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Taurus-Lithography

Photolithography Simulation

Taurus-Lithography performs complete photolithography process simulation, covering all aspec stepper setup, resist processing and mask layout optimization to maximize the capabilities of th photolithographic process. With Taurus-Lithography you can analyze the printability of any very large region of an integrated circuit by simulating its aerial image and comparing it to the origina mask design. Taurus-Lithography can also be used to analyze stacks of photoresists and diele layers to calculate complex layout patterns by simulating the critical exposure, post-exposure b (PEB) and development steps. The Optical Proximity Correction Advanced Application Module (OPC-AAM) automatically modifies layouts to improve their printability characteristics by using a optimization algorithm and a selection of models to calculate the printed contour.

TAURUS-LITHOGRAPHY HELPS YOU:

- Understand critical dimension (CD) variations.
- Simulate the aerial image of large designs using standard GDSII format.
- Analyze photoresist characteristics, including swing curve, focus exposure matrix, proce latitude, photosensitivity and contrast.
- Study PEB processing of deep ultraviolet (DUV) chemically amplified photoresists.
- Automatically evaluate mask printability.
- Evaluate various phase-shift mask strategies (alternating phase shift, phase shift with out-riggers, chromeless, attenuated etc.).
- Extract data such as CD, sidewall angle, image contrast and intensity, either interactivel in batch.
- Calculate reflective scattering from non-planar substrates.
- Compare different projection stepper strategies in terms of lithographic performance.
- Improve layouts by performing optical proximity correction (OPC).

3D PHOTORESIST DEVELOPMENT PROFILES

In state-of-the-art IC design and manufacturing, contact window layers have unique requiremer that are tighter than for non-critical lithography layers. The following approach can be used for contact window design: First, use Taurus-Lithography to explore different lithographic options, t calibrate the simulator to completely utilize its predictive capabilities. The fast three-dimensiona simulation capability of Taurus-Lithography is essential because of the 3D nature of contact windows.

This example demonstrates that achieved simulation accuracy for top/bottom critical dimensior and shape of the profiles is better than 10 percent. Process conditions: 0.45 µm contacts layou binary mask, contact/pitch ratio 1:3, photoresist JSR IX725D2G, i-line, dose 230 mj/cm2, silicor substrate. Figures (1) and (2): experiment and simulation at 0 µm defocus. Figures (3) and (4): µm defocus. SEM pictures (1) and (3) are courtesy of S. Brainerd, Integrated Device Technolog Inc.

PHASE SHIFT MASK ANALYSIS

A powerful characteristic of Taurus-Lithography is its ability to analyze phase shift masks. Note comparison of isointensity contour plots corresponding to the imaging of a set of 90-degree elb with a binary mask (Figure 7) and the considerable improvement in the image for an alternating phase shift mask (Figure 8).

DUV SIMULATION: CHEMICALLY AMPLIFIED PHOTORESIST

New photoresists have been developed recently for DUV lithography. The new photoresists rely chemical amplification of the deprotection mechanisms that make photoresists soluble. Simula of these new chemical systems requires the solution of reaction diffusion equations to simulate post-exposure bake process. With these new types of photoresists it is possible to print lines ar contact holes smaller than 0.25 µm using 248 µm steppers. Figure 5 shows simulation results o DUV photoresist (UVIIHS Shipley). The top left corner shows the intensity distribution for a 0.35 dense line on top of a silicon substrate. The top right image shows the acid concentration immediately after post-exposure bake. In the bottom left the concentration of protected sites is shown. The final developed profile is shown in the bottom right after 60 seconds development t

Post-processing capabilities can be used to perform detailed analysis of simulation results. In Figure 6, the three-dimensional developed contour is shown with a cut-plane showing the intens map through the photoresist thickness. The center panel shows the developed contour after 50 and 70 seconds development time. The right panel shows the intensity distribution for a horizor cut-line at the bottom of the photoresist.

TWO-DIMENSIONAL NON-PLANAR EXPOSURE

Non-planar exposure simulations are necessary to analyze the most advanced designs on non-planarized polysilicon layers. In addition, these types of simulations are needed to study patterning of damascene interconnects. (In these cases the photoresist layer is deposited on pl oxide layers. But the oxide layer is completely transparent and the underlying conductors form non-planar reflective layers.)

Taurus-Lithography incorporates a new module for two-dimensional non-planar simulations. Fig 9 shows the intensity distribution when exposing a 0.4 µm line on top of a non-planar substrate. intensity distribution indicates major differences with an idealized planar substrate simulation.

The electromagnetic field calculation of this module is based on a rigorous finite element metho developed and implemented by H.P. Urbach of Philips Research Laboratory, The Netherlands.

TAURUS-LITHOGRAPHY SPECIFICATIONS

SIMULATION FEATURES

- Fast and accurate aerial image simulation of very large regions of an integrated circuit design. Automatic mask partitioning and manual partitioning enable you to maximize simulation performance.
- Capability for calculating two-dimensional aerial images from complex optical systems:
- Simulates high NA projection steppers.
- Simulates phase shift masks, arbitrary illumination (including off-axis illumination), spatia filtering, magnification.
- Simulates lens aberration effects through Fringe-Zernike polynomial and Seidel aberratio coeficients (coma, astigmatism, curvature and spherical).
- Provides two-dimensional mask layout visualization and interactive phase shift
- Mask Design and Evaluation.

ANALYSIS CAPABILITIES INCLUDE:

- Printability analysis for potential photolithography failure of large design layout.
- Aerial image intensity slope threshold analysis.
- Interactive extraction of one-dimensional intensity distribution for CD measurement and image contrast analysis.
- Avant!-developed 3D High Numerical Aperture (High NA) Exposure Model for deep-submicron lithography, which addresses oblique propagation effects in 3D planar structures, including bulk defocus and damped energy coupling for deep-submicron lithography.
- Avant! proprietary development simulation with resist surface advancement using Level approach. For development rate calculations, Taurus-Lithography incorporates all the be modern models.

PHYSICAL MODELS

- Mask Model representing two-dimensional phase mask layouts of arbitrary complexity.
- Overlapping mask elements in the same layer are merged automatically. Multiplicative transmission rule is used for overlapping mask elements in different layers.
- Fringe-Zernike high-order lens aberration model with greatly increased accuracy for high projection steppers.
- Non-uniform fast Fourier transforms for fast and accurate aerial image simulation.

- Finite element formulation of Helmholtz equation for simulation of two-dimensional non-planar exposure.
- High NA model for three-dimensional planar substrate exposure simulation.
- Fast Marching Level Set Algorithm for three-dimensional development simulation.
- High-performance aerial image simulation based on TCC kernel decomposition.
- Reaction-diffusion model for post-exposure bake simulation of chemically amplified resis
- Extensive photoresist material library.

TAURUS-LITHOGRAPHY SPECIFICATIONS

INPUT/OUTPUT

- Graphical user interface provides:
  - Intuitive setup of stepper and mask characteristics.
  - Simulation control, automatic mask partitioning and manual selection of regions o interest.
  - Selection of post-processing utilities, including printability and intensity gradient analysis, three-dimensional intensity projection plot, two dimensional contour plot visualization of mask layout.
  - Ability to save a simulation run, load saved result.
  - Setup of complete photoresistant processing recipes and material parameters including: exposure, post-exposure bake and development, optical properties, photoresist development and post-exposure bake parameters.
  - Powerful one-, two- and three-dimensional capabilities for data extraction and visualization.

- Mask Layout interface through GDSII stream standard format. Mask layer properties tab enables the specification of any phase shift mask.

SYSTEM REQUIREMENTS

Platforms: UNIX-based computers from Hewlett-Packard and Sun Microsystems.
Memory: 64 Mbytes.
Disk Space: 100 Mbytes

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