Index

α/G ratio, 23

A
absorption coefficient, 21
  extrinsic, 3
  hyperbolic model, 79
  intrinsic, 3
Kane model, 76
  of HgCdTe, 75
Urbach tail, 77
alternative substrates, 44
anodic oxidation, 111
auger mechanism, 83

B
background-limited performance, 18
background radiance, 19
blackbody photon flux density, 18
bolometers, 1, 223
  focal plane arrays, 225
  principle of operation, 3

C
carrier mobility
  in HgCdTe, 394
  in InSb, 328
  in lead salts, 525
coolers, 10
  Joule-Thompson coolers, 11
  Stirling coolers, 12
  thermoelectric coolers, 13
current transport, 93
  for electrons, 93
  for holes, 93
  Poisson’s equation, 93

dark current, 130, 139
Dember detectors, 190
  multiple-cell device, 194
  voltage responsivity, 191
detectivity, 6, 17, 21
  limited by Auger 1 process, 86
  limited by Auger 7 process, 86
  of photodetectors, 21, 23
  of photodiodes, 135
detectivity, 6, 17, 21
  limited by Auger 1 process, 86
  limited by Auger 7 process, 86
  of photodetectors, 21, 23
  of photodiodes, 135
detectors
  comparison of detectors, 4
  Dember detectors, 190
  extrinsic, 3, 15
  intrinsic, 3, 15
  PEM detectors, 178
  photoconductive detectors, 100
  photoemissive detectors, 3
  photon detectors, 1
  photovoltaic detectors, 4, 129
  pyroelectric detectors, 1
  quantum well infrared photodetectors, 3
  SPRITE detectors, 119
  semiconductor materials, 34
  theoretical model, 16
  thermal detectors, 1

e
excluded photoconductor, 106, 118
extrinsic absorption, 3
extrinsic detectors, 3

F
field of view, 19
flux density, 18
f/number, 8
focal plane arrays, 8
  bolometers, 225
  HgCdTe, 167
  lead salts, 204
frequency response, 147

G
generation, 18
  generation-recombination processes, 18, 80
  optical generation, 18
  radiative generation, 20
  thermal generation, 18

H
HgCdTe ternary alloys, 35
  band structure, 35
  effective masses, 37
  intrinsic concentration, 36
  mobilities, 37
  physical properties, 36
HgCdTe crystal growth, 40
bulk crystals, 42
dopants, 40
epitaxial layers, 43
phase diagrams, 41
native defects, 38
HgCdTe Dember detectors, 192
HgCdTe junction formation, 150
doping during growth, 151
Hg-in diffusion, 150
ion implantation, 150
ion milling, 151
reactive ion etching, 151
HgCdTe magnetoconcentration detectors, 187
HgCdTe photodiodes, 129
Auger-suppressed photodiodes, 163, 167
band diagram, 138
basic configurations, 148
contact metallization, 153
current-voltage characteristics, 137
dark current, 133
detected, 135
frequency response, 147
fundamental limitations, 135
ion implantation, 150
ion milling, 151
LWIR photodiodes at low temperatures, 158
MWIR photodiodes, 154
noise, 135
nonequilibrium photodiodes, 163
n-p homojunction, 132
n+ -p homojunction, 132
n+ -i-p structure, 140
N+ -p-n+ structure, 143
N+ -n+ structure, 149
passivation, 152
photocurrent, 129
preparation, 150
proximity-extracting photodiode, 163
RoA product, 136, 155
SWIR photodiodes, 153
triple-layer heterojunction, 133
HgCdTe PEM detectors, 182
fabrication, 185
theory, 178
HgCdTe properties, 35
absorption coefficient, 76
Auger process, 83
band structure, 37
carrier lifetime, 80
carrier mobilities, 38
defects, 38
dopants, 40
energy gap, 36
generation-recombination mechanisms, 80
intrinsic concentration, 36
minority carrier lifetimes, 82
radiative process, 82
Schockley-Read process, 81
HgZnTe detectors, 211
HgZnTe ternary alloys, 47
crystal growth, 48
physical properties, 49
HgMnTe ternary alloys, 47
crystal growth, 48
physical properties, 50
HgMnTe detectors, 211
PEM detectors, 214
photodiodes, 213
HOTELYE camera, 168
I
immersion, 26
hyperimmersion lens, 27
immersion lens, 26, 114
InAs/GaInSb strained layer superlattices, 51
band gap diagram, 52
carrier lifetime, 54
physical properties, 53
InAs/GaInSb strained layer superlattice
detectors, 220
photodiodes, 221
photoconductors, 222
performance 223
InAsSb ternary alloy, 55
crystal growth, 56
physical properties, 55
InAsSb photodiodes, 215
InSbBi detectors, 217
InSb/InAlSb photodiodes, 218
interdiffused multilayer process, 45
interference effects, 24
intrinsic photodetectors, 75
isothermal vapour phase epitaxy, 45
L
lead salts, 59
crystal growth, 60
deposition of polycrystalline films, 61
effective masses, 60
physical properties, 59
lead salt focal plane arrays, 202
lead salt photodetectors, 197
configuration, 200
performance, 200
polycrystalline films, 190
preparation, 198
lead salt photodiodes, 204
liquid phase epitaxy, 44

M
magnetoconcentration detectors, 187
metalorganic chemical vapor deposition, 45
molecular beam epitaxy, 44
multiple-heterojunction device, 146, 148, 161

N
narrow-gap semiconductors, 32
noise equivalent temperature difference, 8
noise equivalent power, 6
noise mechanisms
generation-recombination noise, 21, 101
in photoconductors, 101
in photodiodes, 135
Johnson-Nyquist noise, 101
1/f noise, 101
noise voltage, 7
nonequilibrium devices, 87
detectivity, 89
novel Sb-based materials, 55
InTlSb and InTIP, 57
InSbBi, 58
InSbN, 58

O
optical generation, 18
optical immersion, 27
hemispherical immersion, 26
hyperhemispherical immersion, 26
optically immersed photodetectors, 112
optically immersed Dember detector, 193
optically immersed photodiodes, 161

P
passivation, 110, 152
PbS photoconductive detectors, 198
detectivity, 201
fabrication, 198
focal plane arrays (FPAs), 202
performance, 201
PbSe photoconductive detectors, 198
detectivity, 201
fabrication, 198
focal plane arrays (FPAs), 202
performance, 201
PbSe photodiodes, 205
PbTe photodiodes, 205
PEM detectors, 179
detectivity, 182
fabrication, 185
responsivity, 183
measured performance, 186
PEM effect, 180
Lile model, 181
photoconductors, 99
noise mechanism, 101
nonequilibrium devices, 87
sweep-out effect, 101
ultimate performance, 20
photocurrent, 133
photoelectrical gain, 17, 102
photodetectors, 17
general theory, 17
modeling, 91
photodiodes, 129
configurations, 148
dark current, 137
fabrication, 150
noise, 135
passivation, 152
quantum efficiency, 145
R_A product, 135
physical properties
HgCdTe, 36
HgMnTe, 49
HgZnTe, 49
InAsSb, 326
lead salts, 521
Poisson’s equation, 92
pyroelectric detectors, 1

Q
quantum efficiency, 17, 145
quantum well infrared photodetectors, 4

R
R_A product, 135
recombination mechanisms, 81
Auger 1, 84
Auger 7, 84
Auger process, 83
radiative process in HgCdTe, 82
Shockley-Read process in HgCdTe, 81
refractive index, 20, 24
resonant cavity, 24, 145
responsivity, 5
blackbody responsivity, 6
current responsivity, 17
voltage responsivity, 5

S
SPRITE detectors, 119
principle of operation, 120
performance, 122
<table>
<thead>
<tr>
<th>T</th>
<th>thermal detectors, 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>bolometers, 1, 224</td>
</tr>
<tr>
<td></td>
<td>costs, 226</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>W</th>
<th>Winston cone, 29</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>van Roosbroeck model, 93</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>thermal figure of merit, 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>thermal generation, 21</td>
</tr>
<tr>
<td>time-delay integration, 120</td>
</tr>
</tbody>
</table>
Jozef Piotrowski is a research and development manager at Vigo System S.A., Warsaw, Poland, and a scientific advisor at the Military Institute of Armament Technology, Zielonka.

He started his career with studies of gigantic photovoltaic effects in semiconductors. By the end of the 1960s, he had recognized the importance of sensitive and fast detection of long-wavelength IR radiation without cooling, and this became his main research subject. He proposed numerous concepts and practical solutions related to uncooled detection. In 1972 he demonstrated uncooled 10-µm photoconductive and photoelectromagnetic detection based on HgCdTe epilayers grown by unique vapor phase deposition on hybrid substrates. During the following decades he developed more advanced IR devices (Dember, magnetoconcentration, and photovoltaic) based on HgCdTe and other material systems (HgZnTe, HgMnTe, InAsSb, InGaAs), various bulk and epitaxial growth techniques (quench/anneal, LPE, MOCVD), and specialized processing techniques (ion milling, ion implantation, photolithography, heterostructure passivation).

In the early 1980s, together with some of his students, Professor Piotrowski founded Vigo System S.A. to commercialize uncooled IR detectors. One of their success stories was the development of low-cost and versatile open-tube gas phase epitaxy, a technique that has been used for commercial detector fabrication for many years. Consequently, in the past decade Professor Piotrowski has introduced into practice various uncooled photodetectors with optical, detection, and electronic functions integrated into a monolithic 3D heterostructure chip. He was also involved in developing advanced detector modules and IR systems based on uncooled photodetectors such as thermal imagers, fast pyrometers, gas analyzers, and IR threat warning, surveillance, and guidance systems. Another field of activity was CdZnTe x-ray and nitride UV detectors. At present, Professor Piotrowski’s efforts are concentrated on attaining picosecond response time in the 2–16 µm range with multiple heterojunction IR devices whose performance is close to fundamental limits.

Professor Piotrowski is the author and co-author of about 300 scientific papers, 15 books and monographic papers, and more that 20 patents. Among the honors he has received are the Poland Ministry of Defense Award; the “Photonics Spectra” Circle of Excellence Award (1996) in recognition of excellence, innovation, and achievement in photonics technology; the “Polish Product for Future” Award of the Prime Minister of Poland; foreign membership in the Yugoslav Academy of Engineering; and many others.
Antoni Rogalski, a professor at the Institute of Applied Physics, Military University of Technology in Warsaw, Poland, is one of the world’s leading researchers in the field of IR optoelectronics. During the course of his scientific career, he has made pioneering contributions in the theory, design, and technology of different types of IR detectors. In 1997, he received an award from the Foundation for Polish Science, the most prestigious scientific award in Poland, for achievements in the study of ternary alloy systems for IR detectors—mainly alternatives to HgCdTe ternary alloy detectors such as lead salts, InAsSb, HgZnTe, and HgMnTe. In 2004, he was elected as a corresponding member of the Polish Academy of Sciences.

Professor Rogalski’s most important scientific achievements include determining the fundamental physical parameters of InAsSb, HgZnTe, HgMnTe, and lead salts; estimating the ultimate performance of ternary alloy detectors; elaborating on studies of high-quality PbSnTe, HgZnTe, and HgCdTe photodiodes operated in the 3–5 and 8–12 µm spectral ranges; and conducting comparative studies of the performance limitations of HgCdTe photodiodes versus other types of photon and thermal detectors (especially QWIR photodetectors).

Professor Rogalski has given more than 35 invited plenary talks at international conferences. He is the author or co-author of approximately 200 scientific papers, 10 books (published by Pergamon Press, SPIE Press, Gordon & Breach, Elsevier, Nauka, and WNT), and 20 book chapters. He is a Fellow of SPIE, the Vice President of the Polish Optoelectronic Committee, a member of the Electronic and Telecommunication Division at the Polish Academy of Sciences, the Editor-in-Chief of the journal Opto-Electronics Review, the Deputy Editor-in-Chief of the Bulletin of the Polish Academy of Sciences: Technical Sciences, and a member of the editorial boards of the Journal of Infrared and Millimeter Waves and the Journal of Technical Physics.

Professor Rogalski is also a very active member of the international technical community. He is a co-chair and member of many scientific committees of national and international conferences on optoelectronic devices and crystal growth, the conference chair and organizer of the International Conference on Solid State Crystals and the Material Science and Material Properties for Infrared Optoelectronics conference, the co-editor of six SPIE Proceedings volumes, and a guest editor of Optical Engineering.