**Materials Science / Energy Science and Technology 143**

*Solid State Electrochemistry for Energy Storage and Conversion*

http://addis.caltech.edu/teaching/MS-EST143/MS-EST143.html

Spring Quarter 2011

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| Instructor: | Prof. Sossina M. Haile, 307 Steele, x2958, smhaile@caltech.edu |
| Class Meetings: | MWF 9-10am, Annenberg 105 |
| Teaching Assistant: | Rob Usiskin, 305 Steele, x1760, rusiskin@caltech.edu |
| TA Office Hours: | Wednesdays, 7-8 pm, 110 Steele<br>Thursdays, 12:30-1:30 pm, 110 Steele |
| Recommended Text: | "Physical Ceramics," by Y.-M. Chiang, D.P. Birnie & D. Kingery; "CRC Handbook of Solid State Electrochemistry," Eds. P.J. Gellings & H.J.M. Bouwmeester; "Physical Chemistry of Ionic Materials: Ions and Electrons in Solids," by Joachim Maier; none required |
| Reserved Texts: (coming to SFL) | The three recommended texts, plus "Electrochemical Impedance Spectroscopy," by Mark E. Orazem and Bernard Tribollet |

**Course Content:**

- Introduction to Electrochemical Energy Technologies
  - The Global Energy Landscape
  - Overview: Fuel Cells, Batteries, Sensors, Permeation Membranes
- Solid State and Physical Chemistry Review
  - Crystalline Structure, Microstructure, Amorphous Structure
  - Gibbs Free Energy and Binary Phase Diagrams
- Bulk Defect Chemistry
  - Point Defects, Kroeger-Vink Notation, Brouwer Diagrams
- Internal Interfaces
  - Grain Boundaries; Secondary Phases
- From Defects to Conductivity
  - Purely Ionic Conductors; Mixed Ionic / Electronic Conductors
  - Atomistics of charge transport (focusing on ionic transport)
  - Conductivity in polymers
- Electrodes
  - Electrochemical equilibrium
  - Electrochemical reactions
- Measurement Techniques
  - Bulk conductivities – partial electronic and ionic; grain boundaries
    - A.C. impedance spectroscopy, D.C. methods with blocking electrodes
  - Electrode kinetics
    - A.C. and D.C. methods

**Course Structure**:

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| Homework: | 50% | (weekly) |
| Midterm Homework: | 15% | (Apr 27 – May 3) |
| Final: | 35% | (Jun 1 – 3) |

## Grading

Students may take this course either Pass/Fail or for a letter grade

**Homework** **50%**

Problems are assigned on Fridays and are due at 4 pm on the following Friday, unless otherwise indicated. We aim to make solutions available immediately. Assignments will not be accepted late barring *exceptional* circumstances. Completed sets should be placed in the mailbox labeled "MS/EST 143 in" at the south end of the third floor hallway in Steele.

Students are encouraged to discuss and work on problems together. In the course of this discussion it is acceptable to make notes, however, do not bring and/or exchange written solutions or attempted solutions you generated prior to the discussion. So, if you've worked the problem out and you plan to help a friend, you should know the solution cold.

Do not consult old problem sets, example assignments, exams or their solutions.

**Midterm Homework** **15%**

In lieu of a midterm exam there will be homework to be performed on an individual basis. This homework must be completed without collaborative discussion. The problem set will focus primarily on recent lectures, but material from early topics may also be included. Similar to other homeworks, you will have one week to complete the assignment. You are permitted to utilize all available resources, with the exception of previous solutions, including ones from earlier in the year.

**Final** **35%**

The final will be a closed-book, take-home exam, 3 hours in length. You are permitted one 20 minute break sometime after the first hour. Further details will be given at the time of the exam.

The format for the Midterm homework and Final exam are subject to change, with final instructions to be provided at the time of the respective assignment or exam.

## Content Delivery

Lectures will be held in Annenberg 105, which is equipped for video recording. The intent is to record the lectures (instructor only) so that you may review them at your leisure. It is possible that some students may feel uncomfortable with this format and, if so, video recording will not be implemented. Please notify the registrar, Mary Morley mmorley@caltch.edu, of any concerns by 5pm on Tuesday, March 29. In the absence of objections, all lectures except for the first, will be available through a website to be announced.

## Schedule Modifications

Regrettably, there will be dates on which Prof. Haile will not be able to be on campus to deliver regularly scheduled lectures. Confirmed dates of conflict are March 30, April 15, April 29, and additional dates in May. Information about make-up lectures or lectures by the TA (Rob Usiskin) will be provided as soon as available. The March 30 lecture is rescheduled for March 31, 9am (Annenberg 105).

And kindly remember your commitment to the honor code principle that "*No member of the Caltech community shall take unfair advantage of any other member of the Caltech community.*"