Overview of Sentaurus

Advanced multidimensional semiconductor device simulator

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Modified in 2015 by Prof. J. Poon

Presentation Outline

- Why use Sentaurus?
- Introduction to Sentaurus

  - introduction to Sentaurus main interface
  - overview of main tools

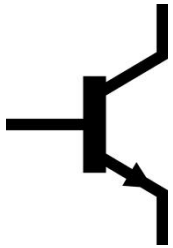
- Step-by-Step Project Walkthrough

Why Do We Use Sentaurus ?

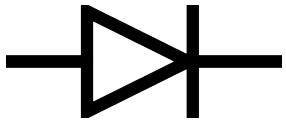
1) To learn and have the experience of carrying out semiconductor (SC) device designs by using one of the **most advanced software tools** in the industry

Sentaurus allows engineers to design the device to meet performance specifications and to design the fabrication process to make the devices.

Resistor



Transistor



Diode

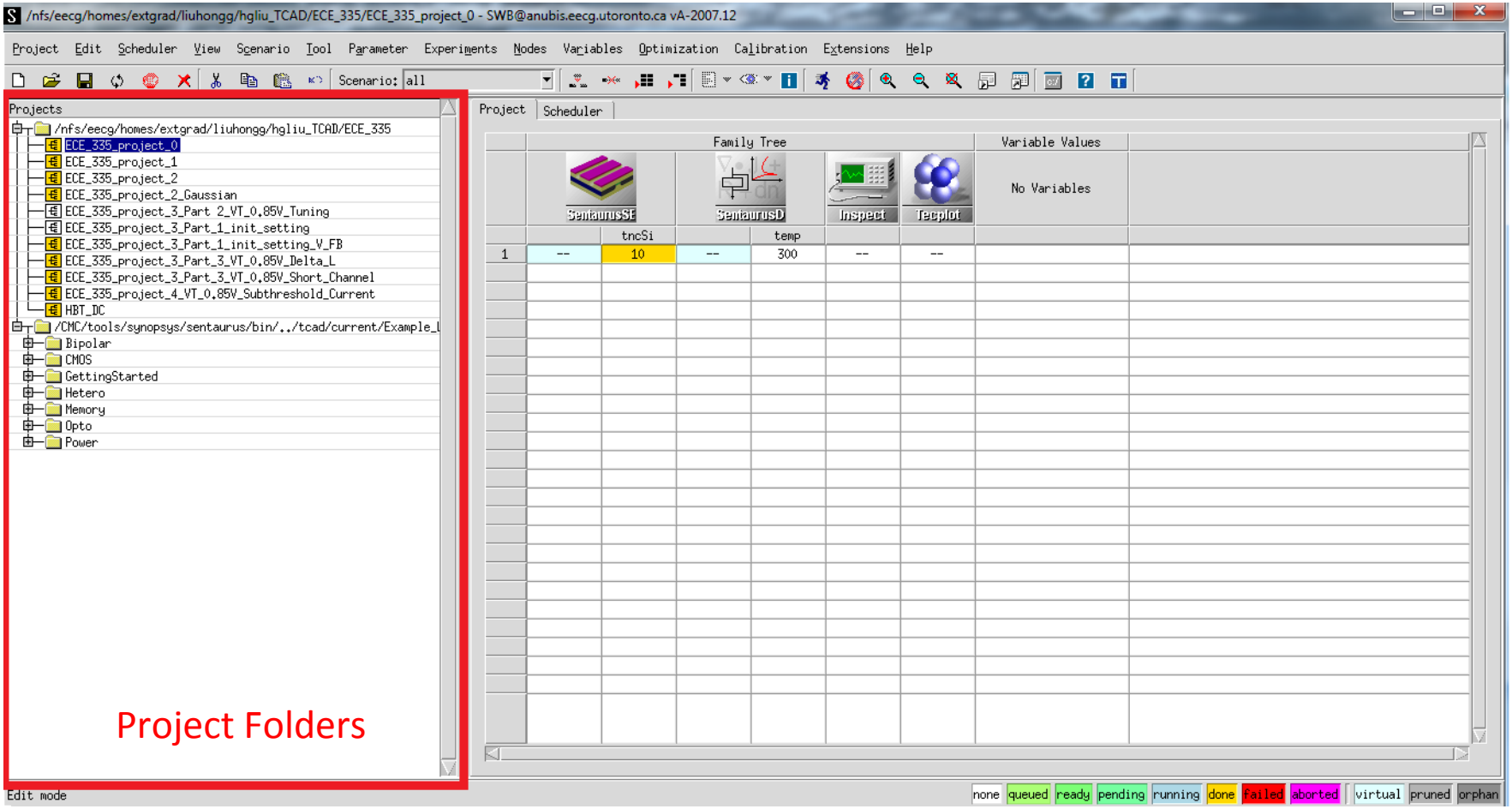
Why Do We Use Sentaurus ?

2) Use the **visual aids** in Sentaurus to help you better **understand** the device physics and concepts presented in ECE 335

3) Through a **better understanding**, you ought to have a better appreciation of the opportunities and challenges in devices.

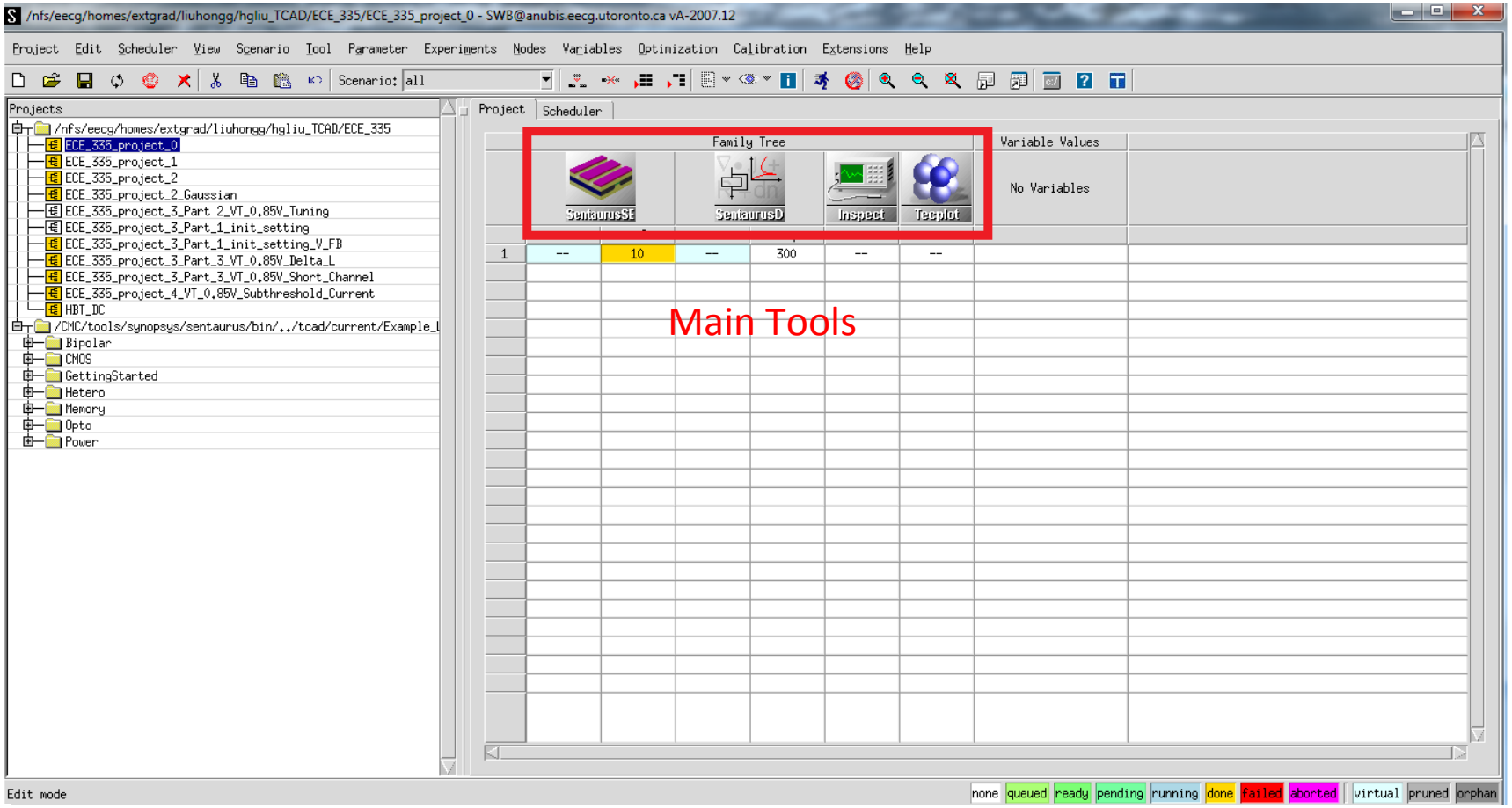
Introduction to Sentaurus

Main Interface



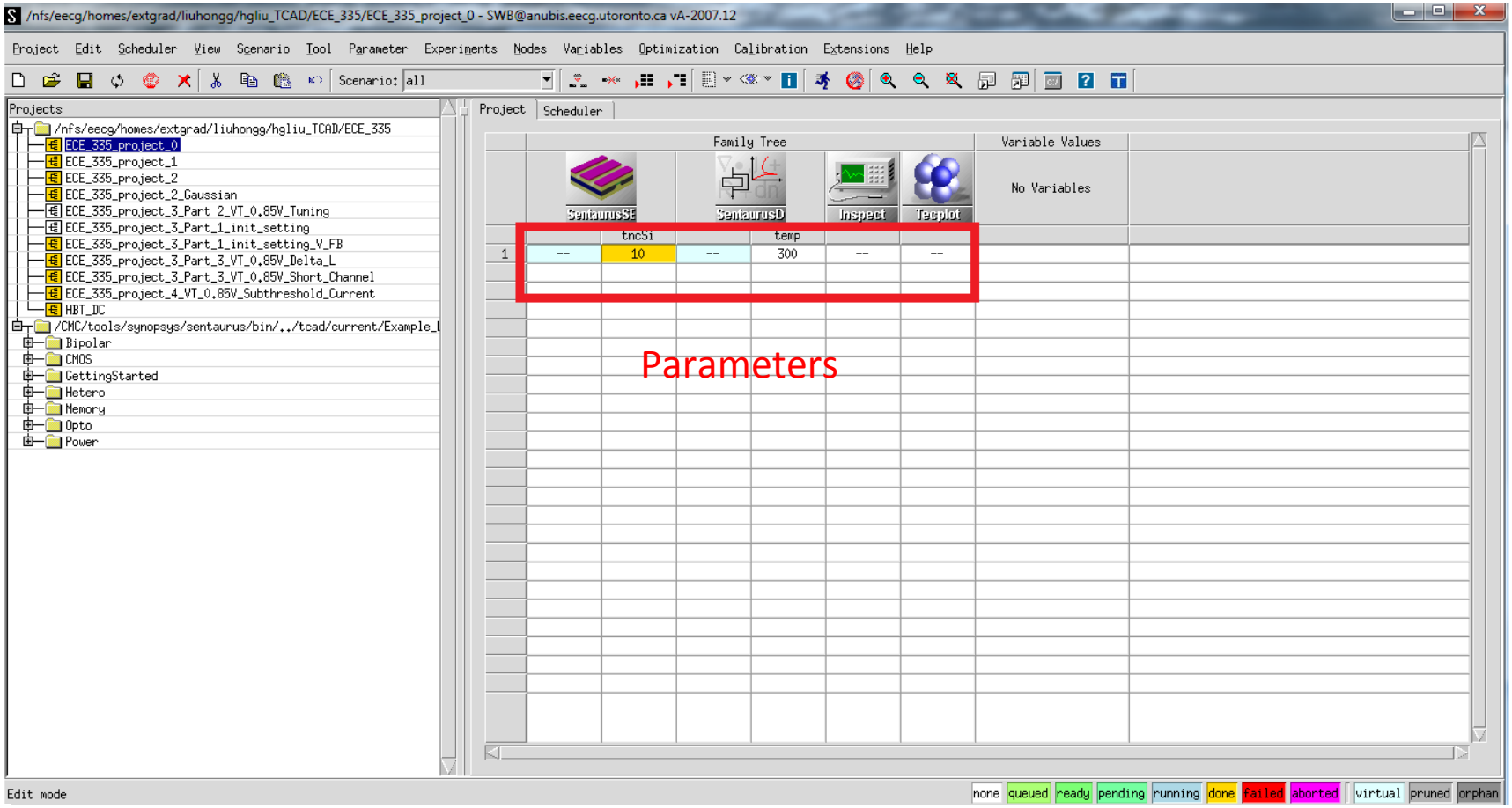
Introduction to Sentaurus

Main Interface



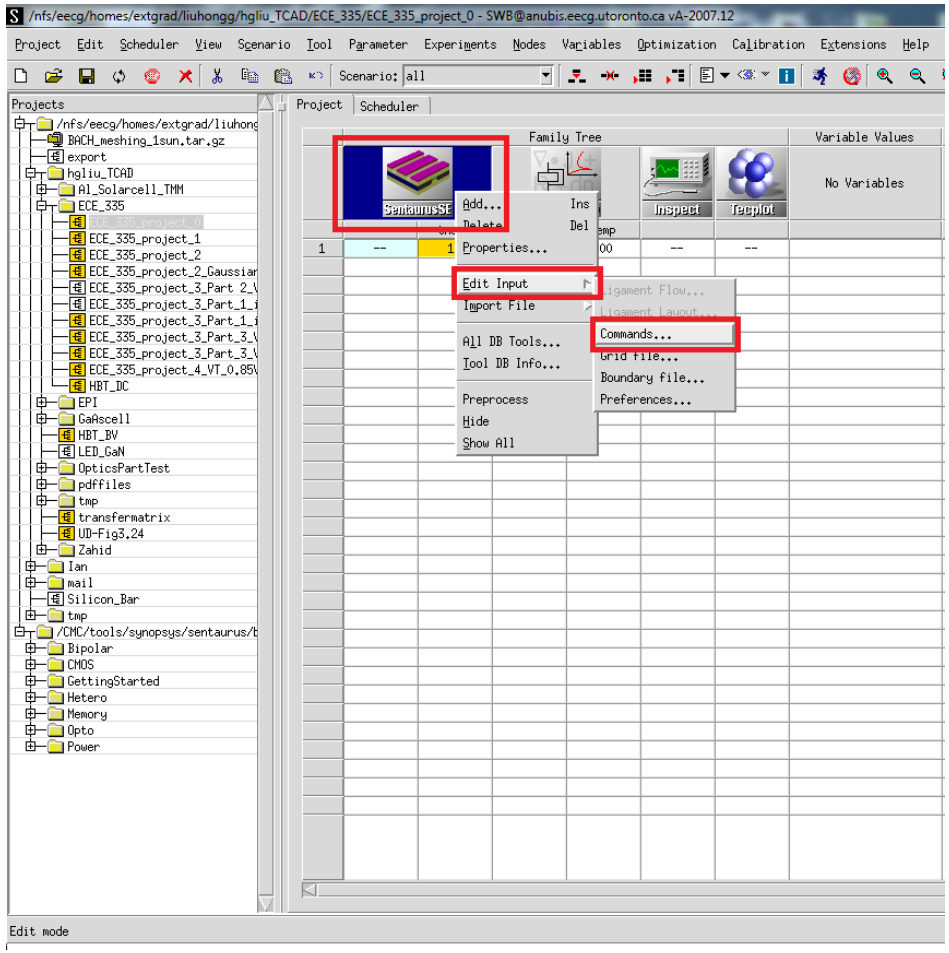
Introduction to Sentaurus

Main Interface



Main Sentaurus Tools

Structure Editor (SDE)



Purpose: Edit device definition, structure, and doping profile

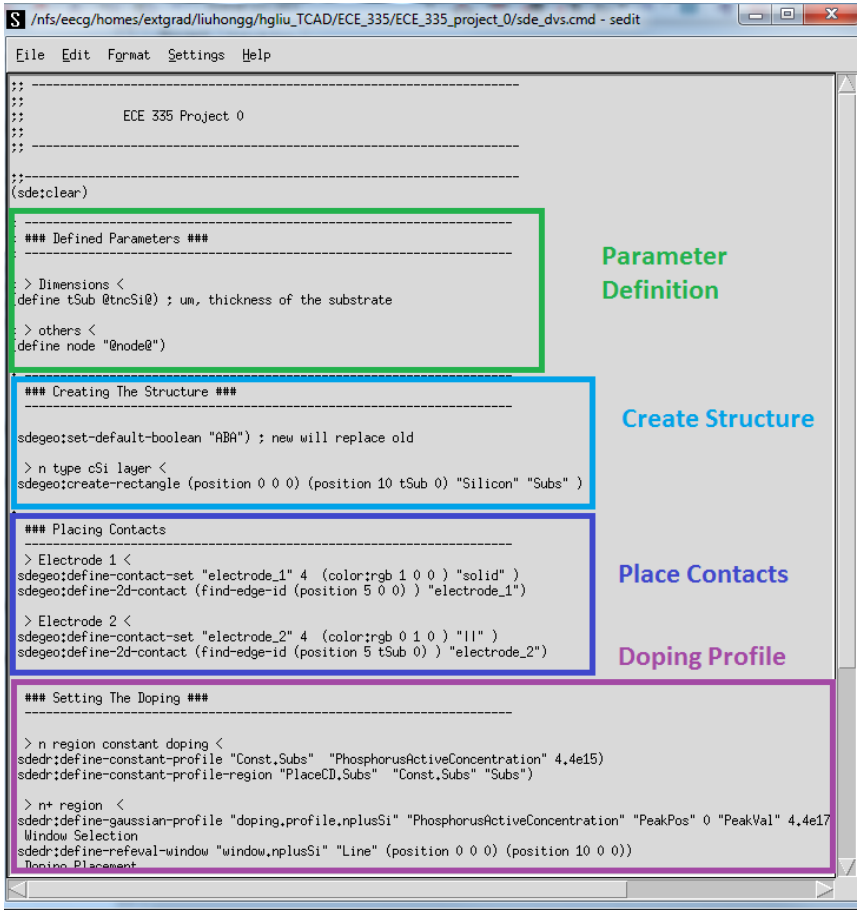
How to use:

1. Right click ***SDE*** at tool bar
2. Click "***Edit Input***" and select "***Command***"
3. Edit command lines to make appropriate device structures and properties

Or, edit ***sde_dvs.cmd*** under project folder

Main Sentaurus Tools

Structure Editor: Command Line



What does it do:

- Defines shapes and dimensions of various regions

- Define electrode placement and specify material

- Define doping profile or distribution

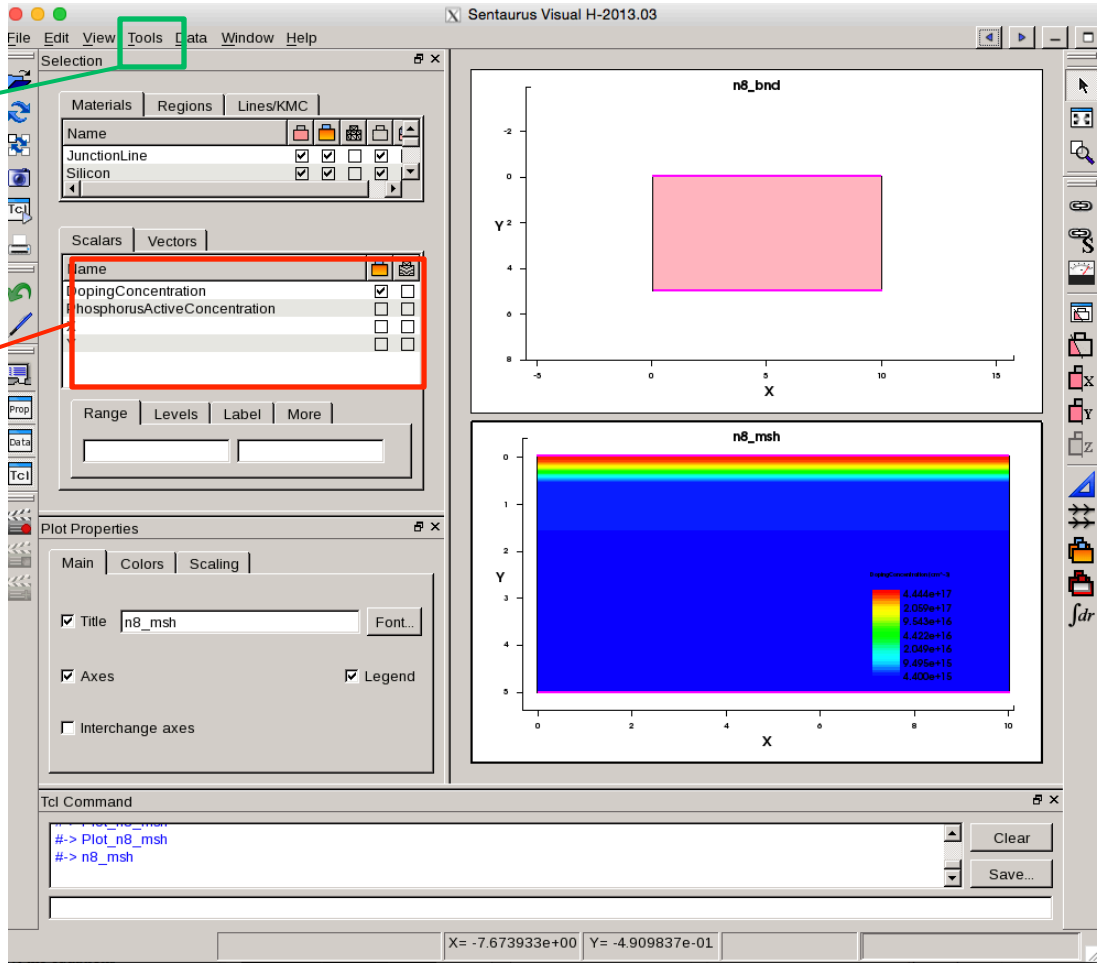
- Define grid points or mesh to solve the structure

Main Sentaurus Tools

Visualization: SVisual

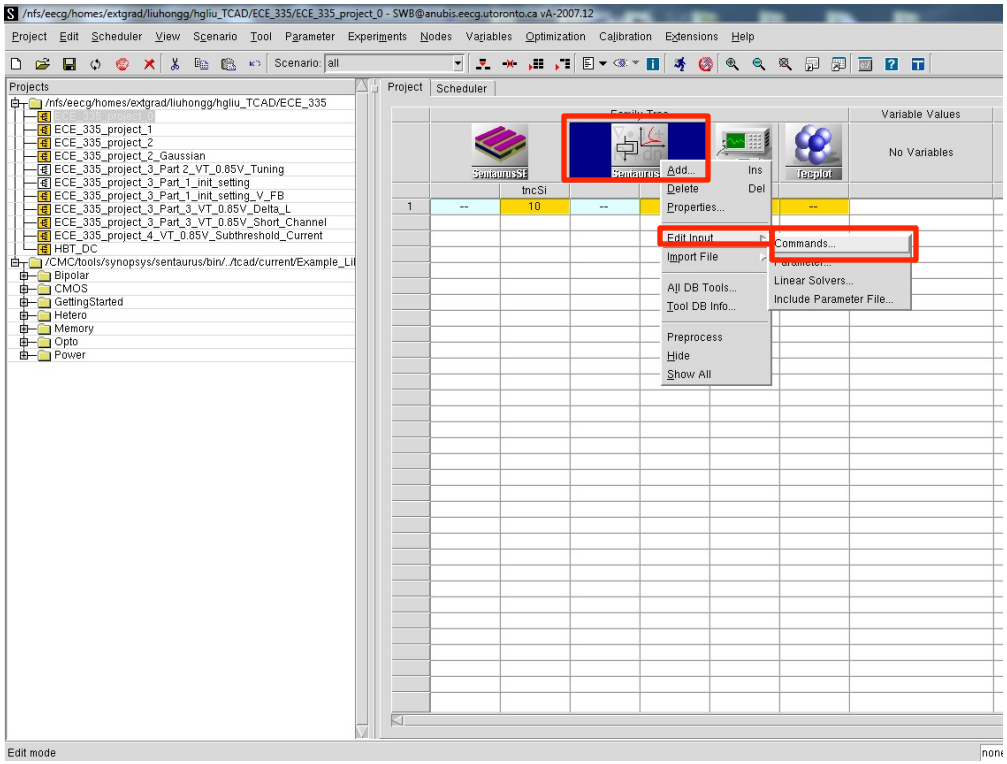
Precision Cuts– take a cross section of the device and see various values on a particular axis

Select a particular value to show on the diagram



Main Sentaurus Tools

Apply Test Conditions: **SDevice**



Purpose: To apply various device physics conditions and bias voltage on the electrodes

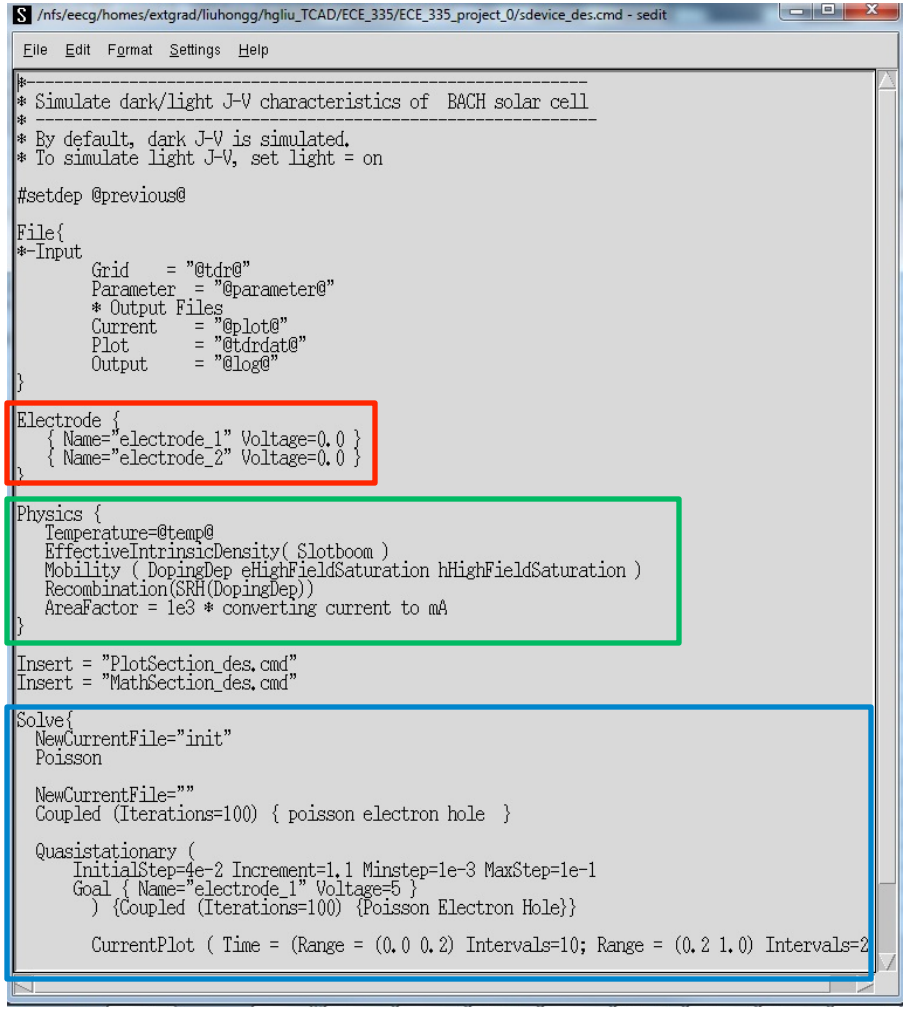
How to use:

1. Right click **SDevice** icon
2. Click "***Edit Input***" and select "***Command***"
3. Edit command lines to define appropriate device structures and properties

Or, edit ***sdevice_des.cmd*** under project folder

Main Sentaurus Tools

SDevice: Command Line



What does it do:

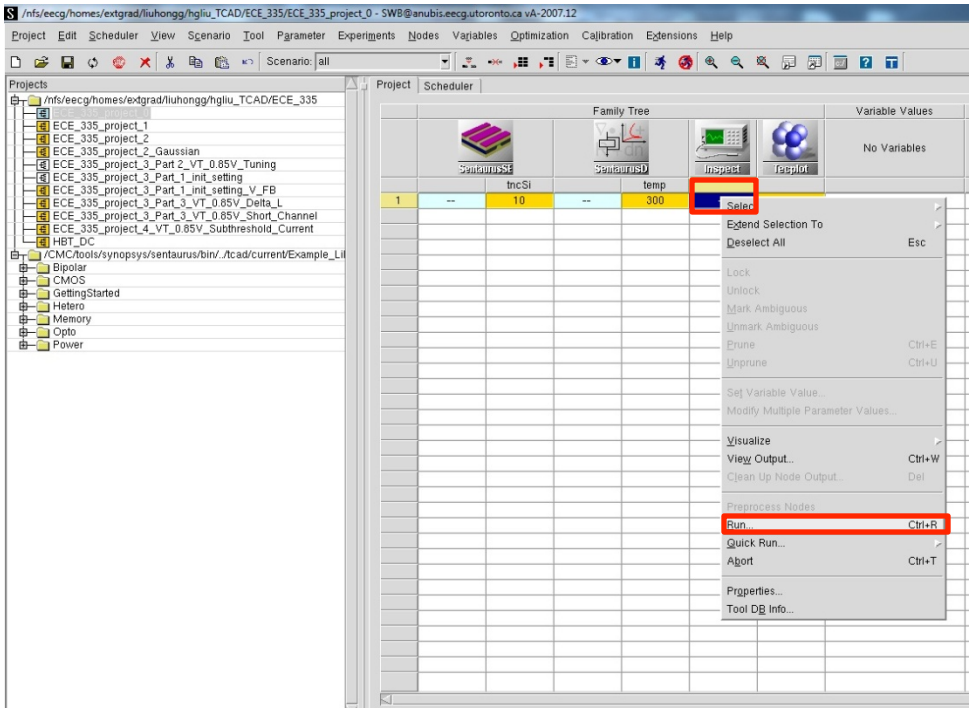
- Apply bias voltage at different electrodes

- Modify operating condition like temperature

- Alter simulation algorithm and device physics

Main Sentaurus Tools

Probing and graphing: **Inspect**



Purpose: Plot and analyze I-V characteristics at selected nodes under desired doping and bias conditions

How to use:

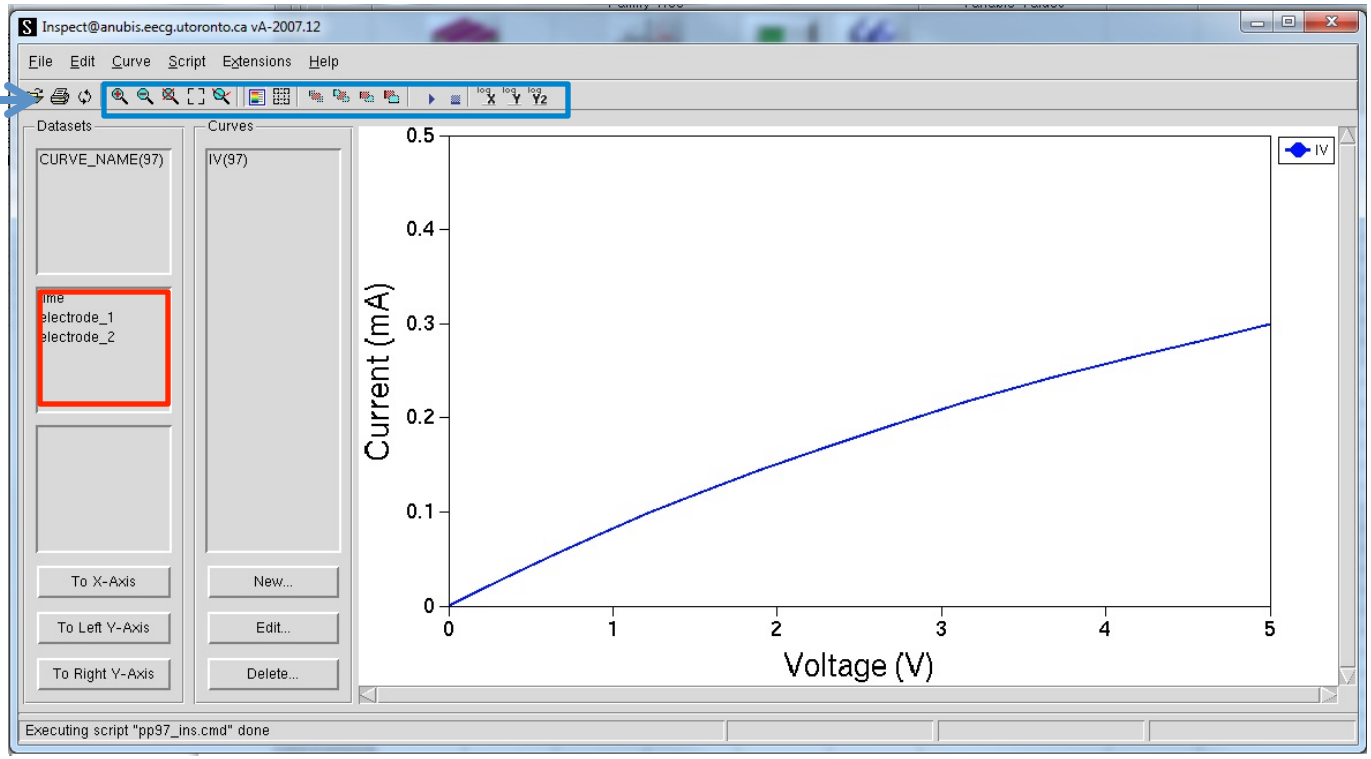
1. Right click the block below **Inspect**
2. Select "**Run**"

Main Sentaurus Tools

Probing and graphing: **Inspect**

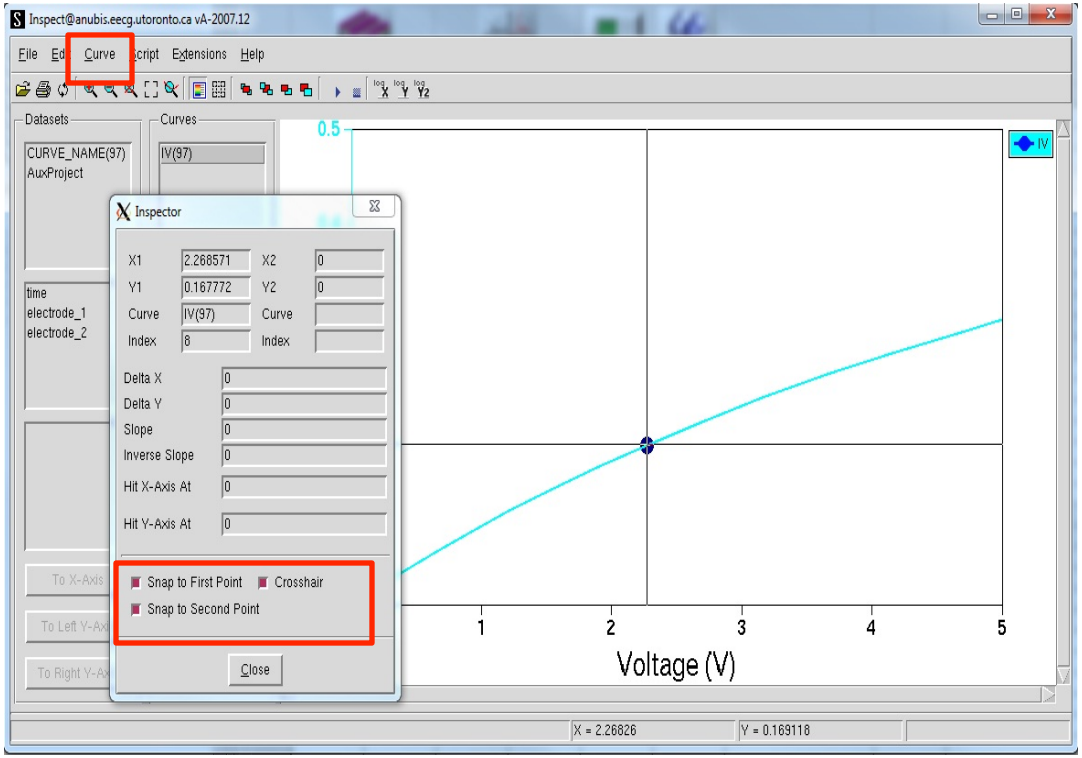
Some useful functions

Select nodes



Main Sentaurus Tools

Inspect Tools: Cursor



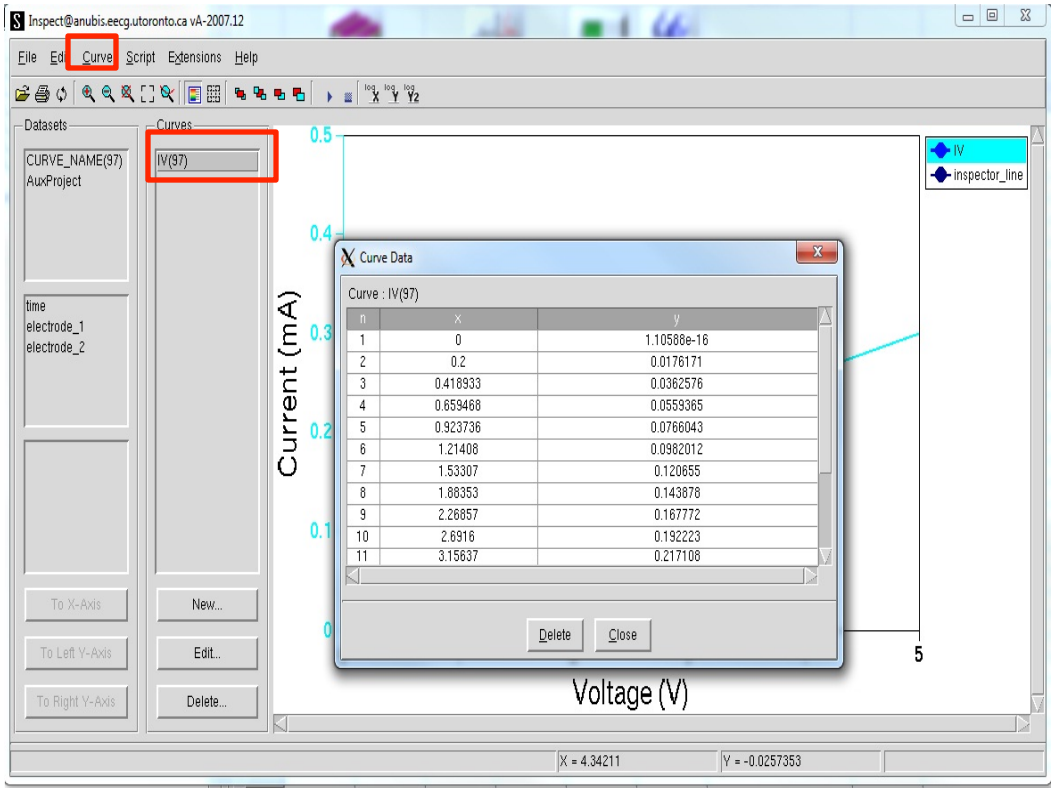
Purpose: Get *specific* values on curve

How to use:

1. Select “Curve” -> “Inspect”
2. Check all boxes at the bottom

Main Sentaurus Tools

Inspect Tools: Cursor



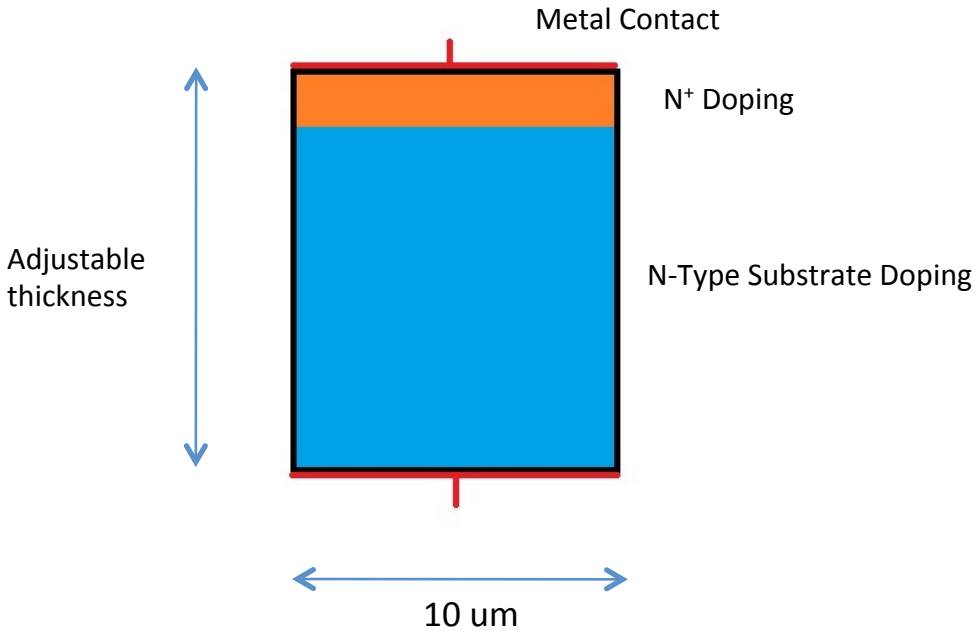
Purpose: Get *list* of values on curve

How to use:

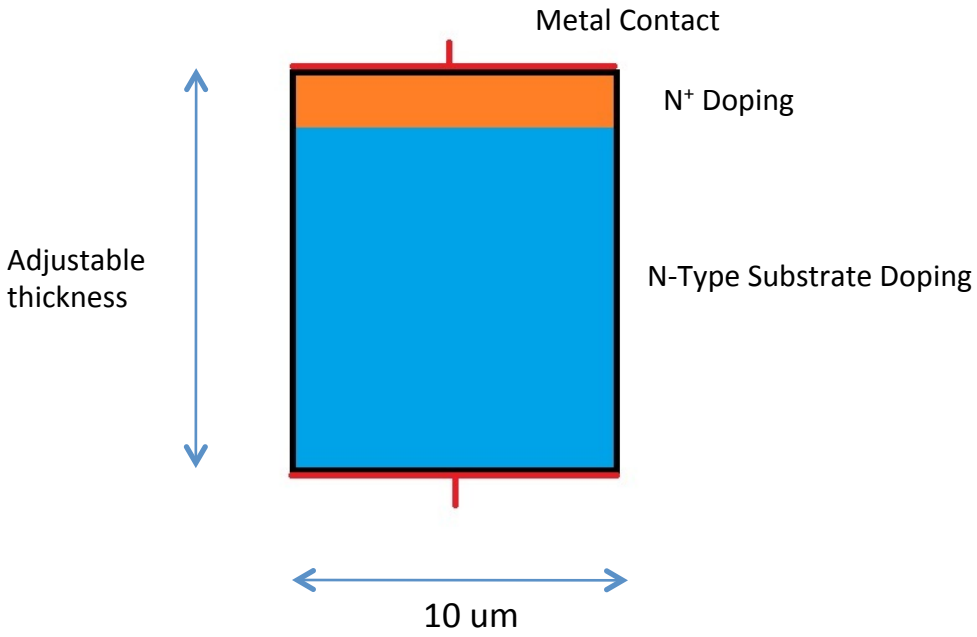
1. Select a curve in "**Curve**" box
2. Click "**Curve Data**" in Curve tab on the top

Project Demonstration

Goal: To set up the structure below and investigate its properties with SVisual and Inspect.



Project Demonstration

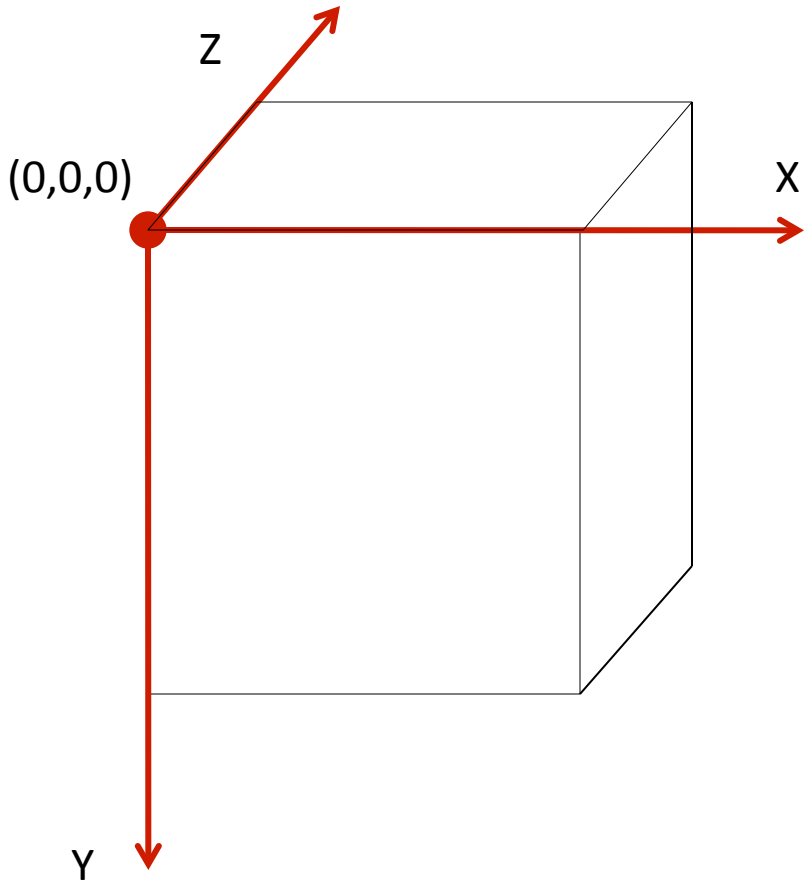


To set up the device:

1. Understand the geometry
2. Set up variables
3. Define substrate region
4. Place contacts
5. Dope the regions

Project Demonstration

Setting up the Device: Geometry



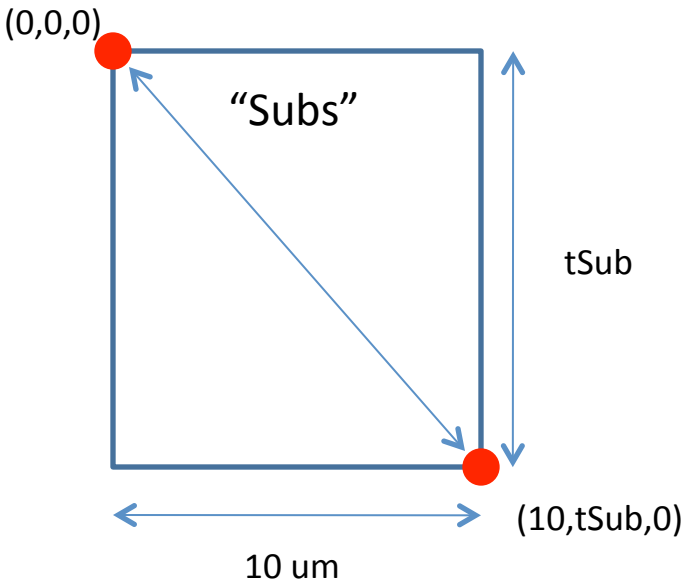
- Sentaurus uses 3D Cartesian coordinate system

- Specify shape and start - end coordinates to set up a substrate region

Project Demonstration

Setting up the Device: Structural Variables

```
; -------------------------------------------------------------------
; ### Defined Parameters ###
; -------------------------------------------------------------------

; > Dimensions <
(define tSub @tncSi@) ; um, thickness of the substrate

; > others <
(define node "@node@")

; -------------------------------------------------------------------
; ### Creating The Structure ###
; -------------------------------------------------------------------

(sdegeo:set-default-boolean "ABA") ; new will replace old

; > n type cSi layer <
(sdegeo:create-rectangle (position 0 0 0) (position 10 tSub 0) "Silicon" "Subs" )
```

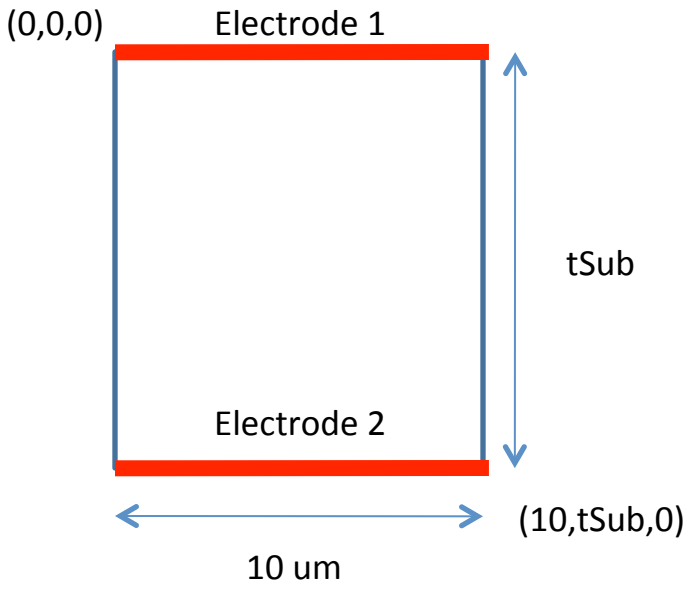


Project Demonstration

Setting up the Device: Placing Contacts

```
; -------------------------------------------------------------------
; ### Placing Contacts
; -------------------------------------------------------------------
; > Electrode 1 <
(sdegeo:define-contact-set "electrode_1" 4  (color:rgb 1 0 0 ) "solid" )
(sdegeo:define-2d-contact (find-edge-id (position 5 0 0) ) "electrode_1")

; > Electrode 2 <
(sdegeo:define-contact-set "electrode_2" 4  (color:rgb 0 1 0 ) "||" )
(sdegeo:define-2d-contact (find-edge-id (position 5 tSub 0) ) "electrode_2")
```

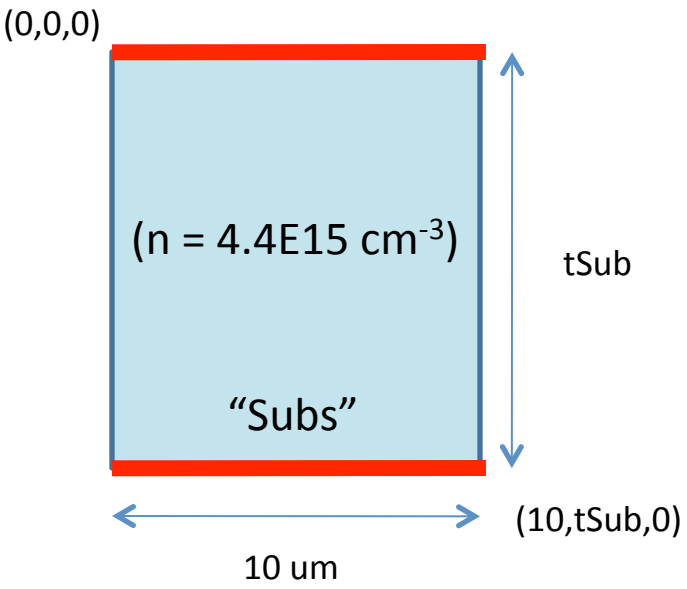
- Attach electrodes as connections between device and external environment



Project Demonstration

Setting up the Device: Background Doping

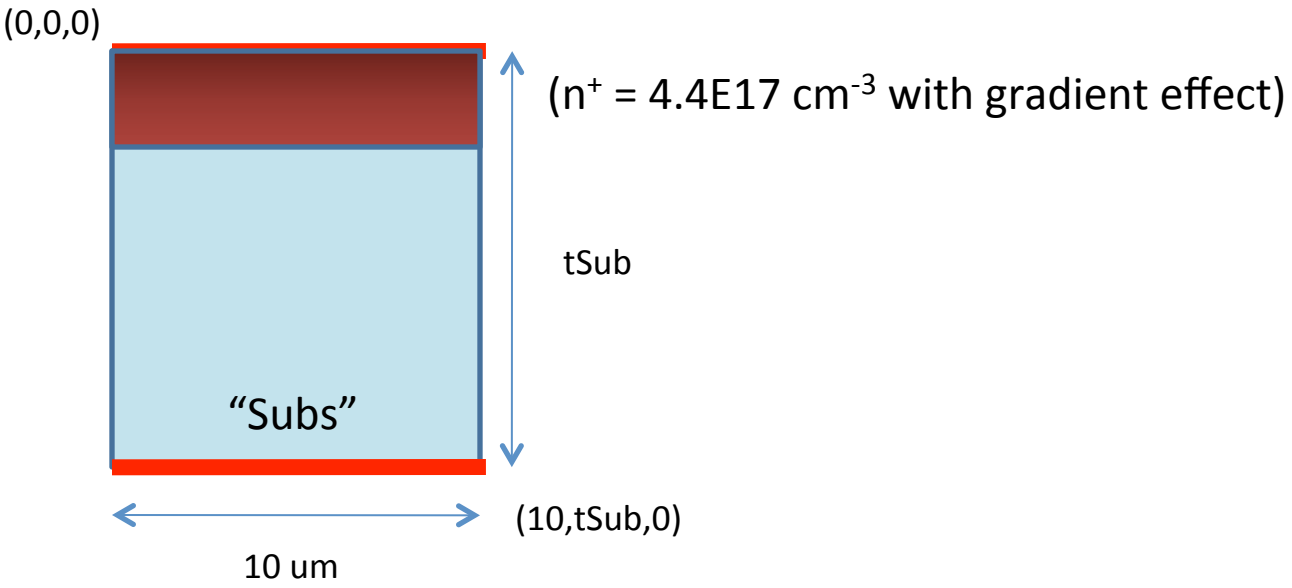
```
; -------------------------------------------------------------------
; ### Setting The Doping ###
; -------------------------------------------------------------------

; ) n region constant doping (
(sdedr:define-constant-profile "Const.Subs"  "PhosphorusActiveConcentration" 4.4e15)
(sdedr:define-constant-profile-region "PlaceCD.Subs"  "Const.Subs" "Subs")

; ) n+ region  (
(sdedr:define-gaussian-profile "doping.profile.nplusSi" "PhosphorusActiveConcentration" "PeakPos" 0 "PeakVal" 4.4e17 "StdDev" 0.15 "Gauss" "Length" 0.1)
; Window Selection
(sdedr:define-refeval-window "window.nplusSi" "Line" (position 0 0 0) (position 10 0 0))
; Doping Placement
(sdedr:define-analytical-profile-placement "place.nplusSi" "doping.profile.nplusSi"  "window.nplusSi" "Positive" "NoReplace")
```



Project Demonstration

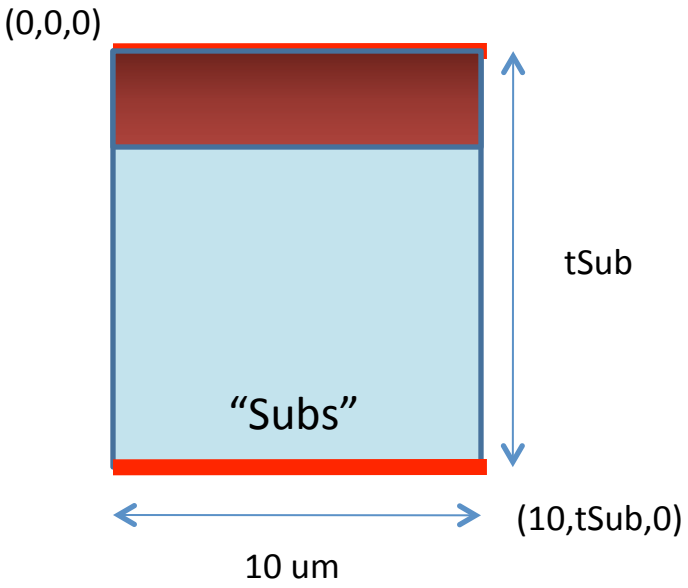
Setting up the Device: N^+ region Doping

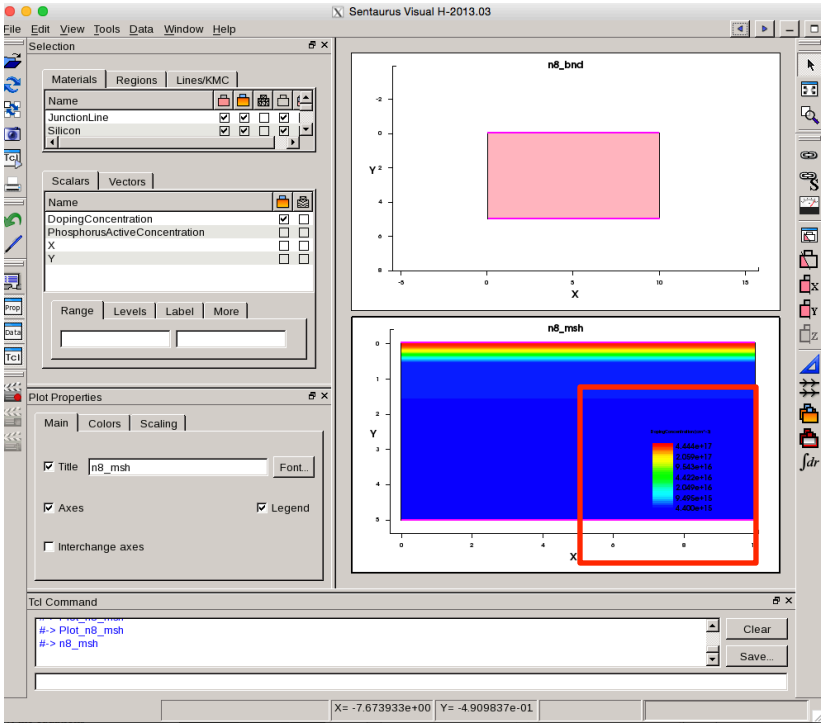
```
; ---------------------------------------------------------------------
; ### Setting The Doping ###
; ---------------------------------------------------------------------

; ) n region constant doping (
(sdedr:define-constant-profile "Const.Subs"  "PhosphorusActiveConcentration" 4.4e15)
(sdedr:define-constant-profile-region "PlaceCD.Subs"  "Const.Subs" "Subs")

; ) n+ region  (
(sdedr:define-gaussian-profile "doping.profile.nplusSi" "PhosphorusActiveConcentration" "PeakPos" 0 "PeakVal" 4.4e17 "StdDev" 0.15 "Gauss" "Length" 0.1)
; Window Selection
(sdedr:define-refeval-window "window.nplusSi" "Line" (position 0 0 0) (position 10 0 0))
; Doping Placement
(sdedr:define-analytical-profile-placement "place.nplusSi" "doping.profile.nplusSi"  "window.nplusSi" "Positive" "NoReplace")
```



Project Demonstration

Visualize with Sentaurus Visual

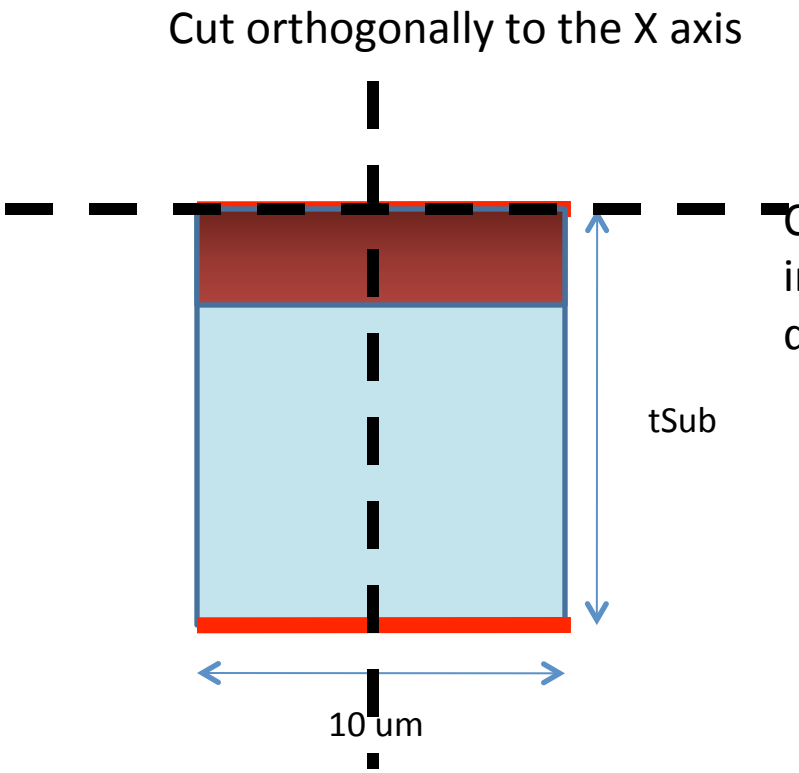




- Pay attention to the scale on the corner to make sure you set up the doping correctly

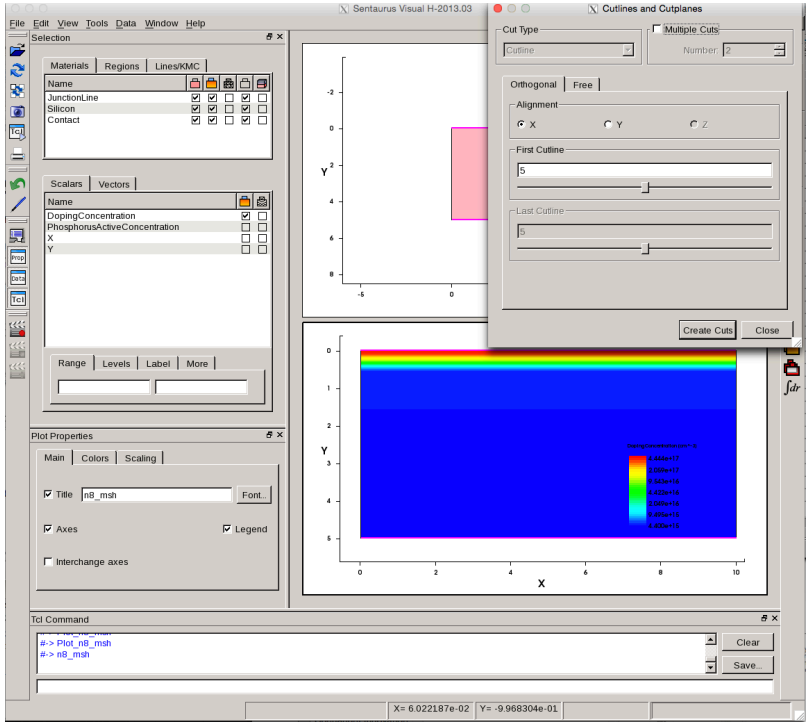
Project Demonstration

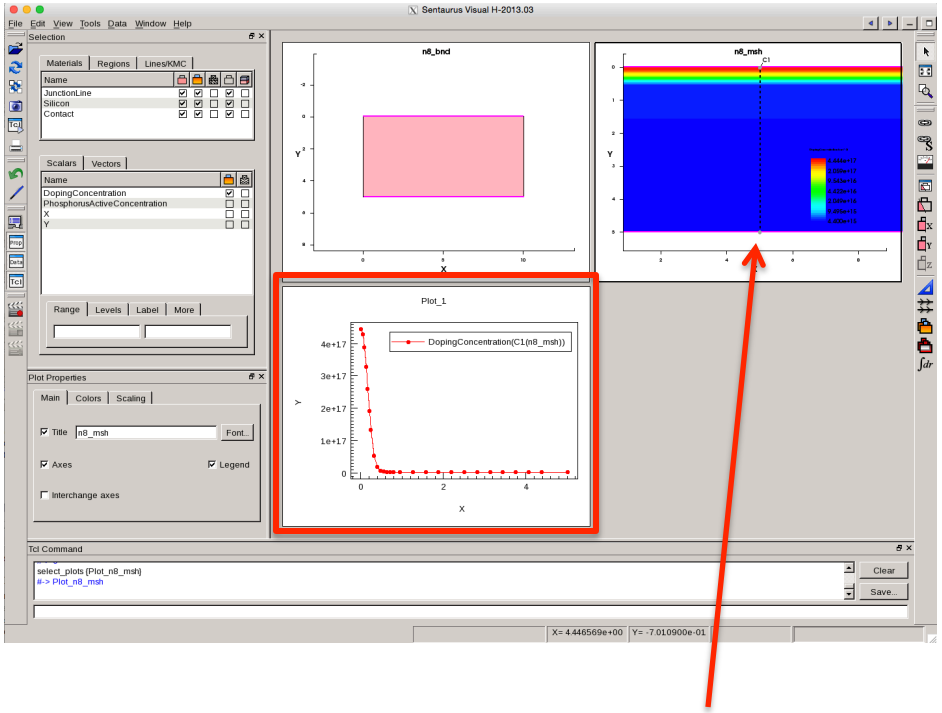
Confirm doping with Sentaurus Visual Cuts



Project Demonstration

Confirming doping with Sentaurus Visual Precision Cut



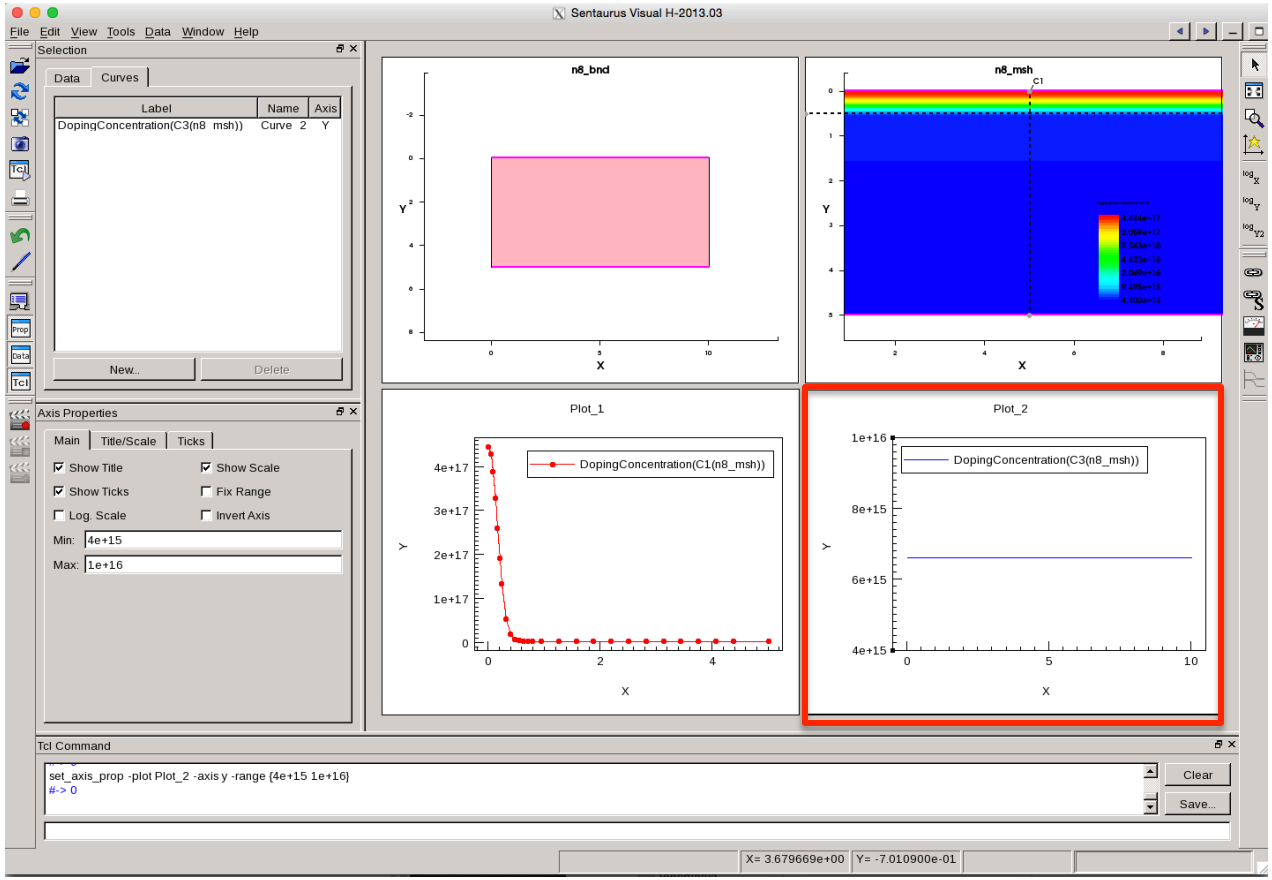


1. Select “Tools” on menu bar, and “Precision cuts”
2. Choose desired cutting direction, i.e. X direction
3. Enter coordinate, such as x= 5 to cut in center of the device

Notice the cut line is indicated

Project Demonstration

Confirming doping with Sentaurus Visual

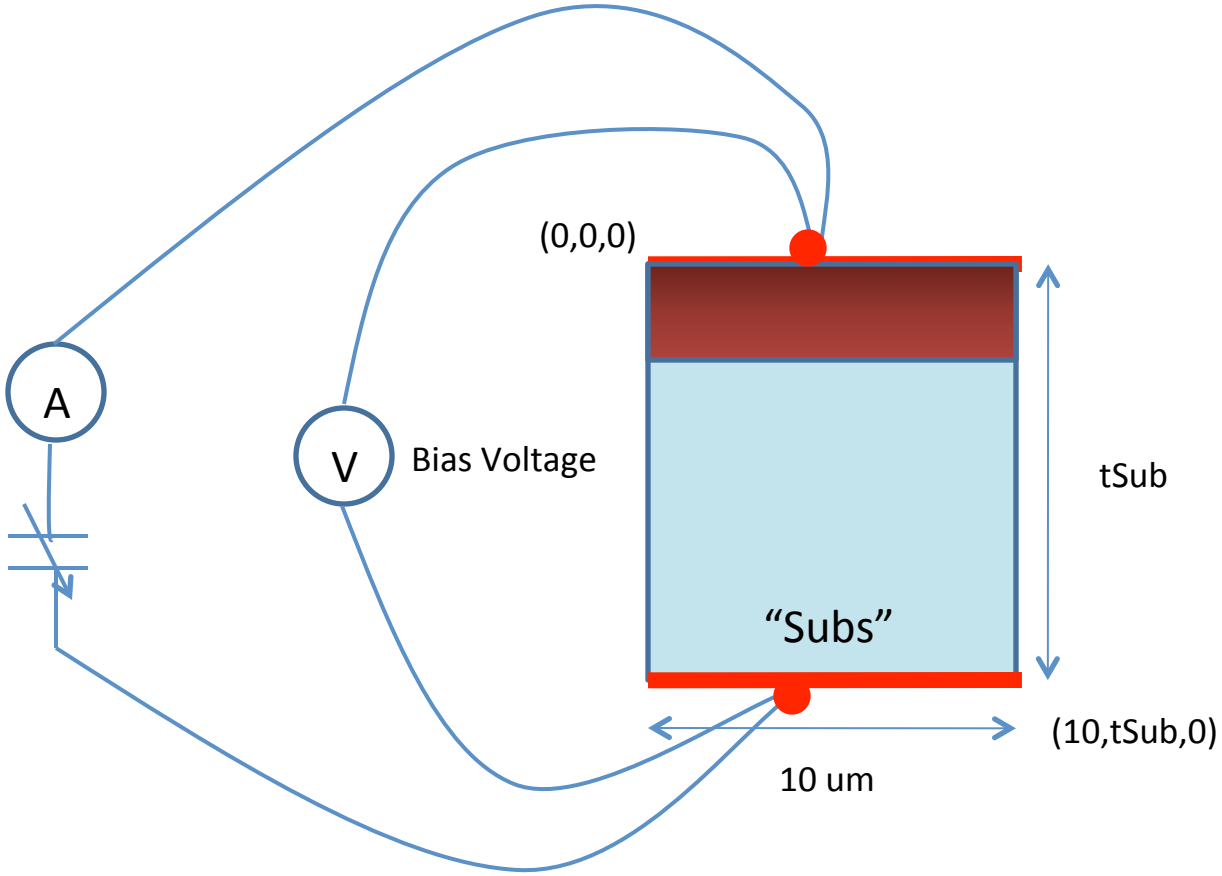


1. Select “Tools” on menu bar, and “Precision cuts”
2. Choose desired cutting direction, i.e. Y direction
3. Enter coordinate, such as y= 0.5 to cut horizontally across

(**do not cut at y = 0** because it’s technically not in the device)

Project Demonstration

Getting IV Characteristic with Inspect



Project Demonstration

Getting IV Characteristic with Inspect

/nfs/eecg/homes/extgrad/liuhongg/hgliu_TCAD/ECE_335/ECE_335_project_0/sdevice_des.cmd - sedit

File Edit Format Settings Help

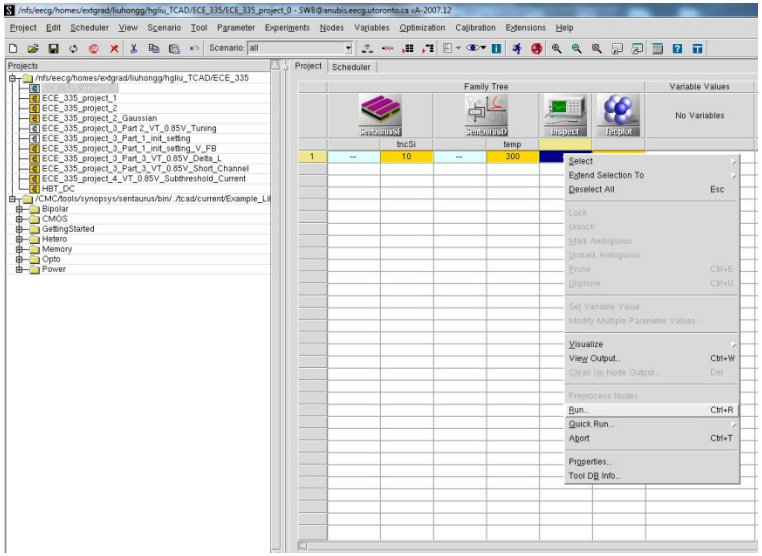
```
*-----------------------------------------------------------
* Simulate dark/light J-V characteristics of  BACH solar cell
* ----------------------------------------------------------
* By default, dark J-V is simulated.
* To simulate light J-V, set light = on

#setdep @previous@

File{
*-Input
        Grid    = "@tdr@"
        Parameter  = "@parameter@"
        * Output Files
        Current    = "@plot@"
        Plot       = "@tdrdat@"
        Output     = "@log@"
}

Electrode {
   { Name="electrode_1" Voltage=0.0 }
   { Name="electrode_2" Voltage=0.0 }
}

Physics {
   Temperature=@temp@
   EffectiveIntrinsicDensity( Slotboom )
   Mobility ( DopingDep eHighFieldSaturation hHighFieldSaturation )
   Recombination(SRH(DopingDep))
   AreaFactor = 1e3 * converting current to mA
}

Insert = "PlotSection_des.cmd"
Insert = "MathSection_des.cmd"

Solve{
  NewCurrentFile="init"
  Poisson

  NewCurrentFile=""
  Coupled (Iterations=100) { poisson electron hole  }

  Quasistationary (
      InitialStep=4e-2 Increment=1.1 Minstep=1e-3 MaxStep=1e-1
      Goal { Name="electrode_1" Voltage=5 }
        ) {Coupled (Iterations=100) {Poisson Electron Hole}}

        CurrentPlot ( Time = (Range = (0.0 0.2) Intervals=10; Range = (0.2 1.0) Intervals=2
```

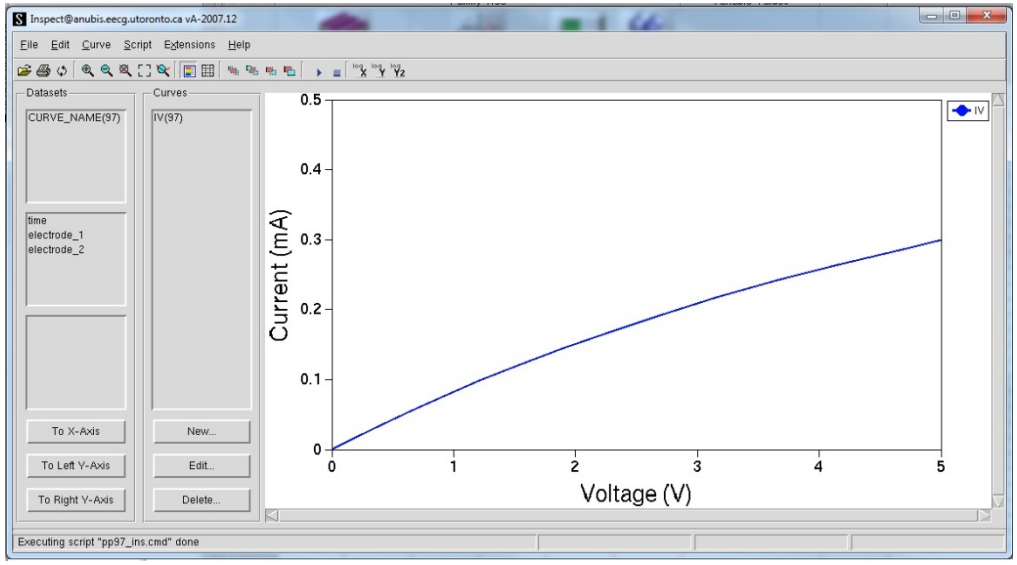
Apply bias if necessary

Adjust calculation parameters if needed

Project Demonstration

Getting IV Characteristic with Inspect





FAQ

1. **Takes forever to compile or get output** -> check account storage quota and talk to lab manager

2. **Changes are not updated** -> make sure to re-compile every block you modify
   and wait until all of them turn yellow

3. **Can't compile and it's read only** -> Select "project“ on workbench , then "unlock”

4. **Remote access with puTTy and Xming dosen’t work** -> Try Cygwin (Net + X11 package)
   i.) Enter “startxwin” in command window of Cygwin
   ii.) Use ssh –Y username@ugXXX.eecg.utoronto.ca