MSE 460/560 – Nanomaterials in Energy Production and Storage

Course Syllabus
Instructor: Peter A. Crozier  
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Meeting Day, Time and Place: Mon, Wed, 4:35-5:45 PM, Room: ECG 236 (Tempe)
Office Hours: Mon 10:00- 12:00, ERC 251

Teaching Assistant: Ethan Lawrence

Course Description
It is now recognized that the key to solving the energy problems of the future rests in part on developing new classes of functional materials that will contribute to energy production and storage. The purpose of this course is to establish a connection between nanomaterials, energy production/storage and the environment. The course will emphasize the relationship between fundamental materials properties, chemical and energy transformation as well as energy storage. Applications will include the role of materials for photovoltaics, nanocatalysts, batteries and fuel cells. The course will stress fundamental principles and charge transfer processes in nanostructured materials in addressing energy needs. Students completing the course will have an appreciation of the critical role of materials in addressing the pressing need for developing sustainable and environmentally friendly energy.

Prerequisites: MSE 250 or equivalent
Text: None – Lecture notes and handouts in class

Summary of Lecture Topics (details may change)

General Background
Lecture 1 – Introduction – energy and sustainability, energy utilization and human development index, energy production today
Lecture 2 - Environmental impacts, climate change, supply issues and Hubbert curve
Lecture 3 – Future demand Issues, energy intensity, thermodynamic considerations, role of materials

Fundamentals of Active Nanostructured Materials
Lecture 4 - Structure and properties of bulk materials surfaces
Lecture 5 – Nanoparticles and nanoparticle surfaces
Lecture 6 – Electronic structure I- basic wave mechanics
Lecture 7 – Electronic structure II- wave mechanics formalism
Lecture 8 – Nanoparticle properties I
Lecture 9 – Nanoparticle properties II

Catalytic Chemical Manipulation and Energy Applications
Lecture 10 - Chemical fuels, energy related reactions, introduction to heterogeneous catalysis
Lecture 11 – Performance parameter for nanocatalysts – surface area, activity, selectivity, chemical kinetics, active sites
Lecture 12- Functionality of Catalytic Materials – chemisorption, adsorption isotherms, activity, kinetics
Lecture 13- Functionality of Catalytic Materials – Sabatier principle, molecular activation and interaction with surfaces, d-band model, dissociation and activation barriers, designer catalysts

**Solar Energy Production**
Lecture 14 - Introduction to Solar Energy- solar resource, solar thermal, thermo-electric, photon excitation in semiconductors, electron-hole pairs, photocatalysis
Lecture 15 – Photovoltaics I - Architecture and Principles – current-voltage characteristic, Shockley-Queisser efficiency, n and p-type doping in semiconductors,
Lecture 16 - Photovoltaics II – charge carrier concentration, majority and minority carriers, p-n junction, depletion layer and electron hole pair separation, band structures and photon absorption in Si and GaAs, materials parameters for single crystal solar cells
Lecture 17 – Photovoltaics – Organic photovoltaics

**Materials for Energy Storage**
Lecture 18 - Electrical Storage - mainly batteries and capacitors – battery principles and architectures, electrochemical potential, Nernst equation, Gibbs free energy, charging and discharging profiles
Lecture 19 - Batteries and Nanomaterials
Lecture 20 - Batteries

**Fuel Cells**
Lecture 21 - Fuel Cells – architectures, thermodynamics, current-voltage characteristics, kinetic losses,
Lecture 22 – Proton exchange membrane (PEM) cell, electrolyte materials, electrode structure and catalysts, thermodynamics of heat engine/fuel cell combinations, solid oxide fuel cells (SOFC)

**Various Topics - Student Presentations**
Lecture 25 - Student Presentations
Lecture 26 - Student Presentations
Lecture 27 - Student Presentations

**Course Content Changes**
Course content may vary from this outline to meet the needs of this particular group. Dates for class tests may also be shifted.

**Disability Policy**
The university will make reasonable accommodations for persons with documented disabilities. Students should notify me of any special needs.

**Course Grading – Undergraduate Students**
1. Homework will count for 20% of the final grade. Homeworks are due one week after being assigned, no late homework is accepted. All homework questions should be attempted. **One question will be selected at random and graded. This grade will count as the grade for the entire homework.** The three lowest scoring homeworks will be dropped in the calculation of the final grade. Participation in class exercises is required.
2. Two midterm tests each worth 20% of the final grade will be held during regular class hours.

3. A final comprehensive exam worth 40% of the final grade will be held on May 1st at 4:50 – 6:40. Score in final exam will replace lowest scoring midterm if the final exam score is higher than the midterm scores. If final exam score is lower than midterm score, no change will be made.

**Course Grading – Graduate Students**

1. Homework will count for 15% of the final grade. Homeworks are due one week after being assigned, no late homework is accepted. All homework questions should be attempted. One question will be selected at random and graded. The three lowest scoring homeworks will be dropped in the calculation of the final grade. Participation in class exercises is required.

2. Two midterm tests each worth 17.5% of the final grade will be held during regular class hours.

3. A final comprehensive exam worth 30% of the final grade May 1st at 4:50 – 6:40. Score in final exam will replace lowest scoring midterm if the final exam score is higher than the midterm scores. If final exam score is lower than midterm score, no change will be made.

4. A 10 page term paper and 15 minute presentation worth 20% of final grade will be due at the end of the semester. Guidelines will be given later.

Plus/minus grading will be used.

**Blackboard**

I will use Blackboard to post lecture notes, homework and other resources that may help you. You can also hold discussions on blackboard with me and other students in the class. To access Blackboard use the follow:

**Accessing Lecture Notes and Homework Assignments on Blackboard**

1. Go to Blackboard: http://myasucourses.asu.edu

2. Under My Courses, select MSE 460: *NanoMaterials in Energy Production and Storage*

3. On lefthand panel, select Course Documents

4. For lecture notes, go to Lectures folder, for homework go to Homework folder etc...