ME555 Electrochemistry in Energy Application
Spring 2021

Updated: 01/20/2021

Instructor: Prof. Po-Chun Hsu

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Office hour: By appointment

Textbook: No textbook. See the recommended reading materials list below.

Schedule: WF - 03:30PM to 04:45PM

Lecture: Online-only until further notice

TA: TBD

Course Description:

Renewable energy and energy efficiency are the twin pillars for sustainable energy. To change from fossil fuel to renewable energy sources, such as solar and wind, it requires drastic revolution for energy generation, storage, transportation, and utilization. One of the most significant difference is that fossil fuels convert chemical energy to thermal energy (and carbon dioxide), while photovoltaic cells and wind turbines directly generate electricity. To better utilize the electricity just like the way we use for fossil fuels, electrochemistry plays an essential role. In this course, you will first learn the basic electrochemistry, which is the groundwork for understanding a wide range of applications in energy and sustainability, such as batteries, super capacitors, electrocatalysis, electrochromic smart windows. This course will use up-to-date research progresses in scientific journals as the examples to introduce these topics and to provide you a comprehensive insight for energy science and technology.

Learning Objectives:

- Electrochemistry fundamental principles and techniques
- Capability to understand and analyze cutting-edge electrochemical research papers
- Holistic and cross-disciplinary view of the influence of electrochemistry on sustainable energy applications

Homework:

3 homework assignments

Exams:

- Midterm: There will be one take-home midterm on March 17th that uses a few research papers as the background to test the fundamental knowledge of electrochemistry.

- Final: Literature review presentation (individual/group). You will be assigned to certain research topics or papers, understand and digest the content, and give the presentation about the technical background, approach, and potential impacts.

Grading:

Homework (25%), midterm exam (25%), final presentation (35%), and in-class discussion (15%)

Lecture Content and Schedule

- Electrochemistry fundamentals:
    - Thermodynamics (Nernst equation)
    - Kinetics (Butler-Volmer equation)
    - Mass-transfer
    - Impedance spectroscopy
    - Electric double layers
- Batteries (focus on lithium-ion batteries)
    - Phase rule
    - Intercalation chemistry
    - Cycle fade mechanisms
    - Safety (dendrite formation and thermal runaway)
- Electrochromic smart windows
    - Short intro of solid physics
    - Light-matter interaction
    - Multispectral tunability
- Electrocatalysis
    - Sabatier principle
    - Water splitting
    - Nitrogen fixation
    - CO_2 reduction
    - Wastewater treatment

Date	Topic
1/20	Introduction
1/22	Thermodynamics (1)
1/27	Thermodynamics (2)
1/29	Batteries: overview
2/3	Lithium-ion batteries (LIB): overview
2/5	Kinetics (1)

2/10	Kinetics (2)
2/12	LIB: Anode
2/17	Performance degradation
2/19	LIB: Cathode
2/24	LIB: Electrolytes and other components
2/26	Electrochromism: overview
3/3	Band theory (1)
3/5	Band theory (2): Optical property
3/10	*No class*
3/12	Smart windows
3/17	**Midterm (take-home)**
3/19	Multispectral control: visible + near-IR
3/24	Smart textiles
3/26	Multispectral control: visible + near-IR + mid-IR
3/31	Electrocatalysis: overview
4/2	Sabatier principle
4/7	Surface chemistry
4/9	Water splitting
4/14	Fuel cell
4/16	CO_2 conversion
4/21	Seawater mining
4/23	**Final presentation**

Reading materials:

- "Electrochemical methods: fundamentals and applications, 2nd edition" by Allen J. Bard, Larry R. Faulkner. ISBN: 978-0-471-04372-0
- "Electrochemical systems, 3rd edition" by John Newman, Karen E. Thomas-Alyea. ISBN: 978-0-471-47756-3
- "Advanced Batteries: Materials Science Aspects" by Robert Huggins. ISBN: 978-1-4419-4550-1
- More books, research papers and review articles will be listed