TCAD simulation II

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Overview

- **Simulation example of 2D PN junction using SDEVICE**
- **IV and CV**

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

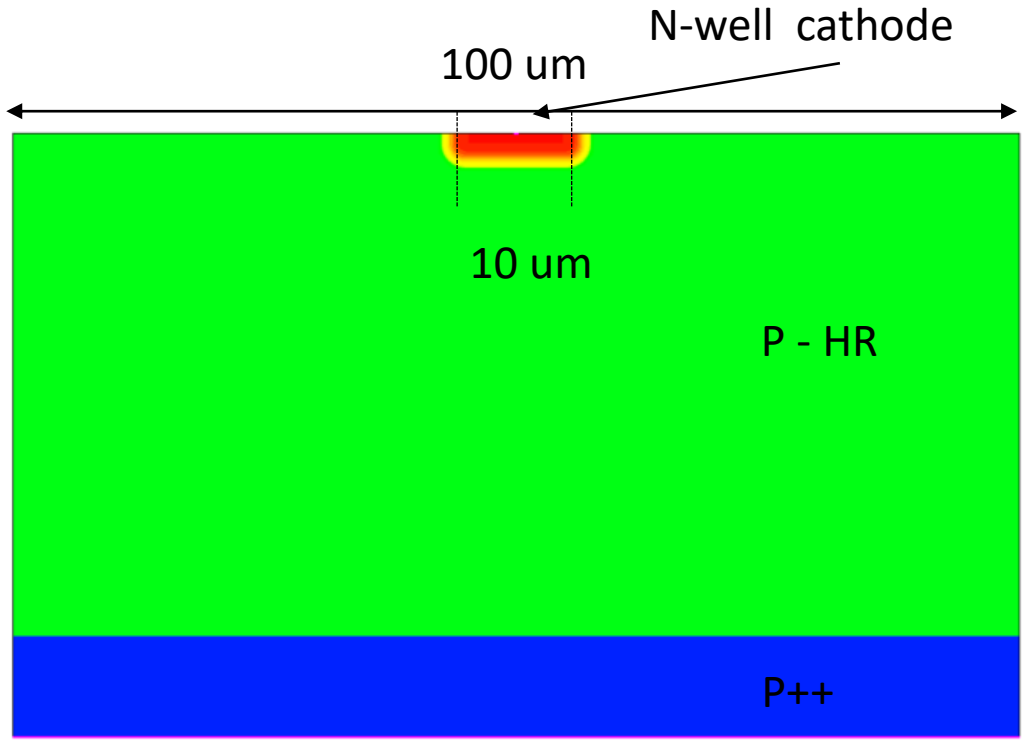
6 **Solve Section**: what to solve (IV,CV, Charge injection)

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
  - **IV**
  - **SC/Depletion region visualisation**
  - **Breakdown voltage**

- The DC analysis is performed by sweeping the voltage across the cathode, keeping the substrate contact grounded



TCAD Synopsys Simulation

- SDEVICE command file:
  - **File Section**: input/output files
  - **Electrode Section**: electrode definition, matching those in the input grid

```
#####          2D PN junction DC bias analysis ######

#define Vdd 1000.

## Input and Output Files

                                File {

                               grid     = "2D_PNjnct_msh.tdr"

                                   }


### Electrode definition

                                  Electrode {

##$ By default Ohmic contact
                               { Name="cathode" Voltage= 0.0    }

###                            { Name="cathode" Voltage= 0.0  Workfunction=4.5  }

                               { Name="substrate" Voltage= 0.0  }

                                                          }
```

TCAD Synopsys Simulation

- SDEVICE command file
  - **Physics Section**: physics models to use in the simulation
  - **Plot Section**: variables to plot

```
### Physics models
        Physics {

                Fermi
                Temperature = @Temp@
                Mobility(
                DopingDep
                PhuMob Enormal (Lombardi PosInterfaceCharge)
                HighFieldSaturation(GradQuasiFermi)

                        )

                Recombination(
                SRH( DopingDep TempDependence ElectricField
(Lifetime = Hurkx  ) )
                Auger
        Avalanche(Okuto EParallel BandgapDependence )
        ##Avalanche(Unibo EParallel BandgapDependence )
                                )
                EffectiveIntrinsicDensity(BandGapNarrowing
(OldSlotboom) )
          }
### Plots definition
Plot
 {
  eDensity hDensity
  TotalCurrent/Vector eCurrent/Vector hCurrent/Vector ….
  eMobility hMobility….
}
```

TCAD Synopsys Simulation

- SDEVICE command file
- **Math Section**: solvers to use

```
### Math definition
Math {

 BreakCriteria{ Current(Contact="cathode" AbsVal=1e-6) }

 extrapolate
 digits= 4
 ##ExtendedPrecision
 numberOfThreads= maximum
 Derivatives
 Avalderivatives
 RelErrControl

method=ILS
 submethod=ILS
 Iterations=20
  Rhsmin       = 1e-20
 ParallelToInterfaceInBoundaryLayer(FullLayer -ExternalBoundary)
                GeometricDistances
                eMobilityAveraging=ElementEdge
                hMobilityAveraging=ElementEdge
      ##AvalDensGradQF
                ErrRef(electron)=1e8
                ErrRef(hole)=1e8
                RefDens_eEparallel_ElectricField_HFS= 1e17
                RefDens_hEparallel_ElectricField_HFS= 1e17
                RefDens_eEparallel_ElectricField_Aval= 1e17
                RefDens_hEparallel_ElectricField_Aval= 1e17
}
```

TCAD Synopsys Simulation

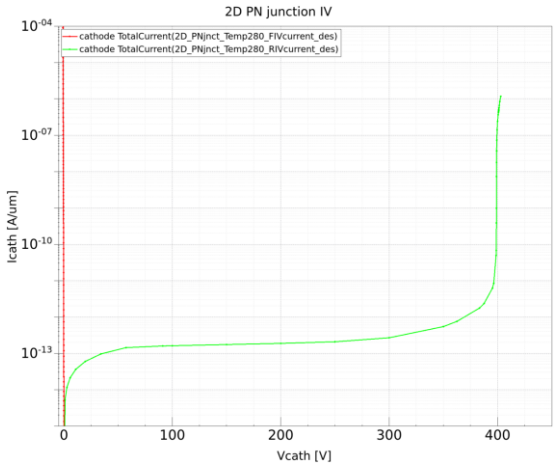
- SDEVICE command file
  - **Solve Section**: what to solve (IV,CV, Charge injection…)

```
### Solve procedure

Solve {

        Coupled(Iterations= 500 LineSearchDamping= 1e-4){ Poisson }
        Coupled(Iterations= 50 LineSearchDamping= 1e-4){ Poisson Electron Hole }
        Plot (FilePrefix = "2D_PNjnct_Temp@Temp@_bias_0V")

          NewCurrentPrefix="2D_PNjnct_Temp@Temp@_RIV"

                  Quasistationary (
                    InitialStep=0.001 Increment=2.0 decrement=4.0
                    MaxStep=0.05 Minstep=1.e-15
         Goal { name="cathode" Voltage= Vdd}
                                                    ) { Coupled { Poisson Electron
Hole }


Plot(FilePrefix="2D_PNjnct_Temp@Temp@_RBias_" Time=(0.1;0.2;0.3;0.4;0.5)
NoOverWrite)
### fixed plot interval
###                                          CurrentPlot( Time=(Range=(0 1) Intervals= 200
)  )
                                                    }

}
```

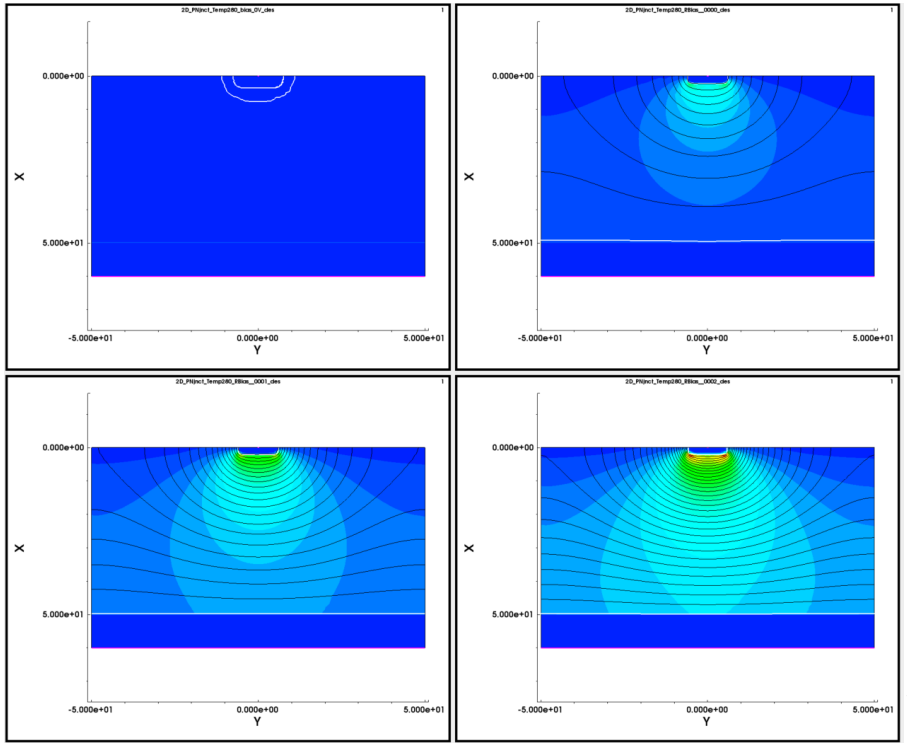
TCAD Synopsys Simulation

- Visualize the resulting mesh using **SVISUAL**
  - **Re-mesh the structure changing the p – doping**
  - **Visualise the meshing Investigate the extension of depletion vs. bias/doping/temperature**

$$w = \sqrt{\frac{2\varepsilon_s(N_A + N_D)}{e(N_A N_D)}(V_{bi} - V)}$$



FWD and REV IV @ 280 K vs. Vbias



Depletion and x-Field vs. Vbias

- Simulation example : 2D pn using SDEVICE
- IV (FWD/REV), SC, Depletion region

Thank you

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