Electron- and Laser-Beam Lithography Software

Optimum productivity, quality and innovation by advanced data preparation for electron- and laser-beam lithography systems
High-resolution and high-throughput electron-beam lithography is severely impacted by process effects, electron scattering effects, and tool artifacts resulting in non-ideal pattern transfer. Although the electron-beam tool is a highly sophisticated and expensive printer, the pattern data needs to be optimized to significantly reduce the effects of various error sources such as beam positioning between shapes, filling shapes with “shots” on a discrete grid, field position dependent aberrations, stitching between fields, the spread of energy by electron scattering (proximity) and process effects.

**BEAMER** is the most comprehensive lithography software for optimum electron- and laser-beam exposure:

- Support for all major electron- and laser-beam exposure systems
- Superior machine specific fracturing of complex curved layouts
- Optimized field and shot placement
- Writing order control and advanced writing strategies
- Library of comprehensive layout processing functions
- Support for all major layout formats
- Integrated layout editor
- Build-in Viewer for immediate inspection, verification, and measurement of patterns
- Powerful proximity and process effect correction technology
- Electron-beam simulation of absorbed energy and resist contours

[Images and captions for Georgia Institute of Technology – USA, Center for Nanoscale Science and Technology – USA, AMO GmbH – Germany, Heidelberg Instruments Mikrotechnik GmbH – Germany]
Productivity, Quality & Innovation

**BEAMER** provides reliable and highly powerful processing of large and complex layout data. It gives the user a large array of functions for extracting, combining and modifying the layout for an optimum exposure. Interfaces for all major electron- and laser-beam exposure tools are developed in close cooperation with machine vendors and are continuously optimized for the best exposure results, thereby extending the limits of these systems by advanced data preparation. Examples include: optimized fracturing for a significant reduction in shot placement artifacts, automated floating field to avoid/reduce field placement and stitching issues, user controlled field placement, and enhanced multi pass strategies. The user can instantly visualize and quickly optimize the exposure process, including field and shot position. Applying techniques such as “bulk & sleeve” or “coarse & fine” combined with proximity effect correction (PEC) to easily and effectively achieve high resolution, smooth edges at increased throughput.

PEC is essential for improving the exposure quality by automatically adjusting exposure doses for optimum CD (critical dimension) uniformity and contrast. Additionally PEC eliminates the need to experimentally adjust the exposure dose for each layout thereby increasing productivity and process reproducibility. Performing traditional “Trial & Error” optimizations is very expensive and time consuming.

Advanced techniques available include: “model-based undersize-overdose” enabling ultra-high resolution in difficult scenarios, 3D PEC for three dimensional resist profiles in single and multi-layer resists, and full process calibration with simulation for quick development of new innovative solutions.

Strong collaboration with leading nanofabrication centers worldwide drives rapid enhancements and allows us to provide the most advanced capabilities to our users, improving their efficiency and effectiveness. **BEAMER** is designed for the industrial user focused on productivity, as well as universities and R & D centers interested in flexibility and high resolution lithography.

![Optimize Your Lithography](image-url)
The VisualFLOW™ user interface allows fast process flow creation by simple drag & drop to connect functional modules, providing increased productivity and efficiency.

A comprehensive library of modules is available for building powerful flows. User Libraries allow storage and easy re-use of common blocks of modules for often-used functions.

The integrated VIEWER provides layout inspection at all stages, comparing layouts in multi-view mode, measurement functions, metrology support, writing field placement, dose assignment, and shot placement. VIEWER is also available as a stand-alone software package.

BEAMER includes Import/Export for all major layout and machine formats, without size limitations. The integrated Layout Editor allows the creation and/or modification of layouts. The machine formats are continuously enhanced in strong cooperation with the machine vendors, to provide the best possible exposure results. Examples of advanced machine features include: optimal fracturing of complex curved layouts, flexible control of field placement and shot placement, writing order definition and control, compensation for tool artifacts by intelligent multi-pass, and powerful data compaction.

BEAMER provides innovative tools for PEC and advanced process correction for nano-scale electron-beam lithography. A robust 2D PEC is complemented by a model based shape and rule based corner correction, plus correction for 3D correction for 3D single and multi-layer resist profiles. The flexible Point Spread Function (PSF) calculated by TRACER, can extend to correcting substrate, resist, and other process effects. Rule-OPC allows angle, size, or density dependent biasing and placement of resolution enhancement features for laser-beam lithography, and mask making in general. Rule-OPC allows angle, size, or density dependent biasing and placement of resolution enhancement features for laser lithography, and mask making in general.

BEAMER integrates electron-beam simulation, allowing for verification and optimization via modeling of the corrected layout. The modeling includes beam positioning for the major electron-beam systems. The combination of Metrology for comparing simulated with experimental data, along with the Optimizer, facilitates the adjustment of model PSF parameters to perform basic process effect correction. The TRACER software package, in combination with BEAMER, allows full process calibration and correction, including not only exposure effects, but also development, process and metrology effects.
BEAMER Major Features

Layout Import/Export
- Layouts of all major formats, without size limitation (GDSII, CIF, DXF, LTXT, OASIS, BMP, DWG)
- Electron- and laser-beam machine formats (Raith, JEOL, Elionix, Crestec, ADVANTECH, MEBES, Vistec, Heidelberg)

Advanced Fracturing
- Support of all major machine formats
- Optimized for arbitrary shapes
- Curved fracturing
- Correction for shot positioning
- Beam Step Size (BSS) fracturing
- Field position control (tiled, floating, manual)
- Multi-pass exposure
- Writing order control

Integrated Layout Editor
- Create new layouts
- Edit layout within flow

VIEWER
- Integrated detachable global viewer
- Multi-view
- Feature Measurements
- Shot and field placement view
- Write order and field visualization
- Dose assignment

Layout and Boolean Operation
- Healing, Biasing, Sizing, Merge, Tone reversal (NOT)
- AND, OR, XOR, P-XOR, MINUS
- Extract layer, datatype, cell, region
- Scale, Shift, Rotation, Mirror
- Filter geometries by width, height, area, angle, and relative dose
- Grid adjustment
- Mapping layout layers and datatypes
- Pre-fracture
- Cell Replace
- Hierarchy Flatten or Build

Flow Control Modules
- Parametrized loops with IF, SELECT, and FILTER operations
- Script for starting command line application from flow
- Optimizer for parameter fitting

Proximity and Process Correction

2D Dose PEC
- Fast and robust edge equalization technique
- Excellent dimension control by optimized dose on feature edges
- Fracturing based on absorbed energy distribution
- Perfectly symmetrical and stable for arbitrary shapes
- Process correction (e.g. lateral development, loading)

Shape Correction
- Model based shape correction of short and mid-range effects
- Combination with long-range correction with dose modulation
- Model based contrast enhancement ("undersize – overdose")

3D PEC
- Correction for defined resist thickness at any layout position (resist profile) for single layer resist (e.g. 3D gratings, 3D holograms, angled sidewalls, lenses)
- Correction for critical dimensions (CD) for each layer for a multi layer resist (e.g. T-gate structures)
- Additional compensation for substrate topography or material variation

Laser-beam Lithography Correction
- 3D Gray Tone Lithography
- OPC for resolution and linearity enhancement

Corner PEC
- Corner sharpening correction
- Dose PEC combined with rule based correction for edges, inner and outer corners.

Flexible PSF and Process Modeling
- PSF from Monte Carlo simulation or experimental table
- Visualization and fit of PSF function
- Apply full PSF data or Gaussian approximation
- Process loading, shot size dependent blur, fogging effect

Electron-beam Modeling
- 2D intensity image, 2D resist contour at multiple thresholds
- 1D/2D image viewing and analysis
- Multi- and matrix-view for automated runs
- Metrology for automated measurement and comparison to experiment
- 3D resist simulation can be performed with the LAB software package
Fast, Easy and Accurate PSF Simulation and Visualization
Manage, Maintain and Archive all PSFs with an Interface to BEAMER & LAB

A Point Spread Function (PSF) is the essential input for any type of Proximity/Process Effect Correction (PEC) or electron-beam simulation. A PSF describes the deposited energy as a function of the distance from the incident beam. In other words, a PSF can be described as the convolution of the electron scattering beam size (or beam blur) and process effects, which can include collateral effects from resist development and pattern transfer. The quality of a process effect correction (PEC) depends entirely on the knowledge of the PSF and process correction parameters such as base dose and process bias. As such, a necessary starting point is a Monte Carlo (MC) simulation of not only electrons backscattered from the substrate, but also fast secondary electrons from both the primary exposure and backscattering events.

TRACER offers an easy-to-use interface for defining the required parameters (material data, stack parameters, acceleration voltage), running the MC simulation, visualizing the 2D r-z simulation results (energy spread at different resist thicknesses), and extracting the 1D PSF which can then be used for PEC.

The comprehensive material database includes all standard materials and can easily be expanded with custom materials by defining the new material’s stoichiometry and mass density. Functionalities such as fitting to Gaussian functions, averaging, convolution of PSFs, determination of base dose factors between PSFs and powerful visualization enable the user to analyze, compare and optimize PSFs.

In addition tool and process effects such as spot size, lateral development, resist diffusion and loading effects need to be quantified and corrected. TRACER has an easy-to-use Calibration feature which determines and corrects these effects using measured CD data (typically CD as a function of dose and layout density) obtained after processing of a calibration pattern. Process parameters such as base dose, process blur and process bias are rapidly computed and the display of calibration versus measured data allows the user to immediately verify the fit quality.

TRACER Major Features
- Monte Carlo simulator that computes the electron-solid interaction for optimal electron-beam exposures, including beam blur
- Process calibration using experimental data
- Archive to maintain and manage all PSFs
- Visualization tool for PSF inspection
- Facilitator to combine electron-PSF and process-PSF into a single-effective-PSF, or to separate out the process-contribution-PSF from an experimental-PSF
- Dose factor calculator between two PSF’s
- Electron trajectory visualization (results can be exported for post-processing)
**VIEWER** is an ideal, ultrafast tool to inspect and compare layouts, that is included in **BEAMER**. On the input side, all major layouts (GDSII, OASIS, CIF, DXF) plus electron- and laser-beam machine formats are supported. Multiple layout files can be loaded to visualize them overlaid. The user has a multitude of viewing options and capabilities. **VIEWER** is also available as a stand-alone software package.

- Extensive color management (user defined palette, transparency and overlay colors, and mapping of colors to layers/datatypes, doses, cells, layouts)
- Hierarchy support (view of the hierarchy tree, selection of cells/layers to be displayed, drawing of features down to a user specified hierarchy depth)
- Metrology support (measure, pick, various snapping options such as snap to edge, snap to corner, snap orthogonal)
- Script generation for automation of metrology equipment and visualization of metrology results added into the layout
- For electron-beam machine formats view deflection fields, beam shots, writing order, and stage traversal order

GenISys products share highly dedicated support, have flexible licensing and are available on various platforms operating systems.

**Flexible licensing and platform support**
- USB license key for dongle and network
- Flexible on-off-the-shelf PCs (> 4 GB RAM recommended)
- Windows 7/8/10 64bit, Linux64 Red Hat 5.4+, Ubuntu 14.04+
- Multithreading

**Maintenance and Support**
- Technical Support Hotline (e-mail, Skype, phone)
- Frequent updates with enhancements, new functions, performance tuning and bug fixes
- Regional trainings, technical workshops, user meetings
- 12 month maintenance service included in license price
- User feature requests are a high priority for implementation in future updates
Based in Munich (Germany), with offices in Tokyo (Japan), and California (USA), GenISys develops, markets and supports flexible, high-performance software solutions for the optimization of micro- and nano-fabrication processes. Addressing the market for lithography and inspection, GenISys combines deep technical expertise in layout data processing, process modeling, correction and optimization with high caliber software engineering and a focus on ease of use.

GenISys products give researchers, manufacturers, and system suppliers unparalleled efficiency, ease of use and optimal value in research, development, and production of future nano-patterning technologies.

As a company focused on customer service, GenISys delivers fast, highly dedicated support for the application and development of the functionality needed to meet demanding customer requirements.