Electrochemical Reactors

Their Science and Technology

Part A

Fundamentals, Electrolysers, Batteries and Fuel Cells

Edited by
M. I. Ismail

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PREFACE

This book was written to provide a guide for professionals interested in energy transfer and electrochemical technology systems. It covers the state-of-the-art of materials, electrochemistry and electrochemical engineering as related to electrochemical reactors, batteries and fuel cells.

The text is divided into 3 parts, the first (Part A) being devoted to fundamentals of reactors, batteries and fuel cells and covering various aspects of design, parts, construction, materials operation and control systems. Part "B" is devoted to specific reactors such as water electroorganic and inorganic synthesis, electrochemical polymerization, molten salt electrolysis, electrochemical machining, metal finishing, reactor performance, failure mechanisms, corrosion control, materials selection and techniques. Part "C: deals with manufacturing techniques and surface treatment of materials for commercial reactors, commercial parts/materials, fastening, assembly and production of reactor parts and mathematical modelling of various reactor processes. The appendix contains useful data for specialists as well as beginners such as selected recent patents, organizations interested in reactors, a glossary, and the biographic profiles of the authors.

It is hoped that this book will be of value to those working in electrochemical engineering and chemical technology as well as to students of materials science and chemistry especially for courses in thermodynamics, kinetics, heat and mass transfer, fluid mechanics, reactor design, control systems, batteries and fuel cells, and materials for chemical industry and aggressive environments.

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CHAPTER 1

INTRODUCTION TO ELECTROCHEMICAL REACTORS

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Electrochemical Reactors (ECRs) have played a vital role in the advancement of modern society. Widespread availability of electricity and the ever-increasing rate of introduction of new technologies during this century have produced a tremendous growth in the number, types and applications of ECRs. whereas prior to 1900 the only ECRs in widespread use were galvanic cells. We now see the ECR employed in such diverse applications as metals and chemicals production, portable and standby power sources, metal finishing, corrosion control, environmental purification, sensors and medical devices. In fact it is difficult to envision an advanced technological society that does not depend on the ECR to a significant degree.

While the diversity of applications for ECRs have resulted in a bewildering number of reactor configurations, sizes and materials of construction, there exists a set of fundamental (thermodynamic, kinetic, transport and conservation) scientific principles that are common to all ECRs. Armed with these principles and a knowledge of pertinent materials science and economics, the scientist/engineer can, in principle, evaluate ECR components and designs. However, the physical nature of the electrochemical cell, e.g. the complex interaction of transport phenomena and electric fields, and its demanding requirements, e.g. stability of diverse components in an aggressive chemical environment, combine to make the optimal design of an ECR one of the most demanding challenges of modern science and technology.

In view of the complex physical nature of the ECR, the number and diversity of academic disciplines (chemistry, physics, chemical engineering, materials science, metallurgy, economics, mathematics, mechanical, engineering, etc.) which must be applied to ECR research, design and development, and the wide range of applications of ECRs, it is not surprising that comprehensive programs in ECR Engineering are rarely found in universities. It is the purpose of this book to provide a resource for ECR science and technology, and to demonstrate the application of certain fundamental principles to ECR design. The remainder of this chapter outlines fundamental ECR principles and describes their application to various ECR designs.

1.1 FUNDAMENTAL PRINCIPLES

A description of fundamental principles that guide research, design and development of ECRs follows. The general application of these principles is described later in this chapter, rigorous mathematical statements of these principles are given in reference (1), and detailed applications of these principles are presented throughout this book.

1.1.1 Thermodynamics

The most useful thermodynamic principles, terms and equations include relations for charged interfaces, electrode potential, Faraday's law and overpotential; these are used to calculate the terminal voltage of the ECR. This calculated theoretical voltage is compared with the measured value(s) in order to assess the efficency and effectiveness of the various ECR designs. More details are provided in ref. 2 and chapter 2.

1.1.2 Kinetics

The experimental electrochemical methods for determination of kinetic parameters (described in ref. 3 and chapter 3), along with transport rates, define ECR space-time yield and often determine the practical stability limits of the materials employed in ECRs. The rate at which any given electrochemical reaction proceeds, including unwanted side reactions, can be calculated/measured.

1.1.3 Transport phenomena

Transport rates, along with kinetics, determine ECR space-time yield. Heat and mass transfer phenomena are covered in chapter 5, and ECR fluid mechanics are discussed in chapter 11.