Contents

List of Contributors *xi*

Volumes in Series *xiii*

Preface *xvii*

Nomenclature *xxi*

1. Overview of Radiation Thermometry **1**
Zhuomin M. Zhang and Graham Machin

1. Introduction 1
2. Basics of Radiometric Temperature Measurements 4
3. Types of Radiation Thermometers 11
4. Terms Commonly Used in Radiation Thermometry 21
5. Summary 24
References 24

2. Temperature Fundamentals **29**
Graham Machin and Benjamin K. Tsai

1. Introduction 30
2. Primary Thermometry 30
3. A Short History of Temperature Scales Leading to the International Temperature Scale of 1990 41
4. Scale Realisation, Calibration and Traceability 48
5. Uncertainty Estimation in Non-Contact Temperature Scale Realisation and Dissemination 55
6. Possible Future Approaches to High-Temperature Scale Realisation and Dissemination 65
7. Summary 67
Acknowledgements 68
References 68

3. Theory of Thermal Radiation and Radiative Properties **73**
Zhuomin M. Zhang and Bong Jae Lee

1. Introduction 74
2. Thermodynamics of Blackbody Radiation 77
3. Radiative Properties of Materials 85
4. Electromagnetic Wave Theory 99
5. Optical Properties 110

6. Radiative Properties of Layered Structures 119
7. Summary 128
Acknowledgement 129
References 129

4. Radiation Thermometer Designs 133
Howard W. Yoon and George P. Eppeldauer

1. Introduction 134
2. Design Considerations 134
3. Basic Optical Designs 135
4. Component Characterizations 137
5. System-Level Characterizations 143
6. Radiation Thermometry below the Silver Point 160
7. Calibration of Radiation Thermometers Using ITS-90 167
8. Thermodynamic Temperature Measurements Using Radiometric Techniques 168
9. Summary 176
References 177

5. Calculation of the Radiation Characteristics of Blackbody Radiation Sources 181
Alexander V. Prokhorov, Leonard M. Hanssen and Sergey N. Mekhontsev

1. Introduction 182
2. Definitions of Principal Quantities 183
3. Deterministic Methods 187
4. Monte Carlo Method 208
5. Numerical Comparison of Results Obtained by Various Methods 231
6. Conclusions 233
Acknowledgement 234
References 234

6. Blackbody and Other Calibration Sources 241
Jürgen Hartmann, Jörg Hollandt, Boris Khlevnoy, Svetlana Morozova, Sergey Ogarev and Fumihiro Sakuma

1. Introduction 242
2. Fixed-Point Blackbody Radiators 254
3. Variable Temperature Blackbodies for Temperatures up to 1,000°C 258
4. Cryogenic/Vacuum Blackbodies 267
5. Variable Temperature Blackbody Sources above 1,000°C 275
6. Lamp Sources 284
7. Summary 289
Acknowledgements 290
References 290

7. Laser Optical and Photothermal Thermometry of Solids and Thin Films 297
Yue Liu and Andreas Mandelis

1. Introduction 297
2. Interferometric Thermometry 299
3. Ellipsometric Thermometry 304
4. Photothermal Radiometric Thermometry 313
5. Thermoreflectance Thermometry 323
6. Summary 331
References 333

Appendix A: Fundamental and Other Physical Constants 337

Subject Index 339