

Index

a

adaptive front-lighting system 75–80
 AlInGaN chip 7
 aluminum encapsulation 41–42
 ambient light 93, 111, 115
 angles of prismatic surfaces 89
 artificial atoms 127
 artificial light, evolution in 1–4
 auto-leveling headlamp system 78
 automated die-attach machines 55
 automotive front lighting (AFL)
 day running light (DRL) 84
 driving forces of 83
 headlamp 80–81
 automotive lighting 71
 interior 92–93
 photometric 72–74
 projection 74–82
 signaling light 83–92
 automotive rear lighting (ARL)
 driving forces of 83
 signaling lights 85–86
 auto vision system process 62–63

b

bandgap 21–23, 42–44, 127
 bulb position 86
 buried micro-reflectors chip 26

c

cadmium-selenium (CdSe) 128
 candela (cd) 72
 candela per m² 74
 carbonization 38, 139
 carbonization effect 38

charge modulation layer (CML) 132
 chip geometrical shaping and type
 26–28
 chip-scale package (CSP) 31
 chip surface roughing 25, 26
 circular economy 147–149
 circular economy material
 enabling healthy natural habitat 158
 with enhanced durability 156
 enhanced properties 153–154
 of higher circularity 155–156
 with higher environmental benignity
 157
 lower material quantities by design
 153–154
 miles 157
 with multifunctionalities 154–155
 with no adverse human health effects
 157–158
 with reduced carbon footprint 156
 with reduced embodied energy 156
 from renewable, recycled, and
 recovered sources 157
 coefficient of thermal expansion (CTE)
 37, 38
 comfort area, headlamp 75
 compound annual growth rate (CAGR)
 5
 consumer indoor lighting 95, 96
 health care and medical treatments
 96–98
 safety and security 98–102
 counterfeit detection 137, 141
 cover lens 86, 87
 cradle-to-cradle analysis 147
 cradle-to-grave analysis 147

d

Dage tester 58, 59
 day running light (DRL) 84
 die attach process 53–56
 die-crack
 electrical properties of 65–67
 optical properties of 65–67
 disability glare 117
 discomfort glare 117
 dynamic auto-leveling headlamp system 78

e

effective light extraction
 on chip technology 23–28
 on high reflective packaging material 28–31
 internal quantum efficiency 21
 light conversion theory 21–23
 luminous efficacy 19–20
 optical interface enhancing light extraction 31–32
 wall-plug efficiency 21
 electrical contact design 49–50
 electrical loss 20, 21
 electroluminescence 21
 electron energy 127
 encapsulation
 aluminum 41–42
 epoxy cap 41
 epoxy compound 37–40
 glass cap on ceramic 41–42
 hermetic sealed package 40–41
 hybrid compound 37–40
 silicone compound 37–40
 encapsulation material
 light extraction efficacy 29–31
 encapsulation materials 7, 27, 29, 33, 34, 36, 37, 39, 40, 61
 encapsulation process 60–62
 energy gap 22
 energy loss 20, 21, 32
 epoxy cap encapsulation 41
 exciton Bohr radius 125, 126
 exterior architectural lighting 117–118

f

Flip chip
 radiation pattern 27, 28
 thinfilm vs. volume emitter chip 27, 28
 fog beam 75, 76

fog beam lamp 77
 food processing, LED 100
 freeform-designed chip-scale package (FDCSP) 31
 fusing current 56

g

gallium arsenide phosphide (GaAsP) 3, 21
 gallium nitrate 3, 105
 GaN/sapphire chip 24
 glass cap encapsulation 41–42

h

headlamp function 75–76
 hermetic sealed package 40–41
 high-beam lamp 76
 high-intensity discharge (HID) headlamp system 78
 high-power LED packages 11, 14–17, 48, 54
 high-pressure metal halide (MH) systems 113
 high-pressure sodium (HPS) lamps 113
 hospitality lighting 111, 112
 housing material reflectivity 29, 30

i

ideality factor 44
 illuminance 74
 injection molding technique 29
 interior lighting 14, 18, 92–93, 107, 110, 112
 internal quantum efficiency 21, 23
 iris recognition system 98–99

k

Kelvin contact failure 35
 K-factor 46

l

lamp reflector 86
 law of energy conservation 22
 law of momentum conservation 23
 LCA, of LEDs
 carbon footprint 151–152
 embodied energy 151–152
 materials footprint 149–151
 leadframe plating surface influence 28–29
 leakage current 65
 leakage current measurement 65

- LEDfit lighting 112
 - custom lighting 122
 - energy efficiency 122
 - exterior architectural lighting 117–118
 - horticulture lighting application 118–119
 - lifespan 122
 - living room lighting 112, 113
 - photomorphogenesis 120–122
 - photosynthesis 119–120
 - plant productivity 122
 - radiant heat 122
 - street lighting 113–117
 - LED package efficiency 21
 - LED packaging
 - effective light extraction 19–32
 - electrical contact design 49–50
 - encapsulation of 37–42
 - light conversion principle 50
 - package design of 32–37
 - thermal management of 42–49
 - lifecycle analysis (LCA), of LEDs
 - carbon footprint 151–152
 - embodied energy 151–152
 - materials footprint 149–151
 - lifted die
 - and performance 67–69
 - thermal behaviour 67–69
 - lifted glue
 - and performance 67–69
 - thermal behaviour 67–69
 - light conversion principle 50
 - light conversion theory 21–23
 - light-emitting diode (LED)
 - impact of 4–6
 - industrial chain 6–8
 - package evolution 8–17
 - light extraction
 - efficiency 21
 - optical interface enhancing 31, 32
 - light guide optics 86–92
 - light guiding 87
 - light intensity 72, 73, 97, 121
 - light projection
 - adaptive front-lighting system 77–80
 - future LED technology of 81–82
 - headlamp function 75–76
 - optical concept automotive front lighting 80–81
 - thermal management 82
 - light wavelengths 96, 97, 99, 119
 - low-beam lamp 75, 76
 - low-power package evolution 12–14
 - lumen (lm) 73, 74
 - lumen/m² 74
 - lumens per watt 74
 - luminance 71, 74, 113, 116, 131
 - luminous efficacy 19, 20, 74, 81, 108, 125
 - luminous flux 19, 20, 50, 73–74, 78, 81
 - lux 74
- m**
- matrix LED headlights 79–81
 - metal can package 40–41, 140
 - metal-organic chemical vapour deposition (MOCVD) reactors 6–7
 - mid-power LED packages 14–15, 54
 - minority carriers 21
 - moisture sensitivity level (MSL) 64
 - monochromatic light 100
- n**
- nanocrystal core 128
- o**
- optical radiation pattern 65, 67
- p**
- package design
 - assembly at second level PCB board for 36–37
 - cost for 33
 - effective light extraction for 37
 - environment for 36
 - manufacturing for 34
 - reliability for 34
 - testing for 34–35
 - packaging process flow 53, 54
 - defects in 65, 70
 - die-attach process 53–56
 - encapsulation process and post-mold curing process 60–62
 - final test and auto vision system process 62–63
 - packing process 63–64
 - singulation process 62
 - surveillance checking 58–60
 - wire bonding 56–58
 - packing process 8, 53, 63–64
 - Palaeolithic lamp 1
 - phosphor conversion material 50
 - phosphor layer 15, 50, 108

photobiomodulation (PBM) 96
 photocatalytic purification 137, 142
 photodiode 97
 photolithography method 133
 photometric
 illuminance 74
 light intensity 72–73
 luminance 74
 luminous efficacy 74
 luminous flux 73, 74
 photomorphogenesis 120–122
 photopic vision 73, 114
 photoplethysmography (PPG) 97
 photosynthesis 118–120, 122
 phytochromes 120, 121
 Planck's constant 126, 127
 post mold curing process 53, 60–62
 psychological glare 116, 117

q

QD-LED fabrication 132–134
 quantum confinement 125, 126
 quantum dot (QD)
 fundamentals of 125–129
 in LED 129–130
 quantum LED
 alternative of organic LED 125
 structures 130–132
 quantum well structures 126

r

radiative recombination 1, 20, 23, 110, 128
 range area, headlamp 75
 reflective optics 86, 87
 refractive optics 86, 87
 RETROFIT
 architecture lighting 111, 112
 lamp 107–111

s

sapphire chip 7, 25–28, 55, 57
 scotopic vision 74, 114
 self-heating 49
 semiconductor material alloys 21
 signaling lights 71
 ARL 85–86
 light guide optics 87–92
 reflective optics 86–87
 refractive optics 86–87
 singulation process 8, 53, 62
 Snail law 24, 25

soldering process 13, 54
 solid and liquid foods treatment 101
 solid-state lighting
 on electrical energy consumption 5
 expanding application 4
 spin coating process 133
 statistical process control (SPC) 58
 surface mount device (SMD) LEDs 8
 surface-mount device (SMD) package 31
 surveillance checking 58–60
 System in Chip (SiC) 3, 8
 System in Package (SiP) 8

t

temperature coefficient 46
 thermal management 42
 design package 46–48
 fundamental of 42–46
 headlamp 82
 performance of 48–49
 thermal testing methods 68
 thinfilm chip 7, 26–28
 to be seen, lighting 71
 to see, lighting 71
 total internal reflection (TIR) 24, 25, 88–90, 110

u

ultra-high power packages 11, 15–17
 ultraviolet exposure 133
 ultraviolet (UV) LED
 advantages and disadvantages of 139
 application 137–140
 light source 138
 novel liquid packaging structure 143, 144
 UV-A and B LED packaging 140–142
 UV-C packaging 142–143
 to UV light source 144
 UV-A and B LED packaging technology 140–142
 UV-C disinfection 138, 142
 UV-C packaging technology 142–143
 UV-C radiation 102, 142

w

wall-plug efficiency 21
 water treatment 102, 158
 width area, headlamp 75
 wire-bonding force 65
 wire bonding process 7, 53, 56–58, 60
 wire interconnect defects, impact on
 electro-optical quality 69–70