

Index

a

- ab initio molecular dynamics (AIMD) 293, 297–298, 300–301
- acetylene black (AB) 26, 225, 226, 228
- AC impedance spectroscopy 282–283
- additives, for SIBs electrolytes 184
- adiponitrile (ADN) 186, 187
- All-PBA aqueous batteries 81–82
- $\alpha\text{-Al}_2\text{O}_3$ -PEO-LiClO₄ CSEs 204
- Al_2O_3 -PEO/PVP-NaNO₃ CPE for SIBs 204
- β -alumina 192–193, 237
- anode materials 4–5, 7, 13–15, 20, 23–24, 34, 37, 60, 70, 80, 82, 109–146, 176, 254, 261, 267, 284, 289, 300, 312, 314–315
- atom centered symmetric function (ACSF) 299

b

- back-end assembly process 319–321
- ball mill method 133, 261
- battery failure phenomenon 327, 328
- battery management system (BMS) 278, 317, 321–322, 332
- battery structure design 318, 319
- Bi-based samples 143–145
- binder
 - and conductive agent ratio 318
 - conductive binders 224
 - crosslinked binders 223–224
 - polyacrylic acid (PAA) 221–222

poly(vinylidene fluoride) (PVDF)

220–221

self-healing binders 225

SIBs 26

sodium alginate 222

sodium carboxymethyl cellulose 222–223

Born–Oppenheimer (BO) approximation 298

Bragg's law 256, 288

button cell assembly order 315

c

- Calix[4]quinone (C4Q) cathode bonding IL-based IL 190
- capacity match 316, 318, 325
- capacity test, SIBs 326
- carbonaceous materials 225, 234
- carbon-based anode 109–110
 - graphite 110–111
 - hard carbon 112–116
 - soft carbon 111–112
- carbon-based current collector 234–236
- carbon black
 - acetylene black 226
 - Ketjen black 227–228
 - Super-P 226–227
 - total mass fraction 226
- carbon nanofibers (CNFs) 26, 120, 133, 141, 144, 202, 225, 230–231, 234, 249, 325

- carbon nanotubes (CNTs) 23, 38, 40, 83, 120, 125, 135, 141, 225, 227–228, 231–232, 234
- carbonyl small molecules 88–89
- cathode electrolyte interphase (CEI) 172–173, 185–186, 188, 210–211, 214–217, 237, 321
- cathode materials of SIBs 21–23
- classification 30
 - organic cathode
 - carbonyl small molecules 88–89
 - conductive polymers 89–90
 - working mechanism 86–88
 - oxide cathode
 - layered transition metal oxides 43–67
 - tunnel-type oxides 67–70
 - perovskite transition metal fluorides
 - metal fluorides 82–84
 - sodium metal fluorides 84–85
 - polyanion cathode
 - borates 37
 - mixed polyanions 38
 - phosphates 31–36
 - silicate 37–38
 - sulfates 36–37
 - Prussian Blue 70
- cell capacity 17–18
- cell design
- basic design principles 318
 - safety design 318–319
- cell energy 18
- cell internal resistance 20
- cell life 20
- cell power 19
- cellulose-based separator 219
- cell voltage 16, 187
- charge/discharge rate 19, 20, 301
- charge retention and recovery 326
- chemical/electrochemical methods 323
- chemical method, EC 323
- chemical shift anisotropy (CSA) 273
- classical molecular dynamics (CMD) 293, 296–298
- CNC/CNF based-GPEs 202
- CNT/FeSe₂/C hybrid anode of SIBs 231
- cobalt hexacyanoferrate (CoHCF) 71, 75, 76, 80
- Co-based oxides 118–119
- Co-based phosphide 120–121
- Co-based samples 118, 119
- Co-based sulfide and selenides 119–121
- coherent diffraction imaging (CDI) 250, 251
- compacted density 318
- composite solid electrolytes (CSEs) 172, 173, 203–211, 237
- with active fillers 208–210
 - with passive fillers 204–208
- conductive agent 2, 20, 25–26, 88, 111, 172, 173, 220, 221, 224–232, 237, 238, 318, 319, 331
- conductive binders 220, 224, 238
- conductive polymers 86, 89–90
- constant current charge and discharge 19
- constant voltage charge 19
- conversion anode
- Co-based samples 118–121
 - Fe-based samples 123–127
 - Mo-based samples 128–130
 - Ni-based samples 121–123
 - other metal-based samples 130–135
- CoSe₂/CNFs composite electrode 230
- cost estimation
- manufacturing costs 331
 - raw materials costs 331
- Coulombic efficiency 19, 23, 72, 75, 84, 111, 118, 182, 256, 259, 269
- Cr-based composites 133
- crosslinked binders 223–224
- cryogenic transmission electron microscopy (cryo-TEM) 213
- Cu-based samples 131–132
- current collector, electrode
- preparation 26
- current state of commercialization 332–333
- cut-off voltage 16, 33, 40, 41, 55, 69, 83, 180, 282, 326

- cycle performance 31, 68, 89, 178, 191, 235, 318, 326
 cyclic carbonates 25, 177
 cyclic voltammetry (CV) 279–281
 cylindrical battery 316, 317, 319–321
- d**
 degree of presodiation 323
 depth of discharge (DOD) 20, 332
 depth potential molecular dynamics (DPMD) 277, 278
 digital frequency response analyzer 283
 dipolar coupling 273
- e**
 electrochemical analysis, of SIBs 283, 286
 electrochemical cell 278, 281, 282
 electrochemical cycle 278
 electrochemical energy storage 1, 282, 286
 electrochemical impedance spectroscopy (EIS) 279, 282–285
 electrochemical performances test 325, 326
 electrochemical stability windows (ESWs), of electrolytes 174, 186, 189, 191, 210
 electrochemical window 24, 79–82, 176, 195, 220, 281
 electrode capacity 316
 electrode size 315–316
 electrolyte additives, for SIBs 183
 film formation additives 185–186
 flame retardant additives 186
 with other functions 187–188
 overcharge protection additives 187
 electrolytes 24, 25
 injection volume of 318
 salt, for SIBs 180–183
 electromotive potential 16, 18
 energy conversion efficiency 1, 2, 20, 313
 ester-based solvents, for SIBs 175–178, 180, 186, 212
- ether-based solvents, for SIBs 175–180, 188, 200, 236
 ethylene sulfite (ES) 185
 extended X-ray absorption fine structure (EXAFS) 264–266, 268
- f**
 failure analysis method 328–330
 Fe-based composites 127
 Fe-based oxides 124
 Fe-based phosphides 126–127
 Fe-based sulfides and selenides 124–126
 film formation additives 183, 185–186, 212, 236
 flame retardant additives 183, 186, 236
 fluorine-based additives 185
 fluoroethylene carbonate (FEC) 185, 187, 188, 212, 256
 fluorophosphates 38–42
 formation and sorting process
 formation 321
 grading 321
 sorting 321
 Fourier transform infrared spectrometry (FTIR) spectroscopy 290–292
 free induction decay (FID) 272
 front-end electrode fabrication process
 coating 320
 rolling 320
 slitting 320
 slurry preparation 319
- g**
 galvanostatic charge–discharge (GCD) 279, 281–283
 galvanostatic intermittent titration technique (GITT) 285, 286
 Ge-based samples 145, 146
 gel polymer electrolytes (GPEs), SIBs 172, 197, 200–203
 Gibbs free energy 3, 16, 21
 glass fiber 26, 172, 205, 217, 218, 292, 315
 glass fiber-based electrolyte (GFs-GPE) 205

- graphene, discovery of 228, 230
 graphite anode 110–111
- h***
 hard carbon (HC) 5, 7, 15, 63, 75, 110, 112–116, 176, 249, 286, 323
 hard XAS 264
 hetero-atoms, doping of 112–114
 structure and morphology designing 114–116
 hexacyanoferrates 77
 high and low temperature test 326
 high temperature Na-S battery 312–313
 high-temperature neutron diffraction (HTND) 289
 hyperbranched β -CD based SPE 200
 hyperbranched star-like β -cyclodextrin (H- β -CD) polymer matrix 199
- i***
 imaging and microscopy
 fundamentals of 248
 impact test 327
 in-based samples 135
 inelastic scattering 292
 inorganic solid electrolyte, SIBs
 β -alumina 192–193
 NASICON 193–194
 sulfides 194–196
 inorganic solid electrolytes (ISEs) 172, 173, 192, 194, 195, 197, 203, 237
 in situ AFM 254, 255
 in situ high-energy X-ray diffraction 274
 in situ TEM technique 249, 250
 ionic liquid (IL)-based electrolytes 188–191
 iron hexacyanoferrate (FeHCF) 71–74, 77, 80, 81
- k***
 Ketjen black 225, 227–228
 Knight shift 273, 278
 Knight Shift Anisotropy (KSA) 273

- l***
 laboratory button battery assembly
 button cell assembly order 315
 matching of positive and negative electrodes 315–316
 metal Na anode materials 314–315
 La Môle frequency 270, 271
 large current discharge test 326
 large-scale ESSs 334
 layered transition metal oxides
 air stability 56
 charge compensation 52–54
 mixed-phase layered oxides 64–67
 O3-type layered oxides 60–64
 P2-type layered oxides 57–60
 P3-type layered oxides 64
 structural classification 43–46
 structural evolution 46, 51
 TM migration and dissolution 53–56
 linear sweep voltammetry (LSV) 279
 low pass filters 278
 low speed electric vehicle market 333–334
- m***
 machine-learning molecular dynamics 293, 298–300, 302
 magic angle spinning (MAS) 274–278
 magnetization enhancement 271
 manganese hexacyanoferrate (MnHCF) 71, 73–75
 manufacturing costs 330, 331
 mental-based current collector 232–234
 mercury cadmium telluride (MCT)
 detector 290
 metal/alloy anode
 Bi-based samples 143–145
 Ge-based samples 145–146
 Sb-based samples 135
 Sn-based samples 138–143
 metal fluorides 82–84
 metal hexacyanometallic compounds 71, 77–79
 metal Na anode materials 314–315

- metal-organic framework 83, 125, 130, 201
micrometer zone plate 251
microwave irradiation method 325
mixed phosphates 42–43
mixed polyanions
 fluorophosphates 38–42
 mixed phosphates 42–43
mixed-phase layered oxides 64–67
Mn-based samples 132–133
Mo-based composites 130
Mo-based oxides 128
Mo-based sulfide and selenides
 129–130
monochromator 264
Moseley's law 250
multivariate curve resolution-alternating
 least squares (MCR-ALS) 266, 268
- n**
NaAlO₂ filler dispersed PEO-NaClO₄-PC
 GPE 209
NaBOB/TMP-based electrolytes 182
nail penetration test 327
nanocellulose-based GPE, of cellulose
 nanocrystal (CNC)/cellulose
 nanofiber (CNF)/NaClO₄/EC/PC
 201
Na salts, for SIB electrolytes 181
NASICON 4, 33, 35, 172, 193–194, 196, 208, 209, 237, 267, 324
 type phosphates 33–35
Na_xMnO₂ 57–59, 67
Nb-based composites 134–135
net magnetization 271
neutron diffraction technique 57, 287–289
neutron imaging 248, 251–254
neutron pair distribution function (nPDF)
 method 288
neutron powder diffraction (NPD) 64, 288, 289
Ni-based oxides/sulfides 122
Ni-based phosphide 122–123
Ni-based selenium 122–123
nickel phosphide (Ni₂P) 122, 123
nickle hexacyanoferrate (NiHCF) 71, 75–77, 79
NMR detection 278
NMR interactions 272, 273
nonwoven separator 217, 219–220
nuclear spin-electron spin 272–273
nuclear spin-nuclear spin 273
Nyquist plot 282
NZP-PEO@IL CSEs 209
- o**
olivine-type phosphates 31–33
open circuit potential 326
open circuit voltage 16, 31, 151, 285
Operando pair distribution function
 (PDF) 55, 259, 270, 274
operating voltage 16, 18, 21, 23, 42, 43, 80, 81, 84, 90, 109, 112, 117, 323, 332
optical microscopy 248, 255–256
organic cathode
 carbonyl small molecules 88–89
 conductive polymers 89–90
 working mechanism 86–88
organic liquid electrolytes (OLEs) 171, 173–191, 236
electrolyte additives 183–191
 film formation additives 185–186
 flame retardant additives 186
 with other functions 187–188
 overcharge protection additives 187
electrolyte salt 180–182
organic solvents 175–180
 ester-based solvents 175–177
 ether-based solvents 177–180
physical and chemical properties 173–174
organic solvents, SIBs
 ester-based solvents 175–177
 ether-based solvents 177–180
O3-type layered oxides 44, 60–64
over charge 327
over discharge 327

- over-sodiated method 323, 324
 overcharge protection additives 183,
 187, 236
 oxide cathode
 layered transition metal oxides
 air stability 56–57
 charge compensation 52–54
 mixed-phase layered oxides 64–67
 O₃-type layered oxides 60–64
 P₂-type layered oxides 57–60
 P₃-type layered oxides 64
 structural classification 43–46
 structural evolution 46, 51
 TM migration and dissolution
 53–56
- p**
 Pake bistate 273
 peak cutting and valley filling 334
 PEGDMA-NaFSI SPE 198, 199
 PEO-base SPEs 199, 200
 PEO/CQDs-NaClO₄ CSEs 206
 PEO-FDE-NaClO₄ CSE 206
 PEO-NaOTf-based GPE 201
 PEO-PVP-based SPEs 208
 perovskite transition metal fluorides
 metal fluorides 82–85
 sodium metal fluorides 84–85
 phase interface between electrode and
 electrolyte 210
 cathode electrolyte interphase
 214–217
 solid electrolyte interphase 211–214
 phosphates
 NASICON-type Phosphates 33–35
 olivine-type Phosphates 31–33
 pyrophosphate Na₂MP₂O₇ 35–36
 Pieter Zeeman effect 270
 polyacrylic acid (PAA) binder 26,
 220–222
 polyanion cathode
 borates 37
 mixed polyanions
 fluorophosphates 38–42
 mixed phosphates 42–43
 phosphates
 NASICON-type Phosphates 33–35
 olivine-type Phosphates 31–33
 pyrophosphate Na₂MP₂O₇ 35–36
 silicate 37–38
 sulfates 36–37
 poly(hexaazatrinaphthalene) (PHATN)
 290, 291
 polymer electrolytes (PEs) 172, 197,
 199–203, 237
 gel polymer electrolytes 200–203
 solid polymer electrolytes 197–200
 polyolefin separator 218–219
 poly(vinylidene fluoride) (PVDF) binder
 197, 220–221
 positive and negative electrodes,
 matching of 315–316
 presodiation techniques 322
 EC/chemical methods 323
 factors of 325
 other novel methods of 324–325
 self-sacrificial additive 324
 pressure relief device 319
 prismatic battery 316, 317, 319, 321
 Prussian blue (PB)
 in aqueous SIBs
 All-PBA aqueous batteries 81–82
 single-Redox-Center PBAs 79–80
 two-Redox-Center PBAs 80–81
 in non-aqueous SIBs
 cobalt hexacyanoferrate
 (CoHCF) 75
 hexacyanoferrates 77
 iron hexacyanoferrate (FeHCF)
 72–73
 manganese hexacyanoferrate
 (MnHCF) 73–75
 metal hexacyanometallic
 compounds 77–79
 nickle hexacyanoferrate (NiHCF)
 75–76
 P2-type layered oxides 44, 55–60
 P3-type layered oxides 64
 PVDF-HFP/PMMA-based composite
 GPE 207

pyrophosphate $\text{Na}_2\text{MP}_2\text{O}_7$ 35–36
 $\text{Pyr}_{13}\text{TFSI}$ -based electrolytes, ionic conductivity of 190

q

quadrupole coupling 270, 273, 278
 quasi-solid electrolytes 200
 quenching method 324

r

Raman effect 292–294
 raw materials costs 318, 327, 331
 raw materials, selection of 318
 Rayleigh scattering 292

s

safety performances test 325–327
 Sb -based alloy samples 135–137
 Sb -based samples 135
 Sb -base oxide 137–138
 Sb -base selenium 137–138
 Sb -base sulfides 137–138
 Sb/CNTs composite anode for SIBs 231
 Sb /interconnected carbon nanofibers networks (ICNNs) composite anode 230
 scanning probe microscopy (SPM) 248, 254–255
 scattering amplitude 265, 287
 self-healing binders 220, 225
 self-sacrificial additive 324
 separator, SIBs glass fiber 218
 nonwoven separator 219–220
 polyolefin separator 218–219
 separators, requirements for 25–26
 shift interactions 272–273
 SHINERS 293
 short-circuit test 326–327
 silicon dioxide (SiO_2) 292
 Single-Redox-Center PBAs 79–80
 slurry preparation 319
 Sn -based oxides 141
 Sn -based phosphide 142–143
 Sn -based samples 138–143

Sn -based selenide 142–143
 Sn -based sulfides 142
 Sn @carbon materials 5, 7, 26, 69, 110, 111, 114, 115, 121–124, 127, 131, 136, 139–141, 145, 206, 225, 312
 sodiation process 34, 48, 63, 64, 83, 113, 227, 267
 sodium alginate (SA) binder 220, 222
 sodium carboxymethyl cellulose binder 26, 220, 222–223
 sodium ion batteries (SIBs) 171 advantages of 2
 binder 172, 220–225 conductive binders 224 crosslinked binders 223–224 functions of 220 poly(vinylidene fluoride) (PVDF) 220–221 polyacrylic acid (PAA) 221–222 requirements 220 self-healing binders 225 sodium alginate 222 sodium carboxymethyl cellulose 222–223 conductive agent 172, 225–232 carbon black 225–226, 228 carbon nanofibers 230–231 carbon nanotubes 231–232 graphene 228–230 current collector 172, 232–236 carbon-based 234–236 mental-based 232–234 requirements 232 development of 4–7 electrolytes 171 electron microscopy studies of 249–250 neutron imaging studies of 251–254 optical microscopy 255–256 organic liquid electrolytes electrolyte additives 183–188 electrolyte salt 180–182 ionic liquid (IL)-based electrolytes 188–191 organic solvents 175–180

- sodium ion batteries (SIBs) (*contd.*)
 physical and chemical properties 173–174
 pack design 321
 scanning probe microscopy (SPM) 248, 254–255
 separators 172, 217
 characteristic properties 217
 glass fiber 218
 nonwoven separator 219–220
 polyolefin separator 218–219
 solid state electrolytes
 composite solid electrolyte 203–210
 inorganic solid electrolyte 192–196
 physical and chemical properties 191–192
 polymer electrolyte 197–203
 synchrotron X-ray imaging studies of 250–253
 sodium metal fluorides 84–85
 sodium-nickel chloride battery 313–314
 soft carbon (SC) 66, 111–112
 soft-pack battery 317
 soft XAS 73, 264, 269
 solid electrolyte interphase (SEI) 172, 210–214
 solid polymer electrolytes (SPEs), SIBs 172, 197–200, 208, 209, 237
 solid-state electrolytes (SSEs) 33, 171, 172, 191, 236
 composite solid electrolyte 203–208
 with active fillers 208–210
 electrochemical properties 204
 with passive fillers 204–208
 inorganic solid electrolyte
 β-alumina 192–193
 NASICON 193–194
 sulfides 194–196
 phase interface between electrode and electrolyte 210–217
 polymer electrolyte 197–200
 classification 197
 gel polymer electrolytes 200–203
 solid polymer electrolytes 197–200
- solid-state nuclear magnetic resonance (ssNMR)
 NMR interactions 272–273
 principles of 271–272
 studies of SIBs 273–278
 shift ranges for battery materials 272–273
 spin lattice relaxation process 271
 spin-spin relaxation process 271
 state of charge (SOC) 20, 285
 Stokes diameter 3, 331
 Stokes Raman scattering 292
 sulfide-based inorganic electrolytes 194, 196
 Super-P 225–227
 synchrotron radiation XRD (SRXRD) 247, 256–259, 261
 synchrotron X-ray imaging 250–253
 synchrotron XAS 263, 266, 268
- t**
 TFSI-based IL electrolytes 191
 thermal stability test 327
 Ti_3C_2Tx filler 208
 Ti_3C_2Tx MXene filler 207
 titanium-based anode 116–118
 TM migration and dissolution 53
 trans-difluoroethylene carbonate (DFEC) 185
 tris(trimethylsilyl) phosphite (TMSP) 187, 188, 280
 tunnel-type oxides
 aqueous SIBs 70
 $2 Na_x[MnM]O_2$ (M=Ti, Fe, Co etc.) 69
 Na_xMnO_2 67–69
 Two-Redox-Center PBAs 80–81
- u**
 UIOSNa-based solid electrolyte 203
 ultrasonic waves 320
 $UPyPEG_n UPy-PEO SH$ binder 225
- v**
 V-based composites 133, 134
 Vienna ab initio simulation package (VASP) 300

vinylene carbonate (VC) 145, 185, 186,
280
voltage-time signals 272

W

W-based composites 133–134

X

X-ray absorption 40, 55, 247, 250,
263–270
X-ray absorption fine structure (XAFS)
264–266, 268
X-ray absorption near edge structure
(XANES) 261, 264, 266, 269
X-ray absorption spectroscopy (XAS)
characteristics of 266, 267

principles of 264–266
studies of SIBs 266–268
techniques 266, 267
X-ray beam path 262
X-ray detector 256
X-ray diffraction (XRD)
characteristics of 257–259
principles of 256–258
studies of SIBs 259–262
X-ray tube 256

Z

zero emission battery research activity
(ZEBRA) battery 4, 312–314
Zn-based samples 130–131
Z-PE separator 219

