Course name: Electrochemical systems (C173/C273)

This course aims to provide a detailed description of the principles in the electrochemical systems. The topics of discussion will be directly relevant to the research of inorganic chemistry, materials sciences, and nanotechnology in the university. With examples in recent literature and discussions of experimental practice, this course focuses on the qualitative and quantitative evaluation of the information obtained from electrochemical characterization methods.

Part I: Introduction

Week 1 Theory and principles. Concepts of electrochemical potentials; Marcus theory for electrochemical charge transfer. Butler-Volmer equation. (Section 1.1, 2.1, 3.1−3.4, and 3.6 in Bard's textbook)

Week 2 Mass transport equation of species in solution. Diffusion-layer model. Geometrical effect (Chapter 4, Section 5.1 and 5.2 in Bard's textbook)

Week 3 Experimental setups. Potentiostats; three-electrode setup; choice of electrodes; supporting electrolyte; series resistance; separators and ion-conductive membranes. (Section 5.1−5.3, Chapter 6 and 7 in Sawyer's textbook)

Exercises 1

Part II: Homogeneous electrochemistry

Week 4 Basics of cyclic voltammetry. Experimental caveats. Numerical simulation. (Section 6.1−6.6 in Bard's textbook, section 1.1−1.3 in Savéant's textbook)

Week 5 Coupling electron transfer and chemical reaction. Proton-couple electron transfer (PCET) reactions. (Section 2.2.1−2.2.4 in Savéant's textbook)

Week 6 Molecular electrocatalysis. Foot-of-wave analysis. How to extract kinetic information from cyclic voltammetry. (Section 2.2.6 in Savéant's textbook and *Nature Rev. Chem.*, **2017**, *1*, 0039)

Exercises 2

Part III: Heterogeneous electrochemistry

Week 7 Electrochemical double layers. Batteries, super-capacitors, and pseudo-capacitors. (Section 13.3, 13.6 in Bard's textbook and *J. Phys. Chem. C*, **2007**, *111*, 14925−14931)

Week 8 Tafel analysis for mechanistic understanding. Rotating disk/ring electrode. (Section 6.1.2−6.1.5 in Gileadi's textbook, Section 9.3 & 9.4 in Bard's textbook).

Week 9 Electrochemical impedance spectroscopy. Randles circuit. (Section 10.1−10.4 in Bard's textbook)

Exercises 3

Part IV: Summary

Week 10 Summarize what we have learned. A decision tree about what techniques to use given a certain scenario in research (if we have time).

Grading: 3 Exercises (20% each) + In-class final exam (40%)

References:

1. Electrochemical Methods: Fundamentals and Applications, A. J. Bard, L. R. Faulkner, Wiley, 2nd Ed., 2000. (Required)
2. Electrochemical Systems, J. Newman, K. E. Thomas-Alyea, Wiley, 3rd Ed., 2004.
3. Elements of Molecular and Biomolecular Electrochemistry: An Electrochemical Approach to Electron Transfer Chemistry, J.-M. Savéant, Wiley, 2006.
4. Electrochemistry for Chemists, D. T. Sawyer, A. Sobkowiak, J. L. Roberts, Wiley, 2nd Ed., 1995.
5. Physical Electrochemistry: Fundamentals, Techniques, and Applications, E. Gileadi, Wiley, 2011.