SPDC : An Automatic Generator of Input Data for Process Simulators from Process Flow Data for Manufacturing

Takaaki Tatsumi, Hisahiro Ansai*, Mikio Mukai and Yasutoshi Komatsu

ULSI R&D Laboratories, Semiconductor Company, Sony Corporation
* Process Development Department, Semiconductor Company, Sony Corporation
4-14-1, Asahi-cho, Atsugi-shi, Kanagawa-ken, Japan, tatsumi@ulsi.sony.co.jp

ABSTRACT

We have developed a system called SPDC, which is designed to automatically generate input data for simulation from process flow data for manufacturing. As this conversion is not one-to-one translation, SPDC prepares databased knowledge called "scenario" from both device and simulation expert engineers. This database is utilized to analyze process flow data for manufacturing and then to synthesize input data for simulation. SPDC enabled device engineers unfamiliar to simulation utilization to prepare input data reducing more than three days work to less than a few minutes work. The quality of the synthesized input data is perfectly comparable to the one written by expert simulation users.

Keywords: process simulation, data conversion, expert system

INTRODUCTION

For the realization of today's miniaturization and low voltage drive of ULSIs, computer simulation has become wide spread use and indispensable for optimizing and predicting the effect of process variations on device performance and determining specifications. However, generating input data for simulation from manufacturing data is not an easy task for device engineers unfamiliar to the utilization of simulation. In order to resolve this difficulty a system called SPDC is developed, which automatically generates input data for simulation from process flow data for manufacturing. As this conversion is not one-to-one translation, SPDC utilizes databased knowledge from both device and simulation expert engineers; for example, to generate process simulation input data for MOS transistors, SPDC distinguishes manufacturing steps between P-type and N-type transistor and extract process parameters separately.

AN AUTOMATIC DATA CONVERTER SPDC

Expert engineers of both device and simulation use three kinds of knowledge to generate input data for simulation from process flow data: general order of process flow; how the process flow data is described; conversion rule from process flow data to input data for simulation. SPDC consists of three modules, each of which corresponds to the knowledge of the experts(Figure 1). Expert knowledge is specified with scenario editor as scenario steps and then used for extracting process parameters from process flow data and generating appropriate simulator input data. Details of the modules are described in the following sections.

Scenario Editor

SPDC extracts expert engineers' knowledge specified above into data file called scenario with the aid of an efficient GUI scenario editor. Scenario consists of a sequence of steps to describe general process flow of manufacturing semiconductors. Every scenario step includes keywords for searching process flow data and a direction for output expressions.

Figure 2 is the main panel of the scenario editor. On upper window, a list of general process steps for manufacturing is shown; on the lower window, process steps for manufacturing which corresponds to selected item from upper window are shown. Figure 2 shows that the user has broken up a general process "gate oxidation" into two simulation process steps "etching" and "oxidation."

Figure 3 is an input window for an oxidization step. Every step of a scenario contains keywords and output expression information. Keywords are used for searching for the corresponding step from process flow data. Output expression is specified when there are more than one possible results; for example, if a thermal oxidation process does not affect on impurity distribution, it can be replaced by SiO2 deposition process to reduce the calculation time. In the oxidization step, thickness can be specified when fixed values are required for simulation. Precise parameters such as ramping rate for up/down and pre/post oxidation time which depends on equipments can also be set with this editor (Figure 4) and are stored in the recipe database which can be referred from the parameter extractor.

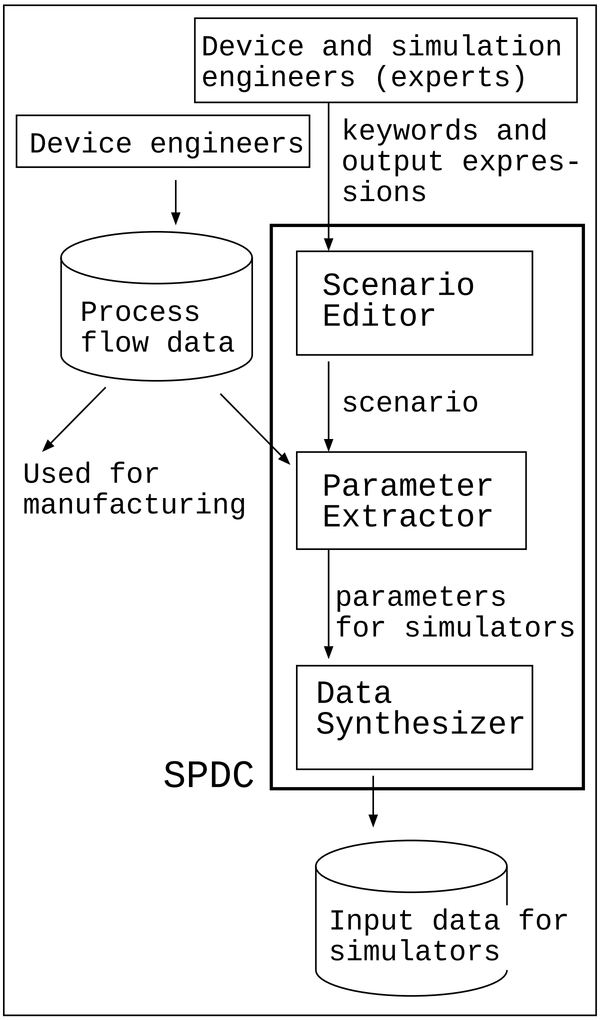

Figure 1 Structure of SPDC

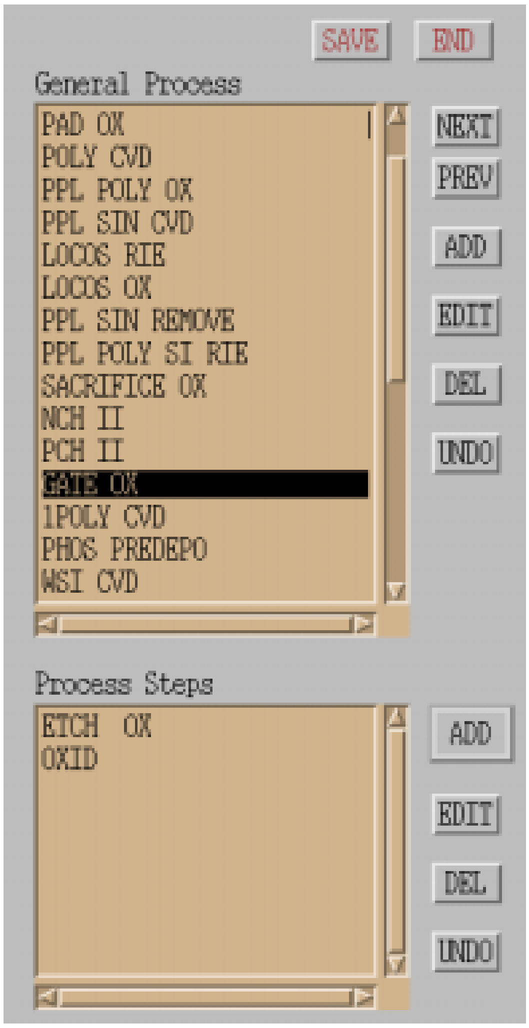

Figure 2 Main Panel of SPDC

Parameter Extractor

For every steps specified with the scenario editor, the parameter extractor searches for a corresponding process steps from process flow data and then extracts process parameters necessary for synthesizing input data for simulators. For example, in order to search for a N-channel ion implantation step shown in the main panel (described as NCH II in Figure 2), process steps following sacrificial oxidation is traced by keywords and then parameters are extracted. In case of an ion implantation step, following parameters are extracted: an ion name which is normally used in ion implantation process such as B, Phos or As; amount of dosage which is followed by strings like "E12", "e13", etc.; implantation energy followed by strings "keV". Precise parameters dependent on equipments are extracted from recipe database. When required process parameters are not specified in neither in process flow data nor in recipe database, the module asks the user if he skips the step or specifies parameters on the spot.

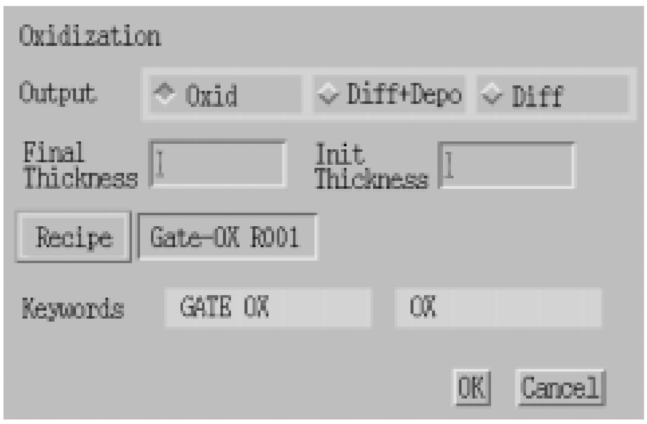

Figure 3 Input Window of Scenario Editor for Specifying an Oxidization Step

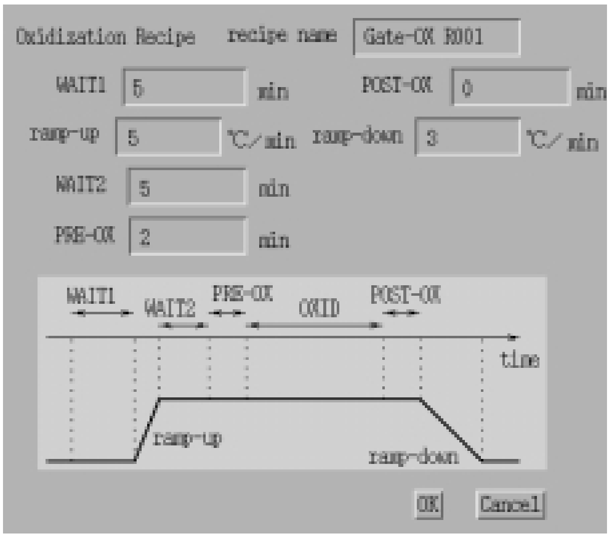

Figure 4 Input Window for Specifying Precise Information of an Oxidization Step

Data Synthesizer

Data synthesizer converts process parameters extracted with the parameter extractor into input data for simulators. This module converts the process steps specified in scenario in order, utilizing a conversion table which describes the correspondence between parameters and input data syntax. The format of synthesized input data is called SPIF (Sony Process Information Format) which has general syntax for describing process parameters and can be converted into input data for target simulator easily. By replacing the conversion table, SPDC can synthesize input data for any simulators directly.

The synthesized data is stored in a database and used as input data for BARAS[1], which supports automatic process and device simulations by sweeping process conditions.

CONVERSION EXAMPLE

An example of conversion from process flow data of N-channel MOSFET used for manufacturing to input data for simulation utilizing SPDC is shown in Figure 5. Three tables corresponding to a part of process flow from sacrificial oxidization to gate oxidization, are shown on the figure: (a) scenario data created with scenario editor at the upper left; (b) process flow data for manufacturing at the upper right; (c) synthesized input data for simulation at the lower.

The sacrificial oxidization is specified to be replaced by two simulation subprocesses in the scenario, etching and deposition. In this case, the expert engineer devised the scenario by replacing thermal oxidation by deposition of 0.03um SiO2 to reduce the calculation time. Keywords "PRE OX" or "OX" are searched from process flow data and then this oxidation process is converted into SiO2 etching and SiO2 deposition of input data for simulation. For N-channel ion implantation process, "1 PWL II" in manufacturing data is omitted from the conversion since the effect of the process is negligible to the simulation result. Following N-channel ion implantation process, P-channel ion implantation processes are described on manufacturing data, which is not necessary for N-channel MOSFET simulation. SPDC, according to the scenario, skips these steps until the keyword for gate oxidization step, "GATE OX" or "OX", is found. In the conversion of gate oxidization step, precise ramping up/down and pre/post oxidation time are retrieved from recipe database.

EVALUATION

SPDC enables device engineers unfamiliar to simulation utilization to prepare input data very efficiently resulting in reducing more than three days work to less than a few minutes work. The quality of the synthesized input data for MOS process simulation by SPDC is perfectly comparable to the one written by expert simulation users.

CONCLUSION

We have developed a system called SPDC which automatically generates input data for simulation from process flow data for manufacturing. The novel point of SPDC is that the system creates a data file called scenario by extracting knowledge of expert engineers and utilizes it for the data conversion. SPDC enables device engineers unfamiliar to simulation utilization to prepare input data very efficiently. Synthesized input data for simulation proved to be reliable for practical use.

Acknoledgements

Authors would like to thank all the members of Sony TCAD group for their discussions and corporation.

REFERENCES

[1] T.Tatsumi, H.Ansai, K.Hayakawa and M.Mukai, "BARAS: Novel and Highly Efficient Simulation System for Process Control Sweeping and Statistical Variation," Proc. SISPAD'96, pp.149-150, 1996.

```
    ....
name "SACRIFICE OX"
*
subprocess ETCH
material OX
keyw ""
*
subprocess DEPO
material  OX
thickness 0.03
keyw "PRE OX"
keyw "OX"
******************
name "NCH II"
*
subprocess IMPL
keyw "2PWL"
*
subprocess IMPL
keyw "NDEEP"
*
subprocess IMPL
keyw "NVA"
******************
name "GATE OX"
*
subprocess ETCH
material OX
keyw ""
*
subprocess OXID
recipe Gate-OX R001
keyw "GATE OX"
keyw "OX"
******************
name "1POLY CVD"
*
subprocess DEPO
    ....
```

(a) Scenario

...

PRE OX	THICK MEASRMNT	MM3	SiO2	30nm	3nm	
PWL PR	IN.PR	INA	3	M9		S2100
PWL PR	MANUAL CHECK		PWL/LOC	0.2um		
1PWL II	1PWL II		B+	600KeV	5.0E12	
2PWL II	2PWL II		B+	250KeV	5.0E12	
NDEEP II	NDEEP II		B+	70KeV	3.0E12	
NVA II	NVA II		B+	20KeV	7.4E11	
NVA AT	Asher			2.5um	70%	
NVA AT	CLN ASH				10 min	
NWL PR	IN.PR	INA	3	M9		S2101
NWL PR	MANUAL CHECK		NWL/LOC	0.2um		
3PWL II	3PWL II		B+	600KeV	5.0E12	
NWL II	NWL II		Phos+	420KeV	5.0E12	
PDEEP II	PDEEP II		As+	270KeV	3.0E12	
PVA II	PVA II		B+	20KeV	5.0E12	
PVA AT	Asher			2.5um	70%	
PVA AT	CLN ASH				10 min	
GATE OX	CLN PRE-SC		PR-SC	SC1 10min	DHF 720sec	SC2 10min
GATE OX	GATE OX		IN/OUT 700C	800C/ 850C	WET/ANL	5'00"
GATE OX	THICK MEASRMNT	MM3	SiO2	5nm	1nm	
1Poly(C)	Poly CVD		Poly	100nm	15nm	

...

(b) Process Flow Data for Manufactiring

(c) Input Data for a Process Simulator

```
          ...
ETCH   MATE=OX
DEPO   MATE=OX THICK=0.3
IMPL   DOPANT=B DOSE=5e+12 ENERGY=250
IMPL   DOPANT=B DOSE=3e+12 ENERGY=70
IMPL   DOPANT=B DOSE=7.41e11 ENERGY=20
ETCH   MATE=OX
DIFF   TEMP=700 TEMPE=850 TIME=30
DIFF   TEMP=850 TIME=5
OXID   PRESS=1.46 TEMP=850 TIME=7 AMBI=WET
DIFF   TEMP=850 TEMPE=700 TIME=50
          ...
```

Figure 5 Conversion Example from Manufacturing Process Flow Data to Input Data for Simulator