Preface

Human civilization revolves around artificial light. From its earliest incarnation as firelight to its most recent as electric light, artificial light is at the core of our living. It has freed us from the temporal and spatial constraints of daylight by allowing us to function equally well day and night, indoors and outdoors. It has evolved from open fire, candle, carbon arc lamp, incandescent lamp, and fluorescent lamp to what is now on our doorstep: solid-state lighting (SSL). SSL refers to a type of lighting that uses semiconductor light-emitting diodes (LEDs), organic light-emitting diodes (OLEDs), or light-emitting polymers. Unlike incandescent or fluorescent lamps, which create light with filaments and gases encased in a glass bulb, solid-state lighting consists of semiconductors that convert electricity into light. Technological developments in the last two decades have allowed LEDs to be used first in signal devices, like traffic lights and exit signs, and then in some limited illumination applications, such as flashlights; and are now on the doorstep of massive general illumination applications, from homes to commercial spaces to outdoor lighting. This penetration is mainly due to the promise of an energy-saving opportunity with an increased and improved reliability at low cost. According to the projections of the Department of Energy (DOE) of the United States, replacing incandescent lamps with SSL would save US $250 billion in energy costs, reduce the electricity consumption by nearly one half, and avoid 1,800 million metric tons of carbon emissions over the next two decades.

Nowadays, the lighting industry experiences the exponentially increasing impact of digitization, and connectivity of its lighting systems. The impact is far beyond the impact on single products, but extends to an ever larger amount of connected systems. Continuously, more intelligent interfacing with the technical environment, and with different kinds of users is being built-in by using more and different kinds of sensors, (wireless) communication and different kinds of interacting or interfacing devices.

An LED system is composed of an LED engine (or LED module) with a microelectronics driver(s) and control gears, integrated in a housing that also provides the optical, sensing, heat dissipation and other functions. Knowledge of reliability at the component and system level is crucial for not only the business success of future SSL applications but also solving many associated scientific challenges. The increasing use of LEDs for intelligent applications will also pose additional reliability issues for SSL systems. It also means that system performance monitoring and further control options become more essential.

This book is part of the Solid State Lighting Technology and Application Series, with Prof Guo Qi Zhang as series editor. It is a continuation of *Solid State Lighting Reliability: Components to Systems* (published in 2013), with W.D. van Driel and X.J. Fan as editors. In that book, we presented the state-of-the-art knowledge and information on the reliability of SSL systems. The book soon became a reference book for SSL reliability from the performance of the (sub-)components to the total system. It was one of the top 25% most downloaded e-books in the relevant Springer eBook Collection in 2015 with up to 35,000 chapter downloads.

In the past 4 years, we have witnessed rapid development in technology and significant market penetration in many applications for LED systems. New processes and new materials have been introduced; new standards and new testing methods have been developed; new driver, control and sensing technologies have been integrated; and new and unknown failure modes have also been presented. In this book, *Solid State Lighting Reliability Part 2: Components to Systems*, we invited experts from the industry and academia to present the latest developments and findings in the LED system reliability arena. Topics in this book cover the early failures and critical steps in LED manufacturing, advances in reliability testing and standards, quality of color and color stability, degradation of optical materials and the associated chromaticity maintenance, characterization of thermal interfaces, LED solder joint testing and prediction, common failure modes in LED drivers, root causes for lumen depreciation, corrosion sensitivity of LED packages, reliability management for automotive LEDs, and lightning effects on LEDs. This book starts with a Quo Vadis and ends with a next frontier discussion in which the accomplishments so far are presented and what next hurdles need to be taken in order to make 100 % LED penetration an optional scenario.

Parts of the contents in this book are first-hand results from research and development projects. We would like to thank all the authors for their contributions to the book. We would like to acknowledge the contributions from the National High-Tech Research and Development Program of China (863 Program, Grant No.: 2015AA03A101), from which seven chapters in this book are supported. Dr van Driel and Prof Zhang would also like to make acknowledgments to many of their colleagues in Philips Lighting and Delft University of Technology who have contributed to this book in one way or another.

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