

Contents

1	Introduction	1
2	Physical and Technical Basics	7
2.1	IR Thermography Basics	7
2.2	The Lock-in Principle and its Digital Realization	14
2.3	Lock-in Thermography	22
2.4	Timing Strategies	26
2.5	Influence of Non-harmonic Heating.....	33
2.6	Noise Analysis	38
2.7	Calibration.....	42
2.8	Heat Dissipation and Transport Mechanisms in Solar Cells	44
2.9	Carrier Density Imaging	51
3	Experimental Technique	61
3.1	Different (Lock-in) Thermography Realizations	61
3.2	Commercial Lock-in Thermography Systems	72
3.3	Illumination Systems	80
3.4	Solid Immersion Lenses	85
3.5	Realization of CDI/ILM Systems	91
3.5.1	Absorption Mode	91
3.5.2	Emission Mode	94
3.5.3	Lifetime Calibration	94
4	Theory.....	101
4.1	Influence of the Heat Conduction to the Surrounding	101
4.2	Temperature Drift Compensation	107
4.3	Thermal Waves of Point Sources	114
4.4	Thermal Waves of Extended Sources	118
4.5	The Quantitative Interpretation of Lock-in Thermograms	125
4.5.1	The Image Integration/Proportionality Method	129
4.5.2	Deconvolution of Lock-in Thermograms	137

5	Measurement Strategies	149
5.1	Which Signal Should be Displayed?	149
5.2	Influence of the Lock-in Frequency	156
5.3	Influence of the IR Emissivity	159
5.4	Influence of the Peltier Effect	168
6	Typical Applications	177
6.1	Integrated Circuits	178
6.2	Solar Cells	186
6.2.1	Dark Lock-in Thermography (DLIT)	188
6.2.2	Illuminated Lock-in Thermography (ILIT)	201
6.2.3	Summary of Solar Cell Applications	212
6.3	Failure Analysis of Solar Modules	213
6.4	CDI/ILM on Solar Materials	219
6.4.1	Analysis of Material Evolution During Processing	219
6.4.2	Temperature-dependent measurements	219
6.4.3	Trap density images from CDI/ILM	224
7	Summary and Outlook	229
	References	235
	Thermal and IR Properties of Selected Materials	245
	List of Symbols	247
	Abbreviations	251
	Index	253