# MAT 68005: Advanced Electrochemistry

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| **Instructor** | Mohammed Ahmed Zabara |
| **Term** | 2022-2023 Spring |
| **Classrooms / Hours** | Wednesday 8:40am-9:30am FENS L063<br>Thursday 11:40am-1:30pm FASS G006 |
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| **Office hours** | Wednesday 3:30pm - 5:30pm<br>Friday 09:30am – 11:30am |

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| **Course Description** | This course provides advance knowledge of electrochemistry required to understand, develop, and monitor various electrochemical systems with the focus on the application of electrochemistry in energy storage and conversion. |
| **Objectives** | - Acquire the fundamental concepts of electrochemistry<br>- Distinguish Faradaic and non-Faradaic processes<br>- Obtain Knowledge about electrochemical cell and electrode processes<br>- Understand types of potential and their governing equations<br>- Understand kinetics of electrochemical charge transfer<br>- Form basic understanding of the electrochemical interface<br>- Distinguish the contribution of mass transfer processes<br>- Gain knowledge of impedance based electrochemical characterization and modeling methods<br>- Understand the working principles and outcomes of step and sweep electrochemical characterization techniques<br>- Recognize the role of electrochemistry in current and future energy storage and conversion applications |
| **Reference Books** | - Bard and Faulkner, **Electrochemical Methods: Fundamentals & Applications,** 2nd edition, (Wiley, 2001)<br>- Wesley R. Browne, **Electrochemistry**, (Oxford, 2018)<br>- Sawyer, Sobkowiak and Roberts, **Electrochemistry for chemists**, (Wiley,1995) |
| **Grading** | Homework 20%<br>Online activity 10%<br>Midterm 20%<br>Project 20%<br>Final 30% |

| Date | Topic | Learning outcomes |
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| **Week 1** | *Introduction to advanced electrochemistry* | • Understand the development of modern electrochemistry<br>• Obtain knowledge about the fundamental concepts of electrochemistry<br>• Understand the terminology used in electrochemistry<br>• Realize the importance of electrochemistry concepts as the working principle for energy applications |
| **Week 2** | *Electrochemical reactions and their applications in energy production and storage* | • Understand and differentiates the cathode/anode reactions<br>• Understand the nature of two and three electrode systems<br>• Comprehend the functions and the working principles of the different types of electrodes and electrolytes |
| **Week 3** | *Electrochemical reactions and their applications in energy production and storage* | • Differentiate Faradaic from non-Faradaic processes<br>• Understand electrochemical potential and current flow<br>• Acquire knowledge of reactions in energy storage and conversion systems such as primary/secondary batteries supercapacitors and Fuel cells |
| **Week 4** | *Thermodynamics of electrochemical reactions* | • Understand reversibility of electrochemical reactions<br>• Comprehend the derivation of Nernst equation and its application in electrochemical processes<br>• Recognize types of potentials in electrochemical systems<br>• Obtain knowledge about conductance in electrochemistry |
| **Week 5** | *Butler-Volmer and Tafel treatment of electrode kinetics* | • Realize the relation between potential and current in electrochemical system<br>• Understand the treatment of electrochemical processes by Butler-Volmer kinetics<br>• Comprehend the Tafel equation and its application |
| **Week 6** | *Electrochemical Interface* | • Understand the structure of the electrified interface<br>• Familiarize with proposed models for the electrochemical interface |
| **Week 7** | *Electrochemical Interface* | • Understand modes of mass transport in electrochemistry<br>• Comprehend the effect of mass transfer on the interface<br>• Recognize the effect of mass transfer on the electrochemical reaction rates |
| **Week 8** | *Midterm* | |
| **Week 9** | *Impedance theory* | • Understand the concept of electrochemical impedance<br>• Acquire knowledge about the theory behind Electrochemical Impedance Spectroscopy |
| **Week 10** | *Impedance based techniques* | • Obtain knowledge on the application and outcomes of EIS technique<br>• Understand the role of EIS technique for energy storage and conversion applications |
| **Week 11** | *Modeling based on impedance* | • Obtain knowledge about used equations and parameters in simulating electrode processes<br>• Recognize the different modeling methods used for electrochemical systems<br>• Differentiate the drawbacks of the proposed models in the literature |
| **Week 12** | *Step and Sweep Electrochemical techniques* | • Acquire knowledge about cells and apparatus used for electrochemical measurements<br>• Understand the working principles, applications and outcomes of step and sweep techniques |
| **Week 13** | *Project presentations* | • Provide examples from literature and/or industry about the applications of electrochemistry and/or electrochemical techniques |
| **Week 14** | *Project presentations* | • Provide examples from literature and/or industry about the applications of electrochemistry and/or electrochemical techniques |