Lecture 2

- Course Overview.
- Course Logistics.
- Regulations.
Course Overview

Safety, Cleanrooms, Cleaning

Wafers

Cleaning solution
Basic Properties of Silicon

Growth of Crystalline Silicon
Vacuum Science

Gas Supply

Pumping System

Exhaust

Gauge

https://www.youtube.com/watch?v=KNsM1pbbvOo

https://www.youtube.com/watch?v=f1SErZyhMe4

Operation of MOS Capacitors

\[ V \gg 0 \]

\[ C_i \]

\[ d \]

\[ W \]

\[ E_{Fm} \]

\[ E_C \]

\[ E_i \]

\[ E_{FS} \]

\[ E_V \]

\[ C \]

Low Freq.

Accumulation

Depl.

Inversion

High Freq.

ECE 418 / 518 – Semiconductor Processing
Spring 2021 - John Labram

7/48

ECE 418 / 518 – Semiconductor Processing
Spring 2021 - John Labram

8/48
Photolithography

- Strip
- Etch
- Develop
-Expose

Etching

- Photoresist
- $\text{SiO}_2$
- Substrate: Si

Solution of reactants

Wafers
### Oxidation

- **Diagram:**
  - Process flow from hydrogen, oxygen, and water vapor to wafer and exhaust.
  - Schematic showing oxygen concentration, SiO₂, and Si with diffusion equations.

### Diffusion

- **Diagram:**
  - Pre-deposition and drive-in stages for dopant gas.
  - Concentration profiles at different times and positions.

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Transistors

$$I_D$$

$$V_D$$

$$V_G$$

**Ion Implantation**

Fixed ion beam

Implant disk

X-scan

Beam of ions

Si Wafer

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Thin Film Growth

Atom arrives: 

Migration:

Collison and Combination:

Nucleation:

Coalescence:

Continuity:

Future of Electronics

Course Logistics

Instructor

- John Labram.
- Assistant Professor, EECS.
- Office Location: 3103 KEC.
- Office Hours: Monday 13:00 – 14:00.
- Office hours will occur remotely in Spring 2021.
- A new Zoom link will be provided each week.
- Email: john.labram@oregonstate.edu.
Lectures

- **All lectures will be delivered remotely.**
- Lectures will be delivered synchronously via Zoom (link distributed ahead of time).
- For **Weeks 1 and 2** there will be two 110 minute slots:
  - Wednesday: 4:00 – 5:50 pm.
  - Friday: 4:00 – 5:50 pm.
- For **Weeks 3-10** there will be one 110 minute slot:
  - Wednesday: 4:00 – 5:50 pm.
- All slots will be **split into two 50 minutes lectures**, with a 10 minute break between them.

Lectures

- A new Zoom link will be distributed via email on the day of the lecture.
- A recording of the lecture will be available after the lecture (via Canvas).
- You can ask any questions by either unmuting yourself or by typing the question in the chat (I will monitor it).
- You can also ask any questions via email in written form after the lecture. I will reply via email.
Lectures

• The PowerPoint slides will be provided online at the start of the week of the lecture.
  • [http://classes.engr.oregonstate.edu/eecs/spring2021/ece418-001/lectures.html](http://classes.engr.oregonstate.edu/eecs/spring2021/ece418-001/lectures.html)
  • If you wish to have a hard copy, please print out the slides before each lecture.
  • It will be helpful to make notes on the slides of any extra / contextual information that is not written down.
  • Some lectures will contain examples, but homeworks will serve as the best place to practice.

Lectures

• Lectures are designed to cover the theory of electronic materials processing, as used by industry.
• They are designed to provide a theoretical background to the things you would have been doing in the lab (but will now be simulating).
• The slides are designed to be self-contained and to provide enough information to complete all the homeworks.
Textbook

- The content of the course is strongly based on this book.
- It is not mandatory to purchase this book.

Course Website

- The course website can be found:
  - http://classes.eecs.oregonstate.edu/eecs/spring2021/ece418-001/index.html
- Homworks, solutions, lecture slides, details for reports, and general information will be located here.
- All documents will be duplicated on Canvas also.
Lecture Schedule

This schedule is subject to change.

<table>
<thead>
<tr>
<th>Lecture #</th>
<th>Week</th>
<th>Day</th>
<th>Date</th>
<th>Month</th>
<th>Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Wed</td>
<td>31</td>
<td>Mar</td>
<td>Introduction</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>Wed</td>
<td>1</td>
<td>Apr</td>
<td>Introduction</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>Fri</td>
<td>3</td>
<td>Apr</td>
<td>Safety, Cleanroom, Cleaning</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>Fri</td>
<td>3</td>
<td>Apr</td>
<td>Basic Properties of Silicon</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>Wed</td>
<td>8</td>
<td>Apr</td>
<td>Silicon Growth</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>Wed</td>
<td>8</td>
<td>Apr</td>
<td>Vacuum Science and Technology</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>Fri</td>
<td>10</td>
<td>Apr</td>
<td>MOS Capacitors 1</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>Fri</td>
<td>10</td>
<td>Apr</td>
<td>MOS Capacitors 2</td>
</tr>
<tr>
<td>9</td>
<td>3</td>
<td>Wed</td>
<td>15</td>
<td>Apr</td>
<td>Photolithography</td>
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<tr>
<td>10</td>
<td>3</td>
<td>Wed</td>
<td>15</td>
<td>Apr</td>
<td>Etching</td>
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<tr>
<td>11</td>
<td>4</td>
<td>Wed</td>
<td>22</td>
<td>Apr</td>
<td>Oxidation</td>
</tr>
<tr>
<td>12</td>
<td>4</td>
<td>Wed</td>
<td>22</td>
<td>Apr</td>
<td>Diffusion</td>
</tr>
<tr>
<td>13</td>
<td>5</td>
<td>Wed</td>
<td>29</td>
<td>Apr</td>
<td>Field Effect Transistors 1</td>
</tr>
<tr>
<td>14</td>
<td>5</td>
<td>Wed</td>
<td>29</td>
<td>Apr</td>
<td>Field Effect Transistors 2</td>
</tr>
<tr>
<td>15</td>
<td>6</td>
<td>Wed</td>
<td>6</td>
<td>May</td>
<td>Ion Implantation</td>
</tr>
<tr>
<td>16</td>
<td>6</td>
<td>Wed</td>
<td>6</td>
<td>May</td>
<td>Thin-Film Growth</td>
</tr>
<tr>
<td>17</td>
<td>7</td>
<td>Wed</td>
<td>13</td>
<td>May</td>
<td>Athena and Atlas 1</td>
</tr>
<tr>
<td>18</td>
<td>7</td>
<td>Wed</td>
<td>13</td>
<td>May</td>
<td>Athena and Atlas 2</td>
</tr>
<tr>
<td>19</td>
<td>8</td>
<td>Wed</td>
<td>20</td>
<td>May</td>
<td>Athena and Atlas 3</td>
</tr>
<tr>
<td>20</td>
<td>8</td>
<td>Wed</td>
<td>20</td>
<td>May</td>
<td>Athena and Atlas 4</td>
</tr>
<tr>
<td>21</td>
<td>9</td>
<td>Wed</td>
<td>27</td>
<td>May</td>
<td>Future of Electronics 1</td>
</tr>
<tr>
<td>22</td>
<td>9</td>
<td>Wed</td>
<td>27</td>
<td>May</td>
<td>Future of Electronics 2</td>
</tr>
</tbody>
</table>

Assessment

The final grade will consist of the following contributions:

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Percentage of Final Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homework</td>
<td>40</td>
</tr>
<tr>
<td>Quizzes on Cleanroom Procedures</td>
<td>30</td>
</tr>
<tr>
<td>Final Report</td>
<td>30</td>
</tr>
</tbody>
</table>
Assessment

• The grade boundaries are as follows:

<table>
<thead>
<tr>
<th>Lower Bound (%)</th>
<th>Upper Bound (%)</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>93</td>
<td>100</td>
<td>A</td>
</tr>
<tr>
<td>90</td>
<td>92</td>
<td>A-</td>
</tr>
<tr>
<td>87</td>
<td>89</td>
<td>B+</td>
</tr>
<tr>
<td>83</td>
<td>86</td>
<td>B</td>
</tr>
<tr>
<td>80</td>
<td>82</td>
<td>B-</td>
</tr>
<tr>
<td>77</td>
<td>79</td>
<td>C+</td>
</tr>
<tr>
<td>73</td>
<td>76</td>
<td>C</td>
</tr>
<tr>
<td>70</td>
<td>72</td>
<td>C-</td>
</tr>
<tr>
<td>67</td>
<td>69</td>
<td>D+</td>
</tr>
<tr>
<td>63</td>
<td>66</td>
<td>D</td>
</tr>
</tbody>
</table>

• Percentages will be rounded-off to the nearest whole percent to determine letter grade.

Homework

• There will be a total of 4 homeworks.
• Each homework carries equal weight.
• The homeworks are designed to test your understanding of the concepts covered in the lectures.
  • Sometimes you will be expected to apply knowledge obtained in the lectures to new (previously unseen) situations.
• The homeworks overall contribute 40% of the course grade.
  • 10% each.
Homework

- There are a total of 4 homeworks:
  - The first two homeworks will be a combination of descriptive and analytical (answerable with pen and paper) questions.
  - For the second two homeworks you will be asked to simulate a set of processes, generate simulated data, and solve problems.
  - Homework will be due 1 week after it is set.

Homework

- Please send an electronic copy of the homework to John (john.labram@oregonstate.edu) and Shirsopratim (chattosh@oregonstate.edu) on the due date at 4:00 pm.
- You can submit the homework as a Word document, pdf, a series of scanned images, or any other reasonable means.
- Please make your name and OSU ID clearly visible.
- If you scan / photograph your homework please ensure the resolution is high!
Homework

- The homework schedule is as follows:

<table>
<thead>
<tr>
<th>Homework #</th>
<th>Set</th>
<th>Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wednesday 04/07/21</td>
<td>Wednesday 04/14/21</td>
</tr>
<tr>
<td>2</td>
<td>Wednesday 04/21/21</td>
<td>Wednesday 04/28/21</td>
</tr>
<tr>
<td>3</td>
<td>Wednesday 05/12/21</td>
<td>Wednesday 05/19/21</td>
</tr>
<tr>
<td>4</td>
<td>Wednesday 05/19/21</td>
<td>Wednesday 05/26/21</td>
</tr>
</tbody>
</table>

- Please use your OSU address (not Gmail etc.)
- The homework will be returned electronically to your OSU email address.
- The solutions will be posted online when the homework are returned.

Homework

- Late homework will be deducted 10% per day late for a maximum of 5 days, after which the homework grade will be zero.
  - E.g. if you scored 85% on a homework, but you hand it in 2 days late, you will receive a grade of 65%.
  - The deadline is 4:00pm, so 4:01pm will be considered one day late!
Laboratory Sessions

• Because of the ongoing pandemic, for Spring 2021 there will be no in-person laboratory sessions.

• In normal years, you would have been expected to attend 2 laboratory sessions per week. Each of these lab sessions were scheduled for 2 hours, but frequently overran to 2½ to 3 hours.

• These will not happen this year unfortunately.

• Instead, a set of videos and written procedures will be created and uploaded to the course website and Canvas.

• The first of these will be available online in Week 3.

Laboratory Sessions

• The videos will be short (5 to 20 minute) demonstrations of the procedures you would have followed under normal circumstances.

• Each video will be accompanied by a pdf document explaining the steps in the procedure.
Laboratory Sessions

- The videos and documents will both be uploaded to Canvas, and will be linked to on the course website:

Laboratory Sessions

- You will be set 6 quizzes on the subjects discussed in the laboratory videos and / or documents.
  - The quizzes will be in Canvas.
  - The quizzes will each constitute 5% of the overall course grade.
  - 30% in total.
  - You will be told when the procedures and quizzes are available online.
  - Each quiz will have a corresponding video and pdf.
Simulations

- Because you will not be able to get into the laboratory this year, a lot of the course content is being converted to simulations of processes.

- You will learn an industry tool used to simulate various steps in semiconductor processing.

Simulations

- In the second half of the course, you will use **Athena** to simulate how the properties of silicon wafers change as they are processed.
- For example, it allows you to calculate impurity concentrations, layer thickness, and much more, for processes such as oxidation, diffusion, implantation and deposition for temperature.
- Athena is the Silvaco version of SUPREM (Stanford University PRocess Engineering Module)
- Instruction will be given in Lectures 17 – 21.
- Homework 3 and Homework 4 will be on simulations.
Simulations

• More details (including example code) will follow, but you will need to access the OSU Unix server to carry out these simulations.
• You will need a College of Engineering username and password to access the Unix server.
  • If you do not have one, please send me an email.
• If you use Windows, you will need to use MobaXterm (https://it.engineering.oregonstate.edu/accessing-unix-server-using-mobaxterm-ssh).
• If you are using Mac OS or a Linux distribution, you will be able to access the server using your terminal.

Examinations

• This year there will be no examinations. Your final grade will instead consist of contributions from homework, simulation assignments, quizzes, and a lab report.
Course Report

- Finally, you will be expected to write a report on a modern topic relating to semiconductor processing or microelectronics.
- The report will be set on Wednesday May 26th (Week 9).
- The report will be due on Wednesday June 9th (Finals Week).
- A document containing regulations and instructions will be available online in Week 9.

Regulations
Cheating and Student Conduct

- Academic dishonesty is defined as an intentional act of deception in one of the following areas:
  - **Cheating** - use or attempted use of unauthorized materials, information or study aids.
  - **Fabrication** - falsification or invention of any information.
  - **Assisting** - helping another commit an act of academic dishonesty.
  - **Tampering** - helping another commit an act of academic dishonesty.
  - **Plagiarism** - representing the words or ideas of another person as one's own.

When evidence of academic dishonesty comes to the instructor's attention, the instructor will document the incident, permit the accused student to provide an explanation, advise the student of possible penalties, and take action.

The instructor may impose any academic penalty up to and including an "F" grade in the course after consulting with his or her department chair and informing the student of the action taken.
Disruptive Behavior

• While the University is a place where the free exchange of ideas and concepts allows for debate and disagreement, all classroom behavior and discourse should reflect the values of respect and civility.
• Behaviors which are disruptive to the learning environment will not be tolerated.
• As your instructors, we are dedicated to establishing a learning environment that promotes diversity of race, culture, gender, sexual orientation, and physical disability.

Disruptive Behavior

• Anyone noticing discriminatory behavior in this class, or feeling discriminated against should bring it to the attention of the instructors or other University personnel as appropriate.
Summary

• We have covered the course content and the course logistics.

Next Time...

• On Friday we will talk about safety, cleanrooms, and cleaning.