Course Instructor:
Prof. Stephen C. Danforth
Phone: (732)-445-2211
Office CCR 204
E-mail: danforth@rci.rutgers.edu

Term:
Fall Semester, 2005

Office Hours:
By Appointment

Description:
Senior CME Lab I is the first of two Senior CME Laboratory classes (where the second is Lab II in the Spring Semester). In this course, students choose an independent research project that they will carry out under the direct supervision of a Faculty member of their choosing. The Faculty member is the one directly interacting with and responsible for the technical oversight of the students research program, progress, lab notebook, etc. I meet regularly with all of the students in this class to discuss their progress and problems in the conduct of the research. I introduce the students to the problems of doing independent research, and discuss with them engineering ethics (as related to research, i.e. use of others work as their own, plagiarism, etc). In addition, I give students (with the class broken up into small teams) a project during the semester that requires that each team pick a research project, and prepare a budget for carrying out this project, as if they are all newly assigned to this project in industry. I also review the importance of keeping a proper lab notebook. The students have opportunities to give literature reviews (scientific and engineering background of their research), formal progress reports, as well as formal reports on the progress of their research at the end of the semester in front of a large audience.

Objective:
The objective of Senior Lab I is to give students the important experience of conducting an independent research project (in a small team) with a Faculty advisor. In addition, this class is intended to improve students ability to communicate their research plans, progress and results in writing, in oral presentations with visual computer graphics.

Prerequisites:
Students must be in good academic standing and have satisfactorily completed the course work appropriate at the junior level.
Attendance:
Attendance is mandatory! Attendance is taken at each class meeting. Only if the students indicate that they have an acceptable reason for an absence, before the class, will they be excused. Students will be excused from class without penalty because of religious observances. Poor attendance will effect the final course grade.

Projects:
Each student will be required to carry out an independent lab-based research project under the direct supervision of a Faculty member (or members). In addition, the students will be required to make several (brief ~ 5-10 minute) formal presentations and a 20 minute presentation at the end of the semester using PowerPoint computer graphics. Initial talks will be critiqued, but not graded. The talks at the end of the semester will be graded and videotaped. The student must make arrangements with their Faculty supervisor to attend the final semester presentation. All seniors and Faculty will be invited to these talks. Students must complete a term paper that summarizes the entire semester project. The term paper must use the American Ceramic Society Journal publications instructions and formatting. Final semester talks and term papers without appropriate references will receive a failing grade. Students will also be required to keep a laboratory notebook of an appropriate style (including carbon paper copies), which must be signed and dated on the bottom of each and every page and submit that for grading on request. Students in small teams will make a presentation to the class explaining the assumptions and the criteria that went into the development of their research budget. These are then discussed with the class. If needed, the teams are asked to revise and resubmit their budgets.

The final term papers and lab notebooks must be provided to the Faculty supervisor 1 week prior to the last day of classes, such that they can read them and provide suggested grades to the instructor. Lab notebooks must be initialed by the Faculty advisor once each month, approving of the content and detail.

At each meeting of this class, the students are asked to give me opinions, input, questions, ideas as to the current conduct of the course and ways to improve the course.

Assignments will be accepted for full credit only on the day they are due. Late assignments will lose one letter grade for each 24-hour period that they are late. There will be no quizzes or exams given in this course. Being on time to class and attending each class are an important component of professional engineering conduct, and will effect the final course grade.

Grading:
The final grade for the course will be compiled as follows:
- Oral presentation at the end of the semester: 25%
- Final term paper at the end of the semester: 25%
- Final laboratory notebook: 25%
- Final outcome of research project, including:
  - understanding of the field, effort and progress: 25%

Prepared by S. C. Danforth
Date of Last Modification: September 1, 2005.
Page 2
Policy on Calculators:
As there are no exams in this class, there is no policy on calculators.

Policy on Other Electronic Devices:
The use of cell telephones, pagers, Walkman or any other electronic device that may disrupt the class is not permitted. Students are encouraged not to bring these devices to class. If it is necessary to bring a device to class, it must be turned off or muted. It is acceptable for students to bring a computer to class if they choose to take notes in this manner (provided it does not disturb anyone in the class) or to make LCD presentations.

Academic Integrity:
Students will be expected to adhere to the Policy on Academic Integrity listed within the New Brunswick Undergraduate Catalogue. Students are encouraged to review this policy.

Professionalism:
Students are expected to conduct themselves in a professional manner during class time. This includes the following: asking appropriate technical questions about work that is presented by others, not wearing hats or chewing gum, being respectful and behaving in a professional manner, being on time, not missing class, no cell phones or pagers ringing, etc. For the formal presentations, students are expected to dress in appropriate professional business attire.

Contribution of Course to Meeting the Professional Component of ABET:
Senior Laboratory I is the capstone course for students who primarily are interested in continuing their education in graduate school. The course integrates the fundamental science, e.g. physics and chemistry, and mathematics with the engineering courses the students completed in earlier semesters. By carrying out an independent research program with the Faculty advisor and the course instructor, the student learns how research into design, new ceramic materials, processes, components, and systems is carried out. This also puts their prior education into perspective with respect to the engineering profession.

Senior Laboratory I is the students’ first course in a sequence of two courses. The course gives the students the final experience of the conduct of independent laboratory based research. This course provides the student with an understanding of the challenges and pleasures of independent laboratory based research. Many students use this course as a yardstick upon which (in part) they will make their decisions about going to graduate school or not.

Relationship of Course to Program Objectives:
Senior Laboratory I develops an integrated opportunity for students to use all of their prior course work to carry out independent research on a ceramic engineering or materials science and engineering problem. In all cases, the students use their understanding and practice their knowledge of structure, processing, properties, and performance (SP³) of materials used in ceramic applications. Students will see how new ceramic materials or processes are developed which allow one to optimize some aspect of ceramic materials. In this manner,
they are conducting research that is directly relevant to current ceramic science and engineering. This research opportunity prepares them very well to enter the Ceramic Engineering or other discipline or to continue on to Graduate School in Ceramics, Materials or other materials related field. The conduct of such independent research is also useful for those planning to enter professional schools such as law or business school.

This course improves their ability to apply knowledge of mathematics, science and engineering. This course improves their ability to design and conduct experiments, as well as to analyze and interpret data. This course improves their ability to design a system, component, or process to meet desired needs. This course improves their ability to function on a team. This course improves their ability to identify, formulate and solve engineering problems. This course improves their ability to understand professional and ethical responsibility. This course improves their ability to communicate effectively. This course improves their ability to understand the impact of engineering solutions in a global and societal context. This course improves their knowledge of contemporary issues related to ceramic engineering. This course improves their ability to use experimental, statistical, and computational methods to analyze the behavior of ceramic systems. This course improves their understanding of the fundamental principles underlying and connecting structure, properties, processing and performance related to the material systems utilized in ceramic engineering.

**Student Input and Instructor Response to Teaching Excellence Surveys in the Prior Semesters – (All comments listed were taken from the recent TEC Surveys):**

*Comments:* Several students commented that there is a serious need to get the projects off the ground faster, i.e. a faster start.

*Response:* This year, the deadlines for choosing a project and providing summaries, progress reports and updates will be accelerated.

*Comments:* A student suggested that I have more regular communications with the faculty advisors regarding progress and problems, etc.

*Response:* I will do this, at least monthly.

*Comments:* Students felt that the course had unrealistic goals for the project.

*Response:* It is generally true that students who have not performed independent research before, are not aware of how difficult it is, and how much work is needed to make significant progress. Thus having expectations that are above what students may expect, while unfortunate perhaps, is appropriate.

*Comments:* Please have the final presentations so that all UG and GS and faculty are invited and able to attend.
Response: I will make arrangements to do so.

Comments: Please give a better explanation (both what you want, and why you are assigning various things) and due dates for assignments.

Response: I will do so.

<table>
<thead>
<tr>
<th>Class Schedule:</th>
<th>Topic</th>
<th>Assignments</th>
</tr>
</thead>
<tbody>
<tr>
<td>September 7, 2005:</td>
<td>Organization</td>
<td>Professor Jun John Xu</td>
</tr>
<tr>
<td>September 14, 2005:</td>
<td>Lab Notebooks</td>
<td></td>
</tr>
<tr>
<td>September 21, 2005:</td>
<td>Ethics</td>
<td>Read Article, Choose Project, Brief Summary (1 page, typed)</td>
</tr>
<tr>
<td>September 28, 2005:</td>
<td>Technical Problem</td>
<td>Review Talks of Research Topic, Find Read and Summarize Patent (1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Page, typed, include copy of patent)</td>
</tr>
<tr>
<td>October 5, 2005:</td>
<td>Technical Problem</td>
<td>Review Talk of Research Topic</td>
</tr>
<tr>
<td>October 12, 2005:</td>
<td>Technical Problem</td>
<td>Review Talk of Research Topic</td>
</tr>
<tr>
<td>October 19, 2005:</td>
<td>Technical Problem</td>
<td>Review Talk of Research Topic</td>
</tr>
<tr>
<td>October 26, 2005:</td>
<td>Research Update</td>
<td>Progress Reports (Budget Submission)</td>
</tr>
<tr>
<td>November 2, 2005:</td>
<td>Research Update</td>
<td>Progress Reports</td>
</tr>
<tr>
<td>November 9, 2005:</td>
<td>Research Update</td>
<td>Progress Reports</td>
</tr>
<tr>
<td>November 16, 2005:</td>
<td>Research Update</td>
<td>Progress Reports</td>
</tr>
<tr>
<td>November 23, 2005:</td>
<td>Term Paper &amp; Presentations</td>
<td>Locate and Review Slides From Professional Technical Presentation, Submit Outline of Talk</td>
</tr>
<tr>
<td>November 30, 2005:</td>
<td>Final Presentations</td>
<td>Final Presentations ~ 10:00 AM – 12:00 Noon (To be video taped. All Faculty and Students Invited), F. O. Auditorium.</td>
</tr>
<tr>
<td>December 7, 2005:</td>
<td>Final Presentations</td>
<td>Final Presentations ~ 10:00 AM – 12:00 Noon (To be video taped. All Faculty and Students Invited), F. O. Auditorium.</td>
</tr>
<tr>
<td>December 21, 2005:</td>
<td>Final Presentations</td>
<td>Final Presentations ~ 4:00 PM – 7:00 PM (To be video taped. All Faculty and Students Invited), F. O. Auditorium.</td>
</tr>
</tbody>
</table>

Prepared by S. C. Danforth
Date of Last Modification: September 1, 2005.
Page 5
December 13, 2005: Final Term papers and lab notebooks due by 4:00 PM.

Project Titles and Faculty Member

Professor Glenn Amatucci

Work on items 1-3 will be at ESRG so transportation is required.

1. In-situ Electrochemical X-ray Diffraction of Nano-enabled High Energy Density Conversion Electrodes
   Goal:
   - Perform in-situ x-ray diffraction on a variety of nanostructured materials during discharge and charge process
   - Analyze data: phase development, lattice parameters
   Requirements:
   - Working knowledge of XRD
   - Good computer skills
   - Electrochemistry knowledge not required

2. Multifunctional Microbattery
   Goal:
   - Assist in development in new concept for micro battery construction
   - Engineering focused project
   - High risk project
   Requirements:
   - Out of box thinking
   - Flexibility
   - Good with hands (miniature mechanical and electronic aspects)

   Goal:
   - Solution based fabrication of new polyanion compound which will play important role in next generation composite battery technology
   - Focus on Characterization of Li transport properties of the new material through electrochemical impedance spectroscopy and pulse techniques
   - Possible expansion to ex-situ Raman characterization

Prepared by S. C. Danforth
Date of Last Modification: September 1, 2005.
Page 6
Requirements:
- Good laboratory skills
  - Flexibility

Professor Dunbar P. Birnie, III:

Project 1. Effect of vapor environment on coating uniformity during spin coating.

Student:

Project 2. Hydrothermal synthesis and growth of nanofibrous zinc oxide "turf".

Student:

Project 3. Surfactants and Self-Assembly in Coatings during Drying

Student:

Professor Manish Chhowalla:

Project 1.

Student: Igor Tikhonov

Project 2.

Student: Bill Coffin

Professors Frederic Cosandey and Glenn Amatucci:

Project 1. TEM Characterization of Li-Ion Electrode Materials.

Student:

Professor Aurelien Du Pasquier:

Project 1. Synthesis of Regioregular poly(3-butyl)thiophene for photovoltaic applications. (See page 10 for project summary).

Student:
Professor Stephen H. Garofalini:

Project 1. Computational studies of crystal/glass interfaces. There are many instances in important applications where these interfaces occur and there is a great need to understand properties at a molecular level.

Student:

Project 2. Intergranular films in alumina and silicon nitride. Intergranular films of only 1-5nm thick in polycrystalline ceramics often dominate material properties. Recent advances enable us to predict the structure of these films and have our predictions corroborated by High Resolution TEM (at Oxford). Evaluating mechanical properties will now be studied and compared to data from Oak Ridge National Lab.

Student:

Project 3. Molecular behavior of constrained films in pores. Water in confined pores play havoc with materials exposed to the environment because of freeze/thaw strains, crystallization, dissolution. Understanding this behavior at the molecular level has become important to actually extending the lifetime of materials.

Student:

Professor Richard Haber:

Project 1.

Student:

Project 2.

Student:

Project 3.

Student:

Project 4.

Student:

Project 5.

Student:

Prepared by S. C. Danforth
Date of Last Modification: September 1, 2005.
Page 8
Project 6.

Student:

**Professor James Harrington:**

Project 1. Hollow Waveguides for the Delivery of THZ Radiation

Student: Isaac Chao

**Professor Klein:**

Project 1. Thick Film Precious Metal Electrodes

Student: Brett Ellerbrock

**Professor Adrian Mann:**

Project 1. Surface Chemistry and Ceramic Mechanical Properties

Student: Nakul Raykar

**Professor M. John Matthewson:**

Project 1. Indentation Behavior of Glasses

Project 2. Atomic Force Microscopy of Glass Surfaces (possible)

**Professor Safari:**

Project 1. Processing and Properties of Non – Pb Based Piezoelectrics Ceramics

Student: Danielle Kienzle

**Professor Tsakalakos:**

Project 1. Synchrotron Based Strain Mapping

Prepared by S. C. Danforth
Date of Last Modification: September 1, 2005.
Page 9
Introduction

McCullogh et al. [1] developed a synthesis for Regioregular poly(3-alkyl)thiophenes (P3ATs). It is based on a coupling by Grignard methatesis (Scheme 1). Polyalkylthiophenes are interesting because they are soluble in organic solvents when the alkyl group is butyl or larger. Regioregularity is important because it ensures overlapping the the pi orbitals along the polymer backbone. This is at the origin of long-range conjugation, which confers good optoelectronic properties to the material. In particular, they are p-dopable with a very high hole mobility, and have absorption peak around 500 nm.

One of the most promising applications for P3ATs is plastic solar cells, and in particular, P3HT is being used by Siemens in blends with a fullerene derivative (PCBM), yielding to 5% efficient plastic solar cells [2]. P3HT and P3OT can be purchased from companies such as Aldrich, Plextronics or American Dye Source. However, poly(3-butyl)thiophene (P3BT) was not commercially available until recently. A study of photocarrier generation in P3ATs by Takayama et al. [3] has shown that the efficiency of carrier generation increases when the alkyl group size decreases (Fig. 1). Thus, one should expect better photovoltaic properties from P3BT than P3OT or P3HT. In this study, we propose to prepare a few P3BT samples in the gram scale, and test them by comparing with P3HT in P3AT-PCBM photovoltaic devices, to verify if this assumption is true.

Prepared by S. C. Danforth
Date of Last Modification: September 1, 2005.
Page 10
Project description

About half of the project will consist in preparing P3HT and P3BT samples by the two step reaction described on scheme 1. The other half will consist in characterization of these materials by UV-vis absorption spectra, proton NMR to assess their regioregularity, and fabrication by spin coating of plastic P3AT and P3AT-PCBM (A = Bu, Hex) solar cells. We will measure the efficiency of the solar cells with a Xe light source, and the external quantum efficiency (EQE) with a monochromator and lock-in amplifier. Knowledge of Labview and some organic synthesis would be a plus.

References


![Scheme 1. Synthesis of HT-PATs by the Grignard Metathesis (GRIM) Method](image)

![Fig. 1. Action spectra of photoresponse in HT-PAT films with various alkyl chain lengths.](image)