LAB

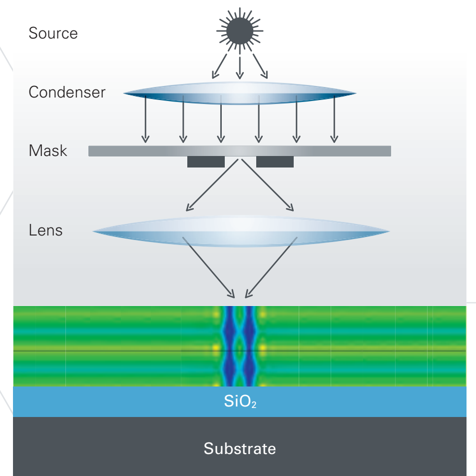
Advancing the Standard

Stepper
Laser
Proximity
e-Beam

Lithography Simulation & OPC

Enables next generation products and faster development by computational design and process optimization

www.genisys-gmbh.com



Layout and process optimization platform for most common lithography technologies

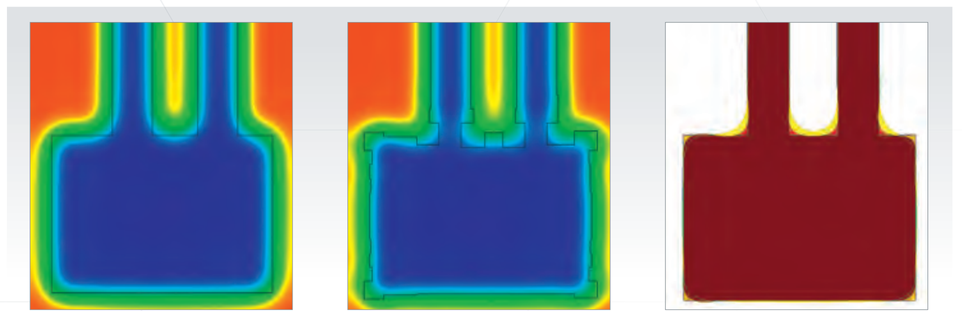
Experimental layout optimization and process development is highly time consuming and cost intensive. Lithography simulation allows access to numerous virtual experiment results in a short period of time and thereby significantly reducing development and production cost, and time to market by fast virtual exploration of a large parameter space. **LAB** enables further reduction in feature size for **proximity, projection, laser and electron-beam lithography,** for applications such as IC manufacturing, flat panel display, LED, MEMS, 3D packaging, mask manufacturing and nano-fabrication. The fast and accurate calculation of the intensity image allows layout optimization via Rule-OPC and Model-OPC, mask layout verification, optimization of process conditions (e.g. illumination, stack) and process window (e.g. gap or defocus and exposure dose variation) by varying the layout and/or exposure parameters. Thousands of experiments can be computed "overnight" without the need to produce masks or "burn" wafers. Once a good image contrast has been obtained, 3D resist development modeling allows further optimization of the resist profiles.

Complex process effects such as lateral development, density dependent bias in electron-beam or in laser lithography can be analyzed and compensated.

Projection Lithography

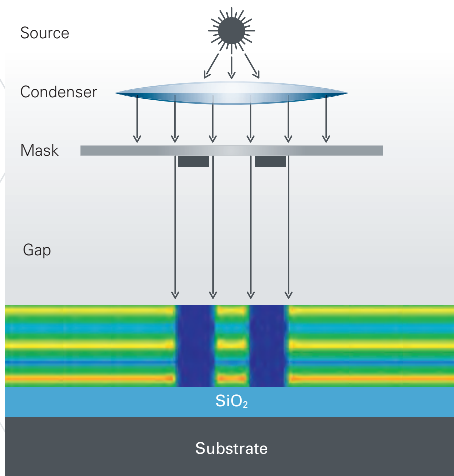
The intensities are computed based on Fraunhofer diffraction theory, followed by propagation in the resist (including absorption, bleaching, and refections within the stack) using the highly accurate transfer-matrix method (TMM).

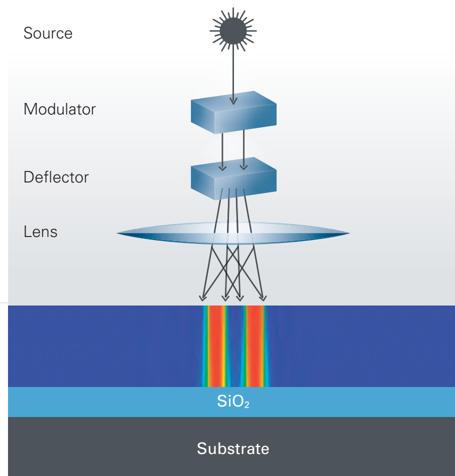
- Models reflective- and refractive-projection lithography, e.g. large area projection-printer, scanner, stepper including high NA and liquid immersion
- Any source types, either laser source (single wavelength) or arbitrary spectrum (e.g. broadband mercury lamp), with any shape (e.g. circular, annular, or user defined source shapes), source polarization
- Binary, gray-tone, or phase shift masks
- Any substrate material, coating, resist, and topography
- Thick resist, resist bleaching, and CAR

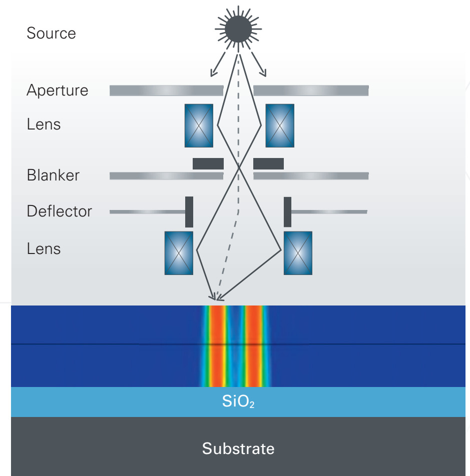


Mask without OPC **Mask with OPC** **Resist contour with and without OPC**

Projection lithography simulation for mask with and without OPC







Proximity Lithography

The intensity at arbitrary distances from the mask, from contact to large gaps, is computed using the Rayleigh Sommerfeld integrals, which takes into account all the diffraction orders scattered from the mask.

- Models reflective- and refractive-proximity lithography, e.g. large area proximity-printers, FPD color filter exposure tools, and mask aligners
- Any source type with arbitrary spectrum and shape, e.g. broadband mercury lamp, laser, collimation angle, and user defined source shapes
- Support for SÜSS MO Exposure Optics®, enabling source shape and source mask optimization (SMO)
- Binary, gray-tone, or phase shift masks
- Any substrate material, coating, resist, and topography
- Thick resist with resist bleaching

Laser Lithography

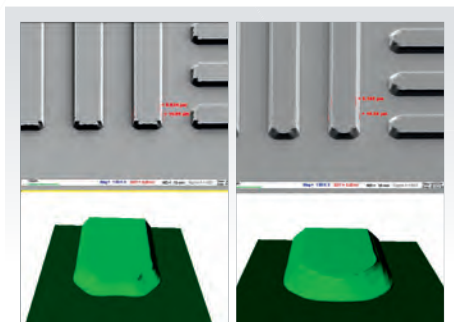
The intensities in the resist are calculated by incoherent superposition of the partially coherent beam using the systems parameters wavelength, numerical aperture (NA), beam size on substrate, (or beam radius) and focal length of the tool optics).

- Models all major exposure tools for mask or wafer exposure
- Includes the illumination optics of HIMT exposure tools
- Simulates gray-tone lithography
- Any substrate material, coating, and resist
- Thick resist with resist bleaching

Electron Beam Lithography

The intensities in the resist are computed using a 3D point spread function (PSF) that describes the stack dependent spread of the energy.

- Models Gaussian-Beam tools
- Interfaces to various 3D Monte-Carlo PSF packages, such as TRACER, or a user defined Multi-Gaussian PSF
- Simulation of dose modulated layouts (e.g. 3D lithography, proximity effect correction)
- Simulation of 3D resist development front over development time

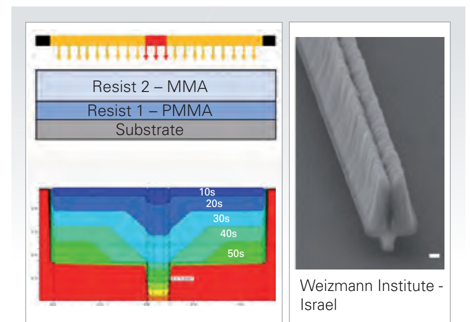


Resist profile optimization using 3D resist modeling

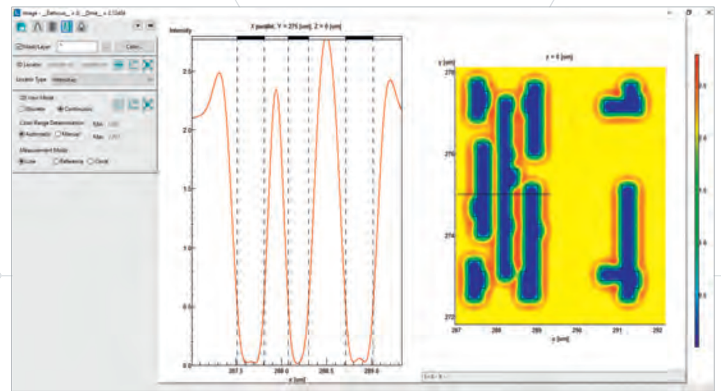
Resist Development Modeling

LAB offers the simulation of the 3D resist development process using models such as Mack4, development rate or simple threshold programs. Resist modelling calibration is based upon experimental data such as contrast curve's or resist profiles. The evolution of development front with time allows depth analysis of the final resist profile and thus helps profile optimization.

The 3D resist development process allows mulit layer resist simulations for T-Gate's and subsequent Lift-off.



T-gate simulation (scale bar is 100nm)



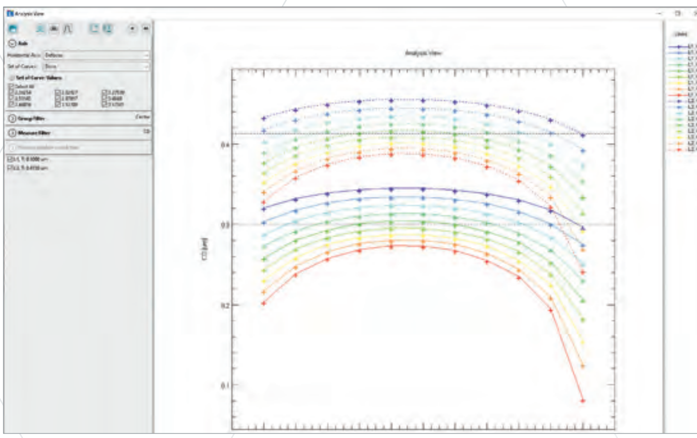
Analysis view – Intensity plot

LAB

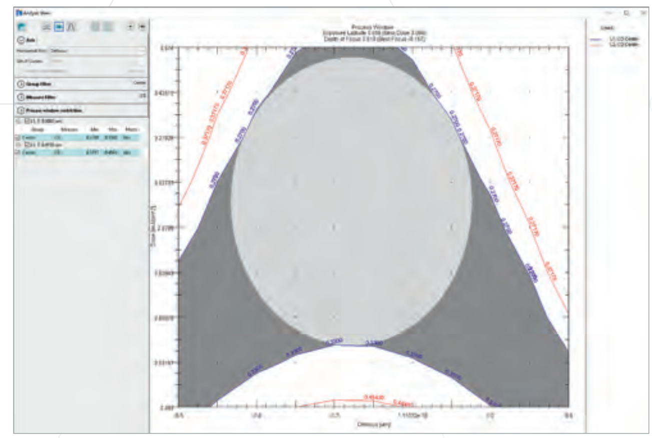
The most powerful lithography simulation tool kit

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 frequently used functions. This simple yet highly functional approach empowers the user to concentrate on the essential simulation tasks. Results can be evaluated by powerful visualization capabilities, including 1D, 2D and 3D views. The combination of 1D and 2D views and the capability of arbitrary cut-lines along with image quality metrics such as slope and log-slope allows a very detailed analysis. Critical dimensions (CD) can be measured either manually within the various views or automated through the metrology module. Process Window, DOF analysis, FEM, MEEF, contrast NILS, and reflectivity analysis are easily available. Optimization of the mask layout can be easily performed either manually through the integrated Layout Editor or semi-automated through powerful layout operations (Extract, Bias, Boolean … or using the optionally available Rule-based OPC function and the Model-based OPC for projection exposure).

LAB combines accurate simulation with strong tools for automated analysis (loop and optimize for varying parameters), metrology (measurement of dimensions) and evaluation (1D, 2D, 3D visualization, Matrix view, Process-Window, etc.).



Analysis view – Bossung plot



Process Window view

LAB Major Features

Layout Operations
- Import and Export of all major layout formats (GDSII, OASIS, CIF, DXF)
- Loading full mask layout data
- Extraction (Region, Layer, Cell), Transformation (Scale, Shift, Mirror, Rotate)
- Heal, Bias, Boolean operations, Merge

Layout Editor
- Creation of new layouts
- Layout modification within flows for manual OPC

Mask Definition
- Arbitrary layouts, regions of large mask data
- Mask corner rounding modelling
- Gray-tone mask
- Phase shift mask

Stack Definition
- Any substrate and coating material with wavelength specific n/k parameters from material database
- Anti reflection coating (ARC)
- Resist with wavelength dependent n/k, bleaching, Dill and development parameters (Mack4, CAR, Percolation, Threshold)
- 3D Topography (optional)

Projection Exposure
- Source spectrum (single line, broad band, peak-width)
- Source shape (circular, standard shapes of major stepper tools, user defined)
- Fast and accurate simulation of 2D or 3D intensities based on Fraunhofer diffraction solving the Hopkins equation and Transfer-matrix method (TMM)
- Projection aligner, scanner, stepper of any NA including liquid immersion

Proximity Exposure
- Source spectrum (single line, broadband, peak-width)
- Source shape (circular with collimation angle, user defined, SÜSS exposure optics),
- Mask/Illumination tilt in X and Y
- Fast and accurate simulation of 2D or 3D intensities based on Rayleigh-Sommerfeld and Transfer-matrix method (TMM)
- Arbitrary gap from contact to large distance

Laser Beam Exposure
- Models all major laser tools for mask or wafer exposure
- Includes the illumination optics of HIMT exposure tools
- Simulates gray-tone lithography

Electron Beam Exposure
- Models Gaussian as well as Variable-Shaped-Beam tools
- Interfaces to various 3D Monte-Carlo PSF packages, or user defined Multi-Gaussian PSF
- Simulation of dose modulated layouts (3D lithography, proximity effect correction)

Resist Development
- Simple and fast threshold and diffused aerial image model
- Mack4 for positive and inverse Mack negative resist development model
- CAR with dynamic Acid/Quencher diffusion/reaction model
- Resist development model using development rate table
- Surface inhibition for Mack4 and Percolation model
- Extract 2D resist contours as layout data

Metrology – Analysis – Calibration
- CD measurements at user defined resist height, or remaining resist thickness measurements
- Dose to Size, Reflectivity for resist and ARC thickness optimization
- Focus Exposure Matrix (FEM), Gap Exposure Matrix for Proximity, Process Window (PW), Depth of Focus (DOF), MEEF, for multiple metrology points
- Optical Proximity Correction (OPC) – Model-based OPC for projection exposure – Rule-based OPC for all exposure systems
- Flow parameters can be optimized to match a specified target using the Optimizer module

Visualization
- 2D visualization of aerial image, bulk image, Photo-Active-Compound (PAC) concentration, resist profile
- 2D views in continuous color mode, or discrete contour lines at user defined thresholds
- Arbitrary cut-lines in 2D views, 1D view along these cut-lines
- Combination of 1D and 2D views next to each other
- Overlay mask and/or target layout in 1D and 2D views
- 2D Matrix views, 1D Matrix or Overlay view
- Analysis of image quality: intensity, image slope, image log-slope
- 3D visualization of resist profiles
- View of collected metrology results as graph, e.g. FE Matrix (Bossung plot), process window

Import 3D – Export 3D
- Save and load 3D simulation data (image intensities, concentration)
- CSV Export

Pushing the limits

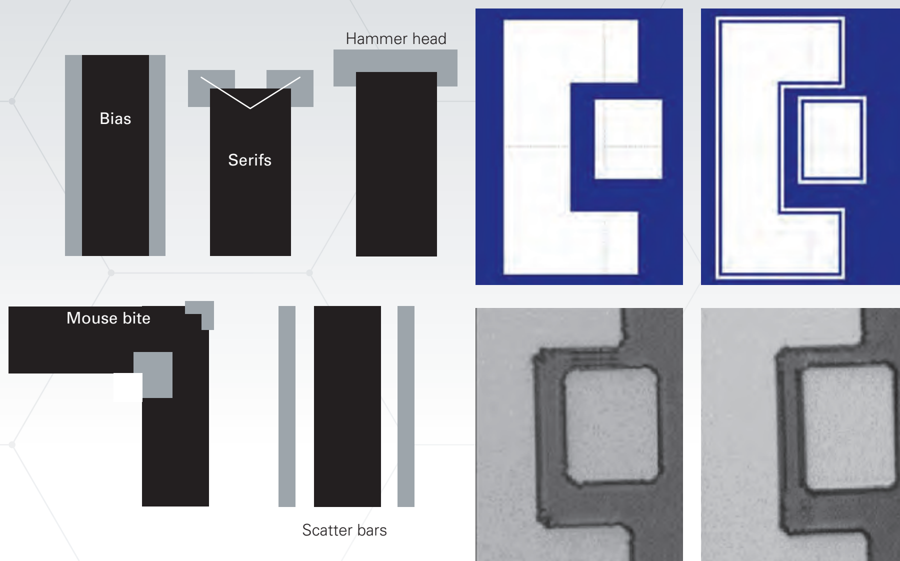
Lithography simulation for projection exposure (i.e. steppers) has been a key enabler for IC manufacturing to keep pace with market demands and Moore's law. Although 30 years ago the end of optical litho-graphy was predicted for feature sizes < 1 µm, optical lithography is currently achieving < 30 nm today in volume manufacturing. Without lithography simulation and the simulation based resolution enhancement techniques such as OPC, source shaping and source mask optimization these dimensions would have never been.

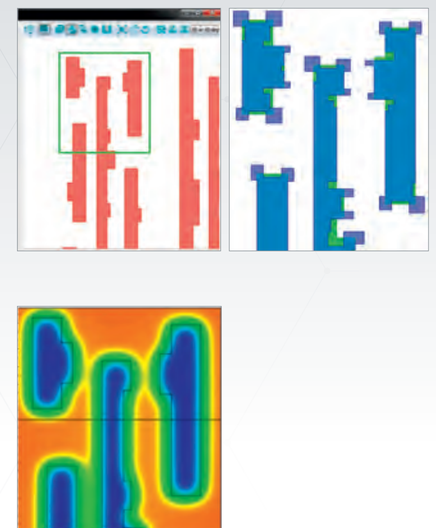
Without lithography simulation and the simulation based resolution enhancement techniques such as Rule-based OPC, Model-based OPC, source shaping and source mask optimization these dimensions would have never been possible.

The Model-based OPC allows efficient resolution enhancement for projection exposure. Rule-based OPC shows its flexibility to apply user-defined pattern correction rule for all exposure types.

LAB offers the power of simulation to push the limits for IC and non-IC applications (e.g. display LED, MEMS, special devices) with the strength of **GenISys** providing flexible packaging and licensing, fast development of needed functions, highly dedicated application support and a strong cooperation with users worldwide.

LAB combines the major lithography techniques used today (projection, proximity, laser, electron-beam) on a single simulation platform. This enables users to compare plus develop mix and match processes.





LAB Packaging

LAB is available in different license packages combining multiple lithography methods with comprehensive layout operations, optional OPC techniques and the power and flexibility of VisualFLOW. The packages allow fast and easy simulations with access to all parameters, powerful analysis features, semi-automated verification and optimization. The computational power can be extended by adding additional parallel users, and increasing the number of cores for parallel processing.

Extensive Tool and File Format Support

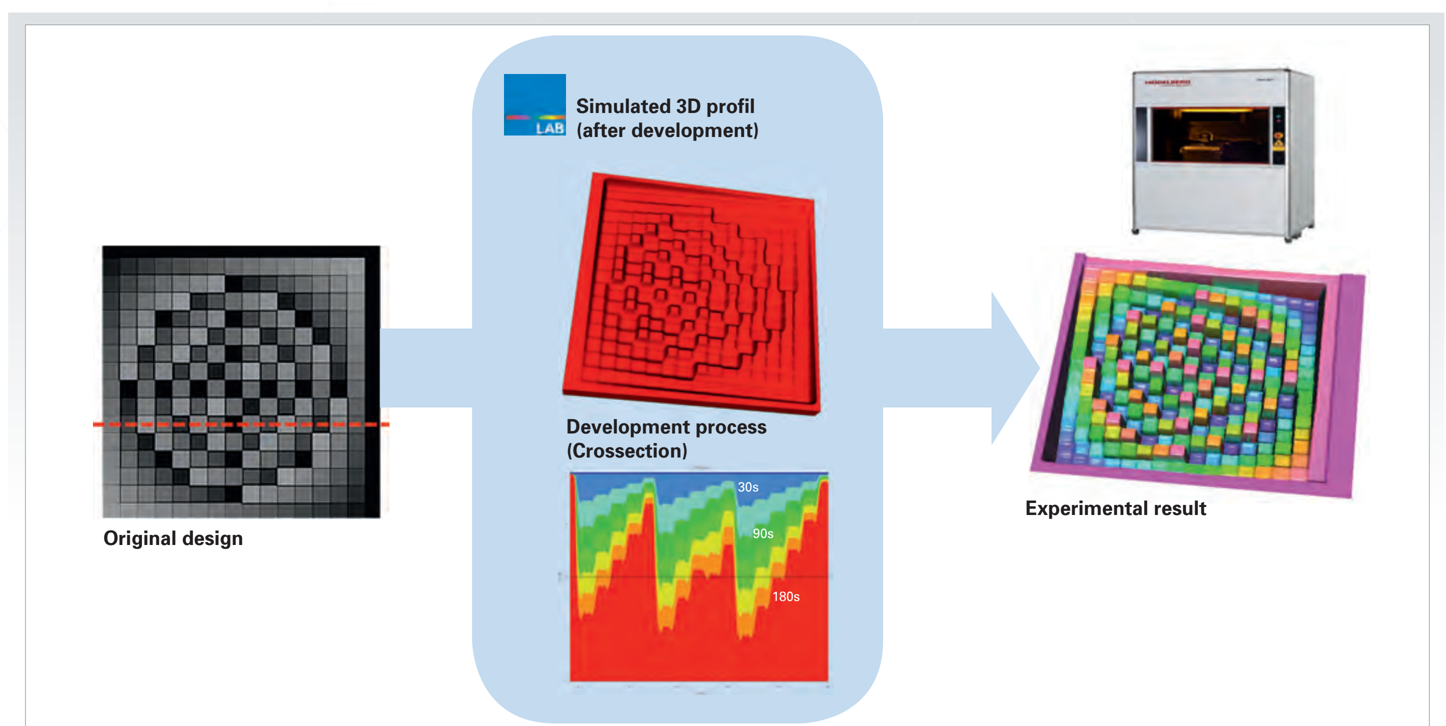
- Models any proximity lithography tool (mask-aligner, contact-printer, proximity-printer), e.g. SÜSS, EVG, and large area FPD exposure tools
- Supports projection lithography tools such as steppers for IC manufacturing, projection scanners
- Laser exposure tools for mask making and direct write (e.g. Heidelberg Instruments and other laser exposure tools)
- Models electron-beam lithography tools (Variable-Shaped-Beam, Gaussian-Spot-Beam) for mask making or direct write
- Import and Export of all major layout formats
- Open format for data-exchange with other software (CSV, GDS, others on request)

Flexible Licensing and Platform Support

- USB license key for dongle and network
- Flexible on off-the-shelf PCs (> 4 GB RAM recommended)
- Windows 10 64bit, Linux64 RedHat 6+, Ubuntu 18.04+
- Multithreading

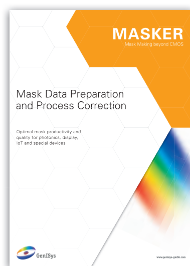
Maintenance and Support

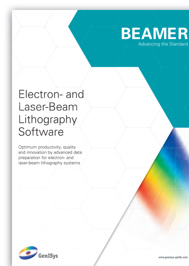
- Technical Support Hotline (e-mail, Skype, phone)
- Frequent updates with enhancements, new functions, performance tuning, and bug fixes
- Regional trainings, technical workshops, and user meetings
- 12 month maintenance service included in license price
- User feature requests have a high priority for implementation in future updates

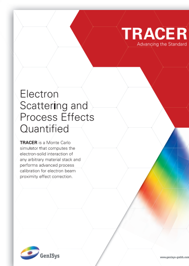


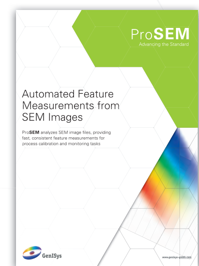
Example of gray scale lithography simulation
Experimental results achived with HIMT DWL 66+

LAB









Europe: **GenISys** GmbH
Eschenstraße 66
82024 Taufkirchen – Germany
Phone +49 (0)89 3309197-60
Fax +49 (0)89 3309197-61
E-mail info@genisys-gmbh.com

North America: **GenISys** Inc
Phone +1 (408) 353-3951
E-mail usa@genisys-gmbh.com

Asia Pacific: **GenISys** KK
Phone +81 (45) 530-3306
E-mail apsales@genisys-gmbh.com

www.genisys-gmbh.com

Based in Munich (Germany), with offices in Yokoyama (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.