Electrochemical Energy Technologies

Date: Sunday, December 8th 2019 to Monday, December 9th 2019

Venue: Nelson Mandela African Institution of Science and Technology (NMAIST)

Purpose of the workshop:

To introduce the technologies at the forefront of clean energy research. Emphasis will be placed on explaining the enabling principles and the opposing challenges at the individual component and cell level. Participants will gain the understanding to jumpstart new research efforts in this field.

Instructors: **Dr. Sheel Sanghvi** (sheel@u.northwestern.edu), Northwestern University;
Matthias Agne (mt.agne.matsci@gmail.com), Northwestern University;
Dr. Nella Vargas-Barbosa (nellamarievargas@gmail.com), Max Planck Institute, Solid State Research;
Dr. Kent Griffith (kentjgriffith@gmail.com), Northwestern University
Prof. Jennifer Rupp (jrupp@mit.edu), Massachusetts Institute of Technology

Schedule:

Day 1 – December 8th, 2019		
8:30 – 9:00	Introduction	Dr. Sheel Sanghvi
9:00 – 10:15	Electrochemistry Fundamentals	Matthias Agne
10:15 – 10:45	**Break**	
9:30 – 12:00	Electrochemistry Fundamentals	Matthias Agne
12:00 – 13:00	**Lunch**	
13:00 – 15:00	Fuel Cells: From Hot to Cold	Dr. Sheel Sanghvi
15:00 – 15:30	**Break**	
15:30 – 17:00	Open-Source Tools for Electrochemical Characterization	Dr. Sheel Sanghvi
Day 2 – December 9th, 2019		
9:00 – 10:15	Photoelectrochemistry	Dr. Nella Vargas-Barbosa
10:15 – 10:45	Break	
10:45 – 12:00	Photoelectrochemistry	Dr. Nella Vargas-Barbosa
12:00 – 13:00	**Lunch**	
13:00 – 14:30	State-of-the-Art Battery Technologies	Dr. Kent Griffith
14:30 – 15:00	**Break**	
15:00 – 17:00	Solid State Battery Materials, Function and Chemistry	Prof. Jennifer Rupp

Outline:

Electrochemistry Fundamentals

1. Introduction to electronic, thermal, and ionic transport in solids
    a. Experimental characterization
    b. Physical models of transport
2. Thermodynamics for materials engineering
    a. Introduction to phase diagrams
    b. Tuning material properties with defects
    c. Electrochemical stability in mixed ionic-electronic conductors

Fuel Cells: From Hot to Cold

1. Key components and reaction pathways
2. Advantages/applications of various types of fuel cells
    a. High temperature solid oxide
    b. Intermediate temperature solid acid
    c. Low temperature polymer
3. Insights through analysis: electrocatalyst testing and the polarization curve
4. Beyond hydrogen: fuel cells as electrochemical reactors

Open-Source Tools for Electrochemical Characterization

1. Why open-source?
2. Tips and tricks for building your own tools
    a. Case study: A modular tube furnace
3. Demonstration/hands-on tutorial of:
    a. The low-cost JUAMI Potentiostat
    b. ECIF.py: Open-source equivalent circuit impedance-fitting

Photoelectrochemistry

1. Solid-Electrolyte Junctions
    a. Electronic density of states: Metals vs. Semiconductors
    b. n-type vs. p-type semiconductors
    c. Current vs. Potential (i-V) characteristics of semiconductor-electrolyte junctions
        i. Dark vs. illumination
        ii. Flat-band potential determination
            1. Mott-Schottky Analysis
            2. Open-circuit potential under illumination
2. Types of photoelectrochemical cells
    a. Regenerative (photovoltaic)
        i. Dye-sensitized solar cells
    b. Photoelectrosynthetic cells
        i. Water-splitting cells
3. Practical considerations
    a. How to select the various components for a photoelectrochemical cell:
        i. Transparent conductive oxide, photoactive material, electrolyte, reference electrode, catalyst, counter electrode, etc.
4. Divide into small groups to work through a short hand-out with problem sets related to photoelectrochemistry.

State-of-the-Art and Advanced Battery Materials

1. Lithium-ion batteries from atoms to devices
2. State-of-the-art for cathode, anode, and electrolyte materials
3. Concepts for advanced batteries:
    a. materials for fast charging
    b. low cost/sustainability
    c. high energy
    d. long lifetime

Solid state battery materials, function and chemistry

1. Solid state vs. liquid/prototype battery
2. Function of a solid state battery
3. Impact on society of solid state batteries – resources: why do it?
4. Solid state electrolytes:
    a. Types of solid state battery electrolytes: basic structure, Li transport and electrochemical stability windows & defect chemistry relations
    b. Chemical ceramic synthesis and its competitiveness to make a cheap and mass manufactural product
    c. From thin films to large scale solid state electrolytes
5. The solid state electrolyte-cathode interface
    a. Engineering fast and stable ceramic interfaces
    b. Stability of pure Lithium towards solid state electrolytes: structural and microstructural challenges
6. Solid state battery testing
7. One crazy outlook for the future: Alternative uses for lithium ceramics