ProLE-LE[™] - the single workstation version of ProLE[™] Workbench

- Efficient batching of PROLITH[™] simulations
 - GUI-based. No ProBATCH commands or syntax needed
 - Perform Monte Carlo Simulations (of aberrations only)
 - Investigate Higher Order Aberrations
 - Eliminate undesired simulation matrix conditions
 - Single workstation version of distributed-computing ProLE system
- Complements and enhances your PROLITH investment

*ProBatch is a set of commands for driving PROLITH™, from KLA-Tencor Inc.

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ProLE™ Workbench Menu Bar

• Workbench embeds ProLE, PROLITH, Data sorter and Automated ProData plus other software utilities.



ProLE™ Workbench Setup Screens

• Select any PROLITH input parameter including File Based inputs

PROLITH Parameters	Selected Simulation Parameters Output Parameters Cluste	r Setup Batch File Setup/Generation	🕆 Parameters
	beceted sindiatorri araneters output raranieters cluste		DD011711 Deventure Selected Simulation Parameters Devents Deventure Colored Co
Current Parameters			PROLITIN Parameters Decord Simulation anameters Dutput Parameters Dutyer Setup Job Setup/Execution
Eiler Check	PROLITHUntitled1		- Selected Parameters
Filli Stack			Selected rataneters
Basist	🗌 Film Stack		Default Stand dame Dimension Dimension
1103130	Layer 1: SPR 500 (resist)	None Selected	
Coat/Prebake	Resist Thickness (nm)		Simulation is a Focus-Exposure Matrix
	Layer 2: Silicon (substrate)	None Selected	- Numerical Inputs
Mask	Refractive Index Substrate (real)		Start Stop Increment # of Steps Order
	Besist		
Imaging Tool	Resist Type: Positive Conventional		Exposure (mJ/cm2) 0.5 2.5 -21 1
	Resist Material: SPR 500	None Selected	
Exposure/Focus	Resist Vendor: Shipley		
	User Defined: No		
Vibrations	Developer: MFT 245/501	None Selected	
	Resist Thickness (nm)		
PEB	Loat and Prebake	Control ProBaka Madal	
	Bake Model, Ideal Prehake Time (sec)		
Development	Prebake Temperature (C)	D 95.000000	· ·
	Resist Thickness (nm)	1000.000000	The Decode lands
Etch	Mask		Frie based inputs
Mahalami	Type: 1D Binary Mask		
Metrology	Feature Type: Line		
Numerics	Hotate 90 degrees: No	Control_Mask_Hotate_90	
Humenes	Mask Width (nm)		
	Mask Bias (nm)		
	ConventionalPartially Coherent		
	Gaussian: No	Control_Source_is_Gaussian	
	Illumination Spectrum: NONE	None Selected	• •
	Pupil Filter: NONE	None Selected	
	Aberrations: NUNE	None Selected	
	Wavelength (nm)		
	☐ Flare ▼		



Input File Selection Screen

Select inputs defined by PROLITH database files and ProLE Workbench will generate simulations varying the selected files automatically.

Available File-based Inputs

Mask Files - .MSK

1D Grayscale Masks -.GRY

Source Shape Files - .SRC

Spectrum Files - .ILL

Resist Files - .RES

Vibration Files - .VIB

Temp.(Bake)Profiles - .TPR

Pupil Filter Files - .FIL

CODE-V Aberrations -.INT

New file type:

High Order Zernikes - .HOZ

User Defined Distribution - .UDD

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File Based Inputs Browse Show List Remove All	Aberrations	
Selected Aberrations files		
I:\Aberrations\TYPICAL 1990 divide by 10.ZRN I:\Aberrations\TYPICAL 1990div3.ZRN I:\Aberrations\TYPICAL 1990div6.ZRN		
3 files selected	Close Window	PETERSEN

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Simulation Matrix Combination Screen

Current Matrix Controls		G	ilobal Matrix Co	ontrols					
Diagonal 1 Diagonal 2 Select All	Clear All		All Cases Diag	gonal1	All Cases Diag	onal2	Select All (lases	Clear All Conditions
	2	D Con	tact Hole	e Width ((nm)				
	Diagonal 2	200	240	280	320	360	400		
2D Contact Hole Height (nm)	200	\boxtimes							
2.5 contact hole height (hill)	240		\square						
	280			\boxtimes					
	320				\boxtimes				
	360					\boxtimes			
	400								

- Eliminate unnecessary simulations by taking control of the Simulation Matrix
- Use ProLE to simulate coupled inputs such as Contact Hole Width/Height, Alt. PSM Chrome Widths, and more



Aberrations Selection

- Investigate Zernike aberrations up to Z136
- Correlate PROLITH aberrations with CODE-V[™] Lens information
- Load and combine .ZRN, .INT and the new .HOZ files

Advanced Aberrations

Available Zernike Terms Selected Zernike Terms

Ten	m	Fringe Term	Aberration Type	Normalization	Formula
	0	(Z1)	Piston	1	1
	1	(Z3)	Y- Tilt	Sqrt(4)	R(sin(ø))
	2	(Z2)	X- Tilt	Sqrt(4)	R(cos(ø))
	3	(Z6)	Primary 45Deg. Astigmatism	Sqrt(6)	$R^2(sin(2\sigma))$
	4	(Z4)	Defocus	Sqrt(3)	2R^2 - 1
	5	(Z5)	Primary Astigmatism	Sqrt(6)	R^2(cos(2ø))
	6	(Z11)		Sqrt(8)	R^3(sin(3ø))
	7	(Z8)	Primary Y- Coma	Sqrt(8)	$3R^{3}(sin(\theta)) - 2R(sin(\theta))$
	8	(Z7)	Primary X- Coma	Sqrt(8)	3R^3(cos(ø)) - 2R(cos(ø)
	9	(Z10)		Sqrt(8)	R^3(cos(3ø))
	10	(Z18)		Sqrt(10)	R^4(sin(4ø))
	11	(Z13)	4th Order 45Deg. Astigmatism	Sqrt(10)	4R^4(sin(2ø)) - 3R^2(sin(
	12	(Z9)	Primary Spherical	Sqrt(5)	6R^4 - 6R^2 + 1
	13	(Z12)	4th Order Astigmatism	Sqrt(10)	4R^4(cos(2g)) - 3R^2(cos

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Example: F/E with auto dose-to-size centering, and Monte Carlo generated aberrations



Input parameter selection

F/E, aberration example page 1

- Select any PROLITH input parameter including File Based inputs
- Example: F/E with file-based aberrations
 - Aberrations selected for later file based input
 - Focus and Exposure selected

(193nm, 0.85NA, 100:100nm line-space Quadrupole 0.8/0.2 center/radius)



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Choose aberrations to be varied

alladie Ze	ernike i er	ms Selected Zernik	e Terms			
Import F	PROLITH	Zemike (ZRN) File	Clear ZRN Data	Import	High Order Zernike (HOZ) File Clear HOZ Data	
ease sele	ect the Ze	ernike Terms to vary			Double-Click any row to display image of Aberration	
Term		Fringe Term	Aberration Type	Normalization	Formula	ŀ
	12	(FZ_9)	3rd Order Spherical	Sqrt(5)	6R^4 - 6R^2 + 1	
	13	(FZ_12)	5th Order Astigmatism	Sqrt(10)	$4R^{4}(\cos(2\theta)) - 3R^{2}(\cos(2\theta))$	
2	14	(FZ_17)	3rd Order Quad-Foil	Sqrt(10)	$R^4(cos(4g))$	
	15	(FZ_27)	3rd Order 45 Deg. Pent-Foil	Sqrt(12)	$R^{5}(\sin(5\theta))$	
]	16	(FZ_20)	5th Order Y- Tri-foil	Sqrt(12)	$5R^{5}(\sin(3\theta)) - 4R^{3}(\sin(3\theta))$	
2	17	(FZ_15)	5th Order Y- Coma	Sqrt(12)	$10R^{5}(\sin(\theta)) - 12R^{3}(\sin(\theta)) + 3R(\sin(\theta))$	
	18	(FZ_14)	5th Order X- Coma	Sqrt(12)	$10R^{5}(\cos(\theta)) - 12R^{3}(\cos(\theta)) + 3R(\cos(\theta))$	
<u> </u>	19	(FZ_19)	5th Order X- Tri-foil	Sqrt(12)	$5R^{5}(\cos(3\theta)) - 4R^{3}(\cos(3\theta))$	
	20	(FZ_26)	3rd Order Pent-Foil	Sqrt(12)	R^5(cos(5ø))	
<u> </u>	21			Sqrt(14)	$R^{\delta}(\sin(6\sigma))$	
4	22	(FZ_29)	5th Order 45Deg. Quad-Foil	Sqrt(14)	$6R^{6}(\sin(4\theta)) - 5R^{4}(\sin(4\theta))$	
4	23	(FZ_22)	7th Order 45Deg. Astigmatism	Sqrt(14)	$15R^{6}(\sin(2\theta)) - 20R^{4}(\sin(2\theta)) + 6R^{2}(\sin(2\theta))$	
-	24	(FZ_16)	Sth Order Spherical	Sqrt(7)	$20R^{\circ}6 - 30R^{\circ}4 + 12R^{\circ}2 - 1$	
	20	(FZ_21)	/th Order Astigmatism	Sqrt(14)	$\frac{15 \text{K O}(\cos(2\theta)) - 2 \text{UK A}(\cos(2\theta)) + 6 \text{K } 2(\cos(2\theta))}{6 \text{K O}(\cos(2\theta)) + 6 \text{K } 2(\cos(2\theta))}$	_
d I	20	(FZ 28)	Stn Order Ouad-Foll	Sart(14)	OK DICOSI4811 - 3K 41COSI4811	Þ
CODE	V D	ilename lu en u			Monte Lario Setup	

F/E, aberration example page 2

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Example: Set aberration file conditions

F/E, aberration example page 3

ProLE Workbench - [Advanced Aberrations]					. D :
[] * * ? <u>=</u> = <u>3</u>					
Available Zernike Terms Selected Zernike Terms					
			Monte Carlo		
Z4 (FZ_4) (Defocus)	Mean	Sigma # of Digits)5 3	Distribution 2 - Gaussian Random	Values are	
Z7 (FZ_8) (3rd Order Y- Coma)	Mean	Sigma # of Digits 15 3	Bistribution 2 - Gaussian Random	user-specified	
Z9 (FZ_10) (3rd Order Tri-Foil)	Mean	Sigma # of Digits 15 3	Distribution 2 - Gaussian Random	distribution	
Z14 (FZ_17) (3rd Order Quad-Foil)	Mean	Sigma # of Digits 15 3	Distribution	generated	
Z17 (FZ_15) (5th Order Y- Coma)	Mean	Sigma # of Digits 15 3	Distribution		
Z19 (FZ_19) (5th Order X- Tri-foil)	Mean	Sigma # of Digits 15 3	Distribution		
CODE-V Base Filename IntFile#	Apply Norr	malization Factor Show in I	List Monte Carlo Setup Number of Monte Zernikes Conditions	te Carlo	
Generate Aberration Files Generate and Impo	ort to ProLE	C Only Fringe	Zemike		
Generate aberrati	on files or	run directly	7	PETERSEN ADVANCED	_ITH(

Enter values for selected parameters

F/E, aberration example page 4

ProLE Workbench			
N 🕅 🕷 🥥 🚰 📕 🔟 💆			
\\Quad550\ProLE_Work\Support Files\PROLITH Ten	nplates\0.85NA.pl2 Parameters	_ 🗆 🗙	<u> </u>
PROLITH Parameters Selected Simulation Parameters Outp	out Parameters Cluster Setup Job 9	Setup/Execution	
Selected Parameters Default Simulations Diagonals	Monte Carlo Autom simula	atic Dose to Size tion enabled.	
Start	Stop Increment # of St	eps Order	
Exposure - Relative .7 Focus (um) 6	3	-47 1 × -	
Selected Aberral Selected Files V(Quad550\ProL) V(Quad550\ProL)	tions files E_Work\Support Files\Aberration File E_Work\Support Files\Aberration File	sVntFile#1.int sVntFile#2.int sVntFile#2.int sVntFile#3.int sVntFile#4.int sVntFile#6.int sVntFile#8.int sVntFile#8.int sVntFile#9.int	
10 files se	lected	Close Window	
			h.

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Case table showing abberation combinations

F/E, aberration example page 5

🜌 Abe	erral	ion Cas	etable.txt - Notepad	- D ×
File E	dit	Format	Help	
		Seleo Z10 (Z17 (ted Zernike Coefficients: Z4 (FZ_4) (Defocus), Z7 (FZ_8) (3rd Order Y- Coma), (FZ_18) (3rd Order 45Deg. Quad-Foil), Z14 (FZ_17) (3rd Order Quad-Foil), (FZ_15) (5th Order Y- Coma), Z19 (FZ_19) (5th Order X- Tri-foil)	*
		Code Code Code Code Code Code Code Code	<pre>V .INT File 01: 0.012, 0.003, -0.0002, -0.004, 0.003, -0.003 V .INT File 02: -0.001, 0.002, -0.002, -0.003, -0.001, 0.002 V .INT File 03: 0.0003, 0.007, -0.0001, 0.008, 0.007, 0.001 V .INT File 04: 0.002, -0.005, 0.003, -0.005, 0.0003, -0.001 V .INT File 05: 0.003, 0.005, 0.003, -0.005, -0.008, -0.001 V .INT File 06: -0.001, -0.004, -0.0003, 0.001, -0.001, -0.009 V .INT File 07: 0.002, 0.007, 0.003, 0.009, 0.006, 0.003 V .INT File 08: -0.01, 0.004, 0.002, -0.003, -0.005, -0.003 V .INT File 08: -0.015, 0.001, -0.003, 0.001, 0.008, 0.002 V .INT File 10: -0.006, -0.005, 0.004, -0.006, -0.001, -0.004</pre>	



F/E process window (with ProDATA analysis option)

F/E, aberration example page 6



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Exposure latitude vs. DoF

F/E, aberration example page 7



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- PAL is the lithography expert
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- Contact us to do the same for your products!

J. V. Beach, J. S. Petersen, M. J. Maslow, D. J. Gerold, D. McCafferty, **"Evaluation of SCAA Mask Technology as a Pathway to the 65 nm Node,"** SPIE paper 5040-17, 2003



75 nm 1:1 dense lines. SCAA mask and 0.75NA, 193nm, 0.15σ

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