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Electron Multibeam Mask Writing for Leading-Edge Chip Manufacturing

The rapid scaling of semiconductor technology toward the 2 nm chip node and beyond demands breakthroughs not only in device architecture but also in mask fabrication. This contribution introduces the electron Multi-Beam Mask Writer (MBMW) as the decisive evolution in 6-inch Mask Fabrication for the Semiconductor Industry, replacing traditional electron single-beam and variable-shaped-beam (VSB) mask writing systems that have reached fundamental limits in productivity and pattern fidelity.

We outline the basic principles of lithography, including the resolution constraints of optical lithography systems governed by the Ernst Abbe equation $\mathrm{R} = \mathrm{k}_1 \cdot \frac{\lambda}{\mathrm{NA}}$, and highlight how curvilinear mask shapes - enabled by modern computational lithography - require a mask writer capable of massively parallel, high-precision electron beam delivery.

The latest IMS MBMW architecture employs 590 thousand finely focused programmable electron beams, enabling true linear and curvilinear mask writing at full mask scale. Compared to VSB systems, MBMW reduces write time by a factor of >10× for 2 nm node EUV masks, transforming mask turnaround time from a bottleneck into an enabler of rapid design iteration. This performance uplift is critical for leading-edge manufacturers such as INTEL, MICRON, SAMSUNG, SK hynix, and TSMC (market valuation > 2 trillion USD) underscoring the economic importance of fast, accurate mask production.

We further present an overview of IMS Nanofabrication's tool generations, from early IMS MBMW prototypes to the latest high-throughput and high-performance systems deployed in advanced mask shops, worldwide. These tools demonstrate continuous improvements in beam stability, data path architecture, and curvilinear pattern fidelity - positioning MBMW as the foundational technology for future nodes, EUV mask complexity, and the emerging era of computationally optimized chip layouts.