

Index

Note: Page numbers in *italics* refers to figures.

a

- acoustochemical method 203, 206
- alkanethiol-coated gold nanocrystals 59
- α -selenium 199
- anisotropy
 - of BP 147–148
 - of electron transport in 2D tellurium nanosheets 181
 - of probe sonication 213
 - of selenium 199, 211
 - of tellurium 172
 - of *t*-Se 206
- antimonene 231
 - preparation of 241–242
 - properties and applications of 242–244
- arc discharge (AD) 10, 11–12
- arsenene 231–232
 - preparation of 241–242
 - properties and applications of 242–244
- atomic force microscopy (AFM) 174, 200–201
- atomic layer deposition (ALD) 70, 151
- Au-Si binary phase diagram 47

b

- ballistic transport mechanism 78–79
- ball milling method 17, 141
- bandgap shift in Si NWs 77
- batteries 189–190
 - Li-Te and Te-Al 190
 - lithium 71

- silicon-based lithium 72
- tellurium NWs 189–190
- Bessel factor of Si NWs 74
- β -selenium 199
- bilayer graphene (BLG) 9
 - twisted 23
- biomedical and sensing 155
- black phosphorus (BP) 139, 145, 153, 154, 175
 - anisotropy of 147–148
 - applications of 148
 - ball milling 141
 - in biomedical and sensing 155–157
 - bottom-up approach 144–146
 - energy band structure of 147
 - field effect transistor 152–153
 - high pressure 140–141
 - lattice structure of 146–147
 - mineralization 141–142
 - nanosheets, synthesis of 142
 - in photocatalytic degradation 157–158
 - in photodetector 148–152
 - properties of 146
 - solar cell 153–155
 - synthesis of 139
 - top-down approach 142–144
- black phosphorus quantum dots (BPQDs) 155–157, 156
- blown bubble film (BBF) method 62
- blue phosphorus 159, 159
- borophene 231, 232

- borophene (*continued*)
 preparation of 232–234
 properties and applications of 234–237
- Bosch process 91, 93
- bottom-up methods 2, 8–9. *see also*
 top-down method
 of BP nanosheets 144
 chemical vapor deposition 144–145
 elementary substances of 1
 etching methods 42
 fabrication of 2
 of graphene 8–9
 for in-plane FET implementations 86
 nanomaterials 1
 for preparing borophene 233
 properties and applications of 17–25
 for Si NWs 77, 84
 solvothermal method 146
- C**
- carbon (C) 1
 for synthesizing selenium nanostructures 199
- carbon nanotubes (CNT) 1, 9
 arc discharge 11–12
 chemical vapor deposition 12
 graphyne 13–17
 laser ablation 12
 properties and applications of 25–29
 types 10
- carbon nanotubes field effect transistors (CNT-FETs) 12
- carbon-thermal chemical vapor deposition method 203
- catalysts 42, 47
 Au 118, 119
 B-type 41
 downscaling strategies 61
 droplets 44, 44
 Fe 58, 59
 formed using pre-patterned layers 45
 metal 12, 45, 46
 non-Au 47
 precursor 13
 residual 12
- structure and components of 13
 TEM image of SWCNTs with marked transition metal 10
 type A gold catalysts 49–50
 type B low Si solubility catalysts 50–51
 type C silicide-forming catalysts 51
 VLS 45
- cetyltrimethylammonium bromide (CTAB) 203
- chemical template method 187–189
- chemical vapor deposition (CVD) 2, 9, 42, 116–118, 175
 borophene preparation using 233
 of BP nanosheets 144–145
 carbon-thermal 203
 of CNT 12–13
 floating catalyst 13
 for GDY synthesis 17, 17
 graphene 17
 PECVD 70
 preparing photovoltaic NW arrays 71
 pulsed plasma-enhanced 51
 schematic of low-temperature 46
 silane 42, 51
 substrate-supported catalyst 12
 tetrachlorosilane 42
- chemical vapor transport (CVT) 145
 BP prepared by 157
 violet phosphorus synthesized using 160
- Chern insulator (CI) 23
- chirality 177
- chiral tellurium nanomaterials, synthesis of 177–179
- chitosan (CS) 208
- CO₂ reduction reaction (CO₂RR) 157
- cocoa bean shell extract (CBSE) 201
- complementary metal oxide semiconductor (CMOS) 41
- initiating pace of “Very Large Scale Integration,” 80
- JNTs compatible with 81
- Si NW fabrication process with 76
- SOI NWs fabricated using 84
- conduction bands (CBs) 149

confinement-controlled sublimation

(CCS) 2, 8

contact gate pitch (CGP) 27

contact printing 44, 62

conventional mechanical stripping
techniques 142–143

conventional MOSFETs 76

Coulombic efficiency 125, 126

Cowley's theory 123

cyclic voltammetry 189

d

deep reactive ion etching (DRIE) 60

dielectrophoresis (DEP) 61

of NWs 61–62

differential web printing method 62

dimethylformamide (DMF) 143

diphenylsilane (DPS) 42

dissolution-based methods 41, 59–60

drain-induced barrier lowering (DIBL) 76

dry exfoliation of graphene 3

dynamic random access memory (DRAM) 84

Si NW-implemented SRAM and DRAM 85

e

E-beam lithography (EBL) 60

electrochemical exfoliation (ECE) 5–6

electrochemical method 217

electrochemical stripping method 143

electronics

BP in 111

fabrication of Si NW transistors 85–94

germanium nanowires in 111

micro 9

properties 77–80

selenium in 216–219

Si NW-based field effect transistors 80–85

electron transport in Si NWs 77

energy band structure of BP 147

energy dispersive spectrometer (EDS) 43

energy storage

applications of Ge nanomaterials 124–128

batteries as 189–190

borophene in 234

BP in 148

and conversion of selenium

nanostructures 219

and conversion of solar cells 219

germanium nanowires 111

epitaxial graphene on silicon carbide 8

epitaxial growth strategy 241

etching methods 42, 60–61, 73

dry etching 60, 181

metal-assisted chemical etching 60–61

reactive ion etching 60

for Si NWs 71

exfoliated tellurium nanosheets 177

extreme ultraviolet (EUV) patterning 88

f

fabrication of Si NW transistors 86

3D-stacked Si NWs 88–94, 92–93

gate-all-around nanowire

transistor 87–88

Si NW Planar transistor 86–87

fast Fourier transform (FFT) 179

feedback effect of weak shock ionization

(FBFET) 85

femtosecond pump-probe ultraviolet

photoelectron spectroscopy

(fs-UPS) 219

few-layer graphene (FLG) 3, 3, 150, 151

field effect transistors (FETs) 43, 111, 142,

217, 231

BP nanosheets and 152–153

carbon nanotubes 12

conventional

metal-oxidesemiconductor 76

fabrication of Si NW transistors 86–94

FinFETs 76

germanium and 128–130

graphene 18

inversion-mode

metal-oxide-semiconductor 80

junctionless 76, 81

memory 85

negative capacitance 80

NW transistors beyond Boltzmann 84–85

reconfigurable NW FETs 82–83

Schottky barrier field effect transistors 82

- field effect transistors (FETs) (*continued*)
 Si NW-based field effect transistors 80
 Si NW-implemented SRAM and
 DRAM 85
 Si NW single-electron field effect
 transistors and Si NW quantum
 dots 83–84
 Si-P-channel metal oxide semiconductor 27
 tellurium NWs 171
 tunnelling 80
 field-effect tunnelling transistors (FETTs) 18
 field-emission scanning electron microscopy
 (FESEM) 206
 Fin field-effect transistor (FinFETs) 76
 floating catalyst CVD (FCCVD) 13
 fluid alignment strategy 61
 fluorine-doped tin oxide (FTO) 219
 fullerenes 1, 2, 10, 11
- g**
 gas–liquid–solid (VLS) mechanisms 12, 71,
 73, 116, 118, 199
 gas-phase deposition 175, 207
 gas sensing 186–187
 gate-all-around FET (GAA FET) 76
 gate-all-around nanowire transistor 87–88
 gate-all-around silicon nanowire transistor
 (GAA SNWT) 88–89, 89
 gated NW resistors. *see* junctionless
 transistors (JLTs)
 Ge NPs 125
 germanium (Ge) 111
 chemical vapor deposition 116–118
 energy storage applications 124–128
 field effect transistor 128–130
 hydrothermal synthesis 118–120
 laser ablation 112–113
 nanomaterials, synthesis of 112
 optical properties 120–122
 properties and applications of 120
 Raman spectrum 122–123, 124
 SFLS method 113–115
 thermal evaporation method 115–116
 germanium nanowires (Ge NWs) 111, 115,
 116, 118, 119
 gate allosteric field effect transistor 130
 preparation 112
 graphdiyne (GDY) 13, 30
 graphene 1, 2, 231
 bottom-up methods 8–9
 electrical properties and
 applications 18–20
 graphene-like elements 231
 layer 11
 monolayers 1
 nonlayered Se nanosheets 212
 optoelectronic properties and
 applications 20–23
 properties and applications of 17–18
 relationship between other carbon
 nanostructures and 2
 spintronic properties 23
 superconductive properties 23
 top-down methods 3–7
 graphene field effect transistors (GFETs) 18
 graphene nanoribbons (GNRs) 1
 graphene oxide (GO) 2
 graphene strain-effect transistor (GSET)
 18, 19
 graphene-WS₂-graphene (GWG) 18
 graphite 1, 2, 11
 graphyne (GY) 1, 13
 containing different numbers of inserted
 acetylene bonds 14
 liquid-phase synthesis 15–16
 properties and applications of 30
 solid-phase synthesis 17
 growth-assembly methods 61
 blown bubble film method 62
 dielectrophoresis of NWs 61–62
 fluid alignment strategy 61
 Langmuir–Blodgett assembly strategy 61
 printing 62
- h**
 hexaethylbenzene (HEB) 15, 17
 high-angle annular dark-field scanning
 transmission electron microscopy
 (HAADF-STEM) 172
 high pressure method 140–141

- high-resolution transmission electron microscopy (HRTEM) 112, 170, 206, 233–234
- Hittorf's phosphorus. *see* violet phosphorus
- horizontal Si NWs 61
- growth-assembly methods 61–62
 - in situ* growth of lateral NWs 62–63
- hybrid C-FinFET common-source amplifier (H-CA) 81
- hydrothermal method 146, 187
- hydrothermal synthesis method 119–120, 175–177, 201
- i**
- in-plane solid–liquid–solid (IPSLS) method 41, 62
- in situ* growth of lateral NWs 62–63
- internal quantum efficiency (IQE) 67
- Internet of Things (IoT) 76
- j**
- junctionless accumulation mode field effect transistors (JAM FETs). *see* junctionless transistors (JLTs)
- junctionless field effect transistor (JL-FETs). *see* junctionless transistors (JLTs)
- junctionless nanowire transistor (JNT) 81
- junctionless transistors (JLTs) 80, 81
- l**
- Langmuir–Blodgett assembly strategy 61
- large-scale integration (LSI) 76
- laser ablation (LA) 10, 12, 55, 62, 112–113, 202
- pulsed 201
- layer-antiferromagnetic insulator (LAF insulator) 23
- layer-by-layer sequential stacked NW transistor 89–91
- layer-engineered exfoliation (LEE) 3
- layer-polarized insulator (LPI) 23
- liquid nitrogen-assisted green stripping method 158
- liquid-phase exfoliation 2, 177
- for biomedical applications 240
 - of graphene 4–5
- selenium nanosheets preparation using 211
- tellurium nanosheets by 186
- liquid-phase stripping method 144, 177
- liquid-phase synthesis of graphyne 15–16
- lithium
- lithium-ion batteries 189
 - reversible precipitation of 125
 - Si NW-based anode materials for lithium batteries 71–73
- m**
- magic-angle tBG (MATBG) 24
- mechanical exfoliation method 142–143
- Meiners effect 239
- metal-assisted chemical etching (MACE) method 41, 42, 60–61
- metal catalysts 10, 47
- classified according to binary phase diagram 47
 - diffusion of 46
 - metal-catalyst-Si clusters 42
 - physical state of 12
 - pre-deposition 13
 - types of 45
- metal NPs 42, 43
- process of patterning 44–45
- metal-oxide-semiconductor field effect transistors (MOSFETs) 76
- metamaterial integration strategy 21
- micromechanical cleavage method 2
- microwave-assisted method 201
- Mie theory 122
- mineralization 141–142
- molecular beam epitaxy (MBE) 45, 233, 237
- monolayer graphene (MLG) 9
- monophenylsilane 42
- Moore's Law 41, 76, 175
- multigate FETs 76
- multi-walled carbon nanotubes (MWCNTs) 10, 11
- n**
- nanocrystalline silicon (i-nc-Si) 67
- nanocrystals
- germanium 118, 120

- nanocrystals (*continued*)
 gold 114
 Ni 115
 tellurium 169
- nanomaterials 111, 170, 199
- nanoparticles (NPs) 42, 115, 156
 Ag 60
 atomic force microscopy images of 200–201
 Au 45, 115–116
 Bi 51
 Ge 117, 118, 124–125
 metal 42, 45
 porous 126
 selenium 60, 200, 202, 222
 tellurium 170, 179
 Zn-BPQDs 156
- nanoribbon 174, 213
 controlled synthesis of tellurium 174
 graphene 1
t-Se 215
- nanotechnology 199
 using open-source tools 83
- nanotubes
 boron nitride 172
 carbon 9–17, 172
 controlled synthesis of tellurium 172–173
 one-dimensional 2
 in semiconductors and energy storage devices 170
 single-walled 172
 synthesis of selenium 206–208
 TEM images of 207, 207
- nanowire field effect transistor (NWFET) 130
- nanowires (NWs) 41, 169
 1D selenium 200
 3D-stacked Si NWs 88, 92–93
 circuit 62
 controlled synthesis of tellurium 171–172
 dielectrophoresis of 61–62
 synthesis 42
 transistors beyond Boltzmann 84–85
 vertically stacked multi-NWs by etching 91–94
- ZnO 152
- near-infrared (NIR) laser irradiation 153, 241
- negative capacitance field effect transistors (NCFETs) 80
- nitrogen reduction reaction (NRR) 157
- N*-methylpyrrolidone (NMP) 144, 177
- noise equivalent power (NEP) 22–23
- nonvolatile memory (NVM) 85
- o**
- optical trapping, Si NW arrays for 64–67
- optoelectronics
 graphene in 20
 selenium in 216–219
- ORADEP 91
- Oriented Attachment (OA) 41
- Oswald maturation 45
- oxide-assisted growth (OAG) 42, 55
 characterization of OAG NWs 57
 development of 55
 growth on substrate 57–58
 precursor states in heat pipes 55–57
- p**
- passivation of Si NW solar cells 69–71
- patterning metal NPs process 44–45
- phase diagrams of metal-Si systems 47–48, 48
- phosphorene 231
- phosphorus
 black 139–158
 blue 159
 violet 160–161
- photocatalytic degradation 157–158
- photocatalytic hydrogen evolution reaction (HER) 157
- photocatalytic nitrogen reduction reaction 157
- photodetectors (PDs) 20, 148–152, 171, 216
- photoelectrochemical (PEC) biosensor 155
- photoluminescence (PL) 120, 215–216
- physical vapor deposition (PVD) 175, 218
- plasma-enhanced chemical vapor deposition (PPECVD) 51
- polydimethylsiloxane (PDMS) 149

- polymethylmethacrylate (PMMA) 149
 poly(triarylamine) (PTAA) 155
 polyvinylpyrrolidone (PVP) 177
 porous anodic alumina (PAA) 44
 power conversion efficiency 219
 projected density of states (PDOS) plot 240
 propylene carbonate (PC) 143
 pulsed laser ablation method 201–202
- q**
 quantum anomalous Hall effect (QAHE) 23
 quantum confinement effects (QCE) 80
 quantum dots, Si NW 83–84
 quasi-equilibrium annealing method 8
- r**
 radial junctions in Si NWs 67
 Raman spectra
 of 0D amorphous selenium NPs 215
 of 2D Se nanosheet 215
 of antimonene 243, 244
 of arsenene 242, 243
 of borophene 234, 235
 BP nanosheets using 143
 of germanium 122–123, 124
 of HCDG and pristine graphite 7
 of selenium nanostructures 214–215
 reactive ion etching (RIE) method 60
 reconfigurable field effect transistors (RFETs) 80
 reconfigurable NW FETs 82–83
 red phosphorus (RP) 139
 reduced graphene oxide (rGO) 6, 7
 resistive interfacial layer deposition technique 217
- s**
 scanning electron microscopy (SEM) 43, 116, 208, 232
 of aligned CNT PD 28
 of borophene 232, 233
 of GDY 16
 of Ge nanostructures 117
 of Ge NWs 115, 116, 118, 119
 of NWs 116, 119
- of planar n-i-p chalcogenide solar cell 154
 of selenium rods 209
 of Si NWs 46
 of strain-induced nanogap across Ni/Au contact 19
 of tellurium nanotubes 173
 of three top-gated CNT-FETs 27
 of vertically stacked multi-NWs 92
 Schottky barrier field effect transistors (SBFETs) 76, 82
 Schottky barrier height (SBH) 82
 Seebeck effect 73
 selected area electron diffraction (SAED) 172
 of ABC-stacked GDY 15
 of AgSeTe NWs 188, 188
 of HCDG basal plane 7
 pattern of GDY 16
 selenium 199
 0D selenium nanostructures 200–203
 1D selenium nanostructures 203–211
 2D selenium nanostructures 211
 AFM image of selenium NPs 202
 nanomaterials, synthesis of 200
 selenium nanorods (Se-NRs) 208
 anticancer properties of synthesized 220
 effect on viability of Hep-G2 and MCF-7 human cancer cells 221
 FESEM image of 209
 inhibitory effect of 220
 synthesis of 208–209
 selenium nanostructures
 1D selenium nanostructures 203–211
 biological applications 220–222
 electronics/optoelectronics 216–219
 energy storage and conversion 219
 optical properties 213–214
 photoluminescence 215–216
 properties and applications of 212
 Raman spectroscopy 214–215
 selenium nanobelts synthesis 209–211
 selenium nanorods synthesis 208–209
 selenium nanotubes synthesis 206–208
 selenium NWs, synthesis of 203–206

- self-assembled layer exfoliation patterning
method 45
- self-selected orbital coupling (SOC) 231
in graphene 23
proximity-induced 23
of stanene 239, 239
- semiconductor epigraphene (SEG) 8
characterization of 8
intrinsic transport properties on SiC 20
p-doped 20
- short-channel effects (SCE) 41, 76
FinFETs suffer from 88
gate-all-around nanowire transistor for 87
NCL scheme for 88
vacuum dielectric structures for 81
- silane chemical vapor deposition 42
- silicon carbide, epitaxial graphene on 8
- silicon nanowires (Si NWs) 41
applications of 41, 63
arrays for optical trapping 64–67
dissolution-based methods 59–60
electronics of Si NWs 76–94
etching methods 60–61
fundamental aspects and morphology
analysis of VLS growth 43–51
horizontal Si NWs 61–63
morphology analysis for VLS or VSS
methods 51–54
oxide-assisted growth 55–58
passivation of Si NW solar cells 69–71
principle and structure of 64
radial junctions in Si NWs 67
Si NW-based anode materials for lithium
batteries 71–73
solar cell performance
improvements 67–69
synthesis of 42
thermal annealing of silicon
substrates 58–59
thermoelectric generators 73–76
- silicon-on-insulator (SOI) 80
- silicon transportation process 45–46
- simple single-step synthesis method 124
- single-electron field effect transistors, Si
NW 83–84
- single-electron transistors (SETs) 80
- single-walled carbon nanotubes
(SWCNTs) 10, 172
aerogel 189
functionalized 189
laser ablation 12
relative junction conductance of 26
semiconductive 25–26
single-chirality SWCNT solutions 26, 26
TEM image with marked catalyst 12
type II 26
in unfolded 2D graphene layer 11
- Si-P-Channel Metal Oxide Semiconductor
Field Effect Transistors
(PMOSFETs) 27
- solar cell 219, 220
BP for 153–155
passivation of Si NW 69–71
performance improvements 67–69
principle and structure of Si NW 64–67
Si NW 63, 65–66
Sn for 51
- solid–liquid–solid (SLS) method 42, 60, 199
precursor states in heat pipes 55–57
- solid-phase synthesis of graphyne 17
- solid–solution–solid growth mechanism 207
- solvothermal method 146
- spin-on doping (SOD) technique 75
- spin-orbit coupling (SOC) 23
in silicon 84
in tellurium 169, 179, 184
- stanene 231–232, 237
preparation of 237–238
properties and applications of 238
- Staphylococcus aureus* 221
- static random access memory (SRAM) 27
6T SRAM 81
Si NW-implemented SRAM and
DRAM 85
- steel gallium-zinc oxide (InGaZnO) 153
- substrate-supported catalyst CVD
(SCCVD) 12
metal catalyst pre-deposition in 13
- supercritical carbon dioxide (SCCO₂) 4

- supercritical flow–solid–solid (SFSS)
method 115
- supercritical fluid (SCF) 4
- supercritical fluid–liquid–solid (SFLS)
method 42, 113–115
- t**
- Tafel slope 234–235
- tangential stress 5
- tellurene 176
- tellurium (Te) 169
chiral tellurium nanomaterials, synthesis
of 177–179
nanomaterials, controlled synthesis
of 170–179
- tellurium-aluminum battery (TAB) 189
- tellurium nanostructures
1D 170–174
2D 175–177
batteries 189–190
chemical templates 187–189
chiral properties 184–186
electrical property 179–181
gas sensing 186–187
photoconductive properties 181–183
piezoelectric thermoelectric
properties 183–184
properties and applications of 179
- template method 125
- tetrachlorosilane CVD 42
- thermal annealing of silicon
substrates 58–59
- thermal evaporation method 115–116
- thermoelectric generators (TEGs) 73
on-chip integration of Si NW-based
thermoelectric modules 76
- Si NW-based TEJs 74–76
- time-of-flight technique 217
- top-down method 2, 199. *see also* bottom-up
methods
of BP nanosheets 142–144
etching methods 42
of graphene 3–6, 7
in-plane FET implementations based on 86
in Si NW technology 84
- transfer printing (TP) 62
- transmission electron microscopy
(TEM) 43, 170, 200, 232
- of antimonene 241
- of arsenene 242
- of as-prepared 2D nonlayered Se
nanosheets 212
- of borophene 232, 233
- BP nanosheets using 143
- of eight MSeTe 189
- of germanium nanowires 111, 113, 114, 127
- of Ge single-crystal quantum wire 114
- image of MWCNTs 11
- of NPs 201
- of selenium nanostructures 200
- of selenium nanotubes 206, 207
- of selenium NP 202, 203
- of Se nanobelts 210
- of Se NWs 204, 205, 205
- of SWCNTs 12
- of synthesized AgSeTe NWs 188, 188
- of tellurium nanosheets 174
- of tellurium nanotubes 173
- of tellurium NPs 170
- of tellurium NWs 179
- of Te nanoseeds 171
- 1,3,5-triethynylbenzene (TEB) 17
- tunneling field effect transistors (TFETs) 80
- two-dimensional materials (2DM) 1
- type A gold catalysts 49–50
- type B low Si solubility catalysts 50–51
- type C silicide-forming catalysts 51
- v**
- van der Waals (vdW) forces 4, 139, 169
epitaxy of 2D materials 177
heterojunction 153
- vapor–liquid–solid (VLS) growth
mechanism 41, 42, 199
Ag-catalyzed 50
Al-catalyzed 50
catalysts 47–51
of CNTs 13
fundamental aspects of 43
gold-catalyzed 52

vapor–liquid–solid (VLS) growth
mechanism (*continued*)
growth for Ge NWs preparation 112
morphology analysis for 51–54
 patterning metal NPs process 44–45
precursor states in heat pipes 55–57
schematic diagram of 43
silicon transportation process 45–46
Sn-catalyzed 51
vapor-phase deposition 175, 199, 211
vapor–solid–solid (VSS) growth
mechanism 12, 13, 41, 42

Al-catalyzed 50
growth of CNTs 13
morphology analysis for 51–54
schematic diagram of 43
for Si NWs preparation 41, 42
vertical GAA SNWT 88–89, 89
vertically stacked multi-NWs by
etching 91–94
violet phosphorus 160–161

W

white phosphorus 139

