The amazing longevity of Moore’s Law - 50 years of progress in Lithography

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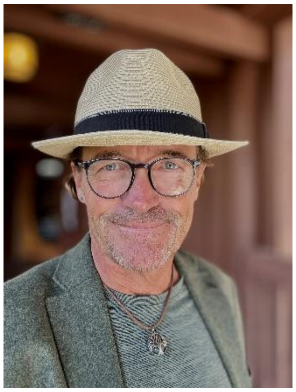
For the past 50 years, advances in lithography have been among the key drivers of Moore’s Law. All this time, these advances were guided by one simple equation that the minimum half pitch is proportional to the k1*lambda/NA. Each new technology generation was somehow enabled by advances in these three fundamental parameters. In this presentation, we will review node-by-node examples of the advances in the light source that drove the wavelength from 436nm to 365nm, then from 248nm to 193nm, and finally to 13.5nm. We will also review parallel advances in optical design and manufacturing that drove the numerical aperture of the projection optics from 0.33 in the early days of 1x g-line lithography all the way to 1.35 for ArF immersion. For EUV lithography, the NA started at 0.25, moved into production at 0.33, is now transitioning to 0.55, with serious exploration of NA of 0.75. And we will review advances in mask and resist technology, in computational lithography, and in and process control that collectively enabled reductions in k1 from around 1.00 in the early days to below 0.30 for the most critical DUV layers today. We will conclude this parade of key innovations with a look forward into what the future might bring in terms of further innovations in these areas that are the fundamental drivers for lithography.

Presenting Author



Ronald Goossens was born and raised in the Netherlands where he studied Physics at Utrecht University. During his Masters study, he worked on computer modeling of nucleosynthesis in stellar interiors and the impact on stellar evolution. This became the start of a life-long love affair with modeling and simulation of complex physical and chemical processes. During his years with Phillips Research, Stanford University, National Semiconductor, and NXP Semiconductor he worked on modeling of electron transport in transistors, of analog circuit behavior, and of system-level digital designs. For the last 20 years, he has worked at ASML on Computational Lithography with emphasis on control applications in semiconductor manufacturing. In early 2022, Ronald retired from full-time work. Currently, he “fills his time” as a part-time Senior

Strategy Manager for ASML, as Adjunct Professor of Nanolithography at Purdue University, as a Board Member of the Boys & Girls Club of Silicon Valley, and as an avid outdoor photographer and skier.