Beyond High-NA EUV: A Dose-Window Framework for Stochastic Integrity at Future Nodes

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As the semiconductor industry pushes to tighter pitches and lower edge-placement-error (EPE) targets, stochastic variability increasingly becomes the dominant manufacturing limiter, not nominal resolution alone. This presentation motivates why a transition beyond high-NA EUV should be framed around reducing stochastic variability and catastrophic failures. Shorter-wavelength exposure (2.5–4.5 nm) operated at low NA in the three-beam regime offers a credible path because increased aerial-image slope can offset reduced photon statistics and improve pattern fidelity at equal dose. Using a dense-pitch case study, we quantify this image-slope-versus-photon-count trade-off and introduce a practical "dose-window" framework that separates two often-conflated knobs: (i) printable dose-window coverage, which governs catastrophic stochastic failures (opens/bridges/missing features), and (ii) local CD-vs-dose sensitivity, which governs LER, LWR, and EPE even when all features remain printable. We translate this framing into measurable resist/process robustness targets and discuss system implications for mask architecture (higher magnification formats to reduce mask-3D effects) and for source/scanner dose stability. We conclude with a concise set of future-node lithography requirements and the key development gaps that must be closed, and we explain why a beyond-13.5-nm path is needed.

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Allen Gabor is an IBM Distinguished Engineer and Chief Patterning Engineer for IBM Semiconductors. He has worked in the field of lithography at Arch Chemicals, GlobalFoundries and IBM. This work has included photoresist development, CD control, overlay minimization, fundamental understanding of EPE, lithographic aware design rules and 193nm dry, 193nm immersion and EUV insertion. He received his PhD in Materials Science and Engineering from Cornell University based on his work on block copolymer photoresists. He is the author of more than 50 journal papers and holder of over 30 patents. He currently serves on the program committee for SPIE Extreme Ultraviolet (EUV) Lithography Conference and is a senior member of SPIE..