

Contents

<i>Foreword</i>	<i>page</i> ix
<i>Preface</i>	xi
Introduction	1
I Electrochemistry and battery technologies	5
1 The electrochemical cell	7
1.1 Definitions	8
1.2 Cell components	8
1.2.1 Electrodes	9
1.2.2 Electrolytes	9
1.2.3 Separators	10
1.2.4 Current collectors	10
1.2.5 Casing	11
1.3 Cell and battery	11
1.3.1 Half cells	11
1.3.2 Full cells: monopolar and bipolar	12
1.3.3 Full cells: three-dimensional	13
1.3.4 Battery	14
1.4 Thermodynamics	14
1.4.1 Chemical and electrochemical potentials	15
1.4.2 Cell voltage	17
1.4.3 Temperature	20
1.5 Electrode and electrolyte processes	21
1.5.1 Electrode kinetics	22
1.5.2 Electrode–electrolyte interfaces	23
1.5.3 Mass transport	24
1.5.4 Ion transport	25
1.5.5 Mass transport in solid states	28
1.5.6 Electrolyte stability	31
1.6 Practical cell measures	32
1.6.1 Cell voltage under load	33

1.6.2	Charge and discharge rates	35
1.6.3	Capacity	36
1.6.4	Energy and power	38
1.6.5	Efficiency	40
1.7	Electrochemical analysis methods	41
1.7.1	Galvanostatic and potentiostatic cycling	41
1.7.2	Cyclic voltammetry	42
1.7.3	Electrochemical impedance spectroscopy	43
1.7.4	Reference electrode	46
2	Battery technologies for electric vehicles	47
2.1	Lead-acid batteries	48
2.1.1	Basics	48
2.1.2	Lead-acid concepts	51
2.2	Nickel metal-hydride batteries	52
2.2.1	Basics	53
2.2.2	NiMH battery materials	55
2.3	Lithium batteries	57
2.3.1	Lithium metal	58
2.3.2	Li-ion and Li-ion polymer	59
2.3.3	Lithium-oxygen	59
2.3.4	Lithium-sulphur	60
2.4	Electrochemical double-layer capacitors	62
2.4.1	Capacitor materials	65
2.4.2	High-energy capacitors	65
2.5	Other battery technologies	66
2.5.1	High-temperature molten-salt batteries	66
2.5.2	Nickel zinc batteries	68
2.5.3	Zinc-air batteries	69
2.5.4	Metal-ion batteries	70
2.5.5	Redox flow batteries	72
2.6	Fuel cells	74
2.6.1	Polymer electrolyte membrane fuel cells	75
2.6.2	PEMFC usage	78
II	Li-ion battery technology – materials and cell design	81
3	Lithium battery materials	83
3.1	Negative electrode materials	86
3.1.1	The solid electrolyte interphase	87
3.1.2	Metallic lithium	89
3.1.3	Carbons	91

התוכן של הספר מוגן על ידי זכויות יוצרים. כל העתקה או הפצה ללא אישור מפורש מהמוציא לאור היא עבירה על החוק. כל הזכויות שמורות.

3.1.4	Alloys	96
3.1.5	Oxides	98
3.2	Positive electrode materials	100
3.2.1	Layered materials	102
3.2.2	The cubic spinel LiMn_2O_4	105
3.2.3	Olivine LiFePO_4	109
3.2.4	Other materials	111
3.2.5	Mixed electrode concepts	113
3.3	Electrolytes and separators	114
3.3.1	Liquid electrolytes	115
3.3.2	Separators	120
3.3.3	Polymer-based electrolytes	123
3.3.4	Ionic liquids as electrolytes	124
4	Cell design	126
4.1	Composite electrodes	126
4.2	Energy and power-optimised electrodes	129
4.3	Energy and power-optimised cells	130
4.3.1	Cell balancing	130
4.3.2	Energy and power relationship	131
4.3.3	Example: energy and power-optimised cells	132
4.4	Cell format and design	134
4.4.1	Cylindrical cells	134
4.4.2	Prismatic cells	135
4.4.3	Pouch cells	135
4.4.4	Cell safety devices	137
4.5	Production processes	137
4.5.1	Safety and reliability	139
III	Battery usage in electric vehicles	141
5	Vehicle requirements and battery design	143
5.1	Vehicle types and requirements	143
5.1.1	Vehicle types	143
5.1.2	Usage conditions	146
5.1.3	Energy and power requirements	147
5.2	Battery design	152
5.2.1	General design criteria	154
5.2.2	Cell selection	156
5.2.3	Additional battery components	163
5.2.4	Design impact on reliability and safety	166

6	Battery control and management	168
6.1	Battery management system	168
6.1.1	Charge and discharge control and methods	171
6.1.2	Thermal control and management	174
6.1.3	Battery monitoring	178
6.2	State functions	179
6.2.1	State of charge	180
6.2.2	State of health	189
6.2.3	State of function	192
7	Battery usage and degradation	194
7.1	Degradation basics and mechanisms	195
7.1.1	Examples: origins of capacity fade	199
7.1.2	Accelerated degradation	201
7.2	Degradation of Li-ion cells	208
7.2.1	General degradation categories	209
7.2.2	Degradation of active materials	212
7.2.3	Degradation of electrolytes	219
7.3	Degradation analysis methods	221
7.3.1	Galvanostatic cycling	222
7.3.2	Electrochemical impedance spectroscopy	223
7.3.3	Incremental capacity	224
7.3.4	Differential voltage	226
7.3.5	Half cell	227
7.3.6	Post-mortem	228
	<i>Glossary</i>	230
	<i>Further reading</i>	234
	<i>Index</i>	235