SubLambda *Systems*

SubLambda Systems Corporation
65 Schlossburg St.
Alburtis, PA. 18011
(610) 682 - 4146 *(Voice/Fax)*

March 3, 2003

LithoWorks PW[tm]

Software Requirements Specification

1. Introduction

Last Modified:	Initial SRS: T. Zavecz 3/3/03
Release No.	1.0 March 3, 2003
Version No.	1.0
Description:	A stand-alone personal computer component for semiconductor production, Photo-lithographic process window calculation.

1.1 Product Scope

LithoWorks PW© addresses the need for a low-cost, simple to use tool for process centering of optimal focus and dose during the lithographic patterning cycle of the semiconductor production process. LithoWorks PW is a stand-alone product that can also be used in conjunction with other modules of the LithoWorks product suite.

1.2 Perspective

The LithoWorks© product suite provides tools for the analysis, control and design of the semiconductor lithographic process. Each module can be used separately or in conjunction with others, sharing a common interface, design and feel for the user. LithoWorks PW© is one offering of this suite of simple to implement data analysis, modeling and visualization tools.

LithoWorks provides an open system of access and versatility for the user. Any form of metrology data can be easily imported into LithoWorks. Data is stored in Microsoft Excel© worksheets for easy access and customization.

1.3 The Customer

The LithoWorks PW product provides valuable information and setup tools for the process, lithography, reticle design and exposure tool engineer.

2. Description

2.1 Objectives

?? Provide a software toolset for the calculation of optimum focus and exposure-dose of a semiconductor device reticle.
?? Calculate the process window size based upon the user's selection of the operating focus /exposure-dose and the constraining functional limits of device critical features.
?? Supply visualization for data and performance using advanced graphics and data plots.

2.2 Supporting Functions

?? Data import from any industry standard vendor format

?? Data conversion into a LithoWorks standard format for storage.
?? Tools for specifying exposure and focus layout of the raw data focus-exposure matrix.
?? Tools for manual specification of critical feature target and threshold size.

2.3 Background

The semiconductor production cycle can embody as many as forty (40) layers during manufacture. Each layer must be patterned to contain the various gates, sources and drains of every active transistor and capacitor in the final design. All of these physical elements must also be connected and linked to the outside world before the final product is functional. Patterns are first generated in each layer using a step-and-repeat (stepper) camera that exposes a product reticle at each grid site on the wafer stage. Newer designs, requiring greater resolution and smaller device geometries are typically exposed using a scanning-slit aperture (Scanner) to increase the effective Numeric Aperture (NA) and thereby enhance resolution locally.

The components of the devices fabricated to constitute a fully functional Integrated Circuit (IC) design each exhibit specific requirements for their size, composition and placement if they are to operate within specification. The scope of pattern sizes can vary from a millimeter or more down to just a few ten's of nanometers in size. Tolerances of variation for the feature size are typically +/- one-quarter (¼) the design specification of each element.

Problems occur when attempting to simultaneously, accurately image isolated features and those in close proximity to other small or large structures. The effective dose varies for each element because of the exposure proximity effects and scatter of the actinic radiation from nearby structures that can add to the local dose level. The objective of the process engineer in these situations is to select an exposure-dose that enables both small and large features to be properly sized as specified in the product design specification.

Feature size is a function of both the exposure-dose and the focus of the exposure tool. Feature sizes vary as a 2nd order function of the error in focus. Optimum focus of an isolated feature will also be different than that of a feature located within a dense grouping of similar features.

There, the engineer must select a nominal operating point that will enable all features to be correctly focused and to receive the optimum dose for size control.

Functional dose and optimum focus will drift during the production sequence as characteristics such as film composition, thickness, photoresist batch and illumination sources age. In addition, focus and exposure are not fixed over the pattern field of the stepper or scanner. Optimum focus will vary according to the aberrations present in the optical stack (lens) and the frequency loading of features on the device. Dose and focus can vary in a scanner due to non-uniformity of the scan-plane and accelerations of the slit at the start or end of each scan.

Optimum focus and dose must therefore be determined on a periodic basis depending upon the requirements of the device design and the capabilities of the exposure tool. When the capabilities of the exposure tool greatly exceed the needs of the device, then the process margin of operation is said to be great. Conversely, when the device needs are very close to the capabilities of the equipment set, then the process margin will be very small or even non-existent.

Production situations with large process margins will require only occasional optimization of the focus and dose. These optimizations typically are conducted on a monthly basis and at the introduction of a new photoresist batch or device design.

When the requirements of the device are very close to the capabilities of the exposure tool, the need for checking and adjusting the correct setting of focus and dose increases in frequency. In demanding environments, the settings should be performed for each individual device and exposure tool in the facility because of unique variations in lens aberrations and dose inherent in each tool.

The optimum dose for each feature is obtained by plotting the measured feature size as a function of the exposure dose. Feature size will typically be a linear function of the dose. Optimum dose will vary according to the relative size of the feature, it's orientation, the density of adjacent features and it's location within the exposure field.

Optimum focus is obtained by plotting the size of the feature against the focus-setting of the exposure tool. Focus will exhibit a 2nd order or quadratic change in feature size as a function of the distance from optimum focus. Best focus for the feature is therefore located at the point at which the first derivative of the curve is zero.

Ideally, focus should be determined at the optimum dose and conversely, dose must be set at optimum focus. Since this is difficult to achieve without a series of iterations, the engineer typically exposure a regular array of images into a focus-exposure matrix (FEM) of values. The Critical Dimension (CD) value of the feature is then plotted as a contour function of the focus and exposure-dose. The target value of the feature determines the unique focus and dose setting for the process and tool.

The set of focus-dose settings that satisfy the specified tolerance of feature size variations defines the process window of acceptable settings for the device. The range of focus values encompassed by this window is defined as the depth-of-focus (DoF) for the process. Similarly, the range of acceptable exposure-dose values defines the exposure latitude.

2.4 User Characteristics

User	Characteristics
Process Engineer	Engineer responsible for daily control and stability of the production process. This is a production function that requires periodic monitoring of the process. The process engineer will use the software to adjust production settings when new photoresist batches are installed and when equipment, wafer tracks and exposure-tools, are returned from maintenance.
Design or Device Engineer	LithoWorks PW will be used as part of the design cycle of the device. Data derived from simulators such as ProLith (KLA-Tencor) and Solid C will be applied to determine the DoF and exposure latitude anticipated from the design. Production's first lots will use the software to select the proper window coordinates based upon the modeling of empirical data.
Stepper Engineer	The tool engineer uses the LithoWorks software to define and confirm the depth of focus as limited by the lens and optical train. Extensive use during initial acceptance of the tool will confirm the capabilities of the tool to meet the purchase specifications. Repairs and maintenance sequences will employ LithoWorks PW to ensure the anticipated level of tool performance.

2.5 Operating Environment

LithoWorks PW will initially be designed as a stand-alone executable, functional under Microsoft Windows NT, 2000 and XP. An alternative would be to allow interface operation as an Internet based application using Netscape or Windows Internet Explorer as the host system. Benefits derived from an internet-based configuration would allow the user to access the software from any point on the customer's intranet. It's usefuln ess would however be limited in those production facilities that have extensive firewall isolation of the production and engineering office facilities such as seen in Taiwan and other far-eastern locations. License control is also more difficult across the Internet.

Data will be acquired from any text, binary or Microsoft Excel formats.

Data will enter the system from local disk storage, floppy, CD-rom or from remote nodes located across the Intranet.

2.5.1 License Control

LithoWorks PW will employ software-only license control that keys to the disk and CPU of the system of installation. Transfer of the license from one computer to a second would require the user to return a license-removal code to SLS confirming removal of the software. Updates for demonstration or permanent licenses are delivered using telephone, email or any other textual means.

LithoWorks PW supports only single-user licenses.

The customer who wants to purchase only one license and "move" the license functional environment among several computers in the fab or office will view software licensing as a drawback to portability. Problems can also arise with customers who attempt to copy the software to another computer and then request a new license because their old disk "died" or "crashed".

An attachment "Dongle" is the alternative method of enforcing licensing. This is a small attachment to the parallel port of the computer. The software accesses and reads the address on this dongle at each startup. Problems can arise from damaged hardware or the inconvenience of having multiple software applications requiring a string of Dongle attachments to the CPU.

2.6 Operational Modes

LithoWorks PW is a user-interactive application. The user is required to tune and guide analysis decisions that will influence the size of the process window.

The product image can be initiated as a stand-alone application from the user's "Start" menu or by sequence calling from a program external to the computer using windows-standard function calling conversions.

Data is stored in Microsoft Excel© workbooks. Output can be printed or cut/pasted into other windows applications.

2.7 Data Import Types

- ?? CD-sem
- ?? Electrical Linewidth Measurement
- ?? KLA Tencor ProData and ProLith formats.
- ?? Optical metrology tools
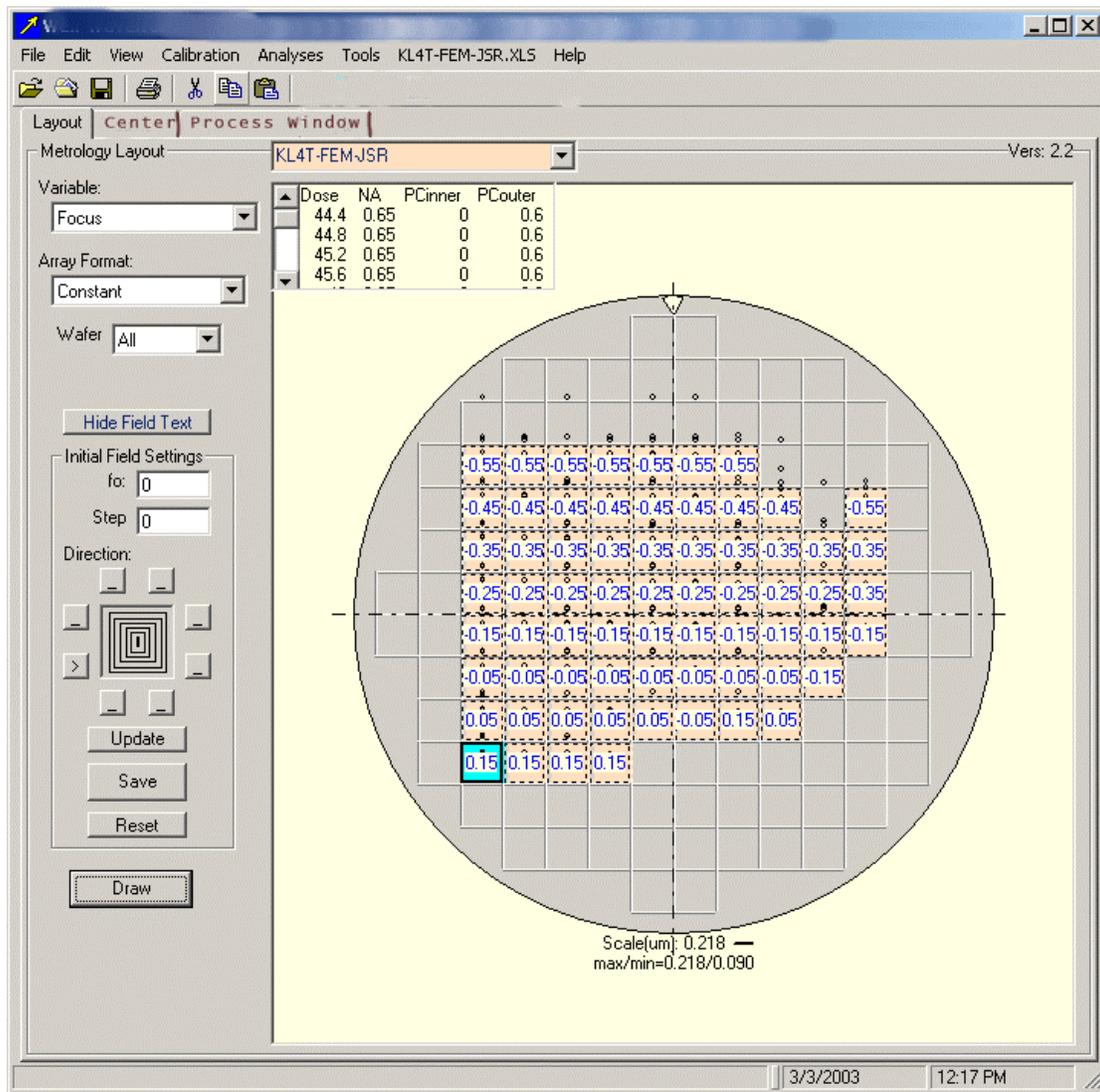- ?? Ellipsometric and scatter based metrology tools.

3. User Interface

Figure 1: LithoWorks Layout Interface

Data import and layout of the focus and dose matrix is performed using the interface shown in figure 1.

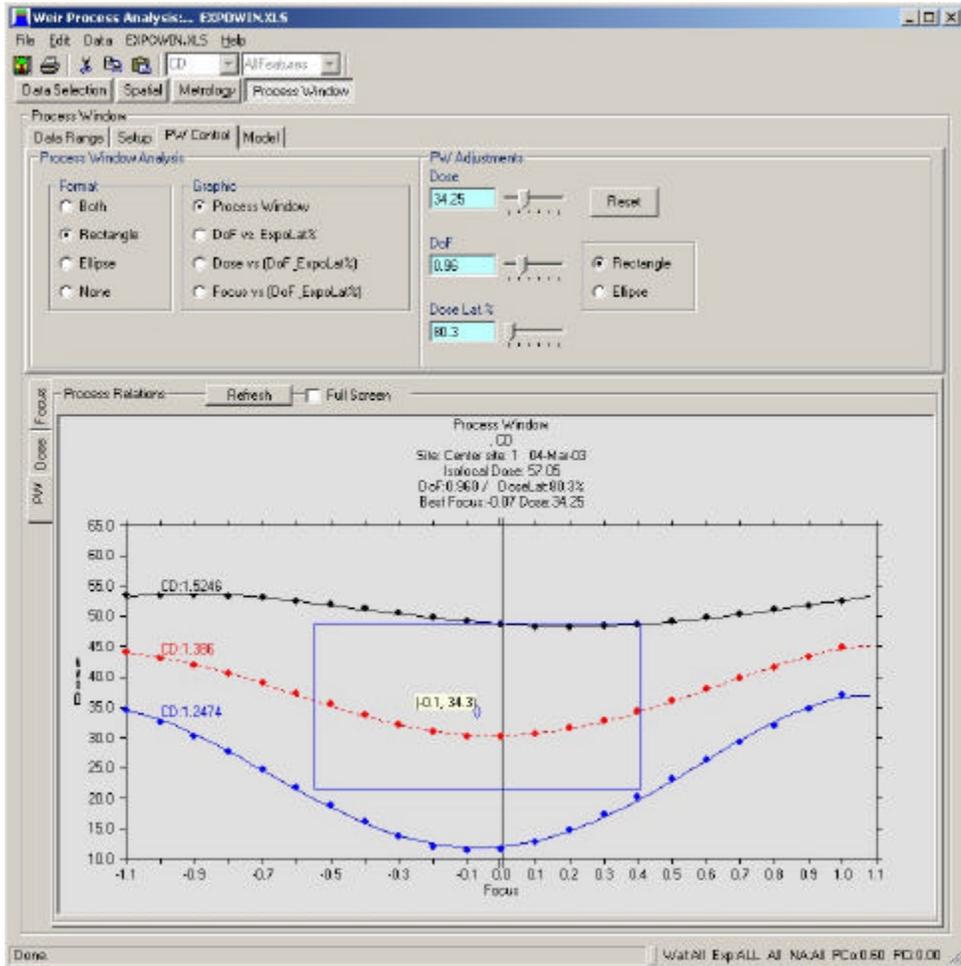Analysis of the data is performed under the "process window" tab, shown in figue 2.

Figure 2: Process window calculation interface.

Figure 3: Target and control limit specification.

Feature target and size limits are specified in the Data Setup window shown in figure 3. This window is accessed from a button-menu item.

A user-options interface will be provided for custom setting of:

- ?? The default data import format
- ?? Data directory location
- ?? Graph colors

4. Features

- ?? Multiple sites per field
    - o Point-and-click user mouse selection of sites
- ?? Multiple features per calculation
- ?? Best Focus Calculation
    - o Depth of focus determination.
    - o Iso-focal point determination.
- ?? Best Dose Calculation
    - o Exposure latitude determination
- ?? Process Window
    - o Maximum rectangular or elliptical window
    - o User-specified dose for depth of focus optimization
    - o User-specified depth of focus for exposure latitude.
    - o Calculation of Exposure-Focus curve for any number of process windows, field sites and features.
- ?? Data culling
    - o Automated, and by mouse-selection
- ?? Mouse function
    - o Point-and-click culling of data.
    - o Editing of plots
    - o Display of selected data points.

5. User Documentation

Documentation is provided as an adobe acrobat "pdf" file on CD-rom.

A hard-copy user manual is provided with every license.