Index

a
abiogenic resource depletion potential (ADP) 551
advanced counter electrodes, inorganic nanocomposites 392
air gap thickness control 429
alkylenedi oxythiophene polymers 130
amorphous silicon 616
analogous devices 96
anodic aluminium oxide (AAO) film 263
anthraquinone imides (AQIs) 217–219
antimony-doped tin oxide (ATO) nanocrystal thin films 374
AQIs, see anthraquinone imides (AQIs)
aqueous processability and compatibility 158
aromatic imides 216
aromatic quinones 212
atom transfer radical polymerization (ATRP) 318
azobisisobutyronitrile (AIBN), photoinitiator 167

b
bandgap energy 114
Baytron® 338
Beer-Lambert law 367
benchmark systems 552
2,1,3-benzoselenadiazole (BSD) 134
2,1,3-benzothiadiazole (BTD) 134
benzyl viologen 68
– polymer based thin-film type ECD 100
Berlin Green (BG) pigment 45
bi-phenazine, redox reactions 408
binary TMOs system 261
BIPV, see building-integrated photovoltaic (BIPV)
bipyrindilium electrochroes, redox chemistry 58
bipyrindilium-N substituent, effect of 62
bipyridilium salts 79
bipyridilium species 57
– electrochromism in 59
bisEDOT-BTD polymer films 134
bisEDOT-benzotriazole polymer 132
bisEDOT-quinoxaline polymers 135, 136
bisEDOT-thiophene 513
bisProDOT-BSD analogue 134
blacklight 518
Bryksin’s theory 11
building energy management systems (BEMs) 578
building-integrated photovoltaic (BIPV) 420
Burstein-Moss effect 374
1-butyl-3-methyl-imidazolium tetrafluoroborate ([BMIM][BF₄]) 301
carbon footprint 558
carbon nanotubes (CNTs) 274, 276, 277, 612
cathodic electrochromic TMO materials 257
cathodically-colouring polymers 232
CdSe nanocrystal film 373
charge transfer absorption, in tungsten oxide 11
charge-transfer transitions (CT) 185
charged polymers 159
Christiansen effect 554
chromatism 503
chromogenic glass 573–574
chromogenic material 241
chronoabsorptometry experiment 165

Edited by Roger J. Mortimer, David R. Rosseinsky and Paul M. S. Monk.
© 2015 Wiley-VCH Verlag GmbH & Co. KGaA. Published 2015 by Wiley-VCH Verlag GmbH & Co. KGaA.
Index

628
circular dichroism (CD) 217
climate-based daylight modelling (CBDM) 583
CNV, see cyanovinylene (CNV)
coating techniques 165
cobalt hexacyanoferrate (CoHCF) 272
cobalt hexacyanoferrate-PANI nanocomposite 272
coinage metals 26
colloidal nanocrystals 383
– ITO and AZO 379
colloidal plasmonic NCs 383
colloidal synthesis
– of doped metal oxide nanocrystals 377
– surfactant-assisted 377
colour control, via copolymerisation 147
colour rendering factor (CRF) 449, 484–487
colour-changing fabric system 506
– non-electrochromic 517
colour-changing technologies 504
complementary electrochromic device 251, 252
composite electrochromic electrodes 391
composite formation 151
composite polymer electrolytes (CPEs) 294
compound annual growth rate (CAGR) 305
comproportionation process 68
conducting polymers 113
conductivity
– hysteresis for 512
– PEDOT–PSS 510, 511
conjugated conducting polymers
– LBL assembly of 338
– material as EC layers 604
conjugated electrochromic polymers 113, 168
conjugated polymer 228
– as electrochromic materials 274
– electrochromism in 113
– nanostructure of 262
conjugated polymer/organic small molecule nanocomposites 272
conjugated polymer/TMOs nanocomposites 269
conventional electrochromic materials 385
– dual-band nanocrystal-in-glass composite electrodes 385
copolymer microphase separation 315–316
copolymerisation 118
– of blue/green polymer 137
– colour control via 147
– of diamine monomers 227
– of multiple monomers 147
copper hexacyanoferrate 49
counter anion, effect of 64
covalent bonds, subitem electrochromic nanohybrids with 278
CPEs, see composite polymer electrolytes (CPEs)
CRF, see colour rendering factor (CRF)
cyanovinylene (CNV) 118
cyclopentadi thiophene (CPDT) polymer 133
d
D-A polymer of ProDOT-BTD 165
dark silver coated glass
– solar radiation glazing factors for 461
– spectroscopic data for 454
daylight factor (DF) approach 582
De Montfort EC Office installation, case study 584–591
– data collection 587
– daylight illumination spectrum 588–591
– EC glazing installation 585–586
– physical quantities measurement 587–588
decyltrimethylammonium bromide (DETAB) 340
derivatised electrodes 69
1,3-diaminopropane (DAP) 302
dichloroacetic acid (DCA) 222
diquinone derivatives 214
directional hemispherical reflectance (DHR) 429
donor–acceptor (D–A)
– approach 118, 212, 232
– conjugated polymers 233
– interaction 134
– polymers 131
donor–acceptor concept
– using donor heterocycles 118
– using donor oligomers 119
donor-acceptor-donor polymer films 132
donor number (DN) 297
doped metal oxide nanocrystals, colloidal
– synthesis of 377, 378
double-gyroid (DG) 313, 316
– template synthesis 318–320
Drude model 366, 379
DTS, see dynamic thermal simulation (DTS)
dual-band nanocrystal-in-glass composite electrodes 385
dual-band solar control 387
dye-sensitised solar cell (DSSC) 306, 593
dye-sensitised TiO$_2$ 594, 610, 613, 616
dynamic thermal simulation (DTS) 582

e
ECPs, see electrochromic polymers (ECPs)
ECWs, see electrochromic windows (ECWs)
elastane 506
electrical double layer (EDL) 253, 256
electro-inactive oil formation 65
electrochemical deposition 154
  – of ECPs 152
electrochemical impedance spectroscopy (EIS) 265, 603
Electrochemical Quartz MicroBalance (EQMB) 43
electrochemiluminescence 79
electrochrome
  – dopants 151
  – on ECPs 148
  – viologen 80
electrochromic active materials,
nanocomposites of 274
electrochromic applications, polymer electrolytes in 290
electrochromic behaviour, of viologens 268
electrochromic chalcogenide nanocrystals 374
electrochromic conjugated polymers 232
electrochromic devices (ECDs) 61, 68–70,
  73
  – challenges in creating versatile for polymer electrolytes for 307
  – characteristic properties 4
  – charge tansport 251
  – commercialization 406
  – configuration 91
  – exemplar bipyridilium 72
  – ion ttransport in 3
  – layered materials 3
  – manufacturing 31, 32
  – properties 91
  – trends in 305
electrochromic electrodes
  – construct from colloidal plasmonic NCs 383
  – nanostructure 311–313
electrochromic fabric 514
electrochromic fabric devices (EFDs)
  503–505, 507, 508, 513–515
electrochromic foil
  – device design and optical properties 528
  – lifetime and durability 532
electrochromic glass 571, 577, 578
electrochromic glazing 575, 576, 578
  – automatic operation of 578
  – effectiveness of 579
  – zoning of 580–581
electrochromic hosts, electrochromic metal oxide dopants in 262
electrochromic layers 559
  – conjugated conducting polymer materials as 604
  – environmental impact of 559
  – inorganic materials as 599
electrochromic materials
  – classes of 504
  – conjugated polymer as 274
  – devices 402
  – multi-phase 269
  – nanocomposites of 269
  – NIR 235
  – optical modulation of 257
  – organic small molecules as 277
  – TMOs as 275
  – types 402
  – world’s most widely used 405
electrochromic metal oxide
  – dopants in electrochromic hosts 262
  – electronic effects 9
  – optical effects 9
  – overview 6
  – thin films 7
electrochromic Mo oxide 8
electrochromic nanohybrids, with covalent bonds 278
electrochromic organic small molecules 272
electrochromic oxide, thin films 7
electrochromic PB film 42
electrochromic performances 258
electrochromic polymers (ECPs) 126, 133, 149
  – electrochemical deposition of 152
  – functionalisation of 156
  – patterning of 166
  – processability of 152
  – electrochromic process 251
electrochromic product details and practicalities 577–578
electrochromic properties 470
  – chromaticity coordinates 470
  – durability 472
  – efficiency 471
  – energy consumption 472
  – general 470
  – memory and switching time 472
  – reflectance induced limitations 474
Index

electrochromic switchable mirror 245
  electrochromic textile
    – effects of colour based fabric on 513
    – fabric and effect of conductivity on 510
electrochromic thermosetting epoxies 228
electrochromic windows (ECWs) 419, 545
  – commercial 475
  – configuration 456, 473
  – durability of 472
  – multilayer coatings 546
  – spectroscopic data for 455
  – solar radiation glazing factors for 465, 466, 468
  – solar radiation modulation by 425
electrochromic-based eyewear 6
electrochromic-based rear-view mirrors 6
electrochromism 251, 503
  – in bipyridilium species 59
  – in CdSe quantum dots 372
  – in conjugated polymers 113
  – in films of mixed oxide 21
  – in polypyrrole complexes 187
  – in thin films of metal oxides 5
  – in Prussian blue 41, 47
electrodeposited PB film 42
electrodeposition 62
electrofluorochromic process 79
electrolyte functionalisation 538
electrolytes, transparent liquid 3
electropolymerise films, polypyrrolid complexes 187
electron mediators 65
electron spin resonance (ESR) 215
electron-deficient acceptors 232
electron-donating monomers 231
electron-rich heterocycle 118
electron-rich monomers 118
electron-rich polyheterocycles 116
  – electron-rich triarylamines 222, 223
electronic transitions 115, 185
  – classification 185
electrophoretic deposition (EPD) 259, 351–353
  – vs. LBL deposition technique 351
  – electropolychromism 79
electropolymerisation 140, 187
  – of tridentate bisruthenium complexes 188
  – of trideconate bisruthenium complexes 188
electropolymerise macromonomer 135
electropolymerism, in oxidative
electropolymerised films 192
  – reduction, viologen 80
emeraldine salt (ES) 146
  emissivity 436
  – by heat flow meter apparatus 437
  – by hemispherical reflectance 440
  – by specular IR reflectance measurements 437
emissivity determination 430
  – by heat flow meter 428
  – by hemispherical reflectance 428
  – by specular IR reflectance 428
enediyne 236
epoxy resins 227
EQMB, see Electrochemical Quartz MicroBalance
3,4-Ethylenedioxy selenophene (EDOS) 234
  3,4-ethylenedioxy thiophene (EDOT) 263
  – polymerization of 263
eutrophication (EP) 558
exemplar bipyridilium ECDs 72
external visible solar reflectance 434
f
  Faradaic process 363
  Fick’s second law 344
  fill factor (FC) 608
  film morphology, effect of 64
  flexible electrochromic fabric device 516
  float glass
  – solar radiation glazing factors for 461
  – spectroscopic data for 452
  Flory–Huggins mean field theory 315
  fluorinated tin oxide (FTO) 257, 619
  Fourier transform infrared (FTIR) 372
  fullerene molecules 27
  fused aromatics 122
  fused ring systems 133
  – black 135
  – cyan/green 133

g
  gallium hexacyanoferrate 49
  gasochromic devices 245
  gasochromic switching 242, 243
  gasochromic system 575
  gel electrolyte 507
  gel polymer electrolytes (GPEs) 292
gelatin 304
  Gentex mirror 74, 76
  glass layers, in window pane 452
  GPEs, see gel polymer electrolytes (GPEs)
  Grätzel ECD device 78
  graphene, Prussian blue on 46
  green neutral-state polyheterocycle 133
  Guyot-Sionnest group 373
gyroid-structure vanadium pentoxide 320–322
gyroid-structured nickel oxide 326–328

h
hammer drill effect 79
head-to-head (HH) arrangement 120
head-to-tail (HT) arrangement 121
heat flow meter
  – emissivity by 437
  – emissivity determination by 428
heat transfer 451
  – coefficients of glazing 441
  – factor 441
hemispherical directional reflectance (HDR) 429
hemispherical reflectance
  – emissivity by 440
  – emissivity determination by 428
heptyl viologen (HV) 65, 69
  – dication salts of 64
  – films 64
  – preparation and characterisation 94
  – reduction potential of 65
  – solid-with-solution ECD 93
  – visible spectra of 94
hexacyanoferrate, PB analogues as 49
hexaniobate 346
high-performance polymers 223
  highest occupied molecular orbital (HOMO) 114
homopolymerisation 118
homopolymers 315
  – selenophene-based 129
  – thiophene-based 127
hybrid ECDs 92
hybrid electrochromic nanocomposites 391
hybrid transparent conductors 29

i
IBM ECD device 74
ICI ECD device 72
immobilising viologen electrochromes 69
In situ polymerisation 30, 155, 265
indigo carmine (IC) dye 274
indium hexacyanoferrate 49
indium-tin-oxide (ITO) 257, 528
infrared (IR) radiation 421
inner Helmholtz plane (IHP) 253
inorganic materials, as EC layers 599
inorganic nanocomposites, for advanced counter electrodes 392

inorganic NIR electrochromic materials 211
inorganic proton electrolyte 559
insulated glass unit (IGU) 529
inter-valence charge transfer (IVCT) 212
internal visible solar reflectance 434
intervalence charge transfer coloration materials, assembly of 340
ion conductor 3
ion functionalised polymers 161
ion transport 3
  – in electrochromic device 3
ionic liquid 300, 353
  – based ECD 97
  – polymer electrolytes 300
iris effect 529

I
Langmuir-Blodgett (LB) process 253
layer-by-layer (LBL)
  – adsorption 337
  – deposition 163, 252
  – for polyelectrolytes 163
  – hexaniobate 346
  – in electrochromic materials 337
  – metal oxides 342
  – nickel hydroxide 349
  – of conjugated conducting polymers 338
  – of intervallence charge transfer coloration materials 340
  – technique 163
  – titanium oxide 348
  – tungsten oxide 344
  – vanadium oxide 346
  – vs. electrophoretic deposition 351
LBL, see layer-by-layer (LBL)
leuco-DMP 75
leucoemeraldine base (LB) 161
LFER, see linear free-energy relationships
life cycle assessment (LCA) 545
  – aircraft case 567
  – automotive sunroof case 564, 565
  – for EC target applications 564
  – goal and scope definition 562
  – house even hold case 566
  – novel plastic-film based EC devices 560
  – to electrochromic smart windows application, 549
ligand vpy 187
ligand-centred (LC) transitions 185
ligand-to-ligand CT (LLCT) 185
ligand-to-metal CT (LMCT) 185
light emitting diode (LED) 504
  – tehnology 518
linear free-energy relationships (LFER) 59
linear poly(ethylene imine) (LPEI) 163
liquid crystal display (LCD) technology 518
liquid electrolytes 289
liquid-crystal displays (LCDs) 73
lithium trifluoromethanesulphonylimide (LiTFSI) 295
localised surface plasmon (LSP) 365
localised surface plasmon resonance (LSPR) 365, 366, 368
– absorption 370, 379
– in colloidal silver 369, 370
– wavelength 369
LUMO, see lowest unoccupied molecular orbital (LUMO)
low band gap polymers 232
low emittance glass
– solar radiation glazing factors for 461
– spectroscopic data for 452
lowest unoccupied molecular orbital (LUMO) 114
LSPR, see localised surface plasmon resonance (LSPR)
lutetium phthalocyanine 235
m
macroporous WO$_3$ film 260, 261
Manos devices 404
Maxwell’s equation 366, 367
mesoporous 3-dimensional nanostructure 312
mesoporous DG templates, synthesis of 318–320
mesoporous electrodes 312
metal hexacyanometallate-viologen based ECDs 104
– prospects 105
metal hexacyanometallates 91
metal hydrides, for smart window application 246
metal metallohexacyanates akin to PB 48
metal oxides
– as electrochromic films 342
– layer-by-layer assembly of 342
metal-based films 26
metal-based nanowires 29
metal-based transparent conductors 26
metal-centred (MC) transitions 185
metal-organic framework (MOF) materials 197
metal-to-ligand CT (MLCT) transitions 185
metal-to-metal CT (MMCT) 191
methacrylate functionality 167
– EDOT and ProDOT monomers 167
methacrylate-substituted ECP-Magenta, photo-patterning 167
methyl viologen (MV) 57, 80
– molar absorptivity 59
micellar viologen species, effect of 62
micro-electromechanical systems (MEMS) 574
microwave-assisted phosphorylation 305
Mie theory 369
minimally colour changing polymer (MCCP) 143
monomers 315
multi-colour electrochromic polymers 145, 148
multi-coloured electrophochromism 144
multi-coloured states, in ECPs 143
multi-electrochromism 91
multi-phase electrochromic materials 253, 269
multi-walled carbon nanotube (MWCNT) 274, 275
multilayer electrodes 347
multiple redox states model 146
Mulvaney group 369, 370
MV, see methyl viologen
n
Nafion® 80, 81
NanoChromics™ cell 76
NanoChromics™ device 71, 76–78
nanocomposites
– of electrochromic materials 269
– of electrochromic/non-electrochromic active materials 274
– hybrid electrochromic 391
– organic small molecule 272
– TMOs 269
nanocrystal-based plasmonic electrochromics, design principles for 382
nanocrystal-in-glass film 386, 389
nanocrystalline cellulose (NCC) 304
nanocrystals (NCs)
– colloidal ITO and AZO 379
– colloidal plasmonic 383
nanoparticles
– electrolyte functionalisation by 538
– immobilisation 351
nanostructural electrochromic materials 251
– classification 252
– preparation method 253
– preparation routes of 254
nanostructure
– of conjugated polymers 262
– electrochromic electrodes 311
– organic metal complexes 267
– PANI 264
– polypyrrole 266
– polythiophene derivatives 263
– of TMOs 253
– viologens 268
nanowire-based coatings 27
naphthalene diimides (NDIs) 212, 216–218
n-dopable polymers 232
near infrared 115
– radiation 421
near-infrared region (NIR) 211, 212
– absorption 212, 214, 219, 228, 229
– chiral signal 219
– electrochromic devices 221
– electrochromic materials 215, 235
– electrochromic polymers 218
– electrochromism 212, 214, 218, 222
Nernst equation 414
Nernst equilibrium 413
nickel hexacyanoferrate 48
nickel hydroxide 349
night-vision system (NVS®) mirror 74–76
NiO electrodes, electrochromic displays based on 328–329
non-colloidal approaches 391
non-electrochromic active material, nanocomposites of 274
non-electrochromic colour-changing fabric 517
non-Faradaic mechanisms 363
non-porous WO₃ films 260
non-symmetric type PECD 613
novel plastic-film based EC devices 560
NTERA ECD device 76

o
occupant-based studies, VTG 583–584
octahedral coordination 10
octyltrichlorosilane (OTS) monolayer 319
operational factors 578
optical density 471
optical switching property 242
organic metal complexes, nanostructure 267
organic NIR electrochromic materials 211
organic small molecule
– as electrochromic materials 277
– nanocomposites 272
organic soluble/processable PPProDOT-ester 165
organic-soluble polymers 163
orthorhombic crystalline vanadium pentoxide 320
outer Helmholtz plane (OHP) 253
oxidation 150
oxidative polymerisation 167
oxide films 25
oxide-based electrochromics 6

P
palladium hexacyanoferrate 49
partial-molar shift parameter 262
PB, see Prussian blue
p-doping 115
PECd, see photoelectrochromic device
PEDOP, see poly(3,4-ethylenedioxyrrrole) (PEDOP)
PEDOS, see poly(3,4-ethylenedioxy-selenophene) (PEDOS)
PEDOT, see poly(3,4-ethylenedioxythiophene)
PEDOT–PSS, see poly(3,4-ethylenedioxythiophene)/poly(styrene sulfonate) (PEDOT–PSS)
Pd, see poly(ethylene glycol) (PEG)
pendant amine groups 163
pentacenediquinone 215
PEO, see polyethylene oxide (PEO)
performance prediction, using building simulation tools 582–583
pernigraniline base 161
peroxy-tungstate complex 260
PHECD
– operating parameters 95
– properties 95
Philips ECD device 72
photo voltaic-ECD device 616
photochemical ozone creation potential (POCP) 558
photochromic fabric 517, 518
photochromism 517
photoelectrochromic cells (PECC) 600
photoelectrochromic device (PECD) 593, 614, 615
– absorption spectra of 598
photoelectrochromic device (PECD) (contd.)
- combine type 610
- configuration 615
- non-symmetric type 613
- optical performance of 610
- parallel type 616,617
- with PEDOT based EC layer 606
- photographs of 598,602
- schematic diagram 599
- separate type 594,609
- solid state 612
- structure of 594
- transient transmittance response 609
- transmittance 613
- transmittance change 603
- transmittance switching 607,608
- transmittance transients of 604
- types 594,595
- wavelength of short-circuit 599
photoelectrochromic windows 619
photolithographic technique 166
photovoltaic (PV) cell 616
plasmonic colloidal nanocrystals 365
- dual-band nanocrystal-in-glass composite electrodes 385
- metal oxide 382
- NIR-selective mesoporous electrodes 384
plasmonic electrochromics
- electrodes 379
- film 381
- materials 377
- nanocrystals 363,382
plasmonic electrochromism 363
plasmonic nanocrystals 365
plasmonic semiconductor nanocrystals 379
plastic film 574
poly (methyl-2-methylpropenoate), see poly(methyl methacrylate) (PMMA)
poly vinyl butyral (PVB) 32
poly(2-acrylamido-2-methyl-1-propane-sulfonic acid) (PAMPS) 146
poly(3,4-(2,2-dimethyl-propylenedioxy) thiophene) (PProDOT-Me₂) 607
poly(3,4-(2-methylene)propylenedioxy-thiophene) (PMPProDOT) 263,264
poly(3,4-alkylenedioxyppyrole) (FXDOP) 117
poly(3,4-ethylenedioxy thiophene)/WO₃ nanocomposite 270,271
poly(3,4-ethylenedioxyppyrrole) (PEDOP) 117,275
poly(3,4-ethylenedioxyxselenophene) (PEDOS) 116
poly(3,4-ethylenedioxythiophene) (PEDOT) 116,128,157,160,229,263,338
- light intensity transmitt 605
- nanotubes 264
- nanostructures 263
- NiO composites 272
- PEDOT-C14 157
- polymer structure 606
- PSS/WO₃ hybrid thin films 270
- synthesis and structure 160
- thin film, spectroelectrochemistry 229
- ZnO composites 272
poly(3,4-ethylenedioxythiophene)/poly(styrene sulfonate) (PEDOT–PSS) 159,160,506,507
- conductivity trends of 510
poly(3,4-propylenedioxyppyrole) (ProDOP) 118,140
poly(3,4-propylenedioxythiophene) (PProDOTMe₂) 296
poly(3-methyl thiophene) (P3MT) 144
poly(AMPS) 69
poly(aniline) (PANI) 340
poly(bisEDOT pyridine) 150
poly(bisEDOT pyridopyrazine-biphenyl) 150
poly(butyl viologen) (PBV) thin films
- electrochemical properties 98
- ECD 97
- optical properties 98
- preparation 97
poly(butyl viologen) (PBV)–PB ECD 99
poly(ethylene glycol) (PEG), polymer electrolytes 295
poly(ethylene oxide) (PEO) 391
poly(methyl methacrylate) (PMMA), polymer electrolytes 296
poly(propylene carbonate) (PPC)-based polymer electrolytes 302
poly(styrene sulfonate) (PSS) 127
poly(styrene) (PS) 318,319
poly(thieno[3,4-b]thiophene) (PT34bT) 160
poly(trans-1,2-bis(thienyl)vinylene) 131
poly(triarylamines) 221,223,225,226,228
poly(vinyl butyral) (PVB) gel electrolyte 384
poly(vinylidene fluoride) (PVDF), polymer electrolytes 297
poly(vinylidene fluoride-co-hexafluoropropene) (PVDF–HFP) 608, 609
– nanofibrous membrane 299
poly(vinylidene fluoride-trifluoroethylene) (PVDF-TrFE) 297, 298
poly(vinylimidazole) (PVI) 297, 298
poly[3,6-bis(2-[(3,4-ethylenedioxy)thiienyl]-N-methylcarbazole] (PBEDOT-N-MeCz) 296
polyallylamine hydrochloride (PAH) 163
polymethacrylates 293
polyaniline (PANI) 146, 222, 392, 604
– EC layers 605, 606
– EC properties of 604
– electrochemical reaction of 605
– films 266
– nanostructure 264
– redox states 604
– synthesis route and performance 280, 281
polyaniline/WO_3 nanocomposite 271
polydimethylsiloxane (PDMS) 263
polyelectrolytes 293
polymer electrolytes, cost and neutrality 291
polyethylene oxide (PEO) 347
– based polymer electrolytes 295
polyethylene terephthalate (PET) 528
polyethyleneimine–lithium bis(trifluoromethylsulfonyl) (PEI) 539
polyhedral oligomeric silsesquioxane core-poly(4-styrenesulfonic acid) (POSS-PSS) 265
polyheterocycles 116
– electron-rich 116
polymer bandgap 118
polymer electrolytes
– bond rotation 291
– cation coordination ability 291
– electrochromic applications in 290
– facile process 290
– flexible, printable, bendable and shape-conformable 303
– functional separator 290
– high ionic conductivity 290
– high transparency in wavelength 291
– ionic liquids-based 300
– low volatility 291
– PEO/PEG-based 295
– PMMA based 296
– potentially green biodegradable polymer 303
– PPC-based 302
– PVDF based 297
– robustness 290
– transference number 290
– trends in 303
– wide potential window 291
polymer electrolytes types 291
– CPEs 294
– GPEs 292
– polyelectrolytes 293
– SPEs 292
polymer self-assembly and gyroid nanomorphology 315
polymer-dispersed liquid crystal (PDLC)
– films 554
– technology 553
polymeric electrolyte (PE) 603
polymeric liquid crystal (PIL) 301
polymeric NIR electrochromic materials 212
polymerisable terthiophene (PTT) 148
polymerisation, of TPA-based dicarboxylic acids 227
polypyrrole complexes, electrochromism in 187
polyoxometalate (POM) clusters 386
polypyrrole (PPy), nanostructure 266
polypyrrole–PB composite film 100
polypyrrole–PB thin film
– performance 101
– preparation 101
polystyrene (PS) 265
polystyrene derivatives, nanostructure 263
porous AAO film 263
PProDOT-Et₂, polymer structure 608
ProDOT, see 3,4-propylenedioxythiophene propylene carbonate (PC) 289, 608
3,4-propylenedioxy pyrrole (ProDOP) 126
3,4-propylenedioxythiophene (ProDOT) 124, 157
– copolymerisation 125
protonic liquid (PIL) 353
Prussian blue (PB) 91, 340
– analogues as hexacyanoferrates 49
– and HV solid-with-solution ECD 93
– direct cell reaction and 45
– electrochromism 41, 47
– on graphene 46
– layer-by-layer deposition of 46
– metal hexacyanoferrates akin to 48
– nanocomposites film structure 278
– preparation 45, 46
– with viologen hybrid ECDs 92
– with viologen solid-solid ECDs 93
**Index**

Prussian blue thin film 42, 102
- ECD 97
- in ionic liquid based ECD 97
- preparation and characterisation 94
Prussian blue film, visible spectra 94, 95
pulse potentials 79
push-pull of electrons 118
PVDF, see poly(vinylidene fluoride) (PVDF)
PXDOP, see poly(3,4-alkylenedioxyppyrole) (PXDOP)
pyrene diimide (PDI) 216–218
pyridopyrazine heterocycle 150
pyrroles 117
- conjugated polymers 229

**q**
quasistatic limit 366
quinone derivatives 213

**r**
radical cation 58, 59
- dimer 68
- effect of dimerised 67
- oxidation to 115
rear-view mirrors, electrochromic-based 6
redox behaviours 94
redox chemistry, bipyridilium
electrochromes 58
redox reaction 251, 256, 257
- of bi-phenazine 408
redox transformation 92
redox-system of azulene-substituted
ediynes 236
reduced graphene oxide (rGO) nanosheets 275
reduction, in single material 150
regioregularity 120, 121
retroreflected radiation beam 423
room temperature ionic liquid (RTIL) 300, 301
RP, see ruthenium purple
RTIL, see room temperature ionic liquid (RTIL)
ruthenium complexes, polymeric films of 188
ruthenium purple (RP) 48

**s**
SageGlass 576–578
Sb-doped tin oxide nanocrystal films 375
secondary heat transfer factor 441
selenophene derivatives 235
selenophene-based homopolymers 129
self-assembled monolayers (SAMs) 196
self-erasing effect 404
self-erasing electrochromism 404
semiconductor nanocrystals 367
semiquinones, physical properties 213
silicon thin-film solar cell (Si-TFSC) 617, 619
silver nanoparticle 347
simulation tools, performance prediction
using building 582–583
single TMOs system 257
single-walled carbon nanotube (SWCNT) 279, 612
Site Saturation Model (SSM) 344
Sken-imines 149
smart window application, metal hydrides for 246
SMPF, see solar material protection factor (SMPF)
solar absorbance 436
solar factor (SF) 430
- calculation 488, 490
- for double glazing 446
- for single glazing 445
- for triple glazing 447
solar heat gain coefficient (SHGC) 440, 575, 578
solar material protection factor (SMPF) 432
solar radiation 421, 479
- modulation by ECWs 425
- through window panes and glass structures 421
solar radiation glazing factor 420
- application of 476
- ECWs 466, 468
- for float glass 462
- measurement and calculation method 430
- modulations 468
solar reflectance 435
- external visible 434
- internal visible 434
solar regulation 419
solar skin protection factor (SSPF) 433, 482
solar transmittance 431
solid polymer electrolytes (SPEs) 292
solid-solid type ECDs 93
solid state photoelectrochromic device 612
solid-state switchable mirror 246
solid state viologens 103
solid-with-solution ECD 93
solution-phase dimer 67
solution-phase EC materials 401
solution-phase EC systems 402
solution-phase electrochromic device 411
solution-phase pH indicators 403
spandex electrode 509, 512
spectroelectrochemical method 343
spectrophotometry 428
specular IR reflectance
  – emissivity determination by 428
  – measurements 437
specular transmission 572
SPEs, see solid polymer electrolytes (SPEs)
starburst polymer 142
steric interactions 120
substituent paraquat 58
substitution effect 214
succinonitrile 97
sulfonated polyimide (SPI) 160
supercapacitors 325
supercritical carbon dioxide (SCCO$_2$) 299
surface confined polymerisation 149
surface plasmon resonance (SPR) 340, 365
surface-confined EC materials 401
surfactant-assisted colloidial synthesis 377
suspended particle device 574
switchable mirror materials 242
switchable mirror thin film 241, 242
switching durability 243
symmetric diblock copolymers 315

t
  tail-to-tail (TT) arrangement 121
template assisted synthesis 257
tetrapentylammonium perchlorate (TBAP) 371
tetrahydrofuran (THF) 265
tetrahydropyranyl (THP) 166
tetramethylphenylenediamine (TMPD) 61
thermal conductance 442
thermochromic fabric 517
thermochromic glazing 575
thermochromism 517
thermoelectrochromic system 516
thienoviolagen electrochrome 80
thiénylenevinylene copolymers 122
thin film deposition parameters 18
thiophene-based conjugated polymers 229
thiophene-based homopolymers 127
thiophene dimers structure 121
3-dimensional nanostructuring ions 312
3-dimensional nanostructuring strategies 313
3D-ordered macroporous (3DOM) 265
  – PANI film 265
titanium oxide 348
TMOs, see transition metal oxides (TMOs)
transition metal oxides (TMOs)
  – binary type system 261
  – as electrochromic materials 275
  – nanocomposites 269
  – nanostructure of 253
  – single type system 257
transition-metal complexes
  – drop-cast thin films of 200
  – electropolymerised films of 192
  – redox properties of 185
  – self-adsorbed multilayer films of 196
  – self-assembled multilayer films of 196
  – spin-coated thin films of 200
transmissive polymers, colour to 123
  – blue and purple 127
  – orange and red 125
  – yellow 124
transmittance modulation 425, 426
transparent conductive oxides (TCOs) 376, 550, 619
transparent electrical conductors 31
  – metal-based films 26
  – nanowire-based coatings 27
  – oxide films 25
transparent liquid electrolytes 3
transparent sate, colour in 244
tridentate bisruthenium complexes,
electropolymerisation 188
triocetylphosphate oxide (TOPO) ligands 373
triphenylamines (TPA)
  – diacids 227
  – diamines 227
  – polyamide polymers 141
  – radical cations of 225
tungsten oxide 8, 344
  – charge transfer absorption in 11
u
  ultraviolet radiation 420, 421
ultraviolet solar transmittance 430, 477
v
  vanadium hexacyanoferrate 48
  vanadium oxide 346
  – electrodes, electrochromic display 322–324
vanadium pentoxide
  – gyroid-structure 320–322
  – orthorhombic crystalline 320
variable optical attenuator (VOA) 211
variable transmission glazing (VTG) 573–577
viologen
- anchored TiO$_2$ based ECD 99
- counter anion in 64
- dication 65
- electrochemistry 58
- electrochemiluminescence 79
- electrochromic behaviours of 268
- electroreduction 80
- in ionic liquid based ECD 97
- incorporate within paper 80
- monomers 69
- nanostructure 268
viologen doped poly(3,4-ethylenedioxythiopene) polymer based ECD 102
viologen electrochromes 79, 80
- immobilising 69
- type 1 61
- type 2 61
- type 3 68
visible (VIS) radiation 421
visible solar transmittance 431, 478

W
W–Ni-oxide 21
W–Ti oxide, electrochromism of 8
water soluble
- ECPs 162
- organic processing to 163
- PThs 162
water switchability, organic processing to 163
water-soluble polymers 163
window pane
- configurations 427
- glass layers in 452
- solar radiation glazing factors for 461
- solar radiation through 421
WO$_3$ nanorods 258, 259
- film 259

Z
zinc hexacyanoferrate (ZnHCF) 274