TCAD simulation IIII

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Overview

- **Simulation example of 2D PN junction using SDEVICE**

- **Charge generation and collection**

TCAD simulation
SDEVICE

TCAD Synopsys Simulation

- **Sentaurus Device** is a numeric semiconductor device simulator, capable of simulating the electrical, thermal, and optical characteristics of various semiconductor devices.

- It simulates 1D, 2D, and 3D device behaviour over a wide range of operating conditions, including mixed-mode circuit simulation, combining numerically simulated devices with their compact modeling, which is performed on a SPICE-based circuit simulation level.

1 **File Section**: input/output files

2 **Electrode Section**: electrode definition, matching those in the input grid

3 **Physics Section**: physics models to use in the simulation

4 **Plot Section**: variables to plot

5 **Math Section**: solvers

6 **Solve Section**: what to solve (IV,CV, Charge injection)

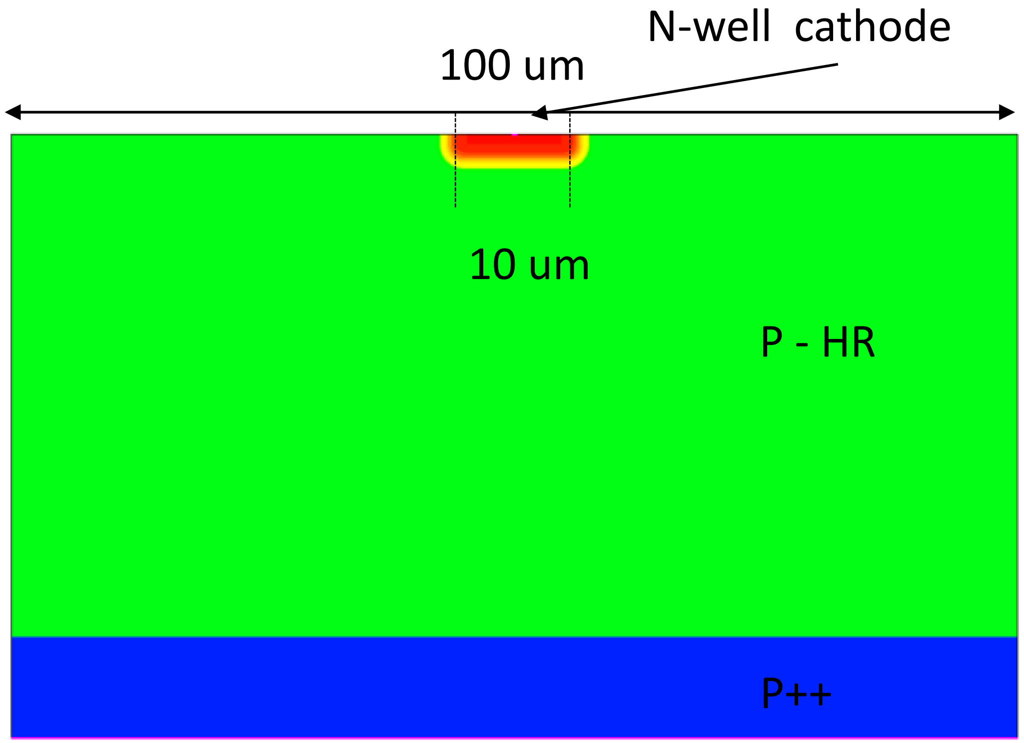
A typical command file of Sentaurus Device consists of several sections (or statement blocks), with each section executing a relatively independent function. The default extension of the command file is _des.cmd, for example, pp1_des.cmd. To start: **sdevice**

TCAD Synopsys Simulation

- SDEVICE simulation of 2D pn junction
  - **Charge generation**

- **Within SDEVICE, charge injection by particles can be modelled using the models for carrier generation by gamma radiation, alpha particles and heavy ions (optical generation is also available)**
- **HeavyIon generation:**

$$G(l,w,t)=Glet(l)R(w,l)T(t)$$



Glet: linear energy transfer(LET) generation density
R(w,t): spatial distribution (exponential/Gaussian)
T(t): temporal profile

TCAD Synopsys Simulation

- SDEVICE command file: transient analysis:
-
  - **File Section**: input/output files
    Electrode Section: electrode definition, matching those in the input grid
  - **Physics Section**: physics models to use in the simulation
  - **System:** defines a mixed mode setup consisting of the device(s) and sources attached to it
    Plot Section: variables to plot
  - **Math Section**: solvers to use

```
######      2D PN junction CCE analysis                    ######

#define Vdd @Vbias@
#define HitTime 1e-8
#define HitTime_Step 1e-11
#define Transient_Time 5e-9

## Input and Output Files

Device PNjnct   {
                File {
                        grid     = "2D_PNjnct_msh.tdr"
                          }
```

TCAD Synopsys Simulation

- SDEVICE command file: physics section

    - **The ionisation is obtained by a Minimum Ionising Particle (MIP)**
    - **Details of the ionisation are included in a file (MIP_EXC) which has the LET and spatial parameters required for MIP emulation**

```
Physics {

####if "@Ionization@" =="MIP"

#include "MIP_EXC"

…

#define WT_hi 0.1

HeavyIon (
Time = HitTime
Location = (0, 0)  ### Hits at the top surface, right in the middle of the device
Direction = (1.0,0.0)            ### Perpendicular hit

###LET_f  = [1.28e-5 1.28e-5 1.28e-5]  ### 80 e/h per micron is 1.28E-5 for THICK sensor
LET_f  = [1.056e-5 1.056e-5 1.056e-5]  ### 66 e/h per micron as MPV for 50 um thick active region
### LET_f  = [1.15e-5 1.15e-5 1.15e-5]  ### 72 e/h per micron as MPV for 300 um thick active region

Wt_hi  = [WT_hi WT_hi WT_hi ] ###            ro = 0.1/0.2 micron
Length = [ 0.0  20 60 ] ### LET @ different depths, irrelevant for a MIP
PicoCoulomb
Gaussian
)
```

TCAD Synopsys Simulation

- SDEVICE command file: solve
  - The voltage is first ramped up to the required bias voltage
  - Then the transient simulation starts
  - The time resolution is increase just before the hit

```
### Solve procedure
Solve {
        Coupled(Iterations= 700 LineSearchDamping= 1e-4){ Poisson }
        Coupled(Iterations= 70 LineSearchDamping= 1e-4){ Poisson Electron Hole }
### DC bias
    NewCurrentPrefix="2D_PNjnct_Temp@Temp@_CCE_DCVbias@Vbias@"

### ramps up to the max Vbias for CCE investigation
                    Quasistationary
            (       InitialStep= 1e-3 MinStep= 1e-15 MaxStep= 0.25
                             Increment= 2.0 Decrement= 4.0
             Goal { Parameter = vc.dc voltage = Vdd   }
            )
                    {               Coupled {  Poisson Electron Hole    } }

### Starts the transient
    NewCurrentPrefix="2D_PNjnct_Temp@Temp@_CCE_TRVbias@Vbias@"

        ### initial reset time until HIT_Time - 10ps...

        Transient (      InitialTime = 0 FinalTime = @<HitTime-0.01e-9>@
                                   InitialStep = 1e-9 MaxStep = 2e-9
MinStep = 1e-15 )
                    {
                     Coupled (Iterations = 10 ) {  Poisson  Electron  Hole }
                    }
```

TCAD Synopsys Simulation

- SDEVICE command file: solve
  - When the particle hits the devices, the temporal resolution is optimised for the first ns, it is relaxed afterwards

starts the transient analysis in 'HiRes' , set by Hit_Time_Step, until Hit_time + 1 ns

```
Transient ( InitialTime = @<HitTime-0.01e-9>@
FinalTime = @<HitTime+1e-9>@
InitialStep = 0.1e-12 MaxStep
= HitTime_Step MinStep = 1e-15 )
{ Coupled (Iterations = 5 ) { Poisson
Electron Hole }

Plot ( FilePrefix =
"2D_PNjnct_Temp@Temp@_CCE_TRVbias@Vbias@"

Time = (
HitTime
) NoOverwrite )
}
```

after the first 1 ns after the hit the transient is in 'MediumRes' of 0.1 ns

```
Transient ( InitialTime = @<HitTime+1e-9>@ FinalTime =
@<HitTime+Transient_Time>@
InitialStep = 1e-12 MaxStep =
.1e-9 MinStep = 1e-15 )
{
Coupled (Iterations = 10 ) { Poisson
Electron Hole }
}
```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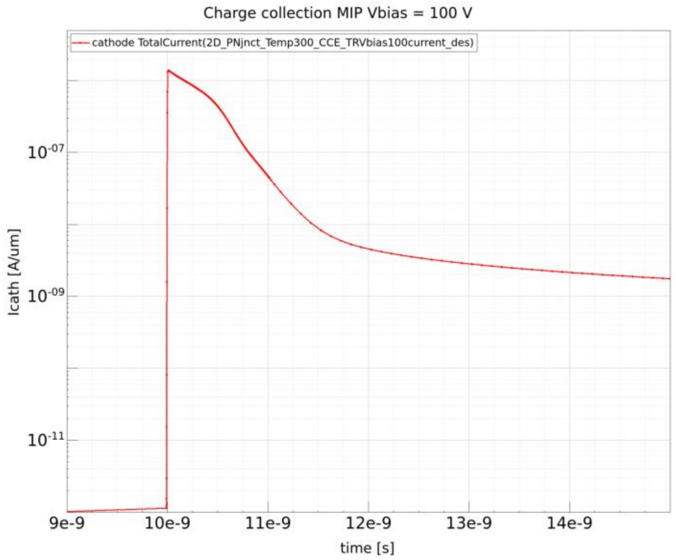
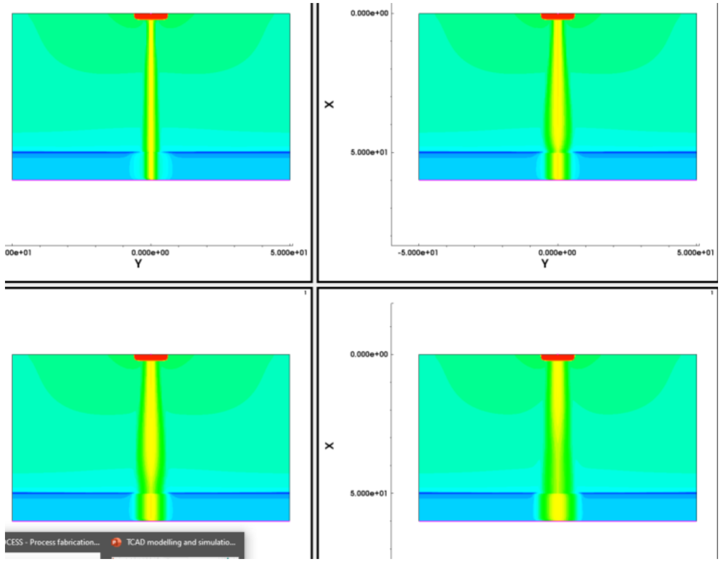
TCAD Synopsys Simulation

- Visualize the resulting mesh using **SVISUAL**
  - **Re-mesh the structure changing the p – doping**
  - **Visualise the meshing**
  - **I transient vs. bias**
  - **Charge collected vs. bias**
  - **Plots of charge density vs. time**



Icathode transient
– MIP hit @ 10 ns -:
No Ramo's theorem used

$$Q = \oint \varepsilon \vec{E} \cdot dS$$



Icathode transient
– MIP hit @ 0, 100,200,500 ps

TCAD and simulation I

Thank you

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- Simulation example : 2D pn using SDEVICE
- Charge generation and collection from MIP hit