

Index

a

- advanced Ohmic contacts technology 117
- AlGaIn deep UV LEDs
 - high-quality AlN growth 278–281
 - internal quantum efficiency 278–281
 - light extraction efficiency (LEE) 282–287
 - potential applications 276
 - UVC LEDs 281–282
- AlGaIn/GaN heterostructures
 - Schottky gate 138
 - transistor with FLG flakes 430
 - two-dimensional electron gas (2DEG) 19–23
- AlGaIn/GaN HEMTs 138–140
 - gate-edge degradation 207–209
 - hot electron degradation 209–211
 - threshold voltage in 22, 138–140
 - trapping effects 204–207
- Arrhenius model 201
- Auger recombination 74, 78, 254–256, 258, 306
- avalanche electroluminescence 178, 186–188

b

- barrier layer 19–23, 28, 114, 115, 117, 118, 138–140, 143–146, 149, 154, 156–158, 163, 205, 212, 233, 269, 377, 415, 420
- bis-cyclo-pentadienyl-magnesium (Cp₂Mg) 66

- blue emitting InGaIn QWs
 - cavity effect 380–381
 - cavity-enhanced green VCSELs 381–384
- blue LEDs 24, 254, 258–263, 265, 267, 271, 272, 276, 277, 287, 336, 367, 375, 381, 408, 425, 427, 431
- blue VCSELs
 - emission properties 388–389
 - index-guided structure, design of 386–388
- broadband amplifiers 30, 99, 102
- buffer trapping 111, 225–229
- bulk GaIn growth
 - ammonothermal growth 46–51
 - hydride vapor-phase epitaxy (HVPE) 43–45
 - sodium flux growth method 45–46

c

- carbon dopants 222
- carbon-doped GaIn buffer
 - insulation 221–223
 - dynamic $R_{DS,ON}$ due to buffer trapping 225–229
 - time-dependent “dielectric” breakdown (TDDb) 223–225
- carrier delocalization 254, 256–257, 262
- cascade 125, 126, 137, 138, 140–142, 165
- cavity-enhanced green VCSELs 381–384
- close-coupled showerhead reactor 56–57, 68, 71

color rendering index (CRI) 253,
267
current aperture vertical electron
transistor (CAVET) 178–182

d

deep ultraviolet (DUV)
AlGaIn-based UVC LEDs 281–282
high-quality AlN growth 278–281
internal quantum efficiency
278–281
light extraction efficiency 282–287
potential applications 276
digital predistortion (PDP) technique
106
distributed feedback laser diodes (DFB
LDs) 321–324, 342–348
Doherty PA technology 106
double dielectric DBR structure
371–373, 379, 381, 386
dual-wavelength lasing 384–386

e

efficiency droop phenomenon 253,
258
electroluminescence (EL) 78, 178,
187, 188, 203, 255, 268, 282, 348,
349
electronic devices
reliability testing and failure analysis
200–204
of 2D materials heterostructures
band-to-band tunneling diodes
413–414
hot electron transistors 414–420
MoS₂/GaIn heterojunctions
413–414
electron leakage
blue LEDs 258–262
green LEDs 262–264
enhanced mobile broadband (eMBB)
103
epitaxial lateral overgrowth (ELOG)
62, 63, 337, 368
external quantum efficiency (EQE) 74,
254, 258, 278

f

fabrication, of 2D materials
heterostructures
direct growth 403–407
foreign substrate, transfer of
400–403
nitride semiconductors films
407–413
facet-assisted epitaxial lateral
overgrowth (FACELO) 62–64
5G network system 103, 108
GaIn base station Pas 106–108
GaIn for 104–105
6G 108
few-layer graphene (FLG) 408
¹⁹F⁺-ion implantation 148
fluorine (F) 138, 140, 145–149, 154,
165
fluorinated HEMT 145–149

g

gallium nitride (GaIn) 1, 99
application
optoelectronic devices 24–26
power-and high-frequency
electronic devices 26–30
avalanche electroluminescence
186–188
base station Pas 106–108
buffer layers 114
channel 114
electronic devices *see* electronic
devices
5G for 104–105
HEMT “cascade,” 140–142
high-voltage diodes 185–186
history 1–4
impact ionization coefficients in
188–193
P–N diodes 186–188
properties 4–6
electrical 16–19
microstructure and related issues
7–13
optical 13–16
two-dimensional electron gas
19–23

- reliability testing and failure analysis 200–204
 - RF applications
 - AlGaN/GaN HEMTs 204–211
 - InAlN/GaN HEMTs 211–215
 - thermal issues 215–219
 - on SiC and Si 60–62
 - V_{th} instabilities in 233–240
 - GaNification 1, 25
 - gate degradation 204, 230–233
 - gate-edge degradation 203, 207–209
 - gate injection transistor (GIT) 3, 157, 158, 221, 228
 - graphene (Gr) 397
 - few-layer graphene (FLG) 408
 - monolayer of 398
 - for thermal management 428–430
 - graphene-transparent conductive electrodes 421–427
 - green gap 4, 24, 25, 74, 262, 266, 268, 273, 307, 309, 310, 313, 369, 375, 377, 379, 389
 - green LEDs 24, 25, 262–264, 288
 - green vertical-cavity surface-emitting laser (VCSELs)
 - advantages 375–377
 - cavity effect 380–381
 - cavity properties 381
 - fabrication process 379
 - InGaN QDs growth and optical properties 377–379
 - properties of cavity-enhanced 381–384
- h**
- halide 42, 48, 335
 - heterojunction tunnel diodes 413
 - hexagonal symmetry 58, 60, 407
 - high electron mobility transistors (HEMTs) 21, 137, 199
 - cascode 140–142
 - normally-off technology
 - fluorinated 145–149
 - p-GaN gate HEMTs 155–162
 - recessed-gate HEMTs 142–145
 - recessed-gate hybrid MISHEMT 149–155
 - threshold voltage 138
 - high-power amplification 100–101
 - high-temperature operating life (HTOL) test 200, 201, 228
 - high-voltage diodes 185–186
 - hot electron degradation
 - AlGaN/GaN HEMTs 209–211
 - InAlN/GaN HEMTs 212–214
 - hot electron transistor (HET) 30, 399, 414–420
 - hot phonons role 214–215
 - hybrid DBR structure 370–371
 - hydride-based vapor phase epitaxy (HVPE) 42
 - hydride vapor phase epitaxy (HVPE) 2, 42–45
- i**
- indium compositional inhomogeneity 75
 - indium inclusions embedded within v-defects 74
 - inductively coupled plasma (ICP) 144, 181, 286, 379
 - InAlN/GaN HEMTs
 - hot electron degradation 212–214
 - hot phonons role 214–215
 - InGaN QDs
 - green VCSELs on 375–377
 - growth and optical properties of 377–379
 - InGaN QWs
 - blue emitting 380–384
 - decomposition 79–82
 - fluctuations 75–78
 - homogenization 78–79
 - polar, nonpolar, and semipolar GaN substrates growth 72–75
 - internal quantum efficiency (IQE) 15, 73, 74, 254, 278–281, 306, 378
- l**
- laser diodes (LDs) 303
 - bulk ammono-GaN 313–316
 - distributed feedback 321–324, 342–348

- laser diodes (LDs) (*contd.*)
 - history and development
 - gallium nitride technology 335–336
 - nitride laser diodes 337–342
 - optoelectronics 333–335
 - plasma-assisted MBE 303–305
 - semiconductor optical amplifiers 354–357
 - superluminescent diodes (SLD)
 - development 348–351
 - optimization 353–354
 - properties 351–353
 - with tunnel junctions 316–324
 - vertically interconnected stacks 319–321
 - wide InGaN QWs 305–313
 - lateral overgrowth from trenches (LOFT) 63
 - light-emitting diodes (LEDs) 253
 - AlGaIn deep UV
 - high-quality AlN growth 278–281
 - internal quantum efficiency 278–281
 - light extraction efficiency (LEE) 282–287
 - potential applications 276
 - UVC LEDs 281–282
 - Auger recombination 255–256
 - blue 258
 - carrier delocalization 256–257
 - inorganic 253
 - electron leakage 257–264
 - green 262
 - white
 - monolithic LEDs 267–268
 - phosphor-covered LEDs 271–275
 - light extraction efficiency (LEE) 254, 258, 276, 282–287
 - liquid phase epitaxy (LPE) 41
 - low-energy electron beam irradiation (LEEBI) 65
 - low-noise amplifier (LNA) 124, 125
 - luminous efficacy (LER) 265–267, 271, 272, 276
- m**
- measurement-stress-measurement (MSM) technique 238
 - median time to failure (MTTF) models 200–202
 - memory effect 66
 - metal–insulator–semiconductor high electron mobility transistors (MISHEMTs) 23, 138, 233–240
 - metal organic chemical vapor deposition (MOCVD) 114, 211, 371
 - metal organic vapor-phase epitaxy (MOVPE) 2, 41, 42, 53
 - basics about nitride 54–57
 - binary and ternary nitrides growth 67–71
 - defect reduction 62–64
 - epitaxy on foreign substrates 58–62
 - in situ ELOG by SiN deposition 64
 - nitrides doping 64–67
 - physical properties of 52
 - metal–oxide–semiconductor field effect transistors (MOSFETs) 137, 140–142, 152, 153, 155, 165, 177, 178, 180, 182, 183, 192, 203, 223, 224, 238
 - millimeter-wave (mmW)
 - applications
 - broadband amplifiers 102–103
 - high-power amplification 100–101
 - 5G 103–108
 - device design and fabrication
 - advanced Ohmic contacts technology 117–118
 - AlN-based devices performances 119–121
 - device scaling 116
 - InAlGaIn-based device performances 121–122
 - intrinsic characteristics 108–113
 - N-polar GaN HEMTs 118–119

- RF devices 114–116
 - state-of-the-art mm-Wave GaN transistors 122–123
 - T-shaped gates 116–117
 - material designs 108–116
- molecular beam epitaxy (MBE) 114
 - III-N growth fundamentals 303–304
 - quantum-confined Stark effect 305–313
- monolithic LEDs 265–268, 270
- monolithic microwave integrated circuits (MMICs) 99, 125
 - Ka-band to D-band frequencies 125–126
 - power amplifier III-N devices
 - III-V materials 123–124
 - low noise amplifiers 125
- multi quantum wells (MQWs) 72, 262, 313

- n**
- nitride laser diodes 335–342, 354, 358
- nonuniform distributed power amplifiers (NDPA) 102
- normally-off HEMT technology
 - fluorinated 145–149
 - p-GaN gate 155–162
 - recessed-gate HEMT 142–145
 - recessed-gate hybrid MISHEMT 149–155
- N-P diode (NPD) 188, 189
- nucleation layer 2, 59–61, 114, 215, 217, 218, 278

- o**
- Ohmic contacts 28, 29, 116, 117, 119, 158–160, 162, 260, 379, 418, 425
- optical absorption (OA) 14
- optical transmission (OT) 14
- optoelectronic devices, of 2D materials
 - heterostructures
 - graphene-transparent conductive electrodes 421–427
 - MoS₂/GaN deep-UV photodetectors 427–428
- oxide gate interlayer field effect transistor (OGFET) 177

- p**
- Pendeo-epitaxy 63
- phosphor-covered LEDs 271–275
- p-GaN gate HEMT 155–162
- p-GaN switching HEMTs 230–233
- phosphor-converted light-emitting diode (pc-LED) 253, 265, 273–274
- piezoelectricity 69, 199, 203, 303, 341
- piezoelectric polarization 3, 8, 20, 21, 23, 114, 257, 308, 309
- planetary reactor 56
- P-N diode (PND) 178, 185–190, 193, 333
- positive bias temperature instability (PBTI) 220, 233, 234, 236–238, 240, 241
- power-added efficiency (PAE) 109
- power and high frequency electronic devices 13, 26–30
- power amplifier GaN MMICs
 - Class A, A/B, and C for 124–125
 - Class D, E, and F for 125
- power average ratio (PAR) 106
- power switching devices, reliability and robustness
 - breakdown vs. trapping 220
 - degradation location 220–221
 - device design 221
 - environment 221
 - stress condition 219–220
- predictive modeling 193
- pyroelectricity 203, 341

- q**
- QD-in-QW active structure 384–386
- quantum barriers (QBs) 72, 311, 313
- quantum-confined Stark effect (QCSE) 69, 305–313, 340, 341, 375
- quantum dots (QDs) 384
 - green VCSELs properties 379
 - vs. quantum wells 375–377

- quantum dots (QDs) (*contd.*)
- quantum wells (QWs) 13, 72
 - decomposition 79
 - in fluctuations 75
 - homogenization 78
 - vs. quantum dots 375–377
 - polar, nonpolar and semipolar GaN substrates 72

- r**
- recessed-gate HEMT 139, 142–145
- recessed-gate hybrid MISHEMT 141, 149–155, 165
- reflection of high energy electron diffraction (RHEED) 55
- reliability 199
 - GaN HEMTs for RF applications 204–219
 - power switching devices 219
 - breakdown vs. trapping 220
 - carbon-doped GaN buffer, parasitic effects 221–229
 - degradation location 220–221
 - device design 221
 - environment 221
 - gate degradation 230–233
 - stress condition 219
 - V_{th} instabilities 233–240
 - testing and failure analysis 200–204
- RF applications
 - AlGaIn/GaN HEMTs 204–211
 - InAlN/GaN HEMTs 211–215
 - thermal issues 215–219
- RF GaN HEMTs 215–219

- s**
- sapphire 2, 5, 8, 9, 14, 15, 26, 42–46, 58–61, 63, 64, 77, 115, 183, 254, 256–258, 277–279, 281, 282, 288, 336–338, 346, 371, 377, 379, 385, 399, 404, 407–411, 413, 424, 428
- Schottky contacts 21, 23, 28, 29, 147, 158, 164, 231, 232
- Schottky gate 29, 122, 138, 139, 149, 159, 201, 214, 233
- secondary ion mass spectrometry (SIMS) 10, 76, 145, 283
- semiconductor optical amplifiers (SOA) 339, 354–357
- sensor electronic technology (SET) 277
- SiN cap layer 114
- Sixth generation (6G) networks 108, 127
- sodium flux growth method 45–46
- static induction transistors (SITs) 178
- strain management 9, 340
- superluminescent diodes (SLD)
 - development 348–351
 - optimization 353–354
 - properties 351–353
- switch amplifier GaN MMICs 125

- t**
- thermal expansion coefficients (TECs) 8, 9, 44, 58, 59, 61, 62, 217, 370, 399, 404
- thermal issues 203, 215–219, 229, 350
- threshold voltage (V_{th}) 4, 22, 29, 137–140, 143–149, 152–154, 156, 157, 159–163, 165, 179–185, 200, 204, 337, 342, 372
- time-dependent dielectric breakdown (TDDB) 203, 223–225
- transition metal dichalcogenides (TMDs) 397, 398, 431
- trapping effects 29, 111, 112, 114, 119, 120, 154, 204–207, 209, 230, 241
- T-shaped gate design 116–117
- tunnel junctions
 - distributed feedback laser diodes 321–324
 - stacks of vertically interconnected laser diodes 319–321
- turbo disk reactor 57
- two-dimensional electron gas (2DEG) 19–23, 137, 178, 205, 415

- v**
- vapor phase epitaxy (VPE) 41
- vertical MOSFETs 182–185
- vertical power devices
 - avalanche electroluminescence 186–188

- current aperture vertical electron transistor (CAVET) 178–182
- ionization coefficients impact 188
- MOSFETs 182–185
- power conversion 177–178
- vertical-cavity surface-emitting lasers (VCSELs) 367
 - with different DBR structure
 - with double dielectric 371
 - with hybrid 370–371
 - efficiency of heat dissipation
 - cavity length 373–375
 - heat profile 372–373
 - green
 - advantages 375–377
 - cavity effect 380–381
 - fabrication process 379

- growth and optical properties 377–379
- properties of cavity-enhanced 381–384
- history and current status 368–369
- lasing characteristics 386
- properties and application 367
- vertically interconnected laser diodes 319–321

W

- white LEDs
 - lighting solutions 266
 - monolithic 267–268
 - phosphor-covered 271–275
 - phosphor free approaches 265
- wide band gap (WBG) 4, 6, 26

