VWF

Virtual Wafer Fab

SILVACO

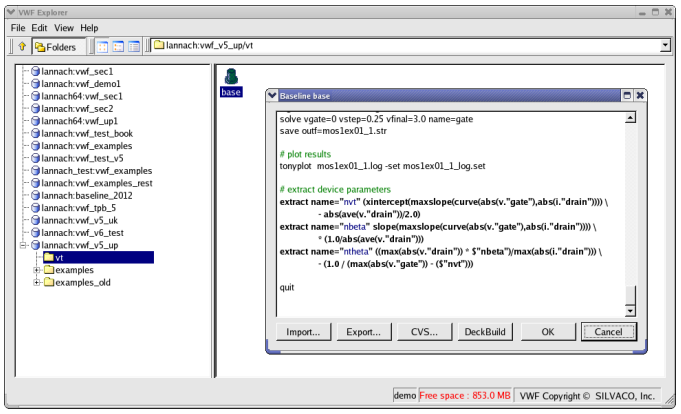
VWF is software used for performing Design of Experiments (DOE) and Optimization Experiments. Split-lots can be used in various pre-defined analysis methods. Split parameters can be defined for any of Silvaco's process, device, parasitic extraction and circuit simulators. All simulations can be carried out in parallel either on a cluster of workstations or on a single SMP machine. VWF comes with a GUI, that also enables examination of experimental results.

Key Features

- VWF can represent an entire flow from process simulation to spice circuit performance, or just part of the flow
- Any mix of masks, process parameters, device parameters, circuit parameters or tuning coefficients can be defined as input variables
- Experiments can be defined by varying the input parameters automatically via a DOE such as Box Behnken, via an optimization algorithm like Levenberg-Marquardt, via a user-definable script or manually
- Powerful scripting interface allows to fully customize DOEs, to run experiments in the background and to compute complex optimization target functions
- Process characteristics such as oxide thickness, device characteristics such as a threshold voltage, or circuit characteristics such as rise time can be measured from the entire flow
- Each experimental variation can be run on a network of hosts to shorten simulation time
- Response models can be generated over the experimental spread and then input parameters can be rubber banded to see the effect on output responses
- A full worksheet of input and measured output responses can be exported to Spayn for additional statistical analysis, or to TonyPlot for viewing purposes
- Advanced security features allowing fine-grained access control

Database Manager

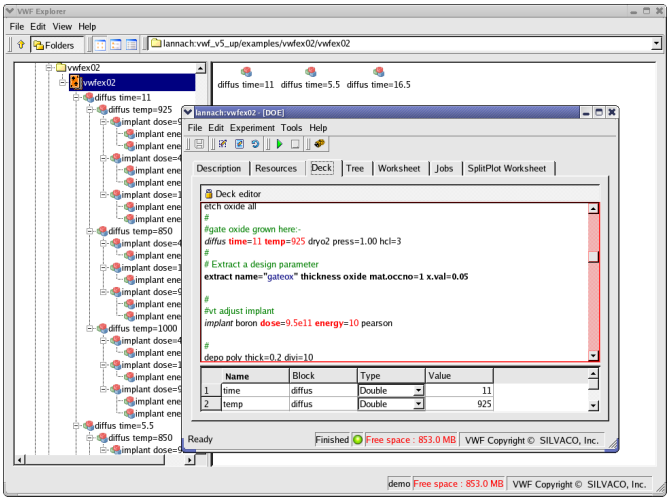
- Archive all experiments and results in a powerful SQL-92 compliant database
- Supports the Silvaco SRDB database to backup and restore databases easily
- Supports both database and file mode data storage environments
- VWF Tar Import/Export – Smooth process to move an experiment from one database to another database
- Supports multiple databases
- Access to multiple databases through a user name and password
- External files used in the input deck are loaded in the database using the resources menu



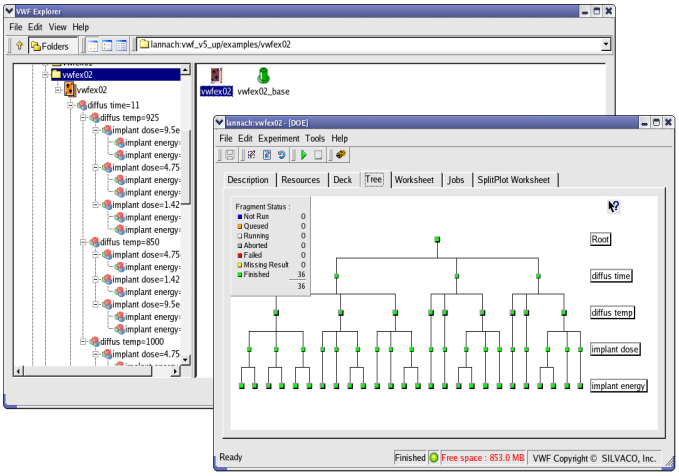
Input decks can be loaded from files, or pasted from another directory in the same database or imported from another database.

Split-Lot Manager

- Allows selection of variables where a design split will occur
- Design split points may occur at any stage of a complete process flow (i.e layout, process, device, parasitic extraction and spice)
- Resultant split tree is visually displayed
- Each leaf of the design tree may be selected to provide information on the simulation runtime output or to plot the current structure for that particular process flow



Split parameters are defined graphically for any type of simulator.

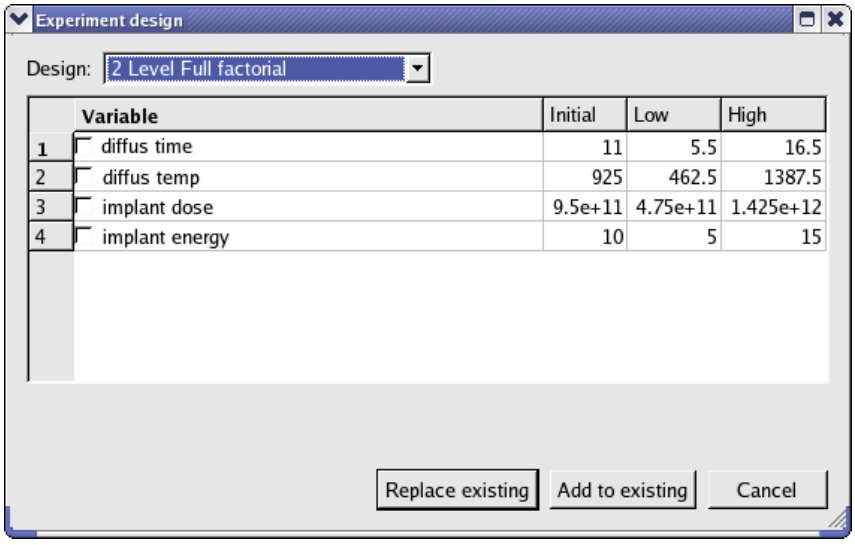


Access experiments through an explorer or tree view graphic.

Experimental Design Generator

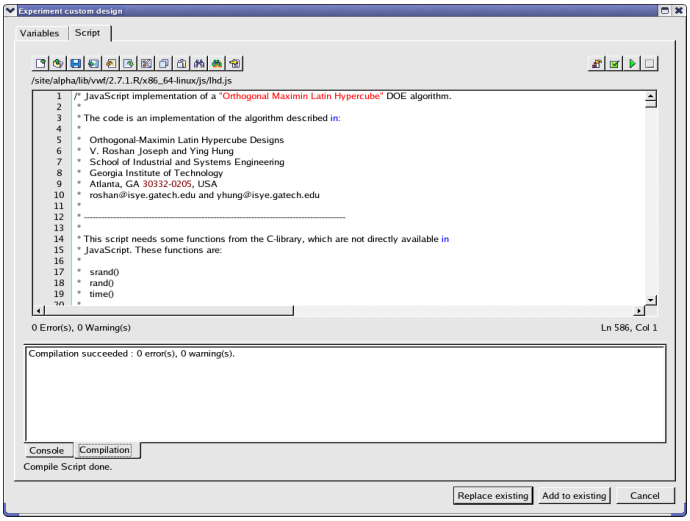
- Shows selectable list of available variables on which split-lots can be performed
- Each split may be chosen independently or based on DOE
- The DOE choices include
  - Full factorial and partial factorial orthogonal designs
  - Box Benkhen, Face Centered Cubic and Circumscribed Composite designs
  - Linear random and latin hypercube designs
  - Gaussian random design
- Scalar and vector optimization can be done using multi-threaded GA and LM optimizer
- Sensitivity analysis where each selected variable is varied +/- a defined percentage
- Design generator fills in the split-lot tree with all selected variations after selection of the range for the DOE

Design of Experiment Generator. The DoE is selected from the pull down menu.

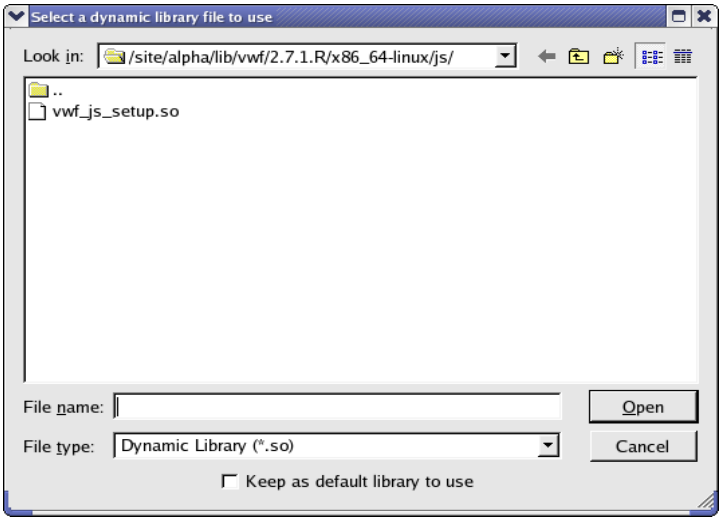


Scripting Interface

- Extensions of DOE capability
- Allows to implement DOE strategies in JavaScript
- Supports execution of experiments in the background without the need to start the GUI (batch mode)
- Allows to use shared libraries to interface functions of the underlying C and math libraries



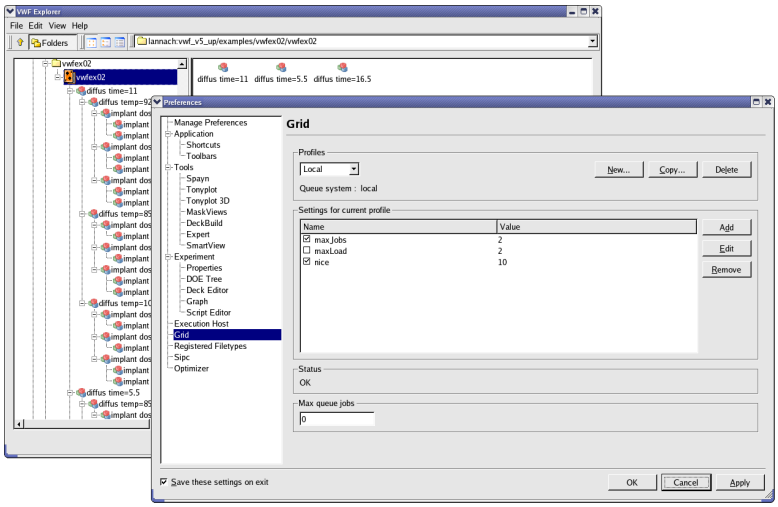
JavaScript editor displaying an advanced Latin-Hypercube algorithm.



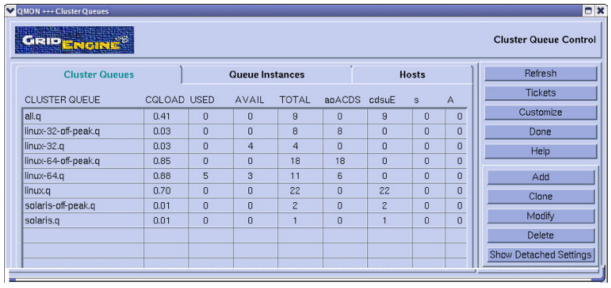
Defining a shared library to load.

Network Job Controller

- VWF supports ORACLE grid engine and Open Grid Scheduler
- VWF supports LSF (Load Sharing Facility)
- Controls distribution of simulation jobs across the network
- Displays all machines on the network
- Shows a complete list of all jobs in the simulation queue for all displayed machines
- Shows the state of each machine to be controlled
- Allows selected jobs to be canceled from the queue
- Controls number of jobs sent to a single machine at any one time (for multi-cpu machines)



Set up CPU numbers on multi-CPU machine when the local queue is used.

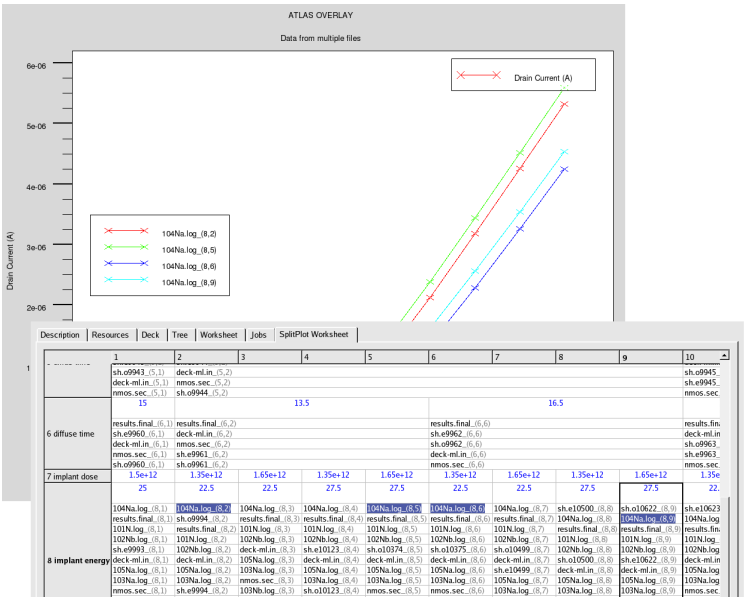


Grid-Engine Cluster Configuration.

Split Plot Worksheet

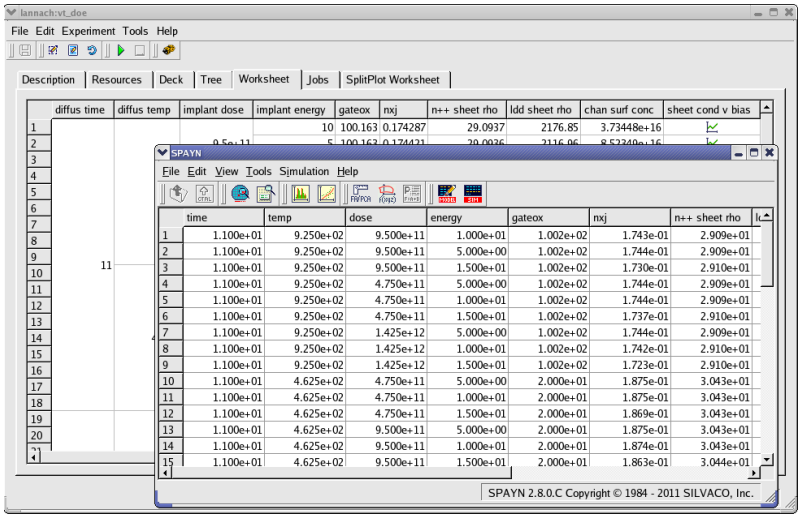
- Extension of Interactive Worksheet Editor
- Different view at worksheet allowing to filter by file-type
- Multiple selection of several files to plot
- Data can either be plotted in a single TonyPlot window or several TonyPlot windows can be opened - one per file

Drain Current vs. Gate Voltage shown for 4 different process parameter combinations. Curves correspond to the selected cells 8.2, 8.5, 8.6, and 8.9 (red, green, dark blue, light blue).



Interactive Worksheet Editor

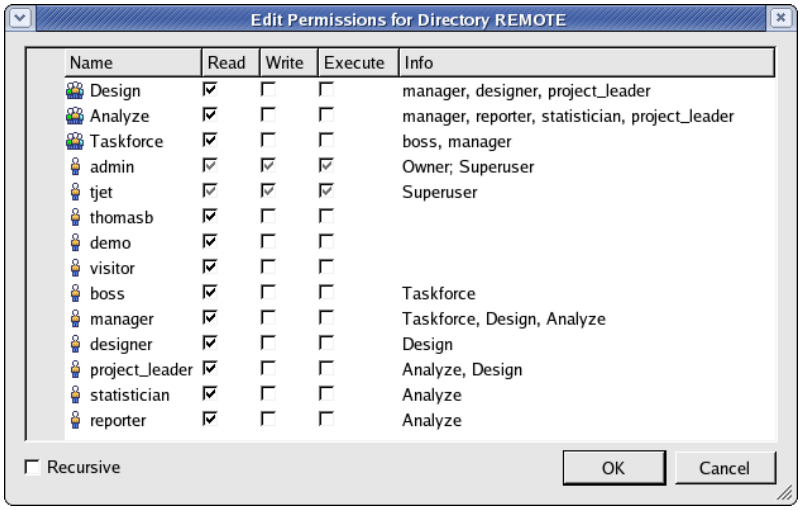
- Display in the worksheet the variations of input parameters
- Additional splits may be added into the worksheet for simulation
- Selection of splits may be enabled or disabled before being simulated
- Results can be selected to be exported to TonyPlot for visualization purpose
- Results can be selected to be exported to Spayn for further statistical analysis



The worksheet can be directly sent either to TonyPlot or Spayn for subsequent statistical analysis and RSM generation.

Security Features

- VWF allows to define read/write and execute permissions for every directory and experiment in the system
- Experiments can be shared between several users in the database
- User groups can be used to define the same permissions for several users
- One pre-defined superuser allows to change ownerships and permissions for all users and groups

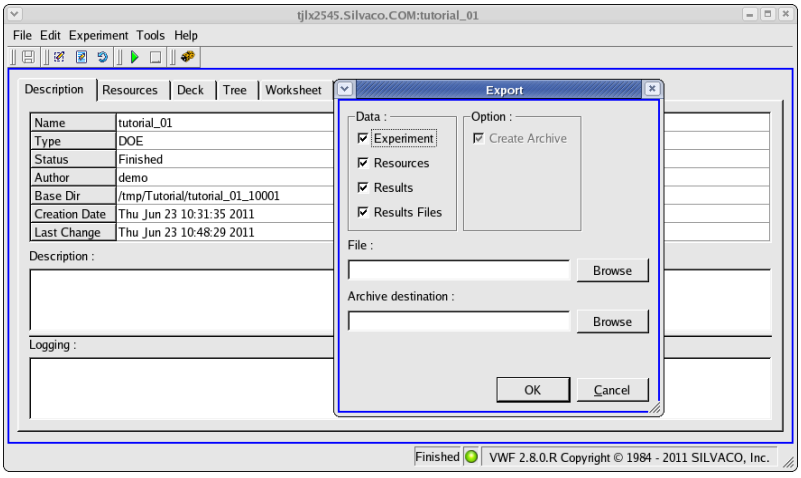


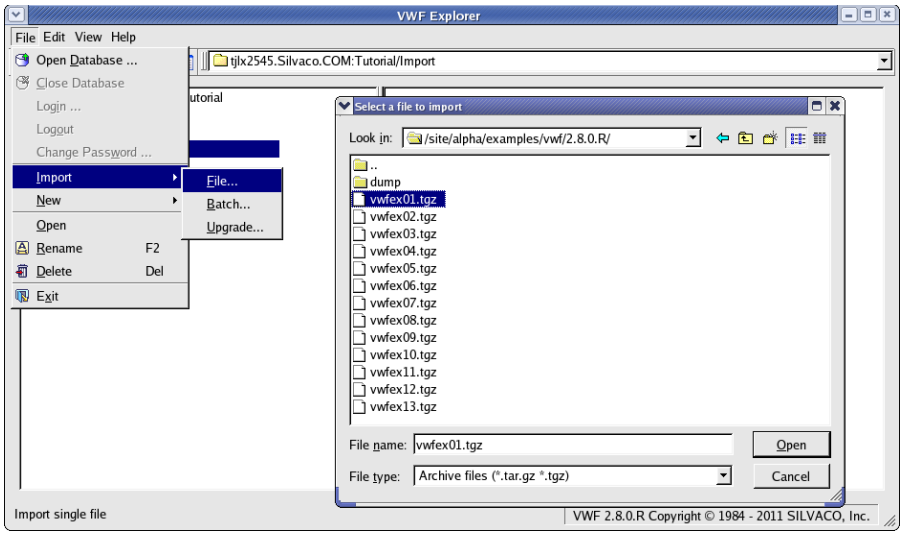
Security dialog showing several groups and users.

Powerful Import/Export Capabilities

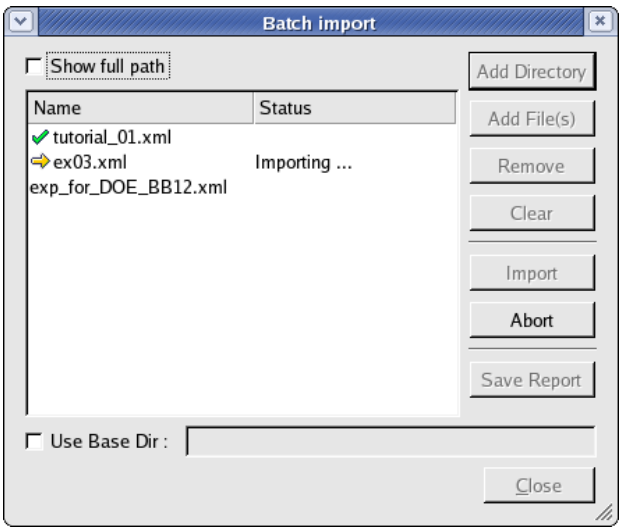
- VWF allows to export a whole experiment from the database into an external TAR representation for inter-site exchange or to open the experiment in VWF filemode
- TAR files can be imported into the database as experiments
- CSV files can be imported to define a DOE
- Worksheet can be exported into CSV
- Simulation decks can be imported from an existing CVS repository

Experiment tutorial_01 is exported to a zipped TAR file. The result can directly be opened in VWF filemode or the file can be imported into another database.

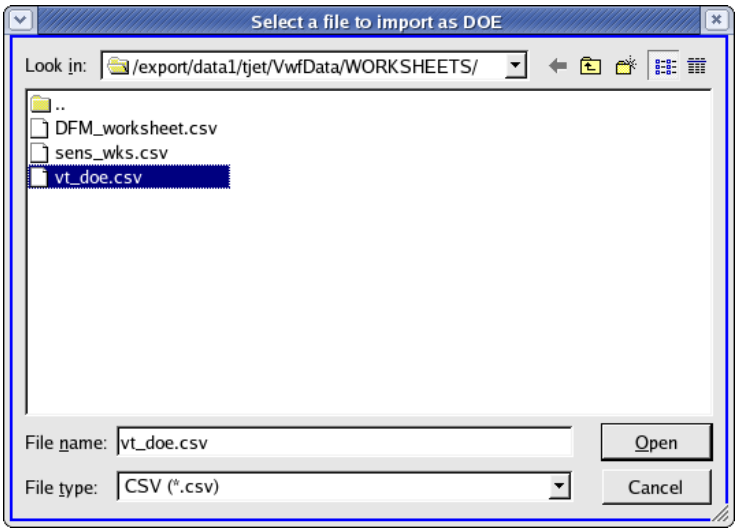




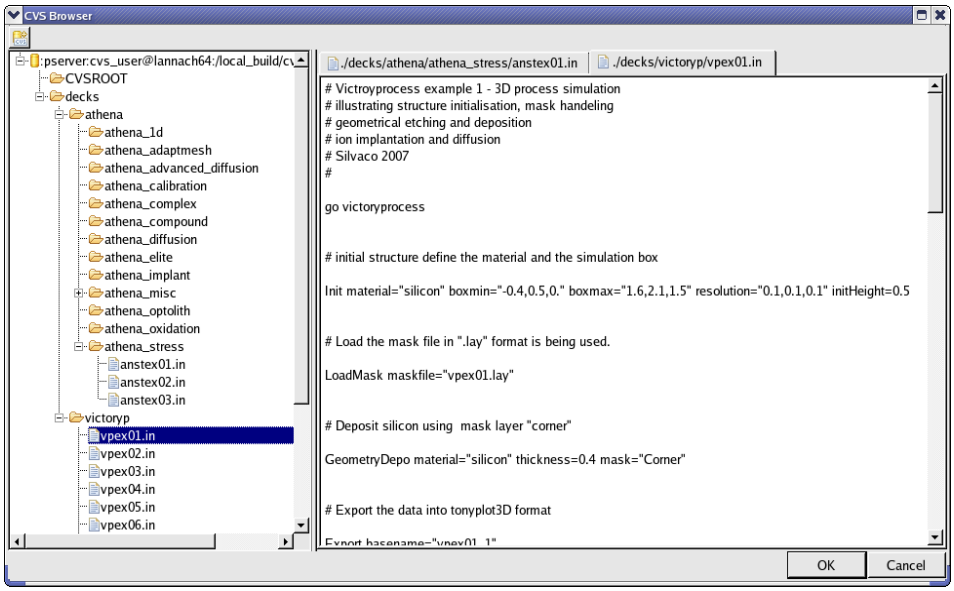
Importing a single TAR file.



Importing several TAR files in batch mode.



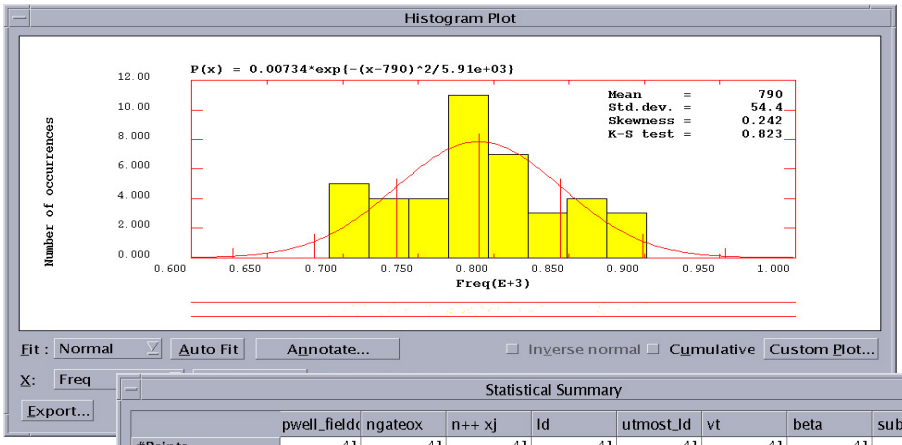
Importing CSV file to define a DOE.



Importing deck from a CVS repository.

Result Analyzer

- RSM model generation
- Interactive model visualization
- Sensitivity analysis
- Process synthesis
- Yield analysis
- Optimization results visualization

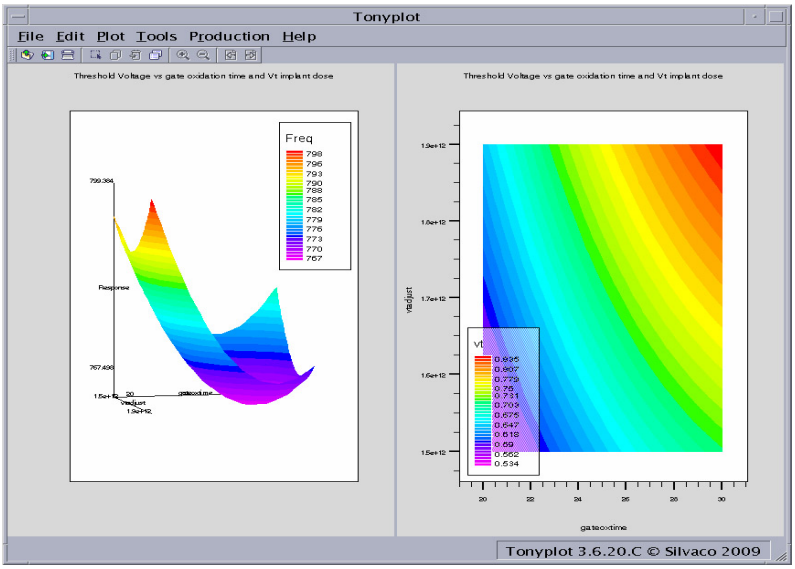


Statistical summary as well as histograms are available in Spayn for of all variables (i.e process parameter) and corresponding extracted parameter (i.e Ring Oscillator frequency).

Statistical Summary

	pwell_field	ngateox	n++ xj	Id	utmost_Id	vt	beta	subvt
#Points	41	41	41	41	41	41	41	41
Distribution	Constant	Normal	Normal	Normal	Normal	Normal	Normal	Normal
Minimum	3.500e+02	1.083e+02	2.597e-01	5.412e+03	5.412e-01	5.315e-01	7.096e-04	8.617e-02
Maximum	3.500e+02	1.366e+02	3.120e-01	6.404e+03	6.404e-01	8.328e-01	1.036e-03	9.842e-02
Mean Value	3.500e+02	1.227e+02	2.832e-01	5.910e+03	5.910e-01	6.917e-01	8.518e-04	9.196e-02
Standard Deviation	0.000e+00	8.915e+00	1.545e-02	3.136e+02	3.136e-02	7.592e-02	7.837e-05	2.646e-03
Coeff. of Variance	0.00%	7.27%	5.46%	5.31%	5.31%	10.98%	9.20%	2.88%
Skewness	N/A	-7.896e-02	4.333e-01	-2.423e-02	-2.423e-02	-1.731e-01	3.680e-01	2.413e-01
Kurtosis	N/A	-3.320e-01	-2.793e-01	-3.338e-01	-3.338e-01	-9.994e-01	-5.230e-01	-3.097e-01
Median	3.500e+02	1.228e+02	2.818e-01	5.912e+03	5.912e-01	7.059e-01	8.406e-04	9.167e-02
Upper Quartile	3.500e+02	1.228e+02	2.835e-01	5.912e+03	5.912e-01	7.610e-01	8.926e-04	9.388e-02
Lower Quartile	3.500e+02	1.228e+02	2.801e-01	5.911e+03	5.911e-01	6.393e-01	7.960e-04	9.005e-02
InterQuartile Range	0.000e+00	3.000e-02	3.376e-03	2.100e-01	2.100e-05	1.216e-01	9.659e-05	3.828e-03

Export... OK



RSM generation done in Spayn and then visualized in TonyPlot. The ring oscillator frequency is shown as a function of process parameter (gate oxidation time and Vt implant dose).

Correlation between user selectable parameter is available directly from Spayn.

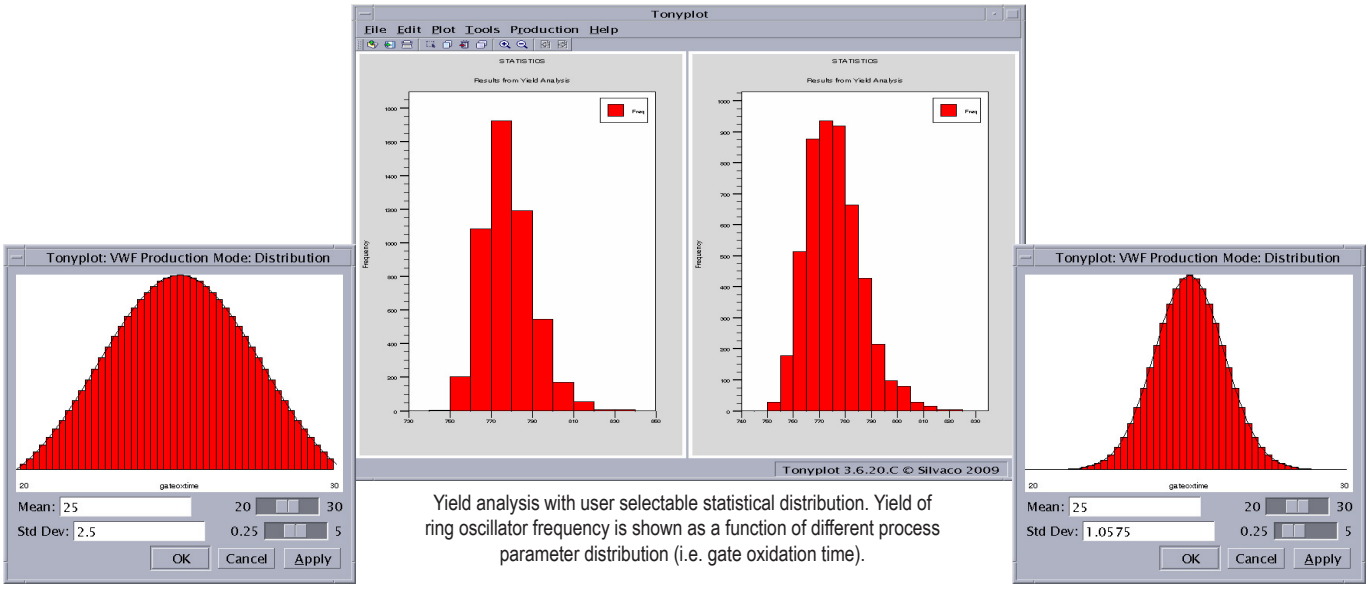
Correlation Matrix

Parameter Selection: pwelldose, nwelldose, gateoxtime, vtadjust, deltacd, ngateox, n++ xj, Id, utmost_Id, vt, beta, subvt, idsmax, N-lin_RMSer, N-lin_AVGer

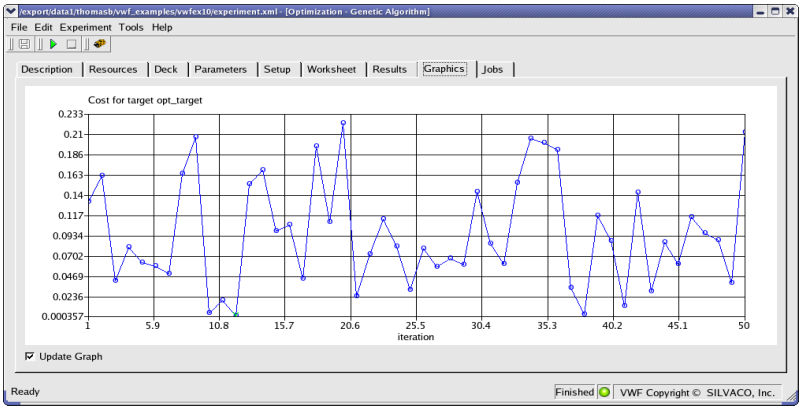
Matrix

	ngateox	n++ xj	vt	idsmax	pgateox	p++ xj	pvt	pidsmax	Freq
pwelldose	−0.0011	−0.9891	0.2793	−0.2336	−0.0000	−0.0000	−0.0000	0.0000	−0.0479
nwelldose	−0.0001	0.0709	−0.0353	0.0188	0.0003	−0.9811	0.7918	−0.4503	−0.3069
gateoxtime	0.9998	−0.0618	0.7948	−0.8923	0.9998	−0.1543	−0.0495	−0.6844	−0.1063
vtadjust	0.0000	−0.0000	0.4997	−0.2391	0.0000	−0.0000	−0.5922	0.1967	−0.0126
deltacd	0.0000	−0.0000	−0.0710	0.2611	0.0000	−0.0000	−0.0708	0.5332	0.9301
ngateox	1.0000	−0.0601	0.7964	−0.8945	1.0000	−0.1537	−0.0478	−0.6855	−0.1066
n++ xj	−0.0601	1.0000	−0.3302	0.2881	−0.0612	−0.0630	0.0628	0.0067	0.0327
vt	0.7964	−0.3302	1.0000	−0.9376	0.7968	−0.0840	−0.3495	−0.4736	−0.1672
idsmax	−0.8945	0.2881	−0.9376	1.0000	−0.8949	0.1150	0.1705	0.7022	0.3505
pgateox	1.0000	−0.0612	0.7968	−0.8949	1.0000	−0.1541	−0.0475	−0.6857	−0.1068
p++ xj	−0.1537	−0.0630	−0.0840	0.1150	−0.1541	1.0000	−0.7742	0.5487	0.3167
pvt	−0.0478	0.0628	−0.3495	0.1705	−0.0475	−0.7742	1.0000	−0.4836	−0.2940
pidsmax	−0.6855	0.0067	−0.4736	0.7022	−0.6857	0.5487	−0.4836	1.0000	0.7076
Freq	−0.1066	0.0327	−0.1672	0.3505	−0.1068	0.3167	−0.2940	0.7076	1.0000

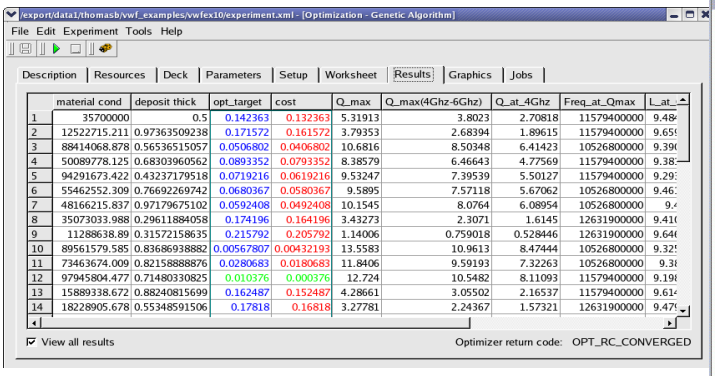
Export... OK Cancel Apply



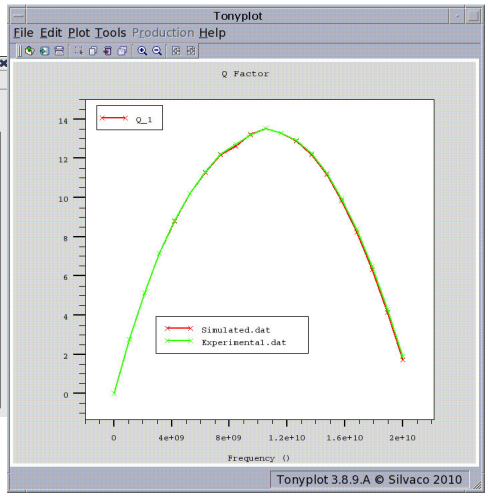
Yield analysis with user selectable statistical distribution. Yield of ring oscillator frequency is shown as a function of different process parameter distribution (i.e. gate oxidation time).



Graphical view of an optimization experiment. In Green the best result that minimize the target.



Optimized process parameters obtained for the targeted experimental Q factor curve.



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Rev 040920_02