Announcements

Term Paper:

- The topics for the term paper are online now.
- There are a total of 12 topics available.
- Please email me a ranked list of your top 5 topics by Sunday November 3\textsuperscript{rd} at 5pm.
- I will assign each of you a topic based on your selection on Monday November 4\textsuperscript{th}.
  - There will be a maximum of 2 students per topic.
  - You will be expected to write your term papers independently however.
- The term paper is due Tuesday November 19\textsuperscript{th} (10:00 am).
Last Time

• We looked at ion implantation.

Lecture 9

• Introduction to Athena.
• UNIX.
• Running Athena on OSU Computers.
• Running an Example Program.
• Saving and Exporting Data.
Introduction to Athena

Athena

- Athena is a commercial version of modeling software first developed by Stanford University in 1977:
  - **SUPREM**: Stanford University Process Engineering Module.
  - The software is now maintained and distributed by Silvaco.
  - **Athena** is a program for simulating the steps of a semiconductor process.
  - **Atlas** is a program for simulating the electrical behavior of the fabricated devices.
  - The intent of the Silvaco software package is to accomplish ‘Virtual Wafer Fabrication’ in which semiconductor process, device, and circuit simulation can be accomplished using a single tool.
**DeckBuild**

- SUPREM was originally command-line only.
- Silvaco provides a range of GUI tools to make Athena / Atlas more user-friendly.
- We will mainly just be using two of these tools:
  - **DeckBuild:**
  - DeckBuild is an Integrated development environment (IDE).
    - Like Visual Studio or Code::Blocks.

**Tonyplot**

- SUPREM was originally command-line only.
- Silvaco provides a range of GUI tools to make Athena / Atlas more user-friendly.
- We will mainly just be using two of these tools:
  - **Tonyplot:**
    - Tonyplot is a visualization tool.
    - Used to display results graphically.
Documentation

- There is a large amount of information on the Silvaco Website:

- The course website also has manuals for the software:
  - [http://classes.engr.oregonstate.edu/eecs/fall2019/ece611/simulations.html](http://classes.engr.oregonstate.edu/eecs/fall2019/ece611/simulations.html)

- These are useful references, but too long to be read in full.
- These notes (Lectures 9 & 10) should serve as your primary source of information.
UNIX

- Athena (and all related Silvaco applications) run on UNIX.

- UNIX is a command-line operating system like MS-DOS etc.
- We will mainly be just using UNIX to run Athena, but we will need to know a few basics before we begin.
- The line with the flashing cursor tells you your username and current directory.
- To execute a command type it then press enter.
UNIX Commands

- We will run through a few basic commands now.
- There is plenty of documentation available online, e.g.:
  - [http://mally.stanford.edu/~sr/computing/basic-unix.html](http://mally.stanford.edu/~sr/computing/basic-unix.html)
- Please be aware that UNIX is case sensitive.
- You can use the up and down arrows to view previously executed commands.
- You can use up and down arrows to view previously executed commands.
- When typing file names or directories you can use the tab key to auto complete. E.g.:
  - Type “cd Dri” then hit tab, it will show: “cd Drivers/”.
- Note UNIX file systems use “/” not “\”.

UNIX Commands

- `ls`: will list all files and folders in current directory.
  - `ls -l`: same as above but each item listed on new line.
UNIX Commands

• `cd`: changes directory to the typed directory.

• `cd ..`: moves up one directory.

• `rm`: deletes the typed file (after confirmation):

• `mkdir`: creates a new directory:
Line Endings

- It should also be noted there is the difference in the way text files are stored in UNIX (& Linux and Mac) vs DOS (Windows).
- When stored in files, data is stored as text.
- E.g.:

  - Text is stored as an array of characters.
  - Although you don’t see it when you open a file in a text editor, Excel, etc., each line of text has a code at the end to indicate the end of a line.
  - Otherwise your text editor etc. would not know when a string is split.

Line Endings

- E.g. character has a number (ASCII Code) associated with it:

  ASCII TABLE

<table>
<thead>
<tr>
<th>Character</th>
<th>ASCII Code</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>\n</code></td>
<td>10</td>
</tr>
<tr>
<td><code>\r</code></td>
<td>13</td>
</tr>
<tr>
<td><code>\t</code></td>
<td>9</td>
</tr>
</tbody>
</table>

ECE 611 / CHE 611 - Electronic Material Processing
Fall 2019 - John Labram
Line Endings

• E.g. consider the following text file:

```plaintext
Hello
Second Line
Third Line
```

• In ASCII it would be the following if written in UNIX:

```
72 101 108 108 111 10 83 101 99 111 110 100 32 76 105 110 101
84 104 105 114 100 32 76 105 110 101
```

• In ASCII it would be the following if written in Windows:

```
72 101 108 108 111 13 10 83 101 99 111 110 100 32 76 105 110 101
13 10 84 104 105 114 100 32 76 105 110 101
```

Line Endings

• Text files created on DOS / Windows computers use a combination of carriage return and line feed symbols to indicate the end of a line.

• Text files created on UNIX / Linux / MAC computers use just a line feed symbol to indicate the end of a line.

• Sometimes when files are transferred between UNIX- and DOS-based computers there can be compatibility issues.

• Normally manifest as text files appearing as one long line.

• The approach I will be demonstrating today automatically manages the conversion, but it is something you should be aware of if transferring data between UNIX and DOS machines generally (especially when writing code).
Running Athena on OSU Computers

COE Account

- OSU provides all the Silvaco software required to run Athena.
- You may need a College of Engineering (COE) account to access the software. I am not sure about College of Science (COS) accounts.
- If you don’t have a COE account you can get one here:
  - https://it.engineering.oregonstate.edu/basics#accounts.
  - Speak to Leanne Lai (leanne@engr.oregonstate.edu) if you have problems. Mention the course code and that I am teaching it.
- Also, you may need access to KEC1130 (in atrium).
  - Speak to student workers on front desk in KEC if you do not have access.
DUO

- COE has recently started using dual-authentication logins for certain things.
- The easiest way to use it is via a mobile app DUO.
- See here for more details:
  - [https://is.oregonstate.edu/duo.](https://is.oregonstate.edu/duo)
- You can get it for free from the app store on iOS etc.

Accessing Unix From Windows

- The steps we follow to run Athena use the COE Windows computers.
- It may be possible to run Athena from MAC or Linux computers, but it is not discussed here.
- We will use a remote access terminal from Windows to run these Linux / UNIX based applications: MobaXterm.
- It should be installed on the PCs in KEC3113.
- It is available through Software Center if you want it on your office PC.
Secure Shell Connection

- When mobaXterm loads up, click on the Session button on the toolbar:

- When the Session Settings Dialog comes up, click SSH.
- SSH stands for Secure Shell, and is a remote access protocol.

SSH Settings

- Enter “access.engr.oregonstate.edu” in the remote host address.
- Other settings should be as the default:
Authentication

- A terminal window should then open, asking for your username:

- Enter your COE username.
- You may be asked for your COE password at this point.
- If so enter it as usual, but be aware that no characters (not even asterisks) will show when entering a password in UNIX.
- If you think you made a mistake hold down backspace for a few seconds.

Authentication

- You will then be asked to authenticate using DUO.

- Type 1 then hit enter to agree.
- The next steps depend exactly how you set up DUO.
- Here we will assume you installed the app on a mobile phone and linked it to your COE account.
Authentication

• You will then be asked to authenticate using DUO.

• You will need to hit approve before you can proceed.

Authentication

• After you hit approve, the SSH terminal may then ask you for a password:

• It rejected my COE password here, but I clicked cancel and it worked fine anyway.
Authentication

• Finally, it will ask you for the terminal type you are running.

• Either type “xterm” or just hit enter for the default option (xterm).

Running DeckBuild

• Once you are connected to the UNIX machine, type “deckbuild” in all lowercase.

• You will probably get the same error message repeated a few times:

• You can ignore this error.
Running DeckBuild

- If everything went ok, the DeckBuild GUI should then appear:

Running an Example Program
Loading an Example

- Finally, we will load and run an example program.
- We will not look any of the details of the code in this lecture.
  - We will look at the code line by line next time.
- It is important to realize that to run a simulation in DeckBuild, you only need the code.
  - You do not need any input data or external libraries.
- DeckBuild will deduce the parameters from your code, pass them on to Athena and Atlas, which will calculate the results, then plot them using Tonyplot.
- You can then export the data from Tonyplot and plot it / use it in other software.
FET Simulation

- We are going to simulate the doping concentration (Athena) and device behavior of a field-effect transistor (FET).
- Specifically an inversion-mode n-type transistor (NMOS).
- Scroll down to the folder labeled “MOS1”, containing “MOS Application Examples” and expand it by clicking the + to the left of the folder button.

FET Simulation

- Select the first item “mos1ex01.in” “Id/Vgs and Threshold Voltage Extraction”.
- If you click on a project the bottom panel will display a summary.
- Click load to load the project.
FET Simulation

• When you load the project DeckBuild should look something like this:

• We are not going to go through the code until next lecture (Lecture 10). For now we will just run it.

Running the Simulation

• To run the simulation just hit the run button on the toolbar:

• The code will then run line-by-line, with the current line highlighted yellow:

• The output box at the bottom will display various data useful for debugging etc.
Results

- Eventually the results from Athena (doping concentration) and Atlas (current vs voltage) will be displayed as new Tonyplot windows.
- Tonyplot can either plot two-dimensional data as a color map or one-dimensional data as a conventional graph.

Results

- You change various aspects of the plot by right clicking anywhere then selecting “Display”
- You can turn on or off various plot overlays (grid, doping concentration etc.).
Saving and Exporting Data

Saving Images

• Finally, we want to export the graphs so we can include them in reports / analyze the data further.
• Let's start with the 2-dimensional doping map.
• We cannot export this as data, so we just export the image.
• The image is fine as presented for your report.
• Click “File” then “Save As” from the main menu.

• You can select the image type from the dropdown.
Saving Images

- We can do the same thing with the current voltage plot to save the image:

![Image of current voltage plot]

Exporting Data

- We can also save the current-voltage data as numerical data.
- To do this we click “File” then “Export”

- I suggest you save the data as Comma Separated Values (.csv).
- Select the data format from the drop down menu.
- This just means the numerical data is stored as a table with a comma “,” separating each column in the table.
Exporting Data

- I suggest navigating to your COE Windows directory, as this is the easiest way to access it from Windows.

- For me it is “labramj/Windows.Documents/Desktop”.
- Alternatively you can move the file from the terminal using the mv command. E.g.:
  - `mv ExampleExport Windows.Documents/Desktop/`

- The data then looks like this if opened in notepad:

- If opened in Excel it will look like:
Summary

- We have covered the basics of modelling using Athena.

Next Time

- On Tuesday we will go through the code line-by-line and cover a few of the details of the Athena language.