



Low-Energy Electrons: From Nanometer-Scale EUV Patterning to Metrology and Inspection

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Semiconductor manufacturing is entering a regime where a limited number of electrons can determine both whether a feature is printed and whether it can be measured. As device dimensions continue to shrink, low-energy electrons are no longer a secondary detail of the manufacturing process. They are increasingly becoming a fundamental factor governing both pattern creation and pattern measurement.

In extreme ultraviolet (EUV) lithography, patterning begins with the absorption of a 92 eV photon, but the subsequent chemistry is largely governed by cascades of low-energy secondary electrons with energies of only a few to several tens of electron volts. The stochastic nature of these interactions contributes directly to line-width roughness, local critical-dimension variations, and edge-placement errors that increasingly challenge pattern fidelity at advanced technology nodes.

Low-energy electrons play an equally important role in metrology and inspection. To maximize material and electrical contrast while minimizing sample damage, electron-microscopes increasingly operate at landing energies of only a few hundred electron volts. However, this imaging regime introduces a new class of challenges. Achieving sufficient throughput demands innovative electron-optical architectures, including high-current low-voltage operation and multi-beam approaches. At the same time, the interpretation of image contrast becomes increasingly dependent on electron-solid interactions occurring at energies below ~100 eV, a regime in which many physical processes remain only partially understood and difficult to model predictively.

The sensitivity of low-energy electrons to local electric fields further amplifies the impact of charging phenomena. Surface-potential variations of only a few volts can significantly modify electron trajectories and signal generation, leading to image artefacts that must be understood, modelled, and mitigated. Conversely, these effects can also be exploited through voltage-contrast imaging, where subtle electrical differences are converted into measurable image contrast.

This presentation will discuss the growing role of low-energy electrons in semiconductor manufacturing, spanning both EUV-driven pattern formation and electron-beam metrology and inspection. Particular emphasis will be placed on the scientific challenges associated with low-energy electron physics, including electron-solid interactions, charging mechanisms, voltage-contrast formation, and low-voltage system design. Continued semiconductor scaling towards 3D is pushing manufacturing into a regime where advances increasingly depend on a fundamental understanding of low-energy electron processes, motivating close collaboration between industry and academia to develop the models, experiments, and instrumentation needed for future semiconductor technologies.

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