Process simulation

The following is a list of the 3 options available to 3D process simulation, in order of decreasing complexity::

1: Sentaurus Process

Full bi and three dimensional process simulation, evolution from the previous FLOOPS tool from ISE –TCAD, it allows simulation of all standard process steps, diffusion, implantation, Monte Carlo implantation (Crystal-TRIM), oxidation, etching, deposition, and silicidation.

- Scripts files are written as a list of TCL commands; Alagator language is fully supported for definition of custom PDE for diffusion of chemical species.

```
# ************* Start simulation of Process Steps *************
init concentration=1.00e+15 field=Phosphorus wafer.orient=100
# p-well, anti-punchthrough & Vt adjustment implants
implant Boron dose=2.00e13 energy=200 tilt=0 rotation=0
implant Boron dose=1.00e13 energy=80 tilt=0 rotation=0
implant Boron dose=2.00e12 energy=25 tilt=0 rotation=0
# p-well: RTA of channel implants )
diffuse time=10.0<s> temp=1050
# gate oxidation
diffuse time=10.0<min> temp=850 dryO2
# poly gate deposition
deposit machine=PoDep time=0.18
# poly gate pattern/etch
mgoals on
mask name=gate_mask left=-1.0 right=0.09
etch poly anisotropic thickness=0.20 mask=gate_mask
etch oxide anisotropic thickness=0.1
struct dfise=n@node@_gate
# poly reoxidation
diffuse time=10.0<min> temp=900 dryO2 pressure=0.5
# nldd implantation
implant Arsenic dose=4e14 energy=10 tilt=0 rotation=0
# Halo implantation: Quad HALO implants:
implant Boron dose=0.25e13 energy=20 tilt=30 rotation=0
implant Boron dose=0.25e13 energy=20 tilt=30 rotation=90
implant Boron dose=0.25e13 energy=20 tilt=30 rotation=180
implant Boron dose=0.25e13 energy=20 tilt=30 rotation=270
……………………………………
```

example of a Sentaurus Process script

2: Ligament Flow editor

This is a graphical editor of process flow. All the scripts written in Sentaurus process can be loaded in Ligament (some of the diffusion commands are not recognized though).

Furthermore, Ligament accepts inputs files from Dios, TSUPREM-4 and Sentaurus Structure Editor and allows conversion from one format to any of the other supported.

File Edit Preferences Extensions Help

Variables & Macros | Flow | Unfolded Flow

Names	Arg	Value	Arg	Value
Flow				
environment	title	nMOS	save	true
advanced-calibra				
remark	text	---------- substra		
substrate	dopant	boron	concentration	0 /cm3
well-channel				
remark	text	---------- well ar		
deposit	material	oxide	thickness	10 nm
implant	species	boron	dose	3e+13 /cm2
implant	species	boron	dose	2e+13 /cm2
implant	species	boron	dose	1e+13 /cm2
implant	species	boron	dose	8e+12 /cm2
anneal	time	+	temperature	+
etch	material	oxide	thickness	default
gate-oxidation				
remark	text	---------- gate o:		
deposit	material	oxide	thickness	1.4 nm
anneal	time	+	temperature	+
MOSLIB_reme				
poly-gate				
remark	text	---------- poly si		
deposit	material	poly	thickness	180 nm
pattern	layer	GATE	polarity	light_field
MOSLIB_refine				
etch	material	poly	thickness	185 nm
etch	material	oxide	thickness	3 nm
etch	material	silicon	thickness	1.5 nm
remark	text	Si overetching		
etch	material	resist	thickness	default
poly-reoxidation				
offset-spacer				
halo-implant				
extension-implant				
spike-anneal-1				
side-spacer				
sd-implant				
spike-anneal-2				

Flow editor example window

3: emulation process (Sentaurus PROCEM, scripts in SCHEME)

PROCEM is part of Sentaurus structure editor: it allows 3D emulation of process but not simulation. That means for instance that an implantation process is described directly in terms of doping an area with a specified species concentration that varies according to a specified function (i.e. exponential), rather than specifying the concentration, energy of the ions and for how long they hit the area. Also diffusion processes of species are not handled. Mask importing, patterning, deposition, etching, filling and implant functions are provided.

- Scripts files are written in Scheme.

```
### Doping profiles
### Substrate and epitaxial constant profiles and placement
(sdedr:define-constant-profile "substrate_doping" "BoronActiveConcentration" 2e+18)
(sdedr:define-constant-profile "epitaxial_doping" "BoronActiveConcentration" 1.7e+15)

### Analytic doping profile for P and N wells

(sdedr:define-gaussian-profile "P_well_doping" "BoronActiveConcentration"   "PeakPos" 0
"PeakVal" 1.2e+17 "Length" 0.52 "Erf" "Factor" 0.0)

(sdedr:define-gaussian-profile "N_well_doping" "ArsenicActiveConcentration" "PeakPos" 0
"PeakVal" 1.7e+17 "Length" 0.52 "Erf" "Factor" 0.1)

……
(if  (not (eqv? '@CTSUB@ 'no ))   (sdegeo:imprint-rectangular-wire (position (- XdomBL 3) (-
YdomBL 3) 0.0 ) (position (+ XdomTR 3) (+ YdomTR 3)  0))  "")
…

### loads first mask-PRIMUS-NWELL for diodes/moses...
(sdepe:pattern "mask" "PRIMUSNW" "polarity" "dark" "material" "Resist" "thickness" 1.0)
### N implant
(sdepe:implant "N_well_doping")
### strip resist
(sdepe:strip-material "Resist")
…
```

example of Scheme script for Sentaurus editor PROCEM

* Process simulator DIOS is part of the Sentaurus package, but it allows mostly 2D simulations, only part of its functionalities are available in 3D.