffusion monitoring [1-3]. Finally, we address the challenge of managing large-scale hyperspectral datasets and the statistical workflows required to extract meaningful insights from this new generation of nanoscale SIMS data, redefining the boundaries of chemical imaging.

[1] J. N. Audinot et al. Reports Prog. Phys. 84, 2021, 105901.
[2] O. De Castro, et al. Anal Chem 94, 2022, 10754.
[3] P. M. Delfino, et al. ACS Appl Mater Interfaces 42. 2024, 57141.