Special Topics on Basic EECS I Design Technology Co-Optimization
Lecture 15

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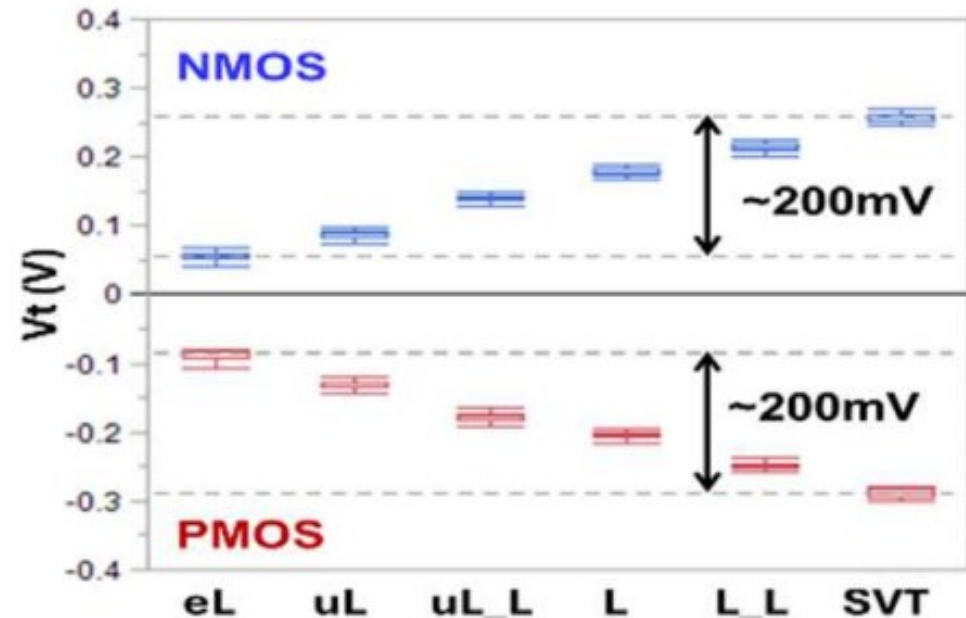Department of Electrical Engineering and Computer Science
Gwangju Institute of Science and Technology (GIST)

L15

Gate workfunction

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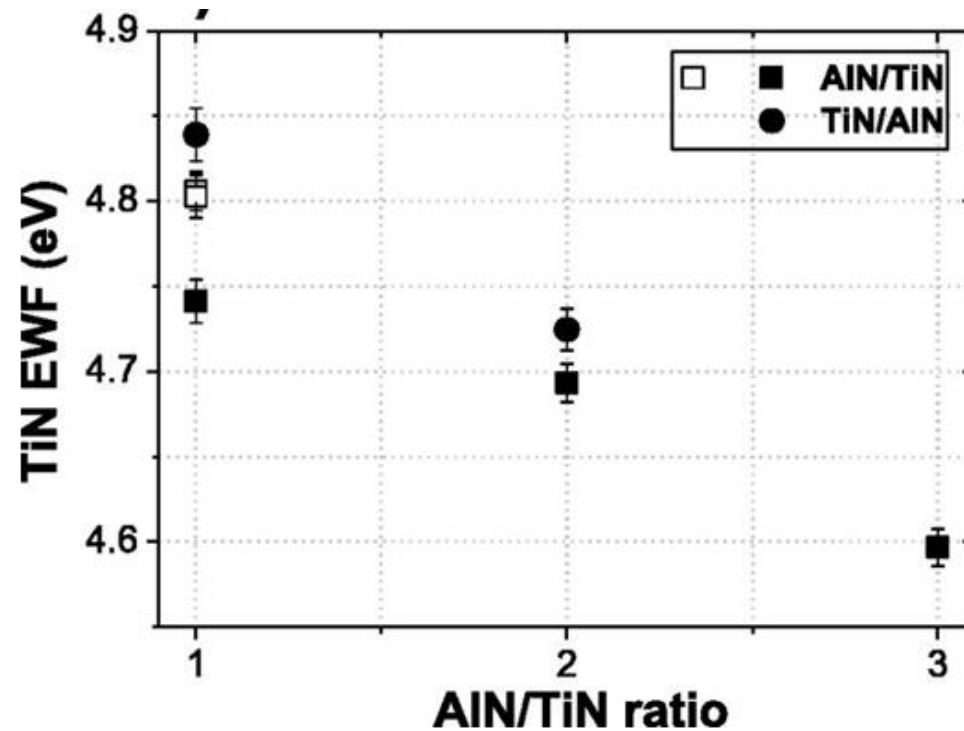   - In these days, dipole-based multi-V_t integration with both n-type and p-type dipoles

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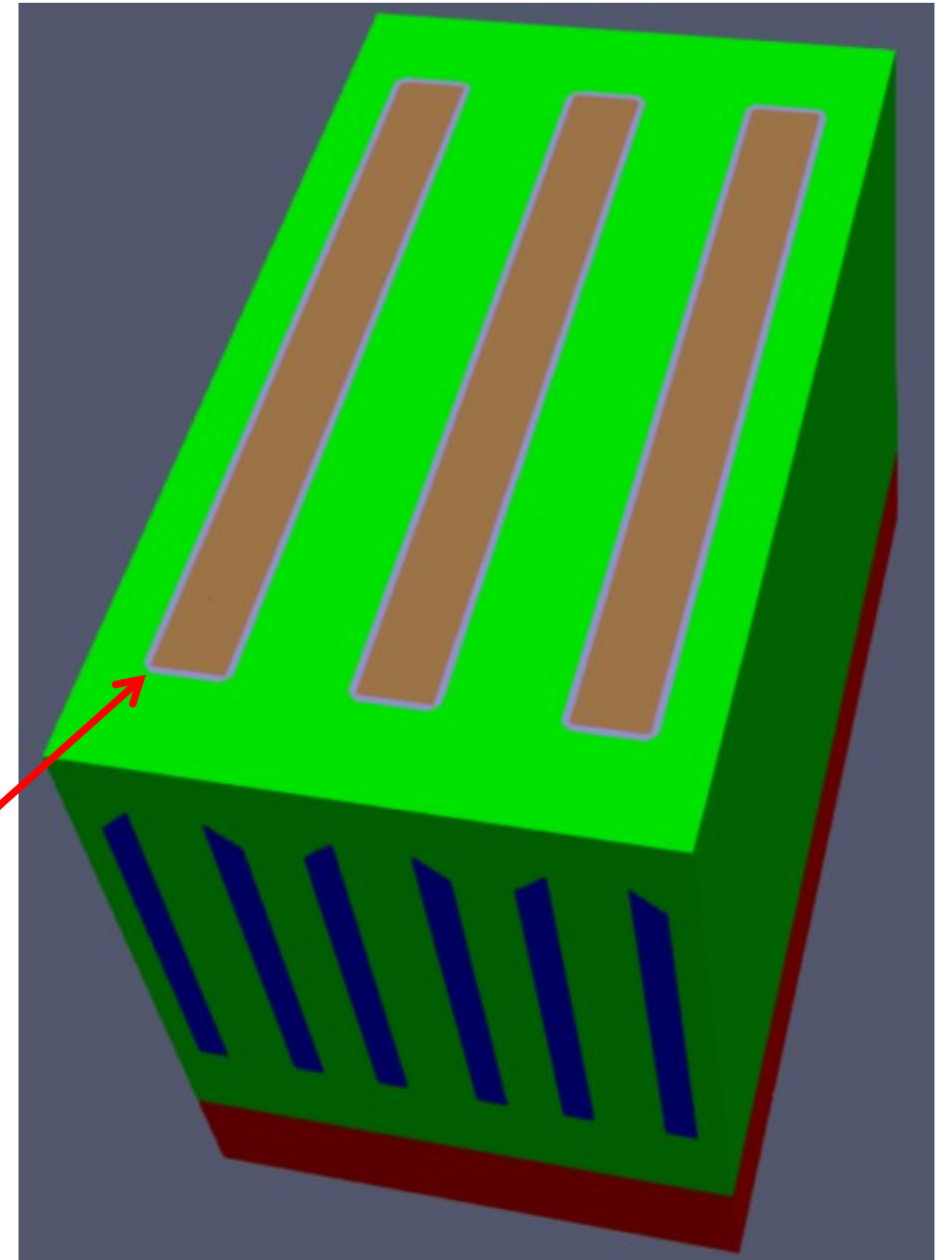ratio for TiN/AlN liminate devices
(L. P. B. Lima et al., IMEC)

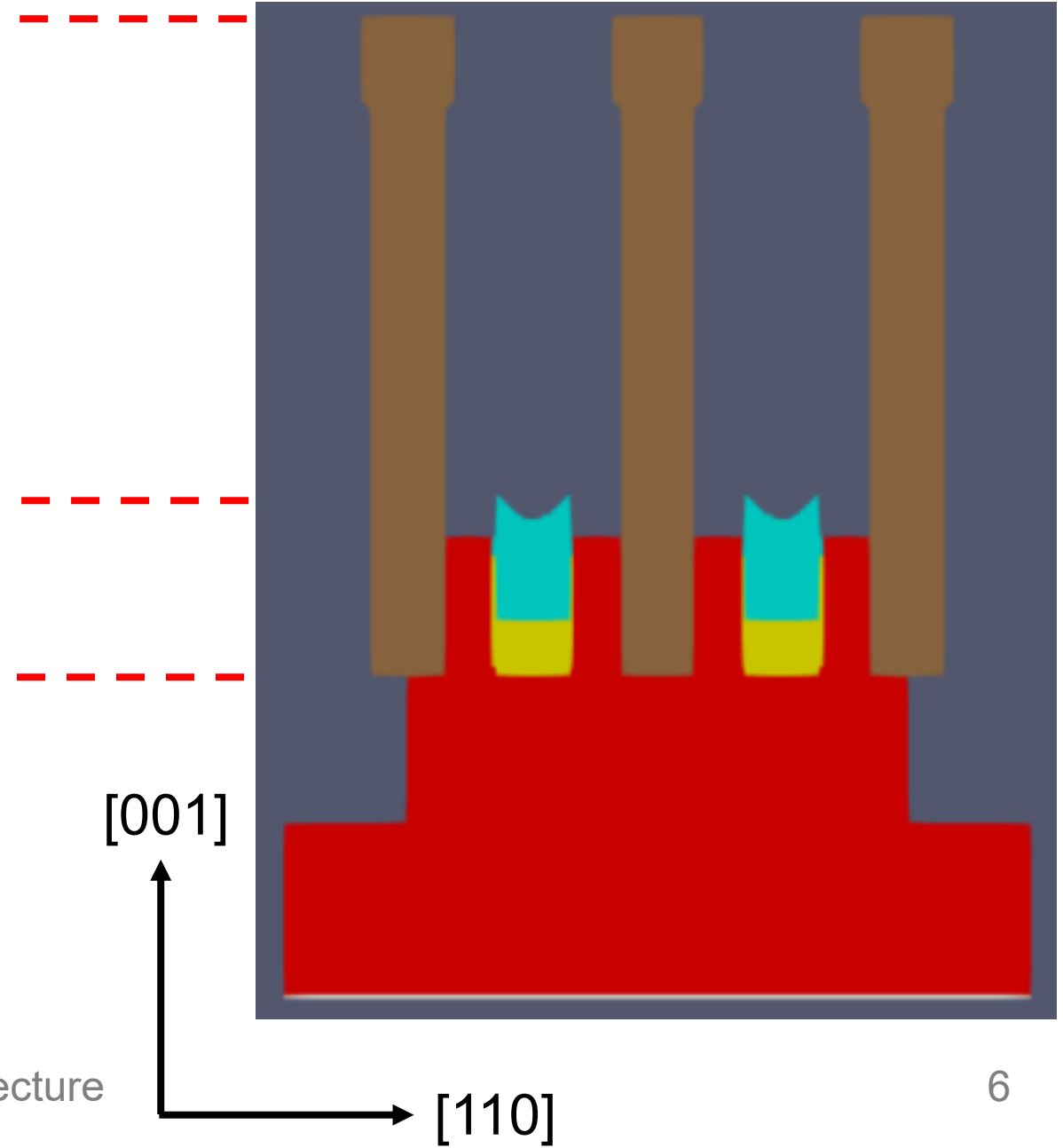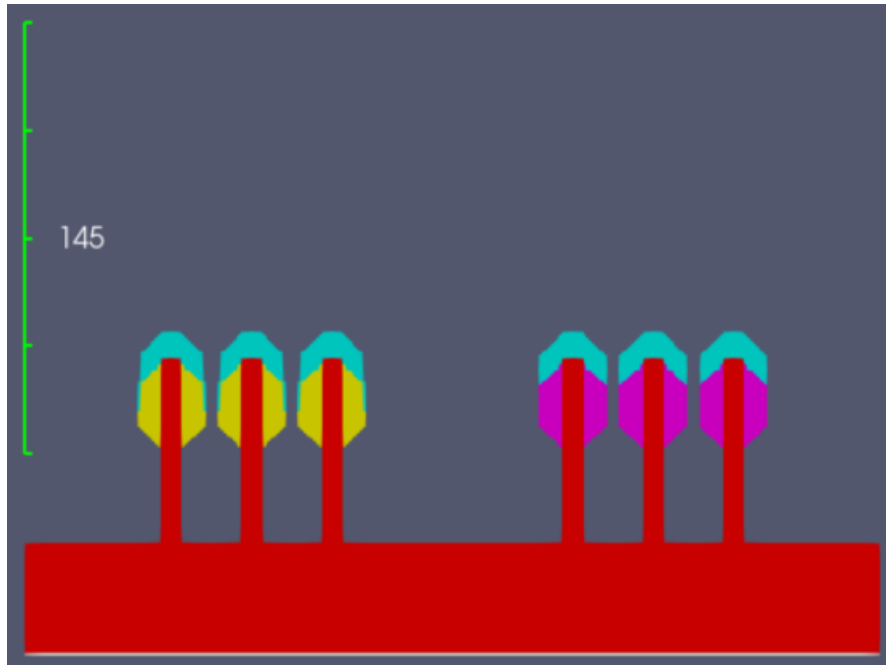
  - (Not considered in this example)

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.

[001]
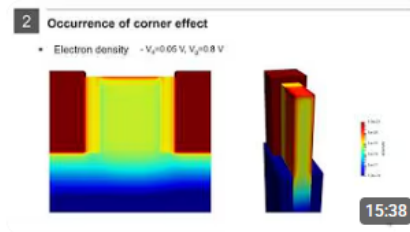
[110]

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)
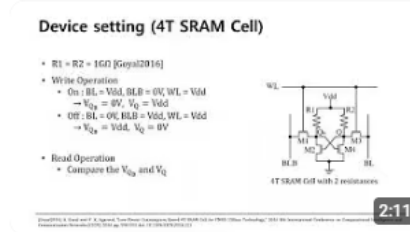 - What's the next? MOL

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.
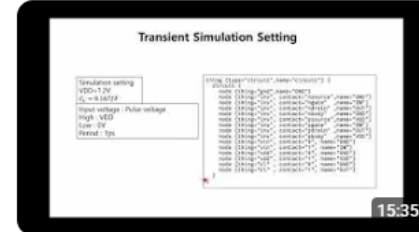
Term project

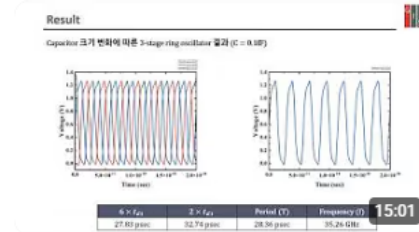- Watch the term project videos in TCAD 2022.

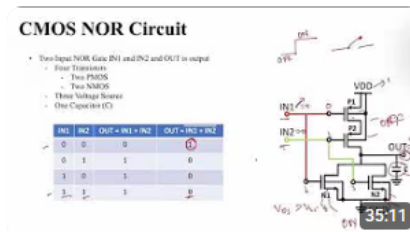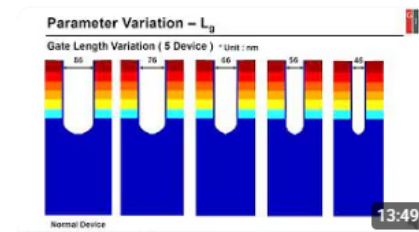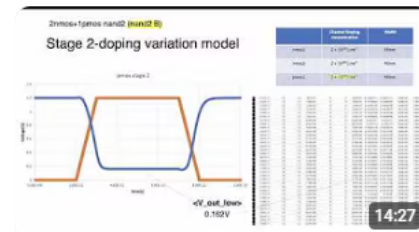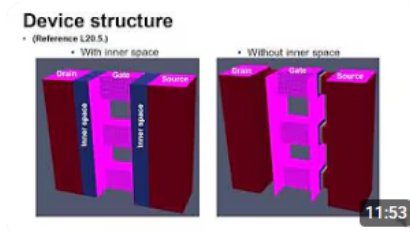|			
[한][TCAD2022] Term project (정상목) 조회수 353회 • 2년 전	[한][TCAD2022] Term project (한승철) 조회수 191회 • 2년 전	[한][TCAD2022] Term project (정길웅) 조회수 196회 • 2년 전	[한][TCAD2022] Term project (한성민) 조회수 379회 • 2년 전
[Eng][TCAD2022] Term project (Ankur Singh) 조회수 194회 • 2년 전	[한][TCAD2022] Term project (심준호) 조회수 230회 • 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                              ***
********************************************************************************
```
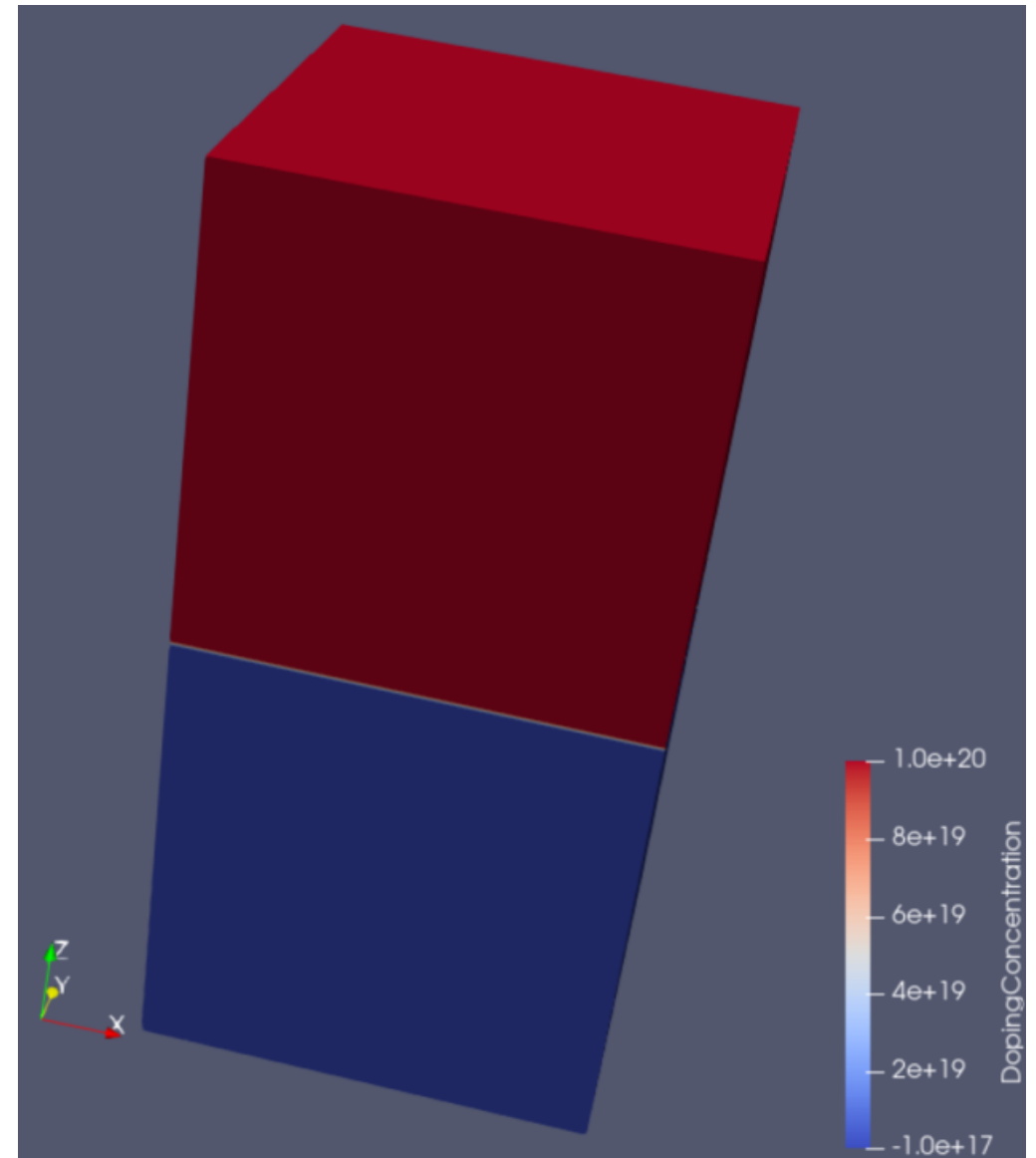
  - We need to specifiy the input file name.
  - Now, let's make a simple example.

A simple PN junction

- You can find it in "[ENG][TCAD2022] L4.5", too.
  - G-Device has its own grammar. Lengthes are in the meter scale.
  - "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!