

Index

a

absorption competition-induced emission (ACIE) 204
 adenosine triphosphate (ATP) 373, 415
 adoptive cell therapy (ACT) 417, 427–429, 432
 agarose gel electrophoresis (AGE) 226
 Ag-based quantum dots 10
 aggregation-caused quenching (ACQ) 18, 95, 160, 278
 aggregation-induced emission (AIE) 95
 luminogens 278, 464
 aggregation-induced luminescence 18
 aggregation-induced photothermal (AIP) effect 457
 aggregation induced quenching 18, 95, 160, 278
 AIE luminogens (AIEgens) 278
 alkali metal halides 314
 alkaline-earth metal halide 314
 alpha-fetoprotein (AFP) 201, 202
 alternating current light-emitting diodes (AC-LEDs) 305
 alternating magnetic field 420
 aminopropyltriethoxysilane (APTES) 285
 4-aminothiophenol (4-ATP) 201
 amphiphilic polymers 192, 353
 antibiotic resistance 449–452
 antibody-dependent cellular cytotoxicity 428
 anti-epithelial cell adhesion molecule (EpCAM) 202, 498

antigen-presenting cells (APCs) 415
 antimicrobial PDT (aPDT) 453, 455
 anti-programmed death-ligand 1 (α -PD-L1) 165
 apoptosis 162, 165, 168, 226, 234, 253, 277, 293, 358, 361, 373, 374, 376–378, 386–389, 414, 420, 508, 526, 527, 539
 aqueous sol-gel method 124
 artificial atoms 10
 automatic nanomaterial synthesizer (ANS) 128

b

benzo[a]phenoxazine (BPOx) 52
 biodegradable nanomaterials 30, 32
 biological detection 137, 354–355
 biomass photothermal nanomaterials 20, 27–29
 biomolecules detection 198–202
 bioreceptors 481, 482
 biorecognition element 40, 41, 478, 481–482, 489, 494, 495, 497
 biosensing, definition 477
 biosensors, UCNM-MOF composites 170–171
 biosynthesis method 348–349
 (4-{2,2-bis[(4-formylphenoxy)methyl]-3-(4-formylphenoxy)propoxy} (BFPB) 453
 black phosphorus (BP) 286, 413
 based nanoprobe 50–51

- black phosphorus nanosheets (BPNSs) 26, 286
- black phosphorus QDs (BPQDs) 461, 463
- Bohr radius 10, 188, 343, 518
- Boltzmann constant 194
- Boltzmann distribution equation 194
- boron dipyrromethene (BODIPY) 18, 277–278, 280, 290
- bovine serum albumin (BSA) 360, 425, 459, 516
- brain natriuretic peptide (BNP) 208, 209
- C**
- Caenorhabditis elegans* 249, 256
- camptothecin (CPT) 386
- Ca²⁺ nanomodulators (CaNMs) 382
- cancer cell membrane (CCM) 422
- cancer immunotherapy 381, 382, 384, 399, 429
- cancer therapy 131
- photodynamic therapy 131
 - photo-gene therapy 135–136
 - photo-immunotherapy 133–135
 - photothermal therapy 131–133
- Carbapenem-resistant Enterobacteriaceae (CRE) 468
- carbon-based nanomaterials 24, 36, 48, 50, 236, 238, 400, 410
- carbon-based nanoprobe 50
- carbon-based photosensitizers 284–285
- carbon-based photothermal nanomaterials 24–25
- carbon nanodots (CD) 238
- carbon nanotubes (CNTs) 24, 50, 220, 410, 411, 457–458
- carbonyl cyanide 3-chlorophenylhydrazone (CCCP) 384
- carcinoembryonic antigen (CEA) 202
- Cas9 227, 290
- Caspases 374–376
- cationic poly(urethane amide) (CPUA) 237
- cationic polymer 19, 26, 196, 223–224, 228, 236–238, 428, 463
- Ce6-loaded mesoporous silica nanorods (CMSRs) 285
- cerium (Ce³⁺) based nanophosphors 512
- cetyltrimethylamine bromide (CTAB) 250
- chemodynamic therapy (CDT) 167, 277, 282, 360, 406, 450
- chemotherapy 95, 135, 148, 160, 165, 168, 233, 235–236, 269, 274, 277, 293, 358, 374, 377, 386, 387, 399, 407, 411, 414, 507, 536
- chimeric antigen receptor (CAR) 399, 427
- chimeric antigen receptor T (CAR-T) 375
- chitosan (Chitosan) 223
- chitosan-CpG nanocomplexes (Chi-CpG-NPs) 425
- chlorin e6 (Ce6) 34, 273
- circulating tumor cells (CTCs) 202, 357, 358, 413, 498
- circulating tumor DNA (ctDNA) 354, 355, 497
- cisplatin 235–236
- clustered regularly interspaced short palindromic repeat (CRISPR)/CRISPR associated protein 9 (Cas9) 227, 290
- combined type I and II X-ray excited PDT 531, 532
- complementary metal-oxide-semiconductor (CMOS) 210
- composite photoelectrochemical materials 480–481
- conduction band (CB), metal oxides-based photosensitizers 288
- conjugated polyelectrolyte (CPE) 226
- conjugated polymers 22, 27
- connective tissue growth factor (CTGF) 234

- cooperative energy transfer upconversion (CET) 82
- cooperative upconversion (CU) 120–121
- copper quinone GOx nanoparticles (CQG NPs) 390, 392
- co-precipitation method 123
- core-shell-shell (CSS) nanophosphors 513
- covalent organic frameworks (COFs) 282–283
- creatine kinase-MB (CK-MB) 481
- CRISPR-Cas gene editing technology 219
- cross relaxation regulation
NIR downshifting modulation 92–93
UCNPs 91–92
- cross-relaxation (CR), UCL process 120
- crystal field (CF) regulation 85–87
- crystal field (CF) theory 85
- cyanine dyes 18, 55, 203, 278, 293, 459
- cyclodextrin (CD) 228
- cytokine release syndrome (CRS) 375–376
- cytotoxicity 253
testing 254
- cytotoxic T lymphocyte (CTL) 415, 416
- cytotoxic T lymphocyte antigen 4 (CTLA-4) 417
checkpoint 418–420
- d**
- damage-associated molecular patterns (DAMPs) 133, 375–379, 390, 393, 400, 414, 415, 425
- Darwin's theory 126
- demethylation-activated pyroptosis 386–389
- dendritic cells (DCs) 377, 414
- density functional theory (DFT) 155, 158, 328
- dexamethasone (DEX) 279
- Dexter energy transfer (DET) 187–190
- diethylaminoethyl Dextran (DEAE-dextran) 223
- 3,4-dihydroxyhydrocinnamic acid (DHCA) 153
- diketopyrrolopyrrole (DPP) 277
- 4,5-dimethoxy-2-nitroacetophenone (DMNPE) 230
- dimethylformamide (DMF) 154, 192
- direct lanthanide-triplet energy transfer (DTET) 290
- direct photoelectrochemical detection 493–494
- dissociation-enhanced lanthanide fluoroimmunoassays (DELFLIA) 202, 203
- donor-acceptor-donor (D-A-D) 277
- downconversion/quantum cutting (QC) 83
- downshifting luminescence 79
5d-4f transition 81
4f-4f transition 79–81
- downshifting nanoparticles (DSNPs), design of 191–192
- doxorubicin (DOX) 27, 165, 403
- dye sensitization 95, 190
dye-sensitized core nanocrystals 95–96
dye-sensitized core/shell nanocrystals 96–97
dye-sensitized core nanocrystals 95–96
dye-sensitized core/shell nanocrystals 96–97
- e**
- electric dipole (ED) operator 80
- electric field modulation 100–104
- electric quadrupole (EQ) operators 80
- electroluminescence (EL) 98
- electron computed tomography (ECT) 356
- electrostatic attraction 159, 171
- endogenous contrast agents 46–47
- energy migration (EM), nonradiative transition 84
- energy migration upconversion (EMU) 82

- energy transfer (ET) 83, 119, 187, 191, 489
 lanthanide doped nanoparticles 187
 multilayer core/shell nanostructure 120
 nonradiative transition 83–84
 phonon-assisted 93–95
 energy transfer (ET) regulation
 energy transfer-triggered novel upconversion excitation 90
 multicolor tuning of upconversion emissions 89–90
 energy transfer upconversion (ETU) 82
 enhanced green fluorescent protein (EGFP) pDNA 223
 enhanced permeability and retention (EPR) effect 220, 273, 357
 enzyme-labeled amplification 484
 enzymes, biorecognition elements 481
 enzyme sensitive probes 53–54
 epigallocatechin gallate (EGCG)-modified BPQDs 461
 eukaryotic translation initiation factor(eIF) 236
 excited state absorption (ESA) 82, 97, 118
 Lanthanide-doped imaging 119
 exogenous contrast agents 47–48
 extended-spectrum beta-lactamase (ESBL) 455, 468
 external field modulation
 electric field modulation 100–104
 magnetic field modulation 99
 plasma resonance enhancement 104–105
 extracellular matrix (ECM) 269, 279, 407, 416
- f**
 few-layer graphene (FLG) 458
 4f-4f luminescence 182
 fibroblast activation protein (FAP) 275
 fluorescein isothiocyanate (FITC) 285
 Fluorescence Resonance Energy Transfer (FRET) 511
 fluorescence spectroscopy (FL) 353
 fluorescent nanomaterials 9
 organic fluorescent nanomaterials 18–20
 quantum dots 10–12
 rare earth luminescent nanomaterials 13–18
 silicon-based fluorescent nanomaterials 12–13
 force-induced charge carrier storage (FICS) 330
 Forster resonance energy transfer (FRET) 14, 96, 165, 187, 290
 framework-8 nanoparticles (ZIF-8 NPs) 382
 functional nanomaterials 3
- g**
 GAG@mSiO₂@RB nanocomposites 514
 gasdermin B (GSDMB) 376
 gasdermin D (GSDMD) 374–376, 379, 390
 gasdermin E (GSDME) 374–376, 379, 382, 386–390
 gene delivery, UCNPs 221
 gene therapy 135, 219
 non-viral vectors 220
 and syndication
 chemotherapy 235–236
 phototherapy 234–235
 genetic algorithm (GA) 126–127
 glucose oxidase (GOx) 165, 166, 207, 390, 403, 419, 494
 gold-based nanoprobe 48
 gold nanomaterials 36, 457
 gold nanoparticles
 NIR-responsive PTT agents 455–457
 UCNP (Au-UCNP) 198, 201
 gold nanorods (GNRs) 455–456
 gold nanoshells 456
 gold silver nanocages (GSNCs) 457
 granzyme A (GzmA) 376
 granzyme B (GzmB) 375
 graphene oxide (GO), carbon-based nanomaterials 410–411

graphene QDs (GQDs) 461
 graphitic carbon nitride 479
 green fluorescent protein (GFP) 224,
 231, 255, 257
 ground state depletion (GSD) 97
 GSDMD N-terminal (GSDMD-N) 374
 GSH-sensitive probes 52–53

h

halogen oxides 317
 harmony search algorithm (HSA) 127,
 128
 heat shock protein 70 (HSP70) 234–235
 heat shock proteins (HSPs) 414, 415, 467
 HeLa cells 164, 166, 223, 224, 248, 255
 hematoporphyrin monomethyl ether
 (HMME) 285
 hemoglobin molecules 28
 hepatitis B virus (HBV) 426
 heuristic algorithms (HAs) 126
 highest occupied molecular orbital
 (HOMO) 402
 high mobility group B1 (HMGB1) 415
 high mobility group protein 1 (HMGB1)
 373
 Hodgkin lymphoma 417
 Hong Kong University of Science and
 Technology (HKUST-1) 150
 hot-injection method 347, 349, 350
 human mesenchymal stem cells (hMSC)
 231
 hybridization chain reaction (HCR) 354,
 484, 485
 hydron-bonded organic framework (HOF)
 284
 hydrophilic polymers 150, 277
 hydrophilic synthesis method 347–348
 hydrothermal method 347, 350–351,
 355, 408, 533
 hydrothermal/solvent thermal method
 122
 hydrothermal/solvothermal method
 122, 190
 hypochlorous acid (HOCl) 205
 hypoxia-sensitive probes 53

i

immune checkpoint blocking (ICB)
 therapy 417, 423
 immune checkpoints 417, 423
 immune therapy 164
 immunogenic cell death (ICD) 400, 415
 characteristics 415
 immunoglobulin G (IgG) 209
 indocyanine dye 278, 293
 indocyanine green (ICG)
 NIR cyanine dyes 459
 organic photothermal nanomaterials
 22
 indoleamine 2,3-dioxygenase (IDO) 423
 inductively coupled plasma mass
 spectrometry (ICP-MS) 248
 inflammasome and pyroptosis 374
 inorganic optoelectronic materials
 N-type semiconductor materials 479
 P-type semiconductor materials 480
 inorganic photoelectrochemical materials
 479–480
 inorganic photosensitizers
 carbon-based photosensitizers
 284–285
 lanthanide upconversion
 nanoparticles-based
 photosensitizers 290
 metal oxides-based photosensitizers
 288–300
 silicon-based photosensitizers
 285–286
 simple substance photosensitizers
 286–288
 inorganic photothermal materials
 carbon-based nanomaterials 410–412
 noble metal nanomaterials 402–405
 PTAs types 413
 semiconductor nanomaterials
 406–410
 in-situ encapsulation 148–155
 interfacial attachment 148, 157–160
 interferon- γ (IFN- γ) 376
 interleukin 18 (IL-18) 373
 interleukin 1 β (IL- β) 373

- intersystem crossing (ISC) 270, 279, 464, 507, 525
- intramolecular charge transfer (ICT) effect 279
- intrinsic photodynamic effects 32–33
- ion channels 8, 43, 379
- ion doping 119, 352
- ion exchange method 350
- ionic liquid method 124, 125
- ion interference therapy (IIT) 168, 379–385
- iron oxide nanoparticles (IONPs) 285, 407
- j**
- Jablonski diagram 270
- J-aggregates 280
- Judd-Ofelt (JO) theory 80, 100
- l**
- lanthanide-based nanophosphors 511–514
- lanthanide-based nanovectors 236–238
- lanthanide-doped nanocrystals 190, 247, 518
- lanthanide doped nanoparticles 96
- bioprobe development 181–182
 - characteristics 182–185
 - cross-relaxation 184–185
 - energy transfer 187–189
 - functionalization 192–193
 - luminescence biosensing and biodetection
 - biomolecules detection 198–202
 - pH sensing 196–198
 - small molecules and ions detection 202–208
 - temperature sensing 193–196
 - NIR biological windows 186–187
 - point-of-care testing 208–211
 - synthesis and functionalization
 - core-shell structured nanocrystals 189–192
- lanthanide-doped nanothermometers 193
- lanthanide-doped upconversion nanomaterials
- bioapplications
 - bioimaging 169–170
 - biosensing 170–172
 - therapy 159–170
 - composites fabrications 148
 - in-situ encapsulation 148–154
 - interfacial attachment 157–159
 - partial embedment 155–157
- lanthanide-doped upconversion nanomaterials (UCNMs) 147, 221
- lanthanide-doped nanocrystals 189–193
- lanthanide elements 256–258
- lanthanide resonance energy transfer (LRET) 222, 228, 233, 237
- lanthanide upconversion nanoparticles-based photosensitizers 273
- latent fingerprint (LFP) 317
- ligand exchange, LnNPs 192–193
- limit of detection (LOD) 41, 199, 202, 494
- lipid-soluble molecules 274
- lipopolysaccharide (LPS) 374, 430, 456
- liposomes, biodegradable nanomaterials 30
- live imaging, QDs 356–357
- LnNP-based bioprobes 193
- local surface plasmon resonance (LSPR) 21, 48, 104, 105, 400–403, 406, 409
- long-afterglow luminescent nanomaterials 516–518
- lowest unoccupied molecular orbital (LUMO) 402
- luciferase quantum dot nanomaterials 33–35
- luminescence biosensing and biodetection
 - biomolecules detection 198–202
 - pH sensing 196–198
 - small molecules and ions detection 202–208
 - temperature sensing 193–196

- luminescence modulation
 combined excitation regulation 97
 cross relaxation regulation 90–93
 crystal field (CF) regulation 85–87
 dye sensitization 95–97
 ET regulation 89–90
 external field modulation 99–105
 NIR downshifting modulation 92–93
 phonon-assisted energy transfer
 93–95
 surface defects passivation 87–89
 luminescence resonance energy transfer
 (LRET) 222
- m**
- macrophage signal-regulated protein a
 (SIRPa) 423
 macroscopic quantum tunneling effects
 2
 magnetic dipole (MD) transitions 81
 magnetic field modulation 98–100
 magnetic hyperthermia (MHT) 420, 421
 magnetic resonance imaging (MRI) 6,
 99, 275, 356
 magnetic-responsive immunostimulatory
 nanoagent (MINP) 425
 magnetoluminescence 98, 99
 major histocompatibility complex (MHC)
 377, 427
 malignant tumors 54, 356, 376, 428, 507
 marker matrix metalloproteinase 13
 (MMP 13) 231
 material informatics
 genetic algorithm 126–127
 particle swarm optimization 127
 simulated annealing 127–128
 matrixmetallo proteinase-2 (MMP-2)
 229
 MDR *Pseudomonas aeruginosa* (MDR-PA)
 456
 mechanisms of interaction between
 X-rays and scintillation materials
 509–511
 Merocyanine 540 (MC540) 131, 514
 mesenchymal stem cell (MSC) 250, 254,
 286
 mesoporous silica nanoparticles (MSNs)
 32, 221, 222, 285
 metal carbon/nitride (MXene) 26
 metal cluster nanomaterials 514, 516
 metal complexes
 COFs 282–283
 HOF 284
 iridium(III) complexes 280, 282
 MOFs 282
 Ru(II) complexes 279–280
 metal ion sensitive probes 55
 metallic photothermal nanomaterials
 20–21
 metal-organic complexes 521–523
 metal-organic frameworks (MOFs) 147,
 149, 282, 381, 523
 nucleation and growth of 151
 PVP-assisted growth 150
 metal organic synthesis method 346–347
 metal oxides, N-type semiconductor
 materials 479
 Methicillin-resistant *Staphylococcus*
aureus (MRSA), NIR-responsive
 treatment 452
 microemulsion method 124–125, 235,
 384, 385
 microenvironments stimulation
 light-caging strategy 230–231
 matrixmetallo proteinase 229–230
 orthogonal control 231–233
 reactive oxygen species 228–229
 release monitoring 233–234
 microwave method 125, 347
 Mn-porphyrin 274, 275
 molecularly imprinted polymers 171,
 481, 482
 monobasic cation oxide 320–321
 Monoclonal antibody 202
 monophosphoryl lipid A (MPLA) 426
 multidrug resistance (MDR) 233, 449
 advantages 450
 antibiotics 468

- multidrug resistance (MDR) (*contd.*)
 - bacteria drug resistance mechanism 467–468
- multidrug resistance-related protein 1 (MRP1) 233
- multifunctional amphiphilic polymer (MFAP) 224
- multifunctional core-shell radiosensitizer 512
- multimodal therapy 135, 164, 167, 168
- multistage nanovectors (MSV) 286
- multi-walled carbon nanotubes (MWCNTs) 411
- myeloid-derived suppressor cells (MDSCs) 377, 386

- n**
- nanobiomedicine 6
- nano-biosensors 8, 357
- nanobubbles (NBs) 278
- nano-diagnostic technology 6
- nano drug delivery systems 6
- nanogels 31
- nanographene oxide (NGO) 238
- nano-imaging technology 6
- nanomaterial-based
 - photothermal/immunotherapy
 - PTT-synergized adoptive cellular immunotherapy 427–429
 - PTT-synergized ICB therapy 417–418
 - PTT-synergized immunoadjuvant therapy 425–427
 - PTT-synergized therapeutic cancer vaccine 429–431
- nanomaterials 1
 - functionalized 3
 - macroscopic quantum tunneling effects 2
 - photofunctional classification 3–6
 - quantum size effect 2
 - small size effect 2
 - special properties of 1
 - surface and interfacial effects 1–2
- nanoscintillators-PS combinations 508
- nanotherapeutic technology 8
- natural killer (NK) cells 376
- natural macromolecules 31
- near-infrared (NIR) 147, 273
 - cyanine dyes 459–461
 - downshifting modulation 92–93
 - light irradiation 399
 - light source 8
 - PDT photosensitizers
 - responsive phthalocyanines 455
 - responsive porphyrins 453–455
- quantum dots 461–464
- region 450
- responsive PTT agents
 - carbon nanotubes 457–458
 - gold nanoparticles 455–457
 - graphene oxide 458
 - semiconductor nanoparticles 458–459
 - UCNPs nanovectors 221
- near-infrared second window (NIR-II), live imaging 357
- necrosis, PTT-induced 414–415
- nickel-coordinated phthalocyanines (NiPc) 455
- nitrogen-doped GQDs (N-GQDs) 461
- NK cell therapy 428
- noble metal nanomaterials 286, 288, 400, 402–406, 488
- nod-like receptor protein 1 (NLRP1) 374
- nod-like receptor protein 3 (NLRP3) 374, 377–379, 390
- Nomenclature Committee on Cell Death (NCDD) 373
- non-degradable nanomaterials 32
- nonmetallic inorganic materials 526–527
- nonradiative transition
 - energy migration 84–85
 - energy transfer 83–84
- N-type semiconductor 479
- nucleic acids, biorecognition element 482

- o**
- oleic acid (OA) 121, 192, 224, 409
- oleylamine (ODE) 121

- organic fluorescent nanomaterials
 - 18–20
 - organic fluorescent polymers 18–20
 - organic materials, nonmetallic materials
 - 525–526
 - organic photoelectrochemical materials
 - 479–480
 - organic photosensitizers 29, 271, 273, 284, 285, 290, 292, 508
 - organic photothermal molecule-based nanoprobes 51
 - organic photothermal nanomaterials 20, 22–24
 - orthogonally emitting UCNPs (OUCNPs) 231
 - oxidative stress defense 465–467
 - oxide PersL
 - aluminate/gallate 323–326
 - monobasic cation oxide 320–321
 - oxide glass 327
 - silicate/germanate/stannate 321–323
 - titanate/zirconate 326–327
 - oxygen-deficient metal oxides 406
- p**
- pan-drug-resistant (PDR) bacteria 449
 - Parkinson's disease (PD), MMP3 229
 - particle swarm optimization (PSO)
 - 126–128
 - pathogen-associated molecular patterns (PAMPs) 377, 425
 - pattern recognition receptors (PRRs)
 - 415, 425
 - PD-1/PD-L1 checkpoint 420–422
 - PDT/PTT agents
 - aggregation-induced emission
 - luminogens 464–465
 - NIR cyanine dyes 459–461
 - NIR quantum dots 461–464
 - PDT/PTT resistance mechanism
 - oxidative stress defense 465–467
 - thermal stress defense 467
 - PEG-UCNPs 248, 251, 253, 256, 257
 - persistent luminescent (PersL) materials
 - 305
 - deep traps 308
 - halides/oxyhalides 309, 314–318
 - nitride/oxy-nitrides 327–330
 - oxides 320–327
 - sulphides 318–320
 - electron-trapping optical storage materials 306
 - information storage capacity 305
 - luminescent mechanism 307–308
 - phonon-assisted energy transfer (PAET)
 - 84, 92–95
 - phospholipid-coated sodium citrate nanoparticles (PSCT NPs) 385
 - phosphorescence 4, 22, 270
 - photoacoustic contrast agents 46–55
 - photoacoustic imaging (PAI),
 - photoacoustic probes 46, 409
 - photoacoustic imaging probes 48, 52–55
 - photoacoustic nanomaterials 45
 - photoactive material 478, 479, 488, 494
 - photochemical internalization (PCI)
 - 135, 224, 231, 232
 - photochemical therapy 160, 164, 167
 - photocleavage methods 225
 - photocurrent signal amplification
 - strategies 484–489
 - photocurrent signal bursting strategies
 - 489–493
 - photocurrent signal nanomaterials
 - 482–484
 - photodegradable polymers 226
 - photodynamic nanomaterials 29
 - intrinsic photodynamic effects 32–33
 - photosensitizer-loaded nanomaterials
 - 29–32
 - photosensitizers energy conversion
 - nanomaterials 33–38
 - photodynamic therapy (PDT) 29, 30, 131, 133, 160, 234, 358, 359, 386, 450, 451, 507
 - basic principles of 273
 - ROS 270
 - tumors treatment 269
 - photoelectric effect 4, 5, 477, 511, 521

- photoelectrochemical biosensors 493
 - direct photoelectrochemical detection 493–494
 - photoelectrochemical enzyme detection 494–495
 - photoelectrochemical immunoassay 497–498
 - photoelectrochemical nucleic acid detection 495–497
 - potential clinical applications 498–499
- photoelectrochemical enzyme detection 493–495
- photoelectrochemical immunoassay 493, 497–498
- photoelectrochemical nanomaterials 38, 477
 - biosensing 477
 - biosensors types 41–44
 - classification 477–481
 - composite photoelectrochemical materials 480–481
 - core elements 40–41
 - inorganic photoelectrochemical materials 479–480
 - organic photoelectrochemical materials 480
 - photocurrent signal 482–484
 - photocurrent signal amplification strategies 484–489
 - photocurrent signal bursting strategies 489–492
 - photocurrent signal generation mechanism 39–40
 - photoelectrochemical biosensors 493–498
 - signal-burst sensors 42–43
 - signal-enhanced biosensors 41–42
 - signal flip-flop sensors 43–44
- photoelectrochemical nucleic acid detection 493, 495–497
- photofunctional antibacterial nanomaterials
 - antibacterial mechanisms 451–452
 - MDR bacteria 452
 - NIR PDT photosensitizers 453–455
 - NIR responsive PTT agents 455–459
 - PDT/PTT agents 459–465
- photofunctional nanomaterials 3, 55, 549, 550
 - absorption and conversion of photons 4–5
 - capture of photons 3–4
 - fluorescent nanomaterials 9–10
 - photoacoustic nanomaterials 45–55
 - photodynamic nanomaterials 29–38
 - photoelectrochemical nanomaterials 38–44
 - photothermal nanomaterials 20–29
 - physical-chemical processes, surface interface 5–6
- photo-gene therapy 135–136
- photo-immunotherapy 133–135
- photoisomerization 225, 228
- photoluminescence, MF modulation 98
- photon avalanche (PA) 82, 118, 119
- photon upconversion, UCL 81–83
- photoprotective protecting group (PPG) 230
- photosensitizer-loaded nanomaterials 29–32
- photosensitizers (PS) 131
 - AIEGens 278–279
 - boron dipyrromethene 277–278
 - indocyanine dye 278
 - metal complexes
 - COFs 282–283
 - HOF 284
 - iridium(III) complexes 280, 282
 - MOFs 282
 - Ru(II) complexes 279–280
 - organic 271
 - phthalocyanines 275–277
 - porphyrin 273–275
- photo-stimulated luminescence (PSL) 307, 309, 317, 321–324, 326–328, 331, 332
- phototherapy, UCNP-based nanovectors 234–235

- photothermal conversion efficiency (PCE), metal nanoparticles 401
- photothermal conversion mechanism 23, 400–402
- photothermal effect of photofunctional nanomaterials 4
- photothermal nanomaterials
 - biomass 27–29
 - carbon 24–26
 - metallic 20–21
 - organic 22–24
 - semiconductor 22
 - two-dimensional (2D) nanomaterials 26–27
- photothermal therapy (PTT) 20, 131, 160, 234, 278, 399, 450, 451
 - immunogenic cell death 415–416
 - mechanism of 413–414
 - necrosis and apoptosis 414–415
 - synergized adoptive cellular immunotherapy 427–429
 - synergized ICB therapy 417–418
 - CTLA-4 checkpoint 418–420
 - immune checkpoints 423, 424
 - PD-1/PD-L1 checkpoint 420–422
 - synergized immunoadjuvant therapy 425–427
 - synergized therapeutic cancer vaccine 429–431
 - tumor cells to heat stress 414
 - tumor microenvironment 416–417
- pH sensing 193, 196–198
- pH sensitive probes 52
- phthalocyanines (Pcs) 455
 - photosensitizers 275
 - structure 456, 467
- pinocytosis 247, 259
- plasma membrane 247, 248, 373, 414
- plasma resonance enhancement 104–105
- point-of-care testing 208–211
- Polo-like kinase 1 (PLK-1) 227, 228, 236
- poly(lactic-co-glycolic acid) (PLGA) 30–31, 357, 425, 526
- polyacrylic acid-g-poly(lactic acid) (PAA-g-PLLA) 411
- polyacrylic acid (PAA), hydrophilic polymers 150, 458
- polyamine dendrimers (PAMAM) 223, 238
- polydimethylsiloxane (PDMS) 26, 315, 330
- polydopamine 23, 27, 44, 131, 168
- polyethyleneglycol (PEG) 30, 150, 192, 277, 406
- polyethylene glycol-poly(lactic-glycolic acid) (PEG-PLGA) polymer 224, 513
- polyethyleneimine (PEI)
 - biological detection 354
 - cationic polymers 223
 - hydrophilic polymers 150
- polymer dots (Pdots) 39
- polymeric nanoparticles 30–31
- polymeric organic materials 480
- poly(ethylene sulfide)-nitrosylated nanoparticles (PES-RSNO NPs) 458
- polypropyleneamine (PAH) 223
- polypyrrole (PPy) 23, 457, 480, 481
- polyurethane (PBAE) 223
- polyvinylpyrrolidone (PVP) 149, 150, 155, 158, 192, 248
- porous coordination network (PCN) 153, 282
- porous organic polymers (POPs) 453
- porphyrin-based porous organic polymers (PPOPs) 453
- porphyrin lipid nanoemulsions loaded with paclitaxel (PLNE-PTX) 274
- porphyrin, PDT 131
- porphyrin photosensitizers 273, 274
- porphyrins, MOFs 282
- positron emission computed tomography (PET-CT) 356
- programmed cell death (PCD) 164, 373, 376, 377, 379
- programmed cell death protein-1 (PD-1) 164, 420, 422

- programmed death-ligand 1 (PD-L1) 420
 protoporphyrin IX disodium salt (PpIX) 273–274
 Prussian blue (PB) 22, 278, 415
 prussian blue nanoparticle (PBNP) 415
 PSL *see* photo-stimulated luminescence (PSL)
 PTA, types of 413
 P-type covalent organic polymers (COPs) 488
- pyroptosis
 Ca²⁺ nanomodulators 383
 definition of 373
 fabrication and mechanism 384
 Lip-MOF nanoparticles 383
 mechanisms 373
 caspases, gasdermins 374–376
 inflammasome 374
 molecular mechanism 375
 tumor immunotherapy 376–379
 demethylation-activated 386–389
 ions interference therapy 379–385
 sonodynamic therapy 389
 TME-responsive therapy 386
- q**
 quantum dots (QDs) 10, 194, 343, 518
 biomedical applications
 biological detection 354–355
 cell imaging 355, 356
 live imaging 356–357
 tumor therapy 357–362
 bulk semiconductor 11
 characterization 353
 fundamental properties 344–345
 modification
 amphiphilic organic macromolecular coating 353
 surfacing ligand molecular exchange 352–353
 performance control
 alloying 352
 core-shell structure 351–352
 loning 352
 sensitization 486
 synthesis methods
 biosynthesis method 348–349
 hydrophilic synthesis method 347–348
 metal organic synthesis method 346–347
 types of 343
 unique optical properties 344
 quantum size effect 2, 344
- r**
 Randall-Wilkins model 309, 330
 rare-earth doped luminescence
 nanomaterials
 downconversion/quantum cutting 83
 downshifting luminescence 79–81
 nonradiative transition
 energy migration 84–85
 energy transfer 83–84
 substrate (host), activator, sensitizer 77–79
 upconversion luminescence 81–83
 rare earth elements 13, 17, 117, 126, 309, 511, 512
 rare earth ions, energy levels of 183
 rare earth luminescent 13
 controlling delivery strategy 225
 carrier surface charge 226–228
 microenvironments stimulation 228–230
 photodegradable polymers 226
 photoisomerization 228
 endosomal escape 224–225
 gene delivery 238
 gene therapy and syndication
 chemotherapy 235–236
 phototherapy 234–235
 lanthanide-based nanovectors 236–238
 surface modification
 cationic polymers 223–224
 silica 221–223
 UCNPs nanovectors 221
 rare earth upconversion nanoparticles 36

- rat mesenchymal stem cells (rMSC)
251–252
- reactive nitrogen species (RNS) 532
- reactive oxygen species (ROS) 18, 131,
148, 228, 232, 358, 360, 382, 421,
451, 465
types of 269
- reduced graphene oxide (rGO) 410, 411
- Renilla luciferase-immobilized quantum
dot 34, 655
- resonance energy transfer (RET) 33, 36,
84, 490
- restriction of the intramolecular rotation
(RIR) 278–279
- restriction on intramolecular vibration
(RIV) 279
- ribonucleoprotein (RNP) 227, 290
- rolling circle amplification (RCA) 484
basic principles of 485
- S**
- scanning laser stimulated luminescence
(SLSL) 309
- second harmonic generation (SHG) 118,
121
- semiconductor nanomaterials 406
transition metal chalcogenides
408–410
transition metal oxides 406–408
- semiconductor nanoparticles 105,
458–459
- semiconductor nanoprobles 48, 50
- semiconductor photothermal
nanomaterials 20, 22
- semiconductor quantum dots 10
- signal flip-flop sensors 43
- silica surface modification 221–223
- silicon-based fluorescent nanomaterials
10, 12–13
- silicon-based photosensitizers 285–286
- silicon phthalocyanine with fluorescein
(SiPc-FITC) 455
- silver-binding peptide (AgBP2) 463
- simple substance photosensitizers
286–288
- simulated annealing (SA) 126–128
- single-photon emission computed
tomography (SPECT) 147, 169,
253, 258
- single-photon emission computed
tomography and X-ray computed
tomography (SPECT/CT) 258
- single-walled (SWCNTs) 411
- small interfering RNA (siRNA) molecules
135
- small-molecule organic materials 480
- small molecules detection 202–208
- sol-gel method 123–124, 151
- sonodynamic therapy (SDT) 167,
358–361, 389, 450
- statistical product and service solutions
(SPSS) 129, 130
- stimulated emission depletion (STED)
97–99
- Stokes' law 5, 14
- Stokes shifts 18, 79, 117, 181, 327, 343,
345, 352, 354
- sulfide PersL 318, 319
- superbugs 449, 456, 458
- superoxide dismutase (SOD) 465
- superoxide dismutase-1 (SOD1) 231, 232
- support vector machine (SVM) algorithm
128–130
- surface defects passivation 87–89
- surface enhanced Raman scattering
(SERS) 485–489
- surface interface chemical reactions 5
- surface modification
cationic polymer 223–224
silica 221–223
- surface plasmon resonance (SPR) 21,
104, 406, 408, 485, 487, 488
- surface silanization 193, 222, 223
- synergistic therapy 135, 285, 286, 292,
293, 419, 536–539
- t**
- Talimogene laherparepvec 430
- T cell receptors (TCR) 427
- temperature sensitive probes 54–55

- ternary QDs
 hot-injection method 349
 hydrothermal method 350–351
 ion exchange method 350
- tetraethyl orthosilicate (TEOS) 250
- 10,10',11,11'-tetrahydro-5,5'-bidibenzo
 [*a,d*][7]annulenyliene (THBA)
 279
- tetrakis-(4-N-methylpyridyl)-porphyrin
 (TMPyP) 453–455
- tetrakis(4-carboxyphenyl) porphyrin
 (TCPP) 153, 274, 282
- 5,10,15,20-tetrakis(4-carboxyphenyl)
 porphyrin (TCPP) 153
- tetraphenylethene (TPE) 279
- T helper 1 (Th1) cell 415
- thermal decomposition method
 121–122, 190, 192
- thermal stress defense 467, 469
- thermoluminescence (TL) 307, 309, 317,
 320, 321, 323–326, 328, 330–332
- [1,2,5]thiadiazolo-[3,4-*i*]dipyrido[*a,c*]
 phenazine (TDP) 280
- thioacetamide 355
- time-temperature indicators (TTIs) 316
- tissue engineering 6, 8–9, 23, 31
- TME-responsive pyroptosis therapy 386
- toll-like receptor 4 (TLR4) 374
- toll-like receptors (TLRs) 425
- traditional photosensitizers 33, 160, 464,
 508
- trans-azobenzene 228
- transition metal chalcogenides 408–410
- transition metal dichalcogenides (TMDs)
 409
- transition metal oxides 401, 406–408
- transmission electron microscopy (TEM)
 152, 153, 353
- tricarboxylic acid (TCA) 152, 385
- triphenylamine (TPA) 280, 525
- triphenylamine thiophen pyridinium
 (TTPy)-based cationic AIEgen
 464
- triphenylphosphine (TPP) 162, 228, 521
- triple-negative breast cancer (TNBC) cells
 228
- tumor-associated antigens (TAAs) 133,
 400, 418, 421, 425, 426
- tumor-associated macrophages (TAM)
 134–135, 286, 386
- tumor immunotherapy 376
 demethylation-activated 386–389
 ions interference therapy 379–385
 sonodynamic therapy 389
 TME-responsive therapy 386
- tumor metastases 399
- tumor microenvironment (TME) 132,
 164, 229, 270, 361, 376, 409, 411,
 414, 416–417, 532, 539
- tumor-targeted photothermal agents 399
- two-dimensional (2D) nanomaterials
 26–27
- two-photon absorption nanomaterials
 33, 35–36
- type II X-ray excited PDT 529–532
- type I X-ray excited PDT 527–529, 531,
 532
- u**
- UCNM-MOF composites 148, 151
 antitumor mechanism 167
 biosensors 171
 chemotherapy 165
 dual-mode imaging 170
 luminescent imaging 169–170
 SiO₂-assisted synthesis 151
- UCNPs *see* upconversion nanoparticles
 (UCNPs)
- ultraviolet-visible-near-infrared
 absorption spectroscopy
 (UV-Vis-NIR) 353
- upconversion luminescence (UCL) 81,
 117, 273, 290
- material informatics 126
 genetic algorithm 126–127
 particle swarm optimization 127
 simulated annealing 127–128
- mechanisms of 118
- typical processes 118

cooperative upconversion 120–121
 co-precipitation method 123
 cross-relaxation 120
 energy transfer 119–120
 excited state absorption 118–119
 hydrothermal/solvothermal method 122
 photon avalanche 119
 second harmonic generation 121
 sol-gel method 123–124
 upconversion nanocrystals (UCNCs) 128, 256
 upconversion nanomaterials (UCNMs) 147
 capping ligands 158
 partial embedment 155–157
 upconversion nanoparticles (UCNPs) 36, 79, 121, 190, 290, 451
 cancer therapy 131
 photodynamic therapy 131
 photo-gene therapy 135–136
 photo-immunotherapy 133–135
 photothermal therapy 131–133
 confining excitation energy 91–92
 distribution of 249–252
 excretion behavior 252–253
 fabrication of 157
 high-density excitation 92
 internalization 247–249
 nanovectors 221
 self-assembled MOF 161
 surface functional group 250
 toxic effect of cell 253–256
 in vivo toxic effect 256–258

V

valence band (VB), metal oxide 288
 Vancomycin-Resistant *Enterococci* (VRE) 468
 4-vinylbenzyl-terminated tetraphenylporphyrin (VBTPP) 275

W

whole-cell vaccine 399

X

X-PDT *see* X-ray-induced PDT (X-PDT)
 X-ray activated nanomaterials 33–34
 X-ray activated therapy
 combined type I and II X-ray excited PDT 531, 532
 reactive nitrogen species (RNS) 532–535
 synergistic therapy 536–539
 type II X-ray excited PDT 529–531
 type I X-ray excited PDT 527–529
 X-ray excited optical luminescence (XEOL) 508, 511, 529, 536, 537
 X-ray-induced PDT (X-PDT) 34, 508, 509, 511–514, 518, 524, 525, 527–533, 536–540
 X-ray powder diffraction (XRD) 353, 528
 X-ray sensitive materials
 metallic materials
 lanthanide-based nanophosphors 511–514
 long-afterglow luminescent nanomaterials 516–518
 metal cluster nanomaterials 514–516
 metal-organic complexes 521–523
 metal-organic frameworks 523–525
 quantum dots 518–521
 non-metallic materials
 inorganic materials 526–527
 organic materials 525–526

Y

yolk-shell cubic nanoframes (YSCNFs) 457

Z

zebrafish genome 256
 zeolitic imidazolate framework (ZIF) 149, 150
 zinc-based quantum dots 10
 zinc selenide (ZnSe) 10, 50, 519
 Z-type heterojunctions 481, 491
 zwitterionic conjugated polyelectrolyte brush (ZCPEB) 227













