

## Index

### **a**

absorbance model 5, 6  
 acetonitrile (ACN) 20, 22, 71, 80, 95,  
 125, 228, 387, 390, 391  
 acid group 111–112, 130  
 aggregation-enhanced emission (AEE)  
 281  
 aggregation-induced emission (AIE) 96,  
 394  
 all-in-one mobile phone 467, 468  
 Ambilight Inc. 483  
*N,N'*-bis(4-aminophenyl)-*N,N'*-  
 diphenyl-1,4-phenylene diamine  
 25  
 amorphous 3PA-TT film 345  
 anion ( $\text{ClO}_4^-$ ) irreversible trapping 493  
 anionic modification 107  
 anodically coloring polymers 22,  
 205–208  
 anodic (4-(diphenylamino)phenyl)  
 methylphosphonic acid (DPP)  
 493  
 anodic electrochromic materials 447  
 anodic materials 108, 112, 129, 447,  
 473  
 anthraquinone imides 434  
 asymmetric substitution 113  
 (Au NR)@PANI nanostructures 365  
 auto-dimming interior mirror market  
 471  
 auto-dimming rearview mirror 450  
 azobenzene 75, 76, 203

### **b**

bacterioRhodopsin (bR) 462  
 benzene/diphenyl ester derivatives 57  
*p*-benzoquinone (BQ) 88, 380  
 benzothiadiazole 210, 236, 237, 249, 403,  
 406, 407  
 bifunctional self-healing EC polymer 25  
 biological ion detection 454  
 bio-polar material PTTzFr 457  
 bithiophene-bridged viologens 118  
 black electrochromic compounds 483  
 black-to-transmissive 5–7, 202, 284, 286,  
 299, 484  
 bleaching/discharging processes 174  
 BOE Technology Group Co., Ltd.  
 477–481  
 bond-coupled electron transfer (BCET)  
 90, 91, 93  
 Bragg optical diffraction 354  
 bridged tetra-aryl-*p*-quinodimethanes  
 (BTAQs) 101

### **c**

camouflage clothing 465  
 Canon Inc. 476, 477  
 carbazole-based conjugated ELC polymer  
 406  
 cathodic electrochromic materials 447  
 cathodic 1-(9-hexyl-9*H*-carbazole)-10-  
 (propylphosphonic acid)-4,  
 40-bipyridilium dichloride (CPD)  
 493

- cathodic materials 108, 129, 132, 447, 473
- cation coordination ability 18, 19
- ceramic electrolytes 17, 30
- ceramic polymer electrolytes 27–30
- chameleon skin 462
- charge transfer complex (CTC) 289
- charge transfer (CT) interactions 288
- chemical oxidation polymerization 365
- chlorotetrazine (TZ) 379
- chronoabsorptometric responses 9
- closed bipolar electrode (C-BPE) system 173
- colloidal crystals 354, 355, 357, 360
- coloration efficiency (CE) 9–11, 318
- combined-type PECD 417, 420–421
- conducting polymers  
 polyaniline (PANI) 432–433  
 poly(pyrrole)s 433  
 poly(thiophene)s 427–432
- conjugated polymers  
 carbazole 406–407  
 fluorene 403–404  
 ProDOT 404–406  
 triphenylamine 399–403
- controllable luminescent switching 373
- core-shell colloidal crystals 357
- cosmetic treatment 454
- coumarin 128, 134, 203, 482
- covalent organic framework (COF) 2, 5, 105, 327–348
- cross-linked polycarbazoles derivatives 249–260
- cross-linking polymer electrolytes (CPEs) 20, 26–27, 34, 37
- cyclic voltammetry (CV) 58, 62, 64, 117, 148, 157, 165, 166, 329, 457, 492
- d**
- dendritic TPA-based polymers 399
- density functional theory (DFT) 81
- DHPV<sup>2+</sup>2Cl<sup>-</sup> 493, 494
- dialkylthiophene (DAT) 196
- 4,4'-diaminotriphenylamine (TPA) 270
- 2,2'-dicyano-1,1'-dimethyl-4,4'-dipyridinium dimesylate 453
- dielectric nanostructures 359
- Diels–Alder (DA) reaction 24
- 3,4-di(2-ethylhexyloxy)thiophene (AcDOT) 193
- 5,7-di(furan-2-yl)-2,3-dihydrothieno[3,4-b][1,4]dioxin (Fu-EDOT-Fu) 492
- 2,5-bis(2,3-dihydrothieno[3,4-b][1,4]dioxin-5-yl)furan (EDOT-Fu-EDOT) 492
- bis(dihydroxyalkyl) viologen 493  
 (1,1'-bis(2,3-dihydroxypropyl)4,4'-bipyridine derivative dichloride 493
- dimerization 107, 111, 112, 121, 128–131, 134, 333
- dimethoxythiophene (DMOT) 193
- 1,1'-di-methyl-4,4'-bipyridilium 425
- 1,1'-dimethyl-4,4'-bipyridine 107
- dimmable rearview mirror 450
- dioxythiophenes (DOTs) 192, 196
- dip-coating methods 314–315
- diphenylacetylenes 84–85
- diphenylarylfuranone 482
- 1,1'-disubstituted-4,4'-bipyridine compounds 105
- dithieno(3,2-b:2',3'-d) pyrrole (DTP)-NH<sub>2</sub> monomer 457, 458
- donor-acceptor approach 236–237, 484
- donor-acceptor OEC materials 492
- donor-acceptor polymers 203
- donor-acceptor structure 78, 193
- drop-on demand (DOD) 498
- dye-sensitized solar cells (DSSCs) 17, 415, 420, 430, 454, 456  
 combined-type PECD 420–421  
 partly covered-type PECD 421  
 separated-type PECD 419–420  
 smart EC window 422  
 structure of 418
- dynamic random access memory (DRAM) 281

**e**

- e-beam lithography 364, 369
- EC COFs 327, 328, 341–348
- EC MOFs
  - guest@MOF composite system 340–341
  - MOF-based double-sided EC device 339–340
  - NDI-based organic linkers 328–335
  - photochromic and electrochromic, multi-responsive MOF 338–339
  - pyrene-based organic linkers 332
  - TPA organic linkers 334
  - transport of electrolyte ions 335–338
- electroactive molecular luminophores 382, 383
- electroalkali 81
- electrochemical contrast measurements 7
- electrochemical degradation 492
- electrochemical deposition method 149
- electrochemical plasmonic switching performances 364–365
- electrochromic (EC) active polymers 214
- electrochromic and multiapplications 170–175
- electrochromic biosensors 457, 460
- electrochromic chromophore 493
- electrochromic contrast 5–8,
- electrochromic devices (ECDs) 1, 132, 143, 150–154, 415, 417, 445, 420
- electrochromic effect 124
- electrochromic-energy storage device (EESD) 174
- electrochromic materials 1, 365–369, 446
  - history of 3
  - nanostructured 365–369
  - near-infrared (NIR) 433–434
  - in PECD 425
  - technology development of small molecule 50
  - viologen structures 110
- electrochromic polymers (ECPs) 213, 362, 484
- carbazole-based polymers, properties of 237
- categories and operation mechanism 183–186
- polypyrroles (PPy)
  - electrochromic properties of 218
  - polypyrrole-based terarylene systems 233
  - structural modification 218–235
- soluble ECPs 208–215
- synthetic methods 186–190
- thiophene-based polymers
  - color-tuning strategies 191–195
  - typical colored polymers 195–208
- electrochromic process 1, 160
- electrochromic windows 415, 425, 445–450
- electrochromism 1, 3
  - electrochromic materials 365–368
  - parameters
    - coloration efficiency (CE) 9–11
    - electrochromic contrast 5–8
    - optical memory 11–12
    - stability 12–14
    - switching time 8–9
  - photonic crystals (PCs) materials 354–359
  - plasmonic structures 359–365
- electrode modification 101, 105, 107
- electrodeposition 149, 156, 161, 359, 361, 366
- electrofluorochromic (EFC) 373
- electroluminescence (ELC)
  - conventional mechanisms of
    - energy transfer (EnT) 376
    - electron transfer (ET) 376
    - intrinsic 375–376
  - definition 373
  - emission contrast
    - intensity difference 377
    - intensity ratio 377
    - spectrum area ratio 377
  - long-term stability/cycle life 377–378
  - nanocomposite films 407
  - polymers 387

- electroluminescence (ELC) (*contd.*)  
 small molecules  
 dyads 378–380  
 electroactive luminophores  
 382–386  
 luminophores system 380–381  
 redox-active moiety 380–381  
 switching time 377  
 transition metal complexes  
 europium complex 386–387  
 iridium complexes 387, 390  
 ruthenium complexes 386  
 working mechanisms of 375  
 electrolytes, PECD 435  
 electron-transfer 391  
 electron transfer mechanism (ET) 90,  
 375, 376  
 electropolymerizable monomer 319  
 electropolymerization 120, 121, 125,  
 128, 216, 221, 230, 238, 241, 247,  
 249, 255, 315, 318, 322, 323, 357,  
 359, 367, 430, 457  
 electro-responsive materials 357  
 electro-responsive polymers 355  
 energy transfer (EnT) mechanism 376  
 Essilor 108, 134  
 ester groups possess 112  
 3,4-ethoxylene dioxy thiophene (EDOT)  
 58, 429  
 3,4-ethylenedioxythiophene (EDOT)  
 121, 492  
 europium complex 386
- f**  
 fabrication procedure 160, 461, 497  
 facile electrochemical 373  
 fiber-shaped dye-sensitized solar cells  
 (FDSSCs) 420  
 film fabrication 318, 341, 348  
 fireproof product manufacturing  
 company 471  
 flat bed screen printing 501  
 fluidic cell method 357  
 fluoran dye derivatives 50, 85–91  
 fluorine 184, 208, 308, 382, 391, 393,  
 396, 403–404  
 fluorescein 88, 89, 92, 94, 95, 203, 380  
 fluorescence quenching 115, 173, 234,  
 382, 386, 391, 406, 407  
 fluorescence spectrum 56, 119, 173, 174,  
 377  
 fluorophore 89, 119, 373, 376, 378–380,  
 382  
 food preservation 451–454  
 food products 452  
 forbidding photo-induced electron 376  
 fructose dehydrogenase (FDH) 456  
 furan 183, 184, 492  
 5-(furan-2-yl)-2,3-dihydrothieno[3,4-b][1,  
 4]dioxin (EDOT-Fu) 492  
 Furcifer Inc. 483–484
- g**  
 gelatine 20, 21, 32–34, 37  
 gel electrolytes 20, 22, 23, 27, 33, 66, 128,  
 129, 134, 151, 156, 249, 311, 404,  
 435, 480, 493, 494, 495  
 gel polymer electrolyte (GPE) 20–21, 35  
 Gentex Corporation 105, 132, 134, 445,  
 450, 471–474  
 graphene-based EC systems 157  
 grazing incidence wide-angle X-ray  
 scattering (GIWAXS) 343  
 green electrochromic compounds 483
- h**  
 Haoruo 134, 482  
 heptyl viologen 4, 107, 113, 130, 285,  
 311, 386, 426, 427  
 hidden rear camera 467, 468  
 honeycomb-like PEDOT (H-PEDOT)  
 nanostructure networks 368  
 hydrogen bonding 24, 92, 94  
 hydrogen silsesquioxane (HSQ) nanoposts  
 362  
 hydrothermal method 149  
 7-hydroxycoumarin 380  
 2-(2-(4-hydroxystyryl)-6-methyl-4H-pyran-  
 4-ylidene)malononitrile 380

**i**

- indium hexacyanoferrate (InHCF) 164
- indium tin oxide (ITO) 50, 124, 154, 157, 285, 339, 379, 430, 435, 476
- inkjet printing 498–500
- inkjet-printed chemical-sensor applications 366
- inkjet-printing method 460, 461
- inorganic films 365
- inorganic kinds 446
- intensity ratio 377
- intervalence charge transfer (IVCT) 318, 345
- intramolecular charge transfer (ICT) 81, 328, 379
- ionic liquid electrolytes 39, 185, 427
- ionic liquids (ILs) 30, 128
- ions transport 5, 348
- iridium complexes 386, 387, 390
- irreversible electrochemical oxidation 492
- isophthalate derivatives 3, 4, 50, 62, 64–79

**l**

- Langmuir–Blodgett (LB) technique 163
- large-area organic thin films 498
- layer-by-layer (LbL) method 115, 150, 314, 315
- ligand-to-metal charge transfer (LMCT) 295, 296
- linear polycarbazole derivatives 241–250
- 3,6-linked polycarbazole derivatives 243
- liquid electrolytes 8, 17, 21, 34, 39, 123, 129, 185, 427, 494, 495
- lithium iodide (LiI) 33, 435
- long-term memory 12
- luminophores system 380–381

**m**

- main-chain polyviologens 120, 122
- Menshutkin reaction 110, 122, 123
- metal-to-ligand charge transfer (MLCT) 295
- metallic plasmonic structure 359

- metallo-supramolecular polymers (MEPE) 460
- Cu<sup>I</sup>-based metallo-supramolecular polymers 305
- Cu<sup>II</sup>-based metallo-supramolecular polymers 305–308
- electropolymerized conducting metallopolymers 315
- Eu<sup>III</sup>-based metallo-supramolecular polymers 308–311
- hetero-metallic system 311–314
- layer-by-layer self-assembly and dip coating methods 314–315
- single metallic system
  - Co<sup>II</sup>-based metallo-supramolecular polymers 299–301
  - Fe(II) and Ru(II)-based metallo-supramolecular polymers 296–299
  - Zn<sup>II</sup>-based metallo-supramolecular polymers 301–305
- metallohexacyanates 143–175
- metal–organic frameworks (MOF) 1, 108, 305, 327–348
- methyl ketone derivatives 4, 50, 79–84
- methyl viologen (MV) 24, 130, 426
- microelectrochemical measurement 214, 367
- microporous organic polymer (MOP) gel 128, 129, 495
- mobile phones 465, 467, 468, 480, 481
- modified atmosphere (MA) packaging 452, 455
- mono-electron oxidation process 270
- multicolored electrochromism 96, 203, 205, 236, 243
- multicolored transformation 203
- multifunctional separator 18
- MV triarylamine systems 272

**n**

- nanobipyramids (NBPs) 364
- nanocomposites 108, 150, 154–160, 213, 353, 378, 407, 408, 429
- nano-imprinting 354, 364, 369

- nanorods (NRs) 160, 171, 335, 364  
 nanospheres (NSs) 3559, 364, 369  
 nanostructures  
   disadvantages 365  
   in electrochromism 353  
 naphthalene diimide (NDI) 5, 328  
 naphthalimide (NI) 4, 281, 378  
 near-infrared (NIR) electrochromic materials 433–434  
 near-infrared (NIR) region 5, 196, 272, 297, 343, 379  
 Ninbo Ninuo Electronic Technology Co., Ltd. 481–483  
 nitrogen heterocycle species 112–113  
 non-conjugated polymers  
   poly(amides) 391–396  
   polyimide 396  
 non-viologen compounds 476  
 NU-901 films 332, 333  
 nucleophilic cyanide anions 407
- O**
- oligofurans 492  
 oligo-/polyfuran 492  
 oligo-/polythiophenes 492  
 oligothiophenes 57–59  
 One Plus Corporation 465  
 open-circuit memory 11, 12, 71  
 open-shell structure 375  
 OPPO Guangdong Mobile Communications Co., Ltd 468, 477–481  
 optical memory 11–12, 76, 150, 183, 297  
 optical transmission 362, 363  
 optimized ITO/PB/CdTe electrochromic fluorescence switching system 174  
 OPV-based PECVD 423–425  
 organic disposable electrochromic time indicator 456  
 organic electrochromic (OEC) devices  
   dimnable rearview mirror 450  
   donor–acceptor compounds 465  
   electrochromic device 460–462  
   full solution method 462  
   mobile phones 465, 468  
   sensors  
   bio-sensing application 454–460  
   food preservation 451–454  
   smart windows  
   electrochromic materials 446–450  
   prospects 450  
   structure and working mechanism of 445–446  
 organic electrochromic (OEC) materials 492  
   inkjet printing 498–500  
   long-term stability of 491–495  
   mechanical stability of 495–498  
   screen printing 501–502  
   slot-die coating 500–501  
   spray coating 500  
   viologens 493  
 organic–inorganic hybrid materials 1  
 organic kinds 446  
 organic soluble polymer 212  
 oxidation/reduction charge 159  
 oxygen transmission rates (OTR) 496
- P**
- PANI@PMMA particles 357  
 PANI/PSS nanoparticles 365, 366  
 partly covered-type PECVD 421–422  
 patterned electrochromic devices 368, 369  
 PBEDOTPh 115  
 PEDOT:PSS cathode 456, 457  
 PEO/PEG-based electrolytes 21  
 perovskite-based PECVD 424  
 peroxidation of thiophene group 493  
 perylene dipentylimide 373  
 phenanthrocarbazole induced a red-to-transmissive polymer (PDEP) 198  
 phenyl-ProDOT-based conjugated polymers 404  
 phosphate ions (PPI) 456  
 photoelectrochromic devices (PECVDs)  
   advantages 417  
   electrochromic materials in

- conducting polymers 427–433
- NIR region 433–434
- small molecule 425–427
- electrolytes in 435
- power supply for
  - DSSC 418–423
  - OPV 423–425
  - PSC 423
- substrates 435–436
- technique development process 416, 417
- photoelectrochromic smart windows (PECSW) 420
- photoluminescence quantum yield (PLQY) 288
- photonic crystals (PCs)
  - advantage 357
  - colloidal 355
  - example 354
  - polyaniline (PANI) 357
  - structural color characteristics of 359
  - tunable color in 355
- photopic contrast 7
- pH-responsive fluorescent fluorescein 380
- phthalate derivatives (PDs) 57, 75
- pi-conjugated chromophores 484
- pigments-1,3-squaraines 451
- plasmonic color laser printing 365
- plasmonic electrochromic switchable configurations 364
- plasmonic nanoslit arrays 362
- plasmonic nanostructures 364, 365, 369
- plasmonic pixels 362
- plasmonic structures 359–365
- plasmon peak shifts 365
- poly(2-acrylamido-2-methylpropane-sulfonic acid) (PAMPS) 150
- poly(alkylenedioxy-pyrrole)s 433
- polyamides (PAs) 4, 269, 391–396
- polyaniline (PANI) 150, 357, 362, 365, 432–433, 492
- polyaniline/manganese dioxide (PANI/MnO<sub>2</sub>) 359, 361
- polyaniline@poly(methyl methacrylate) (PANI@PMMA) core-shell nanoparticles 357
- polyaniline-poly(4-styrene sulfonate) nanoparticles 366
- poly[2,3-bis-(3-octyloxyphenyl)quinoxaline-5,8-diyl-alt-thiophene-2,5-diyl] 214, 367, 493
- poly[3,6-bis(2-(3,4-ethylenedioxy)-thienyl)-*N*-methylcarbazole] (PBEDOT-*N*-MeCz) 22
- poly(butylviologen dibromide) 453, 455
- poly(carbazole) 1, 3, 4
- polycarbazoles (PCARB) 238
- poly(2,5-dimethoxyaniline) (PDMA) 21
- poly(2,2-dimethyl-3,4-propylenedioxythiophene) (PolyProDOT-Me2) 362
- poly(3,4-dimethylthiophene) 4
- poly(3,4-disubstituted thiophenes) 428
- poly(2,2'-dithiophene) 4
- poly(3,4-ethylenedioxythiophene) (PEDOT) 120, 365, 366, 428, 430, 492
- poly(ethylene glycol) (PEG) 435
- polyethylene oxide (PEO) 21
- polyfuran 492
- poly(3-hexylthiophene-2,5-diyl) (P3HT) 367
- polyhydrazides 492
- poly(hydroxymethyl 3,4-ethylenedioxythiophene) (PhmEDOT) 430
- polyimides (PIs) 4, 269, 281, 396
- poly(2-isopropyl-2-oxazoline) (PiPOx-v) 123
- polymer electrolyte
  - ceramic polymer electrolytes 27–30
  - classification 17
  - cross-linking polymer electrolytes (CPEs) 26–27
  - electrochemical devices 17
  - electrochromic applications
    - flexible and mechanically stretchable 18
    - high optical transparency 18
    - multifunctional separator 18
    - safe and environmentally friendly 19

- synthesis 19
    - thermal, photo, chemical and electrochemical stability 19
    - working temperature 18
  - gel polymer electrolyte (GPE)
    - PEO/PEG based electrolytes 21
    - PMMA 21–22
    - PVDF 22–23
  - gelatin 32–33
  - ionic liquid 30–32
  - self-healing material 24
  - types 20
  - polymer electrolytes 17–40, 108, 135, 150, 154, 423, 435, 494
  - polymer formation process 484
  - polymerization method 107, 188, 323, 430, 475
  - polymerized monomer 484
  - polymers
    - advantage 387
    - conjugated
      - carbazole 406–407
      - fluorene 403–404
      - ProDOT 404–406
      - triphenylamine (TPA) 399–403
    - non-conjugated
      - poly(amides) 391–396
      - polyimide 396
  - polymethyl methacrylate (PMMA) 20, 21, 89, 128, 339, 357, 360, 455
  - poly(3-methylthiophene) 4, 165, 203
  - poly(1,3,4-oxadiazole)s 492
  - poly(3,4-propylenedioxythiophene) (PProDOTMe<sub>2</sub>) 22
  - poly(3,4-propylenedioxythiophene) (PProDOT) 430
  - polypyrroles 1, 3, 4, 107, 120, 184, 185, 216–257, 366, 433, 434, 492
  - polyselenophenes 492
  - poly(3-substituted thiophenes) 428
  - polythiophenes 1, 3, 4, 58, 120, 123, 184, 185, 203, 225, 235, 427–433, 492
  - poly(vinyl butyal) (PVB)-carbonate gel electrolyte 493
  - poly(vinylidene fluoride) (PVDF) 20, 22
  - poly(vinylidene fluoride-co-hexafluoropropylene) (PVDF-HFP) 435
  - polyviologen electrochromes 453
  - polyviologens 120, 122, 453
  - porous polymeric microspheres 356, 357
  - power conversion efficiency (PCE) 423
  - Precision Optical Instruments Laboratory 476
  - ProDOT-based copolymers 196
  - 3,4-propylenedioxythiophene 210
  - Prussian blue (PB) 3
    - assembled electrochromic devices (ECDs) 150–154
    - crystal structure of 144–145
    - electrochromic and multiapplication 170–175
    - electrochromic mechanism 145–147
    - metallohexacyanates 160
    - nanocomposites 154–160
    - synthetic technology 147–150
    - technology development of 144
  - Persian blue analogs (PBA) 160–169
  - PSC-based PECD 423
  - pyridinium-based EC materials 76
  - pyronin Y-doped silica (PYDS) nanoparticles 407
- q**
- quantum dots (QDs) 171, 353, 407
  - quinone/hydroquinone 373
- r**
- reactive oxygen species (ROS) sensing 175
  - redox group-controlled material 376
  - redox mediator 33, 125–127, 131, 132
  - refluxing process 357
  - repairable gel 482, 483
  - rhodol 380
  - Ricoh Company, Ltd. 475–476
  - roll-to-roll production method 4, 14, 183, 447, 450, 498
  - ruthenium–bipyridine complex 386

**S**

- Schott company 450
- screen-printed flexible ECDs 501
- screen printing 165, 499, 501–502
- seeded polymerization 356–358
- selected area electron diffraction (SAED)  
pattern 345
- self-erasing effect 11
- self-healing polymer electrolytes 24–27,  
37
- self-powered photoelectrochemical device  
454, 455
- self-powered visual biosensor 459
- separated-type PECD 417, 419–420
- short-term memory 12
- slot-die coating 499–501
- small molecule electrochromics 49–50
- diphenylacetylenes 84–85
- fluoran dye derivatives 85–91
- hydrocarbon derivatives-NIR-OEC  
99–101
- isophthalate derivatives 64–79
- methyl ketone derivatives 79–84
- PH-responsive molecules derivatives  
92–95
- terephthalate derivatives 56–63
- TPA dye derivatives 95–99
- violene–cyanin hybrid material 50–56
- smart EC window 422
- smart windows 415
- electrochromic materials 446–450
- prospects 450
- structure and working mechanism of  
445–446
- social energy consumption 450
- solid electrolytes 8, 29, 34, 421, 435, 494,  
495
- solution processing 198, 364, 365, 498
- solvent pretreatment 483
- spectroelectrochemical cell 373
- spectroelectrochemical method 68, 81
- spectroelectrochemistry (SEC) 5, 6, 228,  
304, 373, 434, 466, 492
- spin coating 2, 148, 149, 165, 167, 169,  
316, 365, 497
- spray coating 2, 148, 149, 495, 498–500
- static random access memory (SRAM)  
281
- steric effects 192–193
- Stille coupling 123, 187, 188
- 5-substituted isophthalate derivatives  
62, 64–66, 68
- 3- and 3,4-substituted polypyrroles  
235–236
- N*-substituted polypyrroles 218–235
- 1,1'-substituted viologen 111–113
- succinonitrile 435
- 1,10-bis (3-sulfonatopropyl) viologen  
(SPV) 493
- Suzuki polycondensation 187
- switching fluorescence 375, 391
- switching fluorescent 376
- switching time 8–10, 33, 73, 79, 81, 84,  
92, 98, 108, 118, 154–156, 159, 213,  
220, 221, 228, 230, 234, 237,  
247–249, 251, 256, 278, 305, 314,  
318, 333, 340, 345, 348, 377, 386,  
399, 426, 430, 432, 434, 436, 450
- synthetic methods 31, 147, 186–190
- synthetic opals 354–355

**t**

- TA-based electrochromic polyimides and  
polyamides
- backbone modulation 283–289
- EC materials 277–278
- electrofluorochromism (EFC) materials  
278
- multiple functions EC material  
281–283
- side group engineering 276–283
- TATF COF film 345–347
- template-assisted electropolymerization  
357
- terarylene systems 233, 237
- terephthalate derivatives 3, 4, 56–64, 69,  
79
- tetra-2-pyridyl-1,4-pyrazine (TPPZ) 315
- tetraphenylbenzidine (TPB) cation radical  
272
- tetraphenylethylene (TPE) unit 394

- tetraphenyl-*p*-phenylenediamine (TPPA) 272
- tetrathiafulvalene–boradiazaindacene (TTF-BODIPY) compound 379
- 2,3,4,5-tetrathiopenyl-thiophene (X-T) 59
- tetrazine compounds 373, 376, 379
- 3D nanopatterning approach 366
- 3D nanostructured conjugated polymers 366
- thermal regulation technologies 1
- thiazolo[5,4-*d*]thiazole-based viologens derivatives 386
- thiazolo-[5,4-*d*]thiazole (TTz) heterocycle 109
- thiazolothiazole (TTz) unit 113–115
- thionine 453, 455
- thiophene 1, 54, 55, 60, 68, 183, 186–188, 190–215, 223, 225, 243, 315, 318, 428, 471, 480, 493
- 5-(2-thiophenyl)-phthalate 64
- time-dependent density functional theory (TDDFT) 64
- time/temperature indicator 451
- titanium isopropoxide 435
- transition metal oxides (TMOs) 1, 3, 49, 433, 446
- transmittance model 5, 6
- transmittance response 160, 166, 168, 449
- transmittance spectra 146, 151, 156, 157, 160, 164, 166, 168, 169, 230
- transparent conducting electrode (TCE) 435, 496
- transparent graphene film 156, 157
- triarylamine (TA) 4, 270, 434
- triarylamine-based aromatic polymers 270–271
- triarylamines (TAAs) 122, 333, 376
- triphenylamine (TPA) 382, 399, 493
- 2,4,6-triphenyl-1,3,5-triazinyl esters 78
- tungsten oxide (WO<sub>3</sub>) 21, 150
- turn-off time,  $t_{\text{off}}$  377
- U**
- ultraviolet radiation polymerization 475
- V**
- violene–cyanin hybrids 50–56
- viologen compounds 4, 128, 131, 134, 386, 425, 453, 476, 477, 482, 493
- viologen molecules 108, 109, 111, 130, 357, 482
- viologen organic electrochromic materials (OEC)
- conjugate ring system expansion 113–119
- direct substitution reaction 110
- electrochromism and electrochemistry 109
- polymerization strategy 119
- research of 105–109
- 1,1'-substituted viologen 111–113
- viologen electrochromic device
- aggregation and solubility 131
- cathodic anode separation structure 125
- conductive medium 128
- dimerization 128–130
- driving voltage 131
- electrolyte layer 126
- five-layer classic structure 124–125
- redox mediator 126–127
- reflective device structure 126
- response time 131
- simple sandwich structure 125
- Zincke reaction 110–111
- W**
- water dispersed electrochromic polymer nanoparticles (WDENs) 214, 366–368, 566
- water vapor transmission rates (WVTRs) 496
- X**
- X-ray diffraction (XRD) 332, 340, 345
- Z**
- zinc hexacyanoferrate (ZnHCF) 165
- Zincke reaction 110–111, 120