Electrochemical Energy Storage and Conversion ESE-837

Description

1. It is not necessary that energy will remain available when we require it and often it is desirable to convert one form of energy into another useful form before using it.
2. There are many different types of needs for energy storage and various solutions available. This course will provide a fundamental understanding of the need for energy storage, overview on different types of energy storage systems and their specific applications.
3. Since electrochemical energy storage is a widely employed technique for energy storage and the focus of this course will specifically be electrochemical processes such as basic electrochemistry, batteries and supercapacitors.
4. Electrochemical energy conversion is getting enormous attraction these days, especially because of hydrogen storage. This course will address the electrochemical production and conversion of hydrogen, fuel cell and CO_2 reduction chemistries.
5. Title, objective and course content of existing energy storage systems ESE-832 is revised to focus on electrochemical storage and conversion technologies.
6. This course is proposed as an elective course for MS Energy Systems Engineering, MS Thermal Energy Engineering and MS Electrical Engineering (Power).

Objectives

1. The objectives of this “Electrochemical Energy Storage and Conversion” course are:
2. To identify the importance of energy and its storage.
3. To review different types of electrochemical energy storage systems and their viability according to specific needs for energy storage.
4. To learn the basics of electrochemistry and to discuss the importance of electrochemical energy storage for transportation, grid, portable electronics and making use of renewable energy resources.
5. To understand the basic chemistries of batteries, supercapacitors, and fuel cells.
6. To understand the key factors involved in evaluating batteries, supercapacitors and fuel cell performance, such as energy density and power density.
7. To provide an insight into nanomaterials for next-generation energy storage and conversion systems.

Outcomes

1. The outcomes of this “Electrochemical Energy Storage and Conversion” course are:
    a. The students will be able to comprehend the importance of energy storage, its various types and application of different electrochemical energy storage techniques according to energy storage needs.

b. The students will become familiar with basic electrochemical reactions and essential components of electrochemical energy storage systems, they will also be able to characterize these systems in terms of energy and power density.

c. The students will be able to differentiate between different batteries, supercapacitors, and fuel cell chemistries.

d. The students will get familiarized with the latest electrochemical energy storage and conversion trends, and will also learn about challenges and opportunities which these systems provide.

Course Contents

No.	Topics	Book	Contact Hours
1.	**Energy Storage** • Importance of energy and its storage • Various energy storage techniques and their applications: thermal energy storage, energy storage in organic fuels, mechanical energy storage, electromagnetic energy storage	A	3
2.	**Electrochemical energy storage** • Importance of electrochemical energy storage systems for transportation, grid, portable electronics and renewable energy sources • Advantages of electrochemical energy storage over other systems.	B&D	1.5
3.	**Electrochemistry** • Basic concepts: thermodynamics, work, energy, enthalpy, entropy and heat equivalent of energy • Chemical and electrochemical reactions and their efficiencies • Chemical and electrochemical potential • Temperature dependence of the reversible cell voltage • The Nernst equation • Electrochemical double layer • Ohmic losses and electrode kinetics • The Butler–Volmer equation • Faradaic reactions	C&E	9
4.	**Electrochemical techniques** • Electrochemical impedance spectroscopy • Dynamics of equivalent circuit • Impedance of electrodes • Linear sweep voltammetry	C&E	9

	• Cyclic voltammetry • Galvanostatic dis/charge process • Ions transport phenomenon • Calculation of diffusion coefficient in electrodes • Galvanostatic intermittent titration technique • Potentiostatic intermittent titration technique		
5.	**Batteries** • General concepts, battery reactions oxidation & reduction reactions, energy density & power density, maximum theoretical specific energy, cell potential • Significance of battery components such as electrolyte, separator, current collector • Primary batteries • Secondary batteries: lead-acid batteries, Ni-metal hydride batteries, Li-ion batteries • Beyond Li-ion batteries • Flow batteries	A&D	9
6.	**Supercapacitors** • Introduction, advantages, basic reactions, applications • Pseudocapacitor and hybrid capacitors • Capacitance, energy and power calculations	A&F	3
7.	**Electrochemical energy conversion** • History, basic reactions, advantages and applications of fuel cells • Polymer Electrolyte Membrane Fuel Cell • Solid Oxide Fuel Cell • Electrochemically H_2 production • CO_2 reduction by electrochemical process	C	6
8.	**Nanomaterials for advanced energy storage and conversion** • Applications of nanomaterials for energy storage systems • Challenges and opportunities for developing nanomaterials for energy storage and conversion • Electrocatalysis	D&F	3
9.	**Recycling of batteries, lab work and workshops practice** • Recycling of batteries • Measurement of cell potential and calculation of energy density		1.5
Total			45

Recommended Reading (including Textbooks and Reference books).

S. No.	Title	Author(s)	Assigned Code	Books
1.	Energy Storage fundamentals, Materials and applications, Springer New York, **2016**, 2nd. Edition	Robert A. Huggins	A	Text
2.	LITHIUM BATTERIES Advanced Technologies and Applications, John Wiley & Sons, Inc., **2013**.	Bruno scrosati, K. M. Abraham, Walter Van Schalkwijk, Jusef Hassoun	B	Text
3.	Handbook of electrochemistry, Elsevier B.V., **2007.**	Cynthia G. Zoski	C	Reference
4.	Advanced Batteries Materials Science Aspects, Springer New York, **2009.**	Robert A. Huggins	D	Reference
5.	Electrochemical Methods: Fundamentals and Applications. 2nd ed. Wiley, **2000**	Bard, Allen J., and Larry R. Faulkner.	E	Reference
6.	Latest research papers published in peer-reviewed scientific journals		F	Reference