

4.3.1	The Balance Equation of a PV Converter	120
4.3.2	The Monochromatic Cell	124
4.3.3	Thermodynamic Consistence of the Shockley–Queisser Photovoltaic Cell	126
4.3.4	Entropy Production in the Whole Shockley–Queisser Solar Cell	129
4.4	The Technical Efficiency Limit for Solar Converters	131
4.5	Very High Efficiency Concepts	132
4.5.1	Multijunction Solar Cells	132
4.5.2	Thermophotovoltaic Converters	135
4.5.3	Thermophotonic Converters	136
4.5.4	Higher-than-one Quantum Efficiency Solar Cells	140
4.5.5	Hot Electron Solar Cells	141
4.5.6	Intermediate Band Solar Cell	144
4.6	Conclusions	148
	References	149
<b>5</b>	<b>Solar Grade Silicon Feedstock</b>	<b>153</b>
	<i>Bruno Ceccaroli and Otto Lohne</i>	
5.1	Introduction	153
5.2	Silicon	154
5.2.1	Physical Properties of Silicon Relevant to Photovoltaics	154
5.2.2	Chemical Properties Relevant to Photovoltaics	156
5.2.3	Health Factors	156
5.2.4	History and Applications of Silicon	157
5.3	Production of Metallurgical Grade Silicon	161
5.3.1	The Carbothermic Reduction of Silica	161
5.3.2	Refining	163
5.3.3	Casting and Crushing	166
5.3.4	Economics	167
5.4	Production of Semiconductor Grade Silicon (Polysilicon)	167
5.4.1	The Siemens Process	168
5.4.2	The Union Carbide Process	172
5.4.3	The Ethyl Corporation Process	173
5.4.4	Economics and Business	175
5.5	Current Silicon Feedstock to Solar Cells	175
5.6	Requirements of Silicon for Crystalline Solar Cells	179
5.6.1	Solidification	179
5.6.2	Effect of Crystal Imperfections	182
5.6.3	Effect of Various Impurities	186
5.7	Routes to Solar Grade Silicon	193
5.7.1	Crystallisation	193
5.7.2	Upgrading Purity of the Metallurgical Silicon Route	194
5.7.3	Simplification of the Polysilicon Process	198
5.7.4	Other Methods	201
5.8	Conclusions	201
	References	202