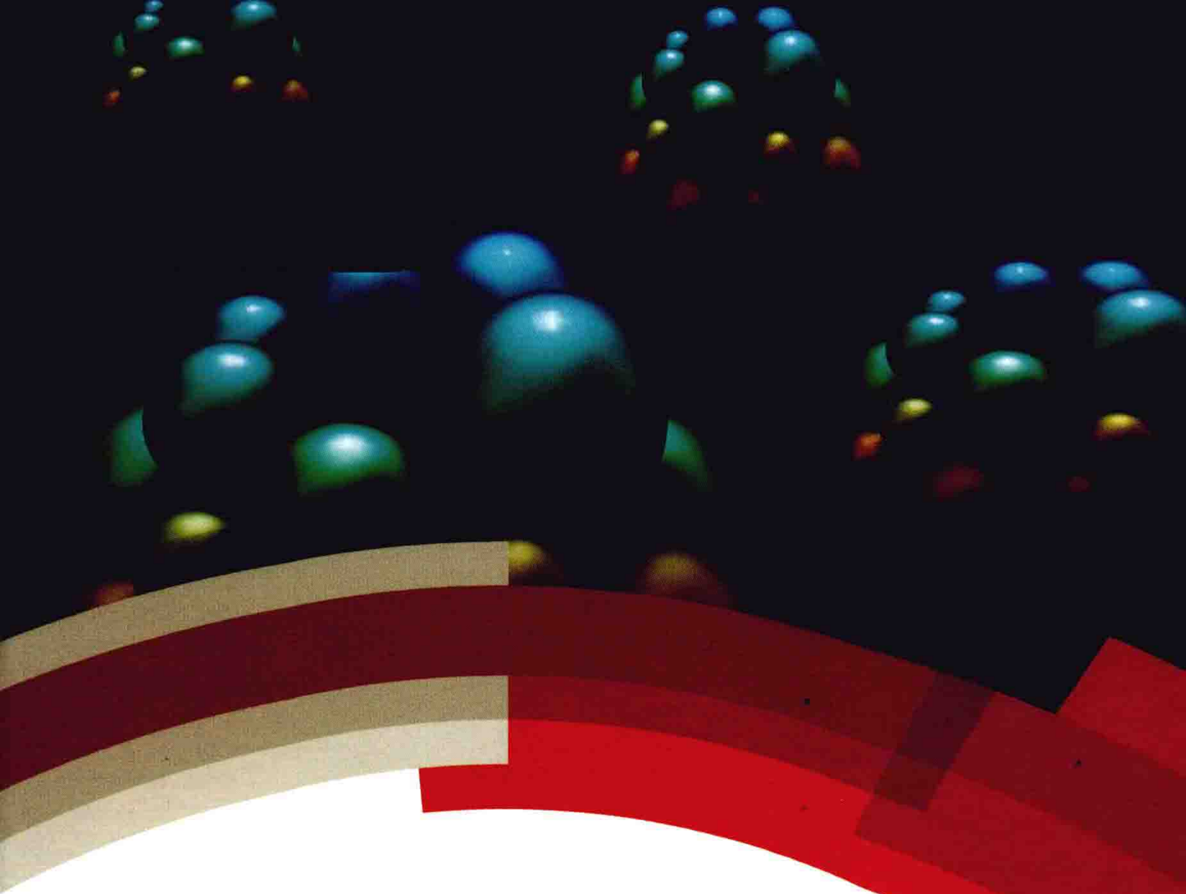

RSC Nanoscience & Nanotechnology

Thermometry at the Nanoscale

Techniques and Selected Applications

Edited by Luís Dias Carlos and
Fernando Palacio

ROYAL SOCIETY OF CHEMISTRY

Thermometry at the Nanoscale
Techniques and Selected Applications

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Preface

Sensing and measuring temperature is a crucial need for countless scientific investigations and technological developments. Consequently, as technology progresses into the nanoscale an increasing demand for accurate, non-invasive and self-referenced temperature measurements at sub-micrometric length scales has been observed. This is particularly so in microelectronics and micro/nanofluidics, for instance, where the comprehension of heat dissipation, heat transfer and thermal conductivity mechanisms can play a crucial role in areas as diverse as reliability and integration of electronic systems, energy transfer, and cell physiology.

The assortment of luminescent and non-luminescent nanothermometers proposed over the last decade clearly point to an emerging interest in nanothermometry in a large variety of fields, from electronic to photonic devices, from optoelectronic to micro/nanofluidics and nanomedicine. At the same time, nanothermometry is a multidisciplinary and challenging subject requiring new approaches and new techniques, since conventional thermometry is not valid at such scales.

Apart from a few pioneering works published at the very end of the past century, the subject of investigating and developing thermometric devices that work with sub-micrometre space resolution has exploded in the last 10 years. Particularly since 2010, the research on the field has been biased towards luminescent nanothermometry and its applications in photonics, electronics, fluids, and nanomedicine. For instance, luminescent nanothermometers have already been used to provide thermal readings during photothermal treatments in both culture cells and living organisms.

Several reviews have recently described the progress on high-resolution thermometers operating at the sub-micron scale, including luminescent and non-luminescent nanothermometers, intracellular measurements, ceramic phosphors that can withstand extreme temperatures, multiple optical

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chemical sensors and temperature-stimuli polymers. Despite the coverage of the subject, we have arrived at the conclusion that this very multidisciplinary subject demands a more solid piece of work, half way between a monograph and a reference book, where specialists in each particular technique can cover it, discussing achievements and limitations as well as future trends and technological possibilities. This was exactly the original purpose of this book.

The book is organized in four quite independent sections (Fundamentals, Luminescence- and Non-Luminescence-Based Thermometry and Applications) comprising sixteen chapters. After a bird's-eye short review on nanoscale thermometry and temperature measurements, the remaining two chapters of the first section encourage the reader to reflect on the basics of nanothermometry, namely the minimal length scales for the existence of local temperature and heat transfer at the nanoscale.

Section II examines in detail luminescent thermometers based on different thermal nanoprobes: Quantum dots (Chapter 4), lanthanide phosphors (Chapter 5), organic dyes (Chapter 6), polymers (Chapter 7), and organic–inorganic hybrids (Chapter 8). Section III provides a comprehensive discussion about three important non-luminescent techniques to measure temperature: Scanning thermal microscopy (Chapter 9), near-field thermometry (Chapter 10) and nanotube thermometry (Chapter 11). Finally, Section IV explores some of the most exciting and intriguing nanothermometry applications, still limited in practice and results, such as cellular thermometers (Chapter 12), thermal issues in microelectronics (Chapter 13), heat transport in nanofluids (Chapter 14), temperature probes in micro/nanofluidics (Chapter 15) and multifunctional platforms for dual-sensing (Chapter 16).

The book renders lucid explorations of a number of significant and difficult problems in nanothermometry providing readers new to the field with a clear overview of this expanding topic, being simultaneously an inspiration to those already well versed in the field. The book is presented in a format that aims to be accessible to postgraduate students and researchers in physics, chemistry, biology and engineering interested in nanothermometry.

This book would have not been possible without the support and contributions from a significant number of people. In the first place it is our pleasure to acknowledge Prof. João Rocha, Series Editor of the *RSC Nanoscience & Nanotechnology Series*, for encouraging us to submit a book proposal to the Royal Society of Chemistry. We are also extremely grateful to the Royal Society of Chemistry for continuous and always stimulating support without which our work would have been much more difficult. Last but not least, we want to deeply thank to all the contributing authors for enthusiastically accepting our invitation and embracing the book's scope and vision. Their time, work and dedication deserve our most profound acknowledgement.

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Aveiro and Zaragoza

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