ENMA614 & ENMA414

**SOLID STATE IONICS**

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Materials Science and Engineering

Solid State Ionics is the study of: point defects in crystalline and non-crystalline solids; defect equilibria and transport; the influence of chemical and electric potentials, interfaces, and association; and the application of ionically conducting solids in solid-state electrochemical transducer systems and devices.

The study of ion conducting solids ushers in a new era of "chemically functional materials." This chemical functionality arises out of the defect equilibria of these materials, and results in the ability to transport chemical species and actively participate in chemical reactions at their surface. Moreover, this chemical functionality provides a promise for the future whereby the harnessing of our natural hydrocarbon energy resources can shift from inefficient and polluting combustion - mechanical methods to direct chemical conversion.

The objective of the course is to develop a fundamental understanding of defect equilibria and transport in ion conducting solids, with emphasis on crystalline and particularly ceramic materials. Furthermore, to understand how these materials can be applied to energy production (fuel cells) and storage (batteries), chemical conversion (membranes), and pollution control (sensors).

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Days/Period: Tuesdays and Thursdays, 11:00 am - 12:15 pm

Location: 1202 Engineering Lab Bldg

Text/Reading: The recommended texts are:

"The CRC Handbook of Solid State Electrochemistry," Edited by P.J. Gellings and H.J.M. Bouwmeester.

"Electrochemistry of Solids," by H. Rickert, Springer - Verlag. This is a classic in this field. However, it is out of print but may be available on amazon.com.

Handouts: Lecture notes and supplementary papers will be posted on Canvas.

Assignments: Homework due typically once a week. A personal computer is recommended for a couple of the assignments; however, no sophisticated programming is required. Homework counts for 25% of grade. **No late homework will be accepted**.

Midterm: One midterm, 25% of the grade.

Final Exam: 50% of the grade.

ENMA614/ENMA414 COURSE OUTLINE

Reading Assignment

PJG = Handbook of Solid State Electrochem.

HR = Electrochemistry of Solids

1. Introduction (1/25) P.J.G Ch. 1 & H.R. Ch. 1

Objectives

Background

What is Solid State Ionics?

Why is it Important?

Intro to Solid-State Electrochemical Cells

Sensors

Fuel Cells

Batteries

Membranes

2. Disorder in Solids (no 1/30, 2/1) P.J.G Ch. 3 VI + VII

Point Defects H.R. 2.0-2.2

Vacancies

Interstitials

Notation

Defect pairs

3. Thermodynamics of Point Defects (2/6, no 2/8) P.J.G Ch. 5 & O. T. Sørensen

Statistical Thermodynamics Lecture Notes

Disorder Equilibria H.R. 2.3

Chemical Potential of Defects H.R. 2.4

Internal Disorder Equilibria H.R. 2.5-2.6

External Equilibria H.R. 2.7-2.8

4. Structural Disorder H.R. 3.3 & Papers 1 + 2

Defect Association Paper 3

5. Electron Occupancy Paper 4

6. Defect Equilibrium Diagrams P.J.G Ch. 5, Paper 6 & Lecture Notes

Schottky Disorder

Frenkel Disorder

Examples H.R. 3.0-3.2

7. Role of Point Defects in Physical Properties Papers

Non-stoichiometry

Conductivity

Thermo-chemical expansion

Elastic modulus

8. Electrochemical Principals and Potentials P.J.G Ch. 2

Electrochemical Potential H.R. 4.0-4.7

Volta Potential H.R. 4.8

Galvani Potential H.R. 4.9

Electronic Disorder H.R. Ch. 5

9. Transport in Solids

Diffusion H.R. 6.0-6.2

Flux

Mobility

Nernst-Einstein Equation

Conductivity

Transference Number

Determination of Transference Number H.R. 6.3 & Papers

EMF

Blocking Electrode

Determination of Conductivity H.R. 6.4 & Papers

AC Impedance Spectroscopy P.J.G. Ch. 2 X

10. Solid Electrolytes P.J.G. Ch. 6, H.R. Ch. 7, & Papers

11. Electronic and Mixed Conductors P.J.G Ch. 7 & Papers

12. Ion Transport Membranes P.J.G. Ch. 14

13. Fuel Cells and Electrolyzers P.J.G. Ch. 12 & H.R. 9.2

14. Sensors P.J.G. Ch. 10, H.R. 9.1, & Papers

15. Batteries P.J.G. Ch 11 & H.R. 9.3-9.4

15. Solid State Reactions and Kinetic Investigations P.J.G. Ch. 8, H.R. Ch.'s 10 & 11

17. Other Solid-State Electrochemical Cells H.R. Ch. 8