Photoelectrochemical and Photocatalytic Processes for Alternative Solar Energy Conversion - EE599

University of Southern California
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Tuesdays and Thursdays 11:00AM-12:20PM
Office Hours: Thursday 9-11AM
Course Website: http://blackboard.usc.edu

This course will focus on photoelectrochemical (PEC) and photocatalytic (PC) processes pertaining to solar fuel production. Shining light on semiconductor surfaces generates free electrons and holes that can be used to drive endothermic redox reactions, such as water splitting (H_2 production) and CO_2 reduction with water to produce hydrocarbon fuels (e.g., $CO_2 + 6H^+ + 6e^- \rightarrow CH_3OH + H_2O$). In many ways, this processes is analogous to solar-to-electrical photovoltaic cells, which have nearly reached the theoretical maximum efficiency. The goal of this course is to bridge the wide gap that currently exists between photovoltaics (very well understood) and photocatalysis (not well understood). This course will focus/emphasize applying what we know about making good solar cells and applying it to PEC and PC processes.

Context: There are currently more than 87 solar power plants (i.e., "solar farms") in operation and 57 that are currently under construction. Over 645,000 US homes and businesses have rooftop solar panels. However, there is currently no way of storing the large amount of electricity generated by solar panels for use during nights, cloudy days, and winter months. As such, solar panel owners still need to obtain a significant fraction of their electricity from fossil fuels and nuclear power. Photocatalysis provides a scalable method for storing the sun's energy in chemical bonds (i.e., H_2) that can later be released in a carbon-free or carbon-neutral cycle. This technology can be implemented on the scale of GigaWatt power plants or individual households with rooftop solar panels.

Course Description: This course will introduce principles and mathematical models of photoelectrochemical energy conversion and storage. Students will study equivalent circuits, thermodynamics, reaction kinetics, and transport phenomena related to PEC and PC processes. In addition, this course will review current literature in the rapidly expanding and progressing fields of photoelectrochemistry and photocatalysis. This is an inherently interdisciplinary field of study requiring knowledge of materials, solid state physics, chemistry, and semiconductor device physics. The course is intended for students from chemistry, physics, electrical engineering, materials science and chemical engineering. As such, there will be no pre-requisite knowledge required for this course.

Goals: The aim of this class is two-fold: 1.) Introduce the basic concepts in photoelectrochemistry and photocatalysis. 2.) Survey recent advances in the broadly defined, rapidly expanding field of photoelectrochemistry and photocatalysis.

Course Structure: Homeworks will primarily consist of 1.) short problem sets requiring some basic calculations and 2.) preparing short presentations to be given in class reviewing current papers from the literature.

Grading: Students' final grades will be calculated from a weighted average as follows:

Homework	40%
Midterm Exam	25%
Final Exam	25%
In-class Assignments	10%

Course Outline: The course will meet for the full semester, which is 15 weeks. Depending on how quickly lecture material is covered, the following is a tentative list of topics to be covered in the class.

1.) Introduction to photoelectrochemistry and photocatalysis
2.) Solar cells, *pn*-junctions, and solar-to-electrical energy conversion
3.) Photoelectrochemical cells, Schottky junctions, and solar-to-chemical energy conversion
4.) Basic electrochemistry
5.) Experimental methods (Lab Demo)
6.) Exploring the roles of photovoltaics, metal co-catalysts, kinetics, and catalytically active sites in PEC and PC
7.) Thermally-driven vs. photocatalytically-driven catalysis
8.) Thermodynamic stability and photo-induced corrosion of semiconductor surfaces
9.) Numerical simulations of *pn*-junctions, Schottky junctions, and the semiconductor-liquid junctions (In-class Lab)
10.) Plasmon resonant photocatalysis
11.) Emerging areas and future directions

Statement on Academic Conduct and Support Systems

Academic Conduct

Plagiarism - presenting someone else's ideas as your own, either verbatim or recast in your own words - is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in*SCampus* in Section 11, *Behavior Violating University Standards*https://scampus.usc.edu/1100-behavior-violating-university-standards-and-appropriate-sanctions. Other forms of academic dishonesty are equally unacceptable. See additional information in *SCampus* and university policies on scientific misconduct, http://policy.usc.edu/scientific-misconduct.

Discrimination, sexual assault, and harassment are not tolerated by the university. You are encouraged to report any incidents to the *Office of Equity and Diversity* http://equity.usc.edu/ or to the *Department of Public Safety* http://adminopsnet.usc.edu/department/department-public-safety/complaint-form. This is important for the safety of the whole USC community. Another member of the university community - such as a friend, classmate, advisor, or faculty member - can help initiate the report, or can initiate the report on behalf of another person. *The Center for Women and Men* http://www.usc.edu/student-affairs/cwm provides 24/7 confidential support, and the sexual assault resource center webpage http://sarc.usc.edu/ describes reporting options and other resources.

Support Systems

A number of USC's schools provide support for students who need help with scholarly writing. Check with your advisor or program staff to find out more. Students whose primary language is not English should check with the *American Language Institute* http://dornsife.usc.edu/ali, which sponsors courses and workshops specifically for international graduate students. *The Office of Disability Services and Programs* http://sait.usc.edu/academicsupport/centerprograms/dsp/home_index.htmlprovides certification for students with disabilities and helps arrange the relevant accommodations. If an officially declared emergency makes travel to campus infeasible, *USC Emergency Information* http://emergency.usc.edu will provide safety and other updates, including ways in which instruction will be continued by means of blackboard, teleconferencing, and other technology.