The Impact of Materials on Society
Module 12 – Semiconductors – Outline of Instruction for Faculty

Semiconductors have forever changed human-human and human-material interactions because they are the foundation of the computing revolution and form the basis of increasingly ubiquitous digital devices. This module looks at how our use of semiconductor-based devices impacts individual human relationships, and draws lessons learned for designing needs-based applications for new semiconductor materials. As semiconducting materials become more invisibly embedded in our everyday lives, and even in our own persons, only intentional design will ensure that they serve us, versus us serving them.

Module Objectives

Students will:

- identify the properties of semiconductors
- identify the properties of graphene and 2D materials
- discover the uses and applications of semiconductors
- examine how materials mediate human relationships
- relate the relationship of industrial to information revolutions

Student Reading Assignment before Day 1
> Read excerpt (pp. 265-276) from
> **Sass, Stephen L.** (1998/2011) *The Substance of Civilization*. New York: Arcade Pub.

Day 1 Class – Material Science & Engineering Lecture on Silicon

Materials Science Professor gives an overview of silicon: This lecture covers the basics of semiconductor physics including why silicon has a bandgap and what it means in terms of electrical conduction. Next the concept of how Si can be doped both n-type and p-type is introduced. This in turn leads to a discussion of how devices can be made specifically the transistor and a simple discussion of how a transistor can behave as a switch is presented. Finally, the refinement of silicon from sand and its production into wafers that are subsequently processed into devices is discussed. The goal is to give the student an appreciation for why semiconductors are such a powerful driver in today's society.

Materials Science Lessons
> Semiconductors possess unique electrical properties that can be manipulated in order to drive the digital revolution

Day 1 Lecture Development Resources:

1. **Lecture:** Silicon PPT Slides
2. **Sample Lecture Video**: Silicon (16:40) (Transcript)
3. **Demo Video:** Silicon Wafer to Chip (2:13)

Classroom Demo: Bring Si wafers of various sizes to class. Scribe and break one of the wafers to demonstrate the brittle single crystal nature of the silicon. Allow a few students to come forward and break pieces of Si (be careful the wear glasses and gloves as Si can be very sharp).

Student Reading Assignment before Day 2

Read the chapter "Semiconductors and Cyborgs: Human-Material Relations in the Networked Society" **by Prof. Sophia Acord** (Chapter in progress)

Read excerpts from
Book: Turkle, Sherry. (2011) *Alone Together: Why We Expect More from Technology and Less from Each Other.* "Always On" (pgs 151-170) and "The Nostalgia of the Young" (pgs 265-277)

Day 2 Class – Lecture on Semiconductors and Cyborgs

Guest Professor presents Semiconductors and Cyborgs: Human-Materials Relationships in the Digital Age.

This lecture begins with an overview of the history of industrial revolutions and information revolutions, observing that the so-called "Silicon Age" is unique in that Silicon ushered in both an industrial and an information revolution. In our contemporary, networked society, the energy that fuels all of our devices is not powered by a fuel derived from the earth, but rather by the human brain. We are the engine feeding our own social networks. So, humans are both the productive forces of our industrial revolution, as well as the mass consumers of the information that it produces. As we rely upon digital devices to do more and more for us in our daily lives (we delegate tasks to them), we find ourselves developing quite curious relationships with these devices, as well as with each other. While semiconductor based devices allow humans to do more things, better, faster, and more globally than ever before, there is also a risk that we become subservient to them. The more we ask our semiconductors to do for us, the more we may end up serving them at the expense of our face-to-face social relationships. (It is also important to discuss the ever-present "digital divide", which excludes large numbers of people globally from this Silicon revolution.)

Social Lesson:
1. **Delegation:** Humans regularly assign human tasks to non-humans. The classic example of this, given by sociologist Bruno Latour, is the "sleeping policeman" (otherwise known as the "speed bump"). In this say, humans *delegate* to material objects work that normally would be done by other humans. This changes not only how humans relate to each other, but also how humans relate to their environments.

Day 2 Lecture Development Resources:
1. **Lecture:** Semiconductors and Cyborgs (PPT) slides by Prof. Sophia Acord (UF)

Student Video and Homework Assignment before Day 3

1. **Video:** 2-D Materials (13:49) (Transcript)
2. **Article**: Kuang, Cliff (2013) "Why a New Golden Age for UI Design Is Around the Corner". *Wired Magazine*, September: 142-147. http://www.wired.com/design/2013/08/design-and-the-digital-world/

After you watch and read, answer the following questions:
The homework has **two parts.**

Part 1: Schedule and conduct a 15-minute interview with someone you know (a friend, roommate, relative, co-worker, etc.). The exact interview questions are up to you, but we suggest that you discuss how people feel about the digital technologies that they use in their everyday lives. What are their personal relationships to these materials and artifacts? How do these artifacts mediate their relationships with other people, and how do they use them to develop their own self-identities? Take notes during the interview (about 1 page, hand-written or typed). **You will submit these notes with the homework below. Please do not include any identifying details about the person that you interviewed (e.g., name, address, job location/title).**

Part 2: Answer the following questions:
a. In the IMOS video on 2-D materials, is the current use of semiconductors being driven by any social needs?
b. In the IMOS video, why is MoS2 being considered for transistors rather than grapheme?

c. In the IMOS video, what are nanomaterials and what are some of the requirements for studying these materials?
d. In the *Wired Magazine* article, what do you think is the most important point made by this article regarding how we think about the social impact of ubiquitous 2D materials?
e. What were the most significant desires and concerns that emerged in your interview about his or her relationship to digital devices? Do you feel that a move to 2D materials will address these desires and concerns or not?

Please answer your chosen question in either bullet points or full sentences. Your response will probably take 1½ to 2 pages. Assignment will be graded on effort, use of the lecture, video, and reading materials, and thoughtful reflection. A cover page is not necessary. Be sure your name is on the assignment. We'll build on your responses with the in-class group activity.

Assignment: Module 12 – Individual Homework Assignment (WORD)
2-D Materials Homework due start of class Day 3.

Your grade will be determined from the following criteria.
Grading Rubric.
2= Responses are appropriate, thoughtful, and indicate engagement with the video and any other required viewing/reading materials. Grammar, sentence structure and punctuation are correct.

1= Responses and arguments are incomplete and/or inconsistent with the required viewing/reading material. Some issues with grammar, punctuation and or sentence structure.

0= Responses are not appropriate to the assignment or missing entirely. Major issues with grammar, punctuation and or sentence structure.

Points = 2

Day 3 Class – Flipped Classroom Activity on Semiconductors

Day 3 Classroom Activity: Semiconductors.

Key Concepts: Examine the interrelated nature of culture and materials engineering.

ASSIGNMENT: Using your interview data, discuss ways to design more experience-centered digital technologies using flexible semiconductors. Make sure that you submit your homework and individual interview notes with this group assignment for full credit.

Part 1 – The affordances of flexible electronics like MoS$_2$. How could using MoS$_2$ instead of silicon potentially affect the speed, weight, and other aspects of semiconductor technologies?

Part 2 – Interview data. (2A) What are the main themes in how your interviewees spoke about delegation and digital technologies in their daily lives? (2B) What do people wish they could do with their digital technologies? (2C) What concerns do people have about their use of digital technologies?

Part 3 – Experience-centered design. Combine your discussions from Part 1 and Part 2 to choose one potential use of of a flexible semiconductor like MoS$_2$ that would address a social need that emerged from your interviews. What is this application? Making sure to address your findings in Part 2, discuss what kinds of features your product would have, and what kinds of features your product would avoid.

- Refer to Day 3 In-Class Activity: Semiconductors worksheet for specific instructions.
- Refer to the rubric for grading criteria.

Your grade will be determined from the following criteria.
Grading Rubric.

5= Responses are appropriate, comprehensive, and indicate thoughtful engagement with the information and concepts from the lecture, readings, and videos. Novel ideas, creativity, and attention to complexity are a plus.

4= Good effort. Responses and arguments are not as clearly presented, or as comprehensive and thoughtful as in a full credit answer.

3= Responses are less appropriate to the assignment, less thoughtful and engaged, with less complete information. Errors in grammar, punctuation and or sentence structure will also result in loss of points.

2= Responses are incomplete, showing little effort, thought, or use of preparatory materials.

1= Responses are not consistent with preparatory materials. Assignment is badly incomplete. Next to no effort.

Day 3 Lecture Development Resources:

1. **In-Class Activity:** Day 3 In-Class Activity: Semiconductors handout (WORD)

Complete Impact Paradigm Assignment:

Thinking about the material that we covered in this week's unit, add another question to the impact paradigm.

- **Assignment:** Module 12—Impact Paradigm Individual Homework Assignment (Word)

Additional Resources

Online Course Module
   a. View the online Module 12 in Word or PDF format
   b. Available soon: The full online course to upload to your Learning Management System. Contact Kevin Jones at kjones@eng.ufl.edu or Pamela Hupp at hupp@mrs.org for more information.

Articles and Books
   a. Kuang, Cliff (2013) "Why a New Golden Age for UI Design is around the Corner." *Wired Magazine*, September: 142-147.
   b. Turkle, Sherry. "Always On" *Alone Together: Why We Expect More from Technology and Less from Each Other*. Basic Books (2011) 151-170. Print.
   c. Turkle, Sherry. "The Nostalgia of the Young" *Alone Together: Why We Expect More from Technology and Less from Each Other*. Basic Books (2011) 265-277. Print.

Videos:
   a. National Science Foundation and NBC Learn. Nanotechnology: Super Small Science Nanoelectronics (Links to an external site.) Video. *National Science Foundation.*
   b. John Boeckl and Mike Patterson - Graphene and other Carbon-based Nanomaterials (24:12) video