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How to leverage Atom Probe Tomography to address characterization challenges in the semiconductor industry

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SIMS has always played a pivotal role in the semiconductor industry. Offering excellent sensitivity, good quantification properties and high depth resolution [1], it became the go-to method for (quantitative) dopant profiling since its early days (~1980) [2]. Later developments such as 1.5D SIMS [3] and self-focusing SIMS [4] innovatively attempt to bypass the spatial resolution limit, thereby enabling the applicability of SIMS to (an assembly of) 3-dimensional device structures [1]. With the recent market debut of automated, inline SIMS tools (e.g. [5]), SIMS has moved into the semiconductor production facilities (FAB), illustrating its eminence in that industry. Despite these encouraging advancements, quantitative dopant profiling and compositional analysis becomes increasingly more challenging due to the aggressive reduction in feature sizes, increased 3D architectural complexity and the expansion of the materials library in semiconductor processing and devices. The need to correlate chemical composition with microstructural features, to verify spatially resolved chemical uniformity in ultra-thin layers, or to reveal the 3D distribution of dopants within high-aspect ratio nanostructures often requires a multifaceted analysis approach for which Atom Probe Tomography (APT) can offer a unique and highly complementary perspective to SIMS.

APT is a high-resolution, time-of-flight mass spectrometry technique [6]. Its tomographic nature enables 3D compositional mapping or dopant analysis within a single nanostructure with down to sub-nm spatial resolution, both lateral and in-depth. Due to the limited analysis volume (few 100.000 to millions of atoms), APT cannot match the unparalleled detection sensitivity of SIMS. In stark contrast to SIMS, APT is still an emerging characterization technique within the semiconductor industry, albeit with a steadily growing interest and acceptance. Confidence is being built based on progress in fundamental understanding, developments around soft- and hardware components as well as benchmarking activities, for which SIMS plays a critical role. APT has revealed unprecedented insights into semiconductor structures (e.g. [1,7]), yet opportunities remain considering the said challenges and stringent requirements in the microelectronic sector [1,8]. This presentation will showcase curated application examples that highlight the synergy between APT and SIMS and discusses how both can be leveraged to address the characterization needs arising from the disruptive technologies depicted on the semiconductor roadmap. As an outlook, we will draw attention to encouraging initiatives in the field of APT, which might further improve its analytical performance and applicability in the long term. Ultimately, this would be a stepping-stone towards accurate, analytical tomography of complex nanostructures.

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