**Spring 2010**

# CPE690/EE610 ST: Power Sources for Portable, Automotive, and Renewable Energy Systems

http://www.ece.uah.edu/~jovanov/CPE690_power_sources

**Lecture:** Monday and Wednesday 5:30pm -6:50 pm, Engineering Building EB239


**Instructors:**

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**Office Hours:** Monday 3-5 pm, Thursday 10-11:30 am, and by appointment.

**Course Description:**

Power sources play a critical role in supplying power for many devices used in our everyday life. Currently, a use of rechargeable batteries dominates in practically all consumer applications. A continuous development of advanced and low cost supercapacitors and fuel cells might allow their increasing applications besides special military and air-space devices. Beyond portable consumer electronics, electrochemical power sources are used in healthcare devices providing free mobility, automotive applications including conventional, hybrid, and electric vehicles, military applications like unmanned flying and underwater vehicles, backup power in stationary telecommunication and power plant systems, power generation and energy storage in distributed and off-grid renewable energy power systems, and in many other areas. This course will teach applied electrochemistry, design, organization and optimization of portable, automotive, and renewable energy power systems. That allows optimization of the use of the available energy provided by the given energy source. Design of power sources will be explained with a focus on current state-of-the-art material development, charging, control procedures and power management. The emphasis of this course will also be on studying operating conditions, comparison and performance of several electrochemical systems and life limiting degradation mechanisms. Students will learn and understand how to design and optimize devices with electrochemical power sources, basic design rules of fuel cell powered devices, and energy scavenging.

**Outcomes:**

By the conclusion of this course, each student should:

- Analyze device/system power and energy demand
  - Select or design the most convenient electrochemical power system in terms of technical and economic viability
  - Identify the current electrochemical power sources, cutting edge research, and predict near future development in batteries and fuel cells.
  - Identify the main application types and their demand for electrochemical power sources. Show the power source influence on the system design.
  - Define needs for new infrastructure with a wide spread application of novel power systems.
- Differentiate between individual types of electrochemical power sources batteries, fuel cells and supercapacitors
  - understand performance behavior, characteristics, charging, power management, operating conditions with respect to application needs.
  - Define charging technique for individual battery types.
- Understand thermodynamic principles of electrochemical power sources, instrumentation, standards, test procedures, data sheets and parameters.
- Understand energy scavenging and alternative power sources.

**Textbook (required):**
***Electrochemistry*** by Carl H. Hamann, Andrew Hamnett and Wolf Vielstich, 2nd Edition, Wiley-VCH, 2007, ISBN 352731069X

Other reference books (optional):
***Electrochemical Methods: Fundamentals and Applications*** by Allen J. Bard and Larry R. Faulkner, 2nd Edition, John Wiley & Sons, Inc., July 2000, ISBN: 0471043729

***Maintenance-Free Batteries: Based on Aqueous Electrolyte Lead-Acid, Nickel/Cadmium, Nickel/Metal Hydride*** by Dietrich Berndt, 3rd Edition, Research Studies Press Ltd, October 2003, ISBN: 0863802796

***Fuel Cell Handbook*** by EG&G Services, October 2000:
http://www.fuelcells.org/info/library/fchandbook.pdf

**Prerequisites:**
Graduate standing.

**Grading** The final grade for the course will be compiled as follows:
- Midterm Exam 20%
- Homework and reading assignments 20%
- Individual assignments and presentations 30%
  - Individual assignments include an approved essay or a project relevant to the course
- Final Exam 30%

**Important dates:**
- Project Selection: February 1, 2010
- Midterm: February 24, 2010
- Project Review: March 10, 2010
- Project Presentations: April 21 & 26, 2010
- Final Exam: Monday, May 3, 6:30-9:00 pm

**Course Outline**

Note: The topics outlined above are subject to change during the semester. Students will be advised of these changes in a timely manner.

- Basics of electrochemistry, basic definitions to understand the principals
  - Electrolytes
  - Ion transport processes
  - Cells: Electrodes, types of electrodes, polarization, overpotential
  - Thermodynamics

- System organization of portable and automotive systems
  - Modes of operation
  - Duty cycles and system operation trade-offs
  - Dynamic power profiling
  - Estimated battery life
  - Hybrid systems and their control

- Batteries, supercapacitors, and fuel cells introduction
  - The global energy picture, why do we need energy storage
  - Battery, supercapacitor, and fuel cell
  - Performance differences, advantages and disadvantages
  - Applications and their requirements

- Definitions and parameters

- Battery electrochemistry – from basic electrochemistry to advanced battery design
  - Short history overview
  - How does battery work
  - Types of batteries
  - Types of electrodes and electrode materials
  - Electrode processes
  - What is happening during discharging and charging
  - Power losses
  - Degradation mechanisms
  - Standards and testing

- Rechargeable batteries: Lead-acid, NiCd, NiMH, rechargeable lithium batteries
  - Principles
  - Design
  - Performance, advantage, disadvantage
  - Charging
  - Applications
  - Current development and research topics

- Supercapacitors

- Alternative power sources
  - Solar cells
  - Energy scavenging

- Instrumentation, Chargers and Power management
  - Charger types and design
  - Power management functions
  - Battery maintenance and lifetime
  - Safety

- Fuel cells
  - Brief historical introduction
  - Fuel cells types, characteristics and operating conductions
  - Applications

- Hydrogen fuel cell, DMFC and biological fuel cells
  - Design
  - Operating conditions
  - Catalysts
  - Performance limiting mechanisms
  - Degradation and durability
  - Applications: advantages and limitations

- Fuel cell engineering design
  - MEA fabrication
  - Fuel Cell assembly & testing
  - Parameters and performance comparison
  - Economic viability

- Fuel cells system design, power management and control
  - System design, buffer battery concept, battery hybrid concept
  - Power management functions

- DC/DC convertors, invertors
- Infrastructure and fuel management

- Electrochemical, Battery, Fuel Cell: research and test instrumentation and technique
  - Potentiostats/galavanostats
  - Electrochemical impedance spectroscopy
  - Material research tools: SEM, AFM, XPS, FT-IR, porosimetry, and others
  - Battery testers
  - Fuel Cell test stands

| Class | Date | Subject |
|---|---|---|
| 1 | Jan 11 | Introduction. Basics I: Basics of electrochemistry, basic definitions to understand the principals: |
| 2 | Jan 13 | Basics II: |
| 3 | Jan 20 | System organization of portable and automotive systems |
| 4 | Jan 25 | Batteries, supercapacitors, and fuel cells introduction |
| 5 | Jan 27 | Battery electrochemistry – from basic electrochemistry to advance battery design |
| 6 | Feb 1 | Rechargeable batteries: Lead-acid |
| 7 | Feb 3 | Rechargeable batteries: NiCd and NiMH |
| 8 | Feb 8 | Rechargeable lithium batteries |
| 9 | Feb 10 | Supercapacitors |
| 10 | Feb 15 | Alternative power sources: Solar cells |
| 11 | Feb 17 | Alternative power sources: Energy scavenging |
| 12 | Feb 22 | Instrumentation, Chargers and Power management |
| 13 | Feb 24 | Midterm exam |
| 14 | Mar 1 | Fuel cells introduction |
| 15 | Mar 3 | Hydrogen fuel cell and DMFC |
| 16 | Mar 8 | Fuel cell engineering design |
| 17 | Mar 10 | Project Review |
| 18 | Mar 22 | Biological fuel cells (class in CFD @ Hudson Alpha Institute for Biotechnology) |
| 19 | Mar 24 | Fuel cells system design, power management and control |
| 20 | Mar 29 | Research and Analytical Techniques |
| 21 | Mar 31 | Battery Testing and Standards |
| 22 | Apr 5 | Selecting power sources for portable applications (density & power requirements) |
| 23 | Apr 7 | Selecting power sources for portable applications (user profiles, recharging/re-fueling) |
| 24 | Apr 12 | Case Studies |
| 25 | Apr 14 | Special Batteries |
| 26 | Apr 19 | Summary |
| 27 | Apr 21 | Project Presentations #1 |
| 28 | Apr 26 | Project Presentations #2 |