

Special Topics on Basic EECS I Design Technology Co-Optimization

Lecture 15

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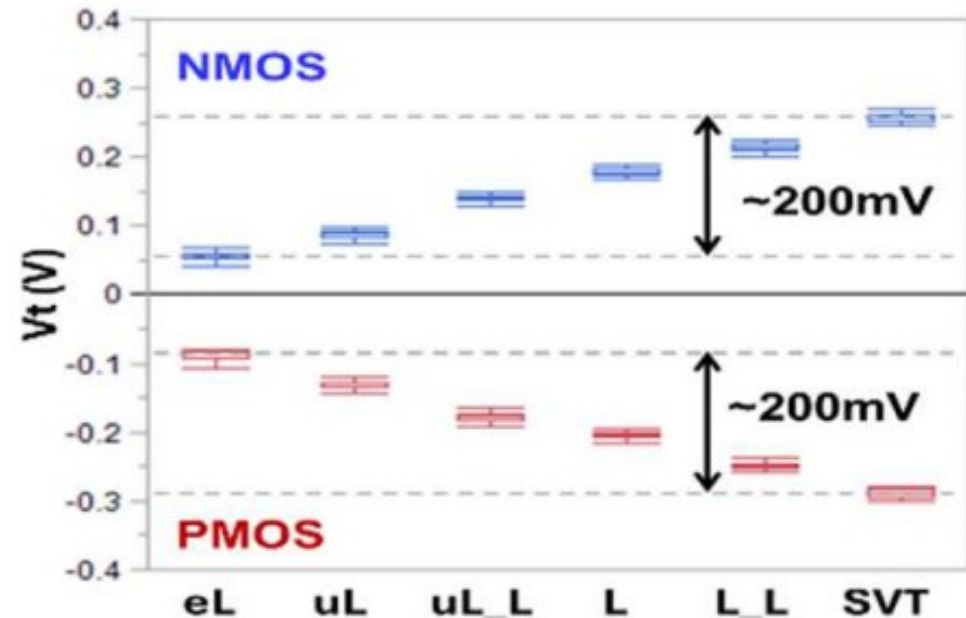
Department of Electrical Engineering and Computer Science

Gwangju Institute of Science and Technology (GIST)

L15

Gate workfunction

- We need multiple threshold voltages (V_t s).
 - Workfunction metal (WFM) was used.
 - In these days, dipole-based multi- V_t integration with both n-type and p-type dipoles

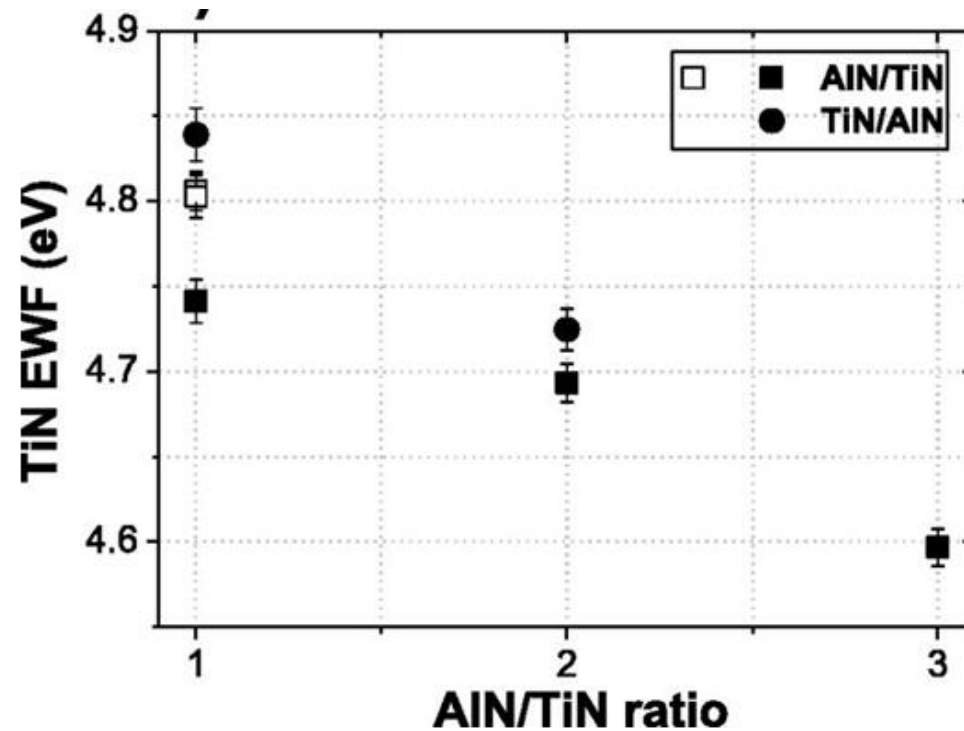


Six threshold voltage available in the N2 technology (TSMC)

TiAlN

- Workfunction of TiN on HfO_2 is 4.8 ~ 5.0 eV.
 - With Al, its workfunction on HfO_2 is reduced. (Suitable for NMOSFETs)

Workfunction versus AlN/TiN ratio for TiN/AlN laminate devices (L. P. B. Lima et al., IMEC)

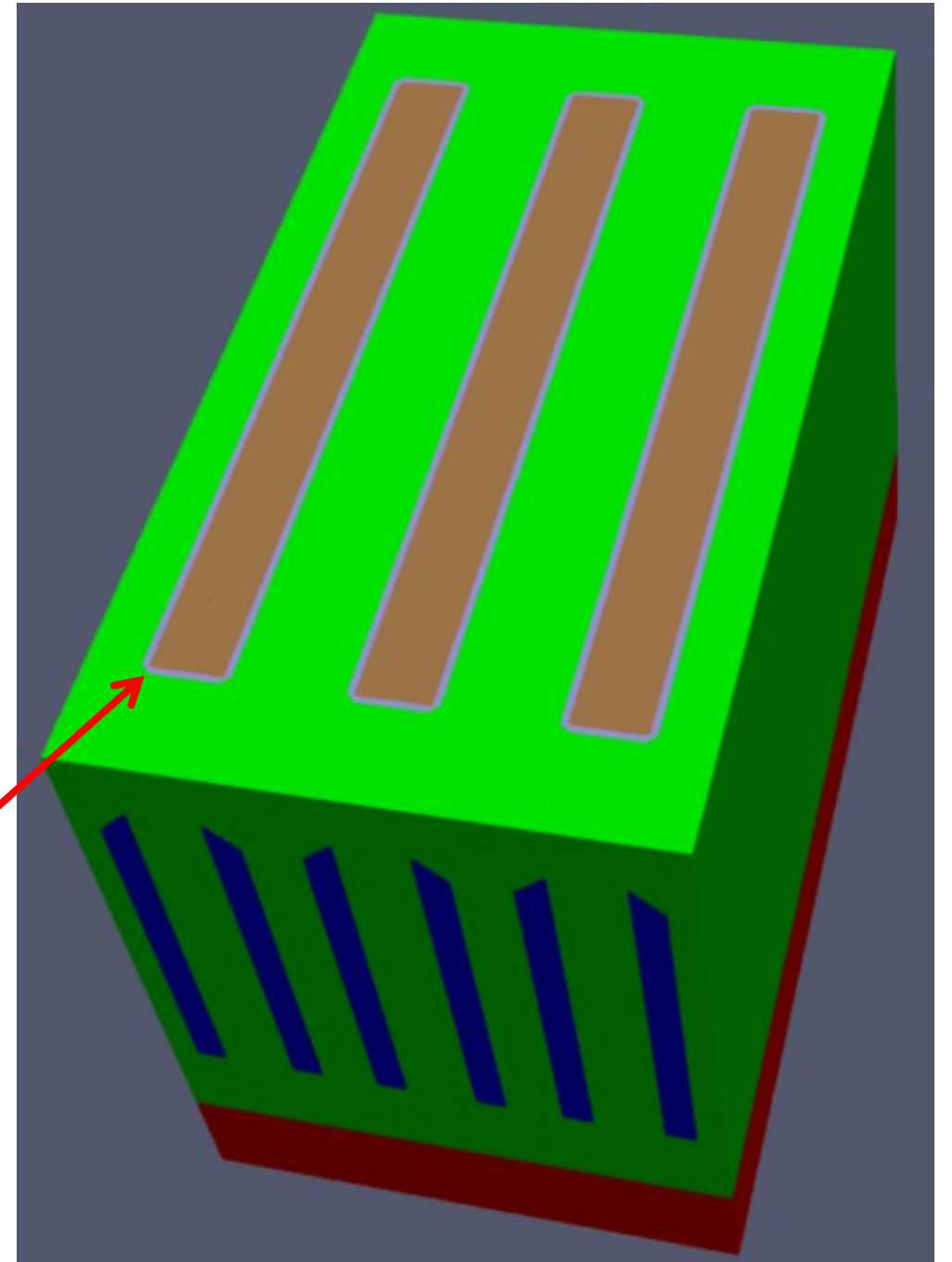


- (Not considered in this example)

Tungsten fill

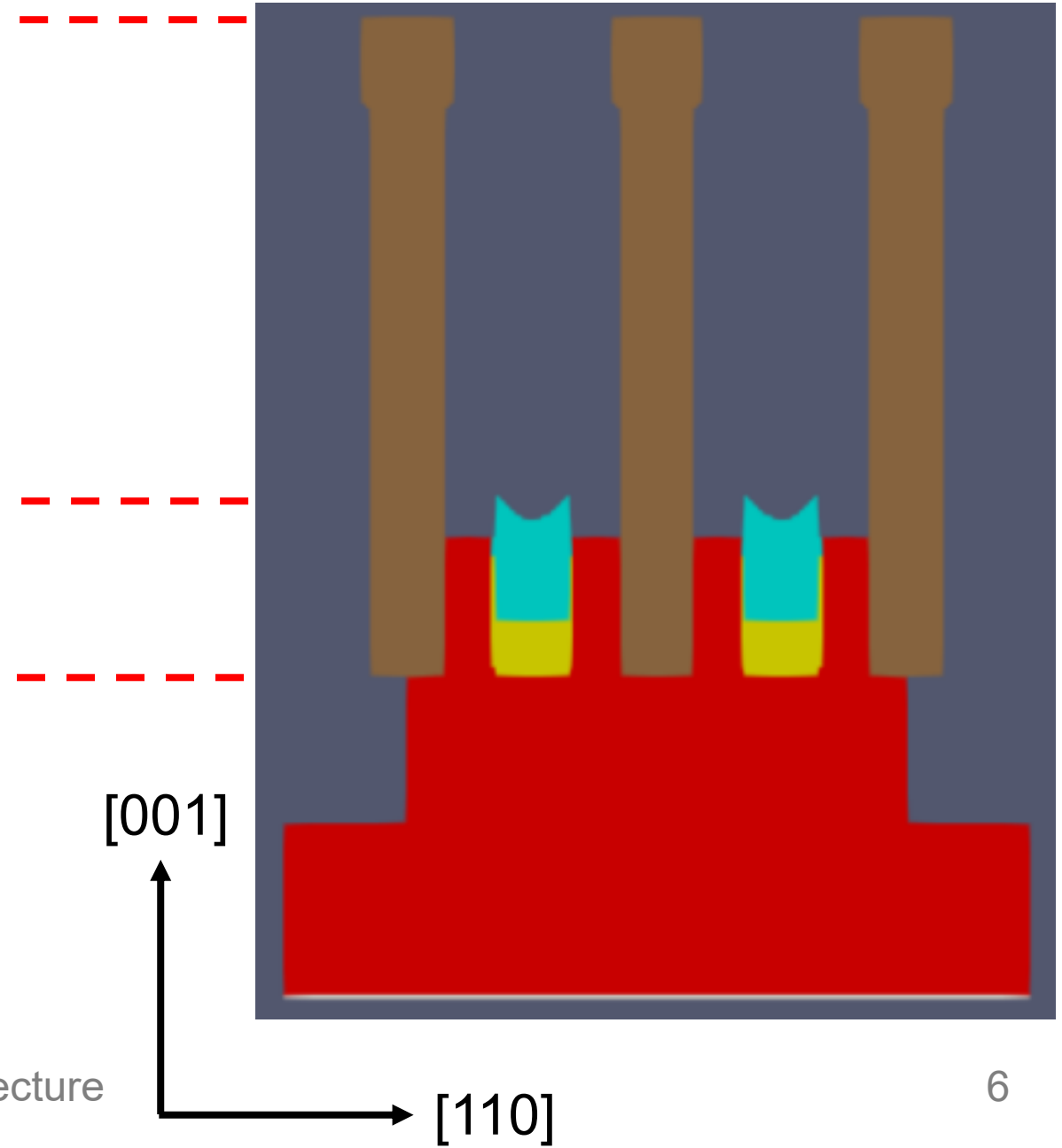
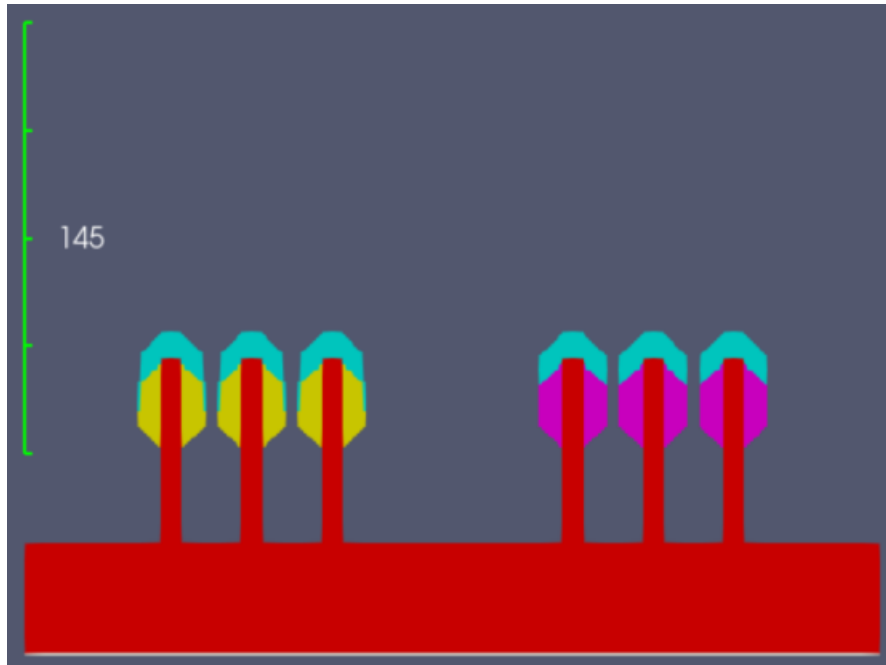
- Now, fill the remaining cavity with tungsten.
 - CMP, again
 - `cmp (position=213)`
 - In this example, the ILD0 thickness is about 145 nm.

In reality, there are more layers between HfO_2 and tungsten to adjust V_t .



Side view

- Some comments
 - In order to prevent the merged S/D epi layers, they are not grown sufficiently.
 - Fins seem to be a little short.



FEOL (Front-end-of-line)

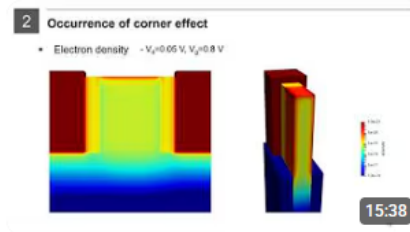
- All process steps up to the completion of the transistor itself
 - Fin patterning (L9. Fins are already cut.) → STI (L9) → Dummy gate (L9) → Spacer (L10) → S/D epi (L13) → Salicide (L14) → Dummy gate removal (L14) → High-k (L14) → Gate fill (L15)
 - What's the next? MOL

Homework#15

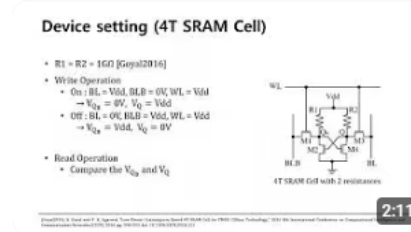
- Due: 08:00 on Nov. 10
- Submit a report through the GIST LMS system.
 - Throughout several lectures (from L6 to L15), we have covered the FEOL processed of a virtual ASAP7 FinFET. Follow the lecture progress.

Term project

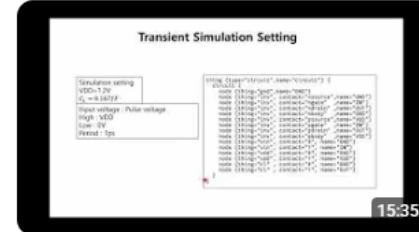
- Watch the term project videos in TCAD 2022.



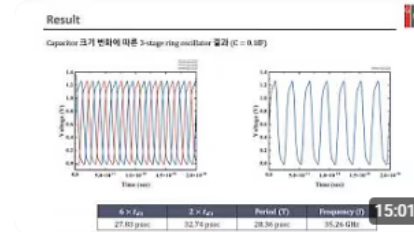
[한][TCAD2022] Term project (정상목)
조회수 353회 • 2년 전



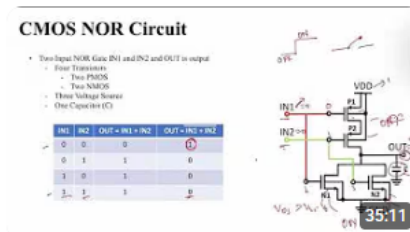
[한][TCAD2022] Term project (한승철)
조회수 191회 • 2년 전



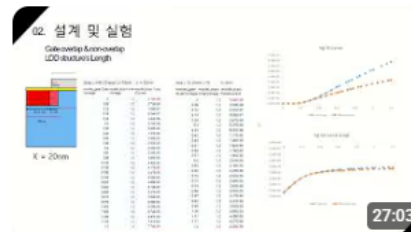
[한][TCAD2022] Term project (정길웅)
조회수 196회 • 2년 전



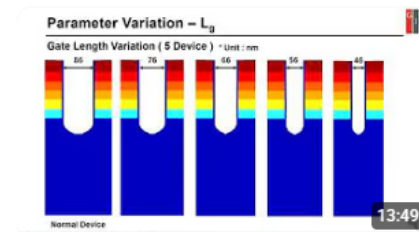
[한][TCAD2022] Term project (한성민)
조회수 379회 • 2년 전



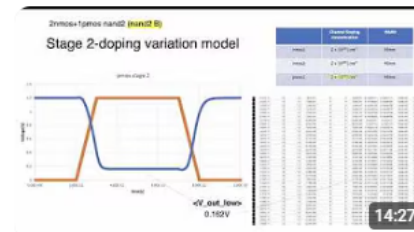
[Eng][TCAD2022] Term project (Ankur Singh)
조회수 194회 • 2년 전



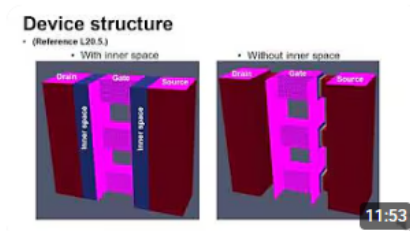
[한][TCAD2022] Term project (심준호)
조회수 230회 • 2년 전



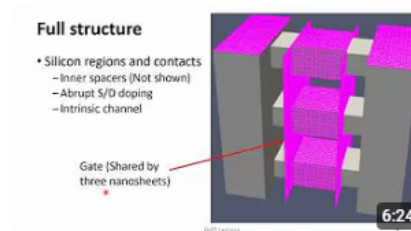
[한][TCAD2022] Term project (박건호)
조회수 506회 • 2년 전



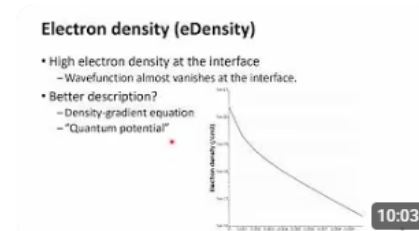
[한][TCAD2022] Term project (윤혜진)
조회수 334회 • 2년 전



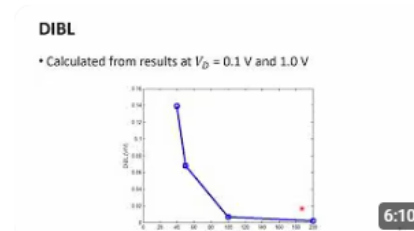
[한][TCAD2022] Term project (이광운)
조회수 368회 • 2년 전



[Eng][TCAD2022] L20.5
조회수 374회 • 2년 전



[Eng][TCAD2022] L19.5
조회수 158회 • 2년 전



[Eng][TCAD2022] L18.5
조회수 173회 • 2년 전

A slide taken from L3

- In this semester, we will use:
 - AngstromCraft (Process emulator) → We have used it.
 - G-Device (Device simulator) → Not used yet
 - Xschem (Schematic editor) → Not used yet
 - Ngspice (Circuit simulator) → Not used yet
 - And other tools
- G-Device will be used.

Type `gdevice` in the terminal.

- It was Homework#3.
 - Maybe you obtained this result.

```
*****
***                               ***
***           G-Device           ***
***       Version P-2025.08       ***
***   Compiled on 2025. 08. 03.   ***
***                               ***
***           Written by         ***
***       Sung-Min Hong         ***
***                               ***
*****
```

- We need to specify the input file name.
 - Now, let's make a simple example.

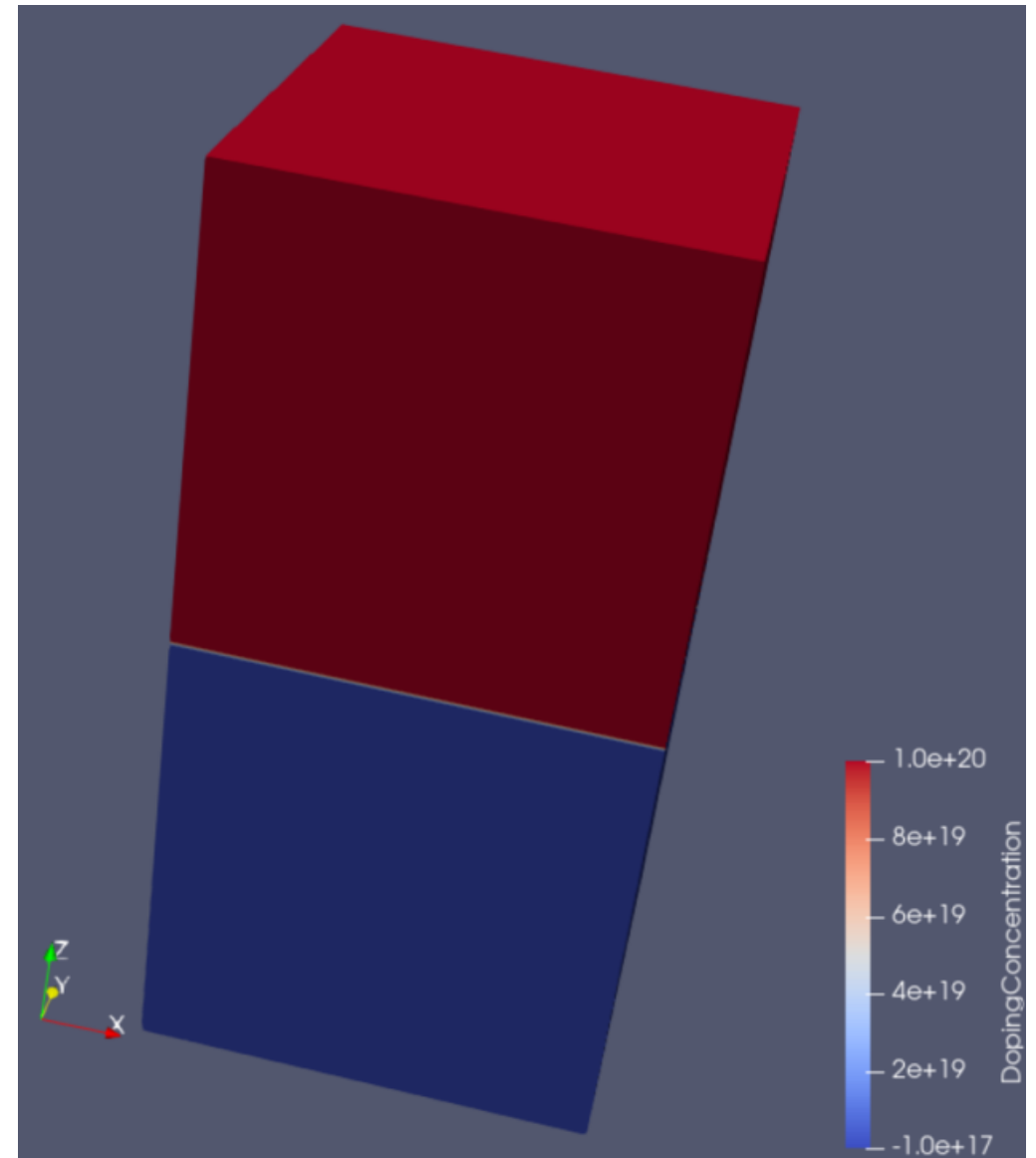
A simple PN junction

- You can find it in “[ENG][TCAD2022] L4.5”, too.
 - G-Device has its own grammar. All lengths are in meters.
 - “doping” and “contact” are used.

```
thing (type="mapmaker", name="structure") {  
  mapmaker (type="3d", cgns="pn.cgns") {  
    cuboid (x0=0.0,y0=0.0,z0=0.0,x1=1e-6,y1=1e-6,z1=2e-6,nx=2,ny=2,nz=201)  
    region (name="ptype",material="silicon",ix0=0,iy0=0,iz0=0,ix1=1,iy1=1,iz1=100)  
    region (name="ntype",material="silicon",ix0=0,iy0=0,iz0=100,ix1=1,iy1=1,iz1=200)  
    doping (region="ptype",ix0=0,iy0=0,iz0= 0,ix1=1,iy1=1,iz1=100,density=-1e17 /cm3)  
    doping (region="ntype",ix0=0,iy0=0,iz0=100,ix1=1,iy1=1,iz1=200,density= 1e20 /cm3)  
    contact (name="cathode",ix0=0,iy0=0,iz0=200,ix1=1,iy1=1,iz1=200)  
    contact (name="anode" ,ix0=0,iy0=0,iz0= 0,ix1=1,iy1=1,iz1= 0)  
  }  
}
```

Visualization

- Now, we have some internal quantities.
 - For example,
“DopingConcentration”
 - Watch “[Eng][TCAD2022]
How to draw a cutline graph”
for visualization.
 - Click your variable from the
left panel and press “Apply.”
Then, in “Coloring,” you can
select it.



Thank you!