SYLLABUS – M2

Instructor: Prof. Scott Bunch Mechanical Engineering
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Office Hours: By appointment

Meeting Times: Class Time: Monday and Wednesday 10:10am-11:55am

All classes meet in room PSY B45 unless otherwise noted.
We will occasionally meet in PHO 629 or EPIC
which are also accessible after hours through your BU ID

Course Description:
Graphene, a single atomic layer graphite, is the thinnest material possible (one atom thin) and has remarkable electrical, thermal, and mechanical properties. It was first isolated a little over a decade ago and is now on a path to commercialization. Potential applications include flexible electronic devices, batteries, coatings, and molecular separation membranes. Students will utilize the state of the art facilities at the BU Photonics Center to fabricate graphene, characterize its properties, and create a functioning electronic device from graphene. In 6 weeks you will have completed a hands-on crash course in material discovery, characterization, scale up, and potential commercialization of an amazing new nanomaterial.

Website:
The course website is on BlackBoard (learn.bu.edu). Electronic materials will be posted periodically throughout the semester, so check the website often for updates. These will include the course syllabus and documents for the design projects.

Note that while grade assignments will be posted for your review, I do NOT use the Blackboard Gradecenter to calculate semester grades. Ignore any interpretation of your grade based on whatever Blackboard reported "points" that are displayed.

Expectations:
- I expect you to attend all classes and be on time. <u>If you are going to miss a class, email me in advance.</u> You do not need to give me a reason.
- I expect you to participate in class.
- I expect you will complete all individual assignments.
- I expect you to contribute to the group projects.
- I expect complete honesty.

Grading:
The course grade will be based on a combination of group work and individual accomplishment:

<u>Group work 40%</u>:

<u>Preliminary Project:</u>

Microscope presentation 10%

Exfoliation Presentation 10%
CVD Growth Presentation 10%
Final Presentation 10%

Individual accomplishments 60%:
Individual writing assignments and Quizzes 25%
Peer evaluations 30%
Attendance 5%

Project Budget:
You might need to purchase additional supplies for your project which will need to be supplemented by funds from you and your team. *Each team member* is expected to contribute up to **$25** to fund the design projects. This cost is in lieu of a course text book, which could easily be much more expensive.

Miscellaneous:
- Students are expected to purchase their own **blank lab notebook** to use as a journal to record their class and project activities.

Course Elements:

1) Week 1: Intro to graphene
   a. **Lab:** Introduction to graphene and microscope project , Introduction to EPIC

2) Week 2: Intro to graphene
   a. **HW Due 9/11/17**: EPIC safety training, Who am I, Materials Due
   b. **Lab (9/11/17 and 9/13/17):** Microscope Construction

3) Week 3: Exfoliation of graphene from graphite.
   a. **Presentations (9/18/17)**: Microscope Presentations
   b. **Lecture (9/18/17)**: Graphene exfoliation
   c. **Lab 9/20/17**: Exfoliation of graphene from graphite. Students will use scotch tape and graphite to exfoliate graphene onto oxidized silicon wafers.

4) Week 4: Chemical vapor deposition (CVD) growth of graphene.
   a. **Presentation (9/25/17)**: Graphene exfoliation results presented.
   b. **Lecture (9/25/17)**: Chemical vapor deposition graphene. We will learn why copper is used. We will learn about graphene impermeability and copper oxidation and how these can be utilized to visualize graphene on copper foils since the graphene acts as a barrier to copper oxidation.
   c. **Lab (9/27/17)**: Grow graphene on copper. Use oxidation resistance to confirm the presence of graphene.

5) Week 5: Graphene field effect transistor fabrication and characterization.
   a. **Presentation (10/2/17)**: CVD Growth Presentations
   b. **Lecture (10/2/17)**: Intro to microfabrication and photolithography. Graphene Transfer. Field effect transistors.
   c. **Lab (10/4/17)**: Transfer graphene from copper to silicon oxide. Make a shadow mask. Submit your chip for metal evaporation.

6) Week 6: Graphene field effect transistor fabrication and characterization.
   a. **Presentation (10/2/17)**: CVD Growth Presentations
   b. **Lecture (10/10/17)**: Electrolytic Gating and FET Measurements.
   c. **Lab (10/11/17)**: Graphene FET Measurements

7) Week 7: Ethical issues in nanotechnology. Future of graphene and potential killer applications.
   a. **Presentation (10/16/17)**: Graphene FET presentation.
   b. **Lecture (10/18/17)**: Hendrik Schon and ethical behavior in science and engineering. Future of graphene and killer applications.

Some resources that may be helpful in your projects:

What	Who	Where
EPIC Manufacturing Center	David Campbell	EPIC dcampbel@bu.edu
Atomic Membrane Lab	David Lloyd	PHO 629 dlloyd1@bu.edu

Omitting names from assignments, firing, and quitting:

• If a team member refuses to cooperate on an assignment, his/her name should not be included on the completed work. Talk with me and the team member first. If the non-cooperation continues, the cooperating team members may notify the uncooperative member in writing (copy to instructor) that he/she is in danger of being fired, and the team should meet with the course instructor and attempt to resolve the problem. If no resolution is achieved, the team should send a memo to the person (copy to the instructor) that he/she is no longer part of the team.
• A student who is consistently doing most of the work on a team may issue a warning memo (copy to instructor) that he/she will quit unless more cooperation is forthcoming. The team should meet with the instructor at this point to attempt to resolve the problem. If the noncooperation continues, the student doing the work may notify the others in writing (copy to instructor) that he/she is no longer part of the team.
• *Students who are fired or who quit must find another team unanimously willing to accept them as a member, otherwise they get zeroes for the remaining assignments.*

Team work isn't always easy: team members sometimes cannot prepare for or attend team sessions because of other responsibilities, and conflicts often result from differing skill levels and work ethics. When teams work and communicate well, however, the benefits more than compensate for the difficulties. One way to improve the chances that a team will work well is to agree beforehand on what everyone on the team expects from everyone else.

Ethical Responsibilities:
Cheating or plagiarism on homework, quizzes, project reports, or any form of assignment is an infringement engineering ethics and will be dealt with accordingly. Plagiarism is a serious academic offense and should not be taken lightly. Understanding your ethical responsibilities is an integral part of becoming a professional engineer. Please recall that when you enrolled at Boston University, you agreed to an Academic Honesty Pledge. A

copy of this pledge can be found in your student handbook. It details your responsibilities as well as the results of code violations.

Incompletes:
Incompletes will be permitted only for extenuating circumstances, and must be arranged before the end of the semester.

Students with Disabilities

If you qualify for accommodations because of a disability, please submit to me a letter from Disability Services in a timely manner so that your needs can be addressed.

Religious Observation

I respect individuals' rights to follow their own religious expression. Please let me know if a religious observation conflicts with a due date.