

Contents

Preface — V

Table for physical constants — XI

Periodic table — XIII

1 Energy — 1

- 1.1 What is energy? — 1
- 1.2 Fermions and bosons — 2
- 1.3 Important physical constants in the universe — 4
- 1.4 Four fundamental forces of nature — 4
- 1.5 The mass of light — 6
- 1.6 The materialization of light and antimatter — 7
- 1.7 Bose-Einstein condensation and freezing light — 8
- 1.8 Quantum brain theory and light — 10
- 1.9 The materialization of vacuum — 11
- 1.10 The energy constitution of the entire universe — 12
- 1.11 Cosmological constant — 15
- 1.12 Bibliography — 15

2 Solar energy — 19

- 2.1 Energy problems and entropy on Earth — 19
- 2.2 The energy circulation of photons and electrons — 21
- 2.3 Homeostasis of life and civilization — 22
- 2.4 Global warming — 23
- 2.5 Solar light and Earth — 25
- 2.6 Renewable energy — 27
- 2.7 Solar energy plan — 28
- 2.8 Bibliography — 29

3 Basics of solar cells — 31

- 3.1 Properties of semiconductors — 31
- 3.2 *pn* junction — 33
- 3.3 Photovoltaic effect — 34
- 3.4 Energy loss and the requirements for high efficiency — 36
- 3.5 Characterization of solar cells — 38
- 3.6 Internal and external quantum efficiency — 40
- 3.7 Series and shunt resistances — 40
- 3.8 Bibliography — 42

4	Inorganic solar cells — 43
4.1	Comparison of solar cells — 43
4.2	Amorphous Si — 44
4.3	HIT — 46
4.4	CdTe — 46
4.5	CIGS — 47
4.6	Spherical Si — 48
4.7	ZnO/Cu ₂ O — 60
4.8	Bibliography — 65
5	Organic-type solar cells — 69
5.1	Donor-acceptor type organic solar cells — 69
5.2	Exciton — 71
5.3	Bulk heterojunction — 72
5.4	P3HT:PCBM — 73
5.5	Phthalocyanine dimer — 76
5.6	ZnTPP:C ₆₀ — 78
5.7	Diamond:C ₆₀ — 82
5.8	Ge nanoparticles — 86
5.9	Dye-sensitized solar cells — 88
5.10	Polysilane system — 92
5.11	PCBM:P3HT with SiPc or SiNc — 97
5.12	Bibliography — 103
6	Perovskite-type solar cells — 109
6.1	Perovskite structures and synthesis — 109
6.2	Crystal structures of CH ₃ NH ₃ PbX ₃ (X = Cl, Br, or I) — 110
6.3	X-ray diffraction of CH ₃ NH ₃ PbI ₃ — 113
6.4	Electron diffraction of CH ₃ NH ₃ PbI ₃ — 119
6.5	Other perovskite structures for solar cells — 124
6.6	Basic device structures — 126
6.7	Enlargement of cell — 133
6.8	Electron transport layers — 136
6.9	Halogen doping to CH ₃ NH ₃ PbI ₃ — 140
6.10	Metal doping to CH ₃ NH ₃ PbI ₃ — 144
6.11	Bibliography — 147
7	Future solar cells — 153
7.1	Next generation solar cells — 153
7.2	Multi-junction — 153
7.3	Quantum size effect — 155
7.4	Quantum dots — 157

- 7.5 Intermediate band type — 157
- 7.6 Multi-exciton — 159
- 7.7 Hot carrier type — 160
- 7.8 Space solar power system — 161
- 7.9 Bibliography — 162

8 Nuclear fusion materials — 165

- 8.1 Nuclear fusion in the sun — 165
- 8.2 DT and DD fusion — 167
- 8.3 Fusion conditions — 168
- 8.4 ITER — 169
- 8.5 Muon catalyzed fusion — 171
- 8.6 Pyroelectric fusion — 172
- 8.7 Condensation fusion in solids — 173
- 8.8 Fusion reactor materials — 179
- 8.9 Bibliography — 183

9 Other energy materials — 187

- 9.1 Hydrogen storage materials — 187
- 9.2 BN nanomaterials — 189
- 9.3 Calculations of hydrogen storage — 192
- 9.4 Thermoelectric power generation — 199
- 9.5 Icosahedral boron — 202
- 9.6 Titanium dioxide — 203
- 9.7 Zeolite — 205
- 9.8 Lithium-ion batteries — 206
- 9.9 Si clathrate — 207
- 9.10 Ice and hydrate — 208
- 9.11 Fuel cells — 209
- 9.12 SiC FET — 212
- 9.13 Two Concluding Asides — 218
- 9.13.1 The energy of a vacuum — 218
- 9.13.2 The energy of the mind — 219
- 9.14 Bibliography — 219

Index — 225