Preface

Light emitting diodes (LEDs) are a solid-state lighting source increasingly being used in display backlighting, communications, medical services, signage, and general illumination. LEDs offer design flexibility, have small exterior outline dimensions, higher energy efficiency, have longer life, provide higher performance, a wider range of controllable color temperatures, are eco-friendly products, and don't suffer from low-temperature startup problems, as compared to conventional lighting sources. Unfortunately, they produce heat, and contrary to conventional lighting sources this does cause serious problems (please keep in mind that if the bulb would have been invented today it would never have been legalized because of the excessive touch temperatures).

This book is about thermal management of LEDs and especially LED applications. The main question to be addressed is why we need thermal management in the first place. As Christian Belady put it eloquently in 2001:

> The ultimate goal of system thermal design is not the prediction of component temperatures, but rather the reduction of thermally associated risk to the product.

Hence, if your boss asks you: "Take care that the junction temperature does not exceed 125 °C", you may answer: "Why? Do we sell temperatures?" and then you may educate your boss: "The real objectives to realize are: we want to keep the Lifetime beyond x years, we want to keep the Color Point within margin y, and we want to raise the Efficiency to z %. And yes, these objectives that determine the quality of our LED-based products are linked to the junction temperature, but never as a goal in itself."

The book is divided in four parts: Part A: Basic Physics, Part B: Testing and Standardization, Part C: Advances in Cooling Technologies, and Part D: Applications.

Part A: Basic Physics

The evident link between temperature and various quality-related issues is the rationale behind Chap. 1, an Introduction to LED Thermal Management and Reliability, presenting a general overview of LED basics, LED manufacturing and LED failure mechanisms. Obviously, the first step in reaching the aforementioned goal of LED thermal design is to understand the basics of LED physics: what are the reasons that the temperature is rising anyway? This subject is treated in Chap. 2 on the basics of solid-state physics of LEDs. To be able to perform back-of-the-envelope calculations to get a rough idea about the feasibility of your design from a thermal point of view is an important first step: this topic is treated in Chap. 3.

Part B: Testing and Standardization

This part starts with Chap. 4 dealing with basic thermal characterization and testing. How to test LEDs from a lighting point of view is the subject of Chap. 5. Chapter 6 discusses the increasing need for a more sophisticated thermal characterization of LEDs and LED-based products. Unfortunately, the progress in thermal characterization has not kept pace with the exponential growth of the LED-business. Due to the lack of worldwide-accepted standards a manufacturer can publish whatever thermal information she/he wants. Hence, it becomes a problem for the experienced user because the thermal data that are published are often rather useless in practice when accuracy is at stake.

Part C: Advances in Cooling Technologies

Air cooling is by far the most frequent cooling method and will be for a long time to come. Natural and forced convection cooling, including synthetic jet cooling, is discussed in Chap. 7. Another important thermal management control option is the thermal interface material (TIM). For high-performance LED-based products it may even be the limiting factor in the thermal resistance chain. Current and future thermal interface materials are dealt with in Chap. 8. An even more important thermal control option is area enlargement, either by heat sinks attached to the LED substrate or by first transferring the heat through heat pipes to a location where area enlargement is easier to handle. Chapter 9 deals with the fundamentals a designer should master to enable an optimal choice out of the thousands of heat sinks available on the market.

Part D: Applications

Chapter 10 is related to Chap. 9 but focuses on applications in practice. Problems inherent to LED manufacturing from a thermal point of view are the subject of Chap. 11. Thermal management of sophisticated LED solutions is treated in Chap. 12, while another important application field, namely LED-driven display technologies, is discussed in Chaps. 13 and 14, the first providing a historical overview, and the second the state-of-the-art. Many LED applications are designed for use in harsh environments, for example automotive, aircraft, outdoor lighting, and signage everywhere on earth. Chapter 15 provides insight in the challenges these applications are facing. The book closes with Chap. 16 showing an overview of future directions in LED applications.

In summary, the editors are convinced that this book covers (almost) all aspects of thermal management that are relevant to the design of LEDs and LED–based systems.

In closing this preface, the editors would like to express their sincere thanks to all authors who made this book possible.

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