Electronics and 2D Materials: Leveraging SIMS Capabilities and Navigating Instrument Trade-offs

Paweł Piotr Michałowski[1]

(1) Łukasiewicz Research Network - Institute of Microelectronics and Photonics
al. Lotników 32/46, 02-668 Warsaw, Poland

Secondary Ion Mass Spectrometry (SIMS) is available in a wide variety of instrument configurations, including magnetic sector, time-of-flight, and quadrupole analyzers, employing different primary ion sources and increasingly complemented by advanced technologies such as Orbitrap mass analyzers or correlative approaches, including in situ AFM and glovebox integration. Each configuration offers unique strengths, while also introducing specific limitations that influence the type and quality of information that can be obtained.

As a result, researchers often perceive certain classes of materials or analytical problems as being accessible only with a particular SIMS instrument. For example, dynamic SIMS is commonly considered the preferred choice for hydrogen analysis, whereas ToF-SIMS is typically associated with organic and molecular characterization. Although such generalizations are often justified, they can also lead to unnecessary misconceptions. Many practical problems do not require the ultimate performance of a dedicated instrument, and valuable information can frequently be obtained using alternative SIMS platforms when their capabilities are properly understood.

This tutorial will present a systematic framework for evaluating SIMS capabilities for the characterization of electronic materials, devices, and two-dimensional materials. Key analytical parameters, including detection limits, mass resolution, lateral resolution, depth resolution, and quantification, will be discussed alongside practical challenges such as sample charging, non-planar surface morphology, ion-beam-induced material modification, preferential sputtering, and matrix effects. Particular emphasis will be placed on understanding which limitations are fundamental and which can be mitigated through thoughtful experimental design, optimized measurement conditions, or a reformulation of the analytical question.

Rather than focusing on the superiority of individual instrument designs, the tutorial aims to provide participants with a practical strategy for selecting the most informative measurement approach for the available instrumentation. The objective is to help researchers recognize both the capabilities and the limitations of their SIMS platform, enabling them to extract the maximum meaningful information from challenging electronic and two-dimensional material systems.