ESE-836 Li-ion and Next-Generation Batteries

Course Description

1. In recent years, energy storage has become one of the big challenges of our planet in order to utilize more renewable energy and to reduce fossil fuel consumption.
2. Electrochemical energy storage offers the advantage of electricity storage in the form of chemical energy. Both, the electrical and chemical energy use electrons to store the energy, thus offering less loss of energy and ultimately provide high efficiency.
3. Lithium-ion batteries (LIBs) are known as the highest energy and power densities devices and already been used in the portable electronics industry.
4. Recently, LIBs are introduced in electric vehicles (EVs) which supply energy to the electric motors. However, for the use of EVs, more efficient LIBs with high energy and power densities are required.
5. There is also a need to develop next-generation battery systems for the readily availability of energy storage at different scale levels. For this, there is an ongoing trend to develop sodium-ion, zinc-ion, lithium-sulfur, and metal-air batteries.
6. Sodium-ion batteries (SIBs) are getting much attraction due to similarities of LIBs as an affordable energy storage system. This course will focus on the recent development of SIBs.
7. This course is proposed as an elective course for MS Energy Systems Engineering, MS Thermal Energy Engineering and MS Electrical Engineering (Power).

Educational Objectives

1. The objectives of this “Li-ion and Next-Generation Batteries” course are:
2. To understand the importance of LIBs.
3. To learn the basic working principle of LIBs.
4. To understand the important parameters of LIBs such as the selection and design of electrode materials.
5. To discuss how the performance of LIBs can be improved by controlling the parameters.
6. To learn the fabrication process and effect of cell design on performance.

7. To understand the electrical, mechanical and thermal behavior of LIBs.
8. To understand the reaction and degradation mechanism of LIBs under in-situ and ex-situ experiments.
9. To understand the importance and working principle of next-generation batteries.

Outcomes

1. The outcomes of this "Li-ion and Next-Generation Batteries" course are:
2. The students will be able to know the importance of the development of LIBs especially for the use of electric vehicles.
3. The students will become familiar with basic components and will learn how to improve the performance of LIBs.
4. The students will be able to know the important factors to determine the performance and reaction mechanism of electrodes in LIBs.
5. The students will get knowledge and the importance of developing next-generation batteries.

Contents

No.	Topics	Book	Contact Hours
1.	**Li-ion batteries (LIBs)** • Importance of energy storage • Introduction of LIBs and importance in electric vehicles (EVs) • Basic working principle and important components • Important practical parameters of LIBs such as voltage and capacity. • The function of separator and electrolyte	A	6
2.	**Cathode materials** • Importance of developing cathode materials • Cathodes materials and their types	A&B	6

	• Selection of cathode materials depending on capacity and voltage. • De/intercalation and conversion reactions in cathodes • Layered, olivine, and spinel cathodes • Cathode materials for electrical vehicles (EVs) • Performance enhancement strategies		
3.	**Anode materials** • Graphite and other carbonaceous anodes • Silicon-based high capacity anodes • Ti-based long cycle life anodes • De/interaction, de/alloy, and conversion type anode materials • Determination of the lithium insertion/extraction process in poor crystalline/amorphous anodes	B&C	4.5
4.	**Electrolyte and separator** • Selection parameters for electrolyte • Non-aqueous organic liquid electrolytes • Polymer electrolytes • Solid electrolyte for Solid State LIBs • Polymer separator • Glass fiber and other separators	A&D	4.5
5.	**Parameters affecting LIBs performance** • Temperature dependence performance of LIBs • Fast charge-discharge and related polarization effect • Introduction, advantages, basic reactions, applications	A&B	3

6.	**Electrochemical techniques to measure lithium diffusion** • Importance of measuring the lithium diffusion coefficient • Cyclic voltammetry (CV) • Electrochemical impedance spectroscopy (EIS) • Galvanostatic intermittent titration technique (GITT) • Temperature-dependent diffusivity	B	4.5
7.	**Reaction and degradation mechanism** • Introduction of and importance of developing in-situ and ex-situ techniques • In-situ XRD of electrode materials to probe the structural changes • In-situ X-ray absorption spectroscopy to investigate the local geometry of the electrode • Ex-situ TEM of electrodes to observe the surface and bulk changes • Investigating the degradation factors of LIBs such as thermal, structural, and gas evolution.	B&E	4.5
8.	**Next-generation batteries** • Recent development of LIBs • Importance of developing next-generation batteries • Introduction and development of SIBs • High capacity layered cathode materials for SIBs • Development of anode materials • Solid state SIBs • Li-S batteries • Metal-air batteries	E&F	9

	• Dual ion Mg and Zn batteries • Flow batteries • Re-cycling of batteries		
9.	**Lab work and workshops practice** • Demonstration of fabrication process of cells		3
Total			45

Recommended Reading (including Textbooks and Reference books).

S. No.	Title	Author(s)	Assigned Code	Books
1.	Lithium Batteries, Springer, **2016**	Chrisstian Julien, Alain Mauger, Ashok Vijh, Karim Zaghib	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.	Lithium Batteries and Other Electrochemical Storage System, Wiley, **2013**	Robert A. Huggins	C	Reference
4.	Advanced Batteries Materials Science Aspects, Springer New York, **2009.**	Robert A. Huggins	D	Reference
5.	The Lithium Air Battery: Fundamentals, Springer New York, **2014**.	Nobuyuki Imanishi, Alan C. Luntz, Peter G. Bruce.	E	Reference

6.	Latest research papers published in peer-reviewed scientific journals	F	Referenc e