

# LED

## 及其应用技术

刘木清 主编



 化学工业出版社

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·北京·

《LED 及其应用技术》由复旦大学电光源研究所的专家编写。

全书按照 LED 产业链的主线进行编写, 试图从 LED 的原理、材料、芯片、封装、应用等阐述 LED。全书分为 16 章, 第 1 章电光源综述, 主要介绍光源的历史并对 LED 与传统光源进行比较; 第 2 章介绍 LED 的发光原理; 第 3 章介绍 LED 的材料体系; 第 4 章介绍 LED 的光取出; 第 5 章介绍 LED 的芯片制造技术; 第 6 章介绍 LED 的封装技术; 第 7 章介绍白光 LED; 第 8 章介绍 LED 器件的性能; 第 9 章介绍 LED 光及热特性的测试; 第 10~12 章分别介绍 LED 应用技术的三个重要方面, 即光学设计、驱动技术与散热技术; 第 13、14 章分别介绍用于普通照明的中小功率、大功率 LED 灯具; 第 15 章介绍 LED 的信号显示与背光应用; 第 16 章介绍 LED 的非视觉应用。

本书可作为光源照明和建筑行业的工程师及相关爱好者的参考书, 也可以作为大专院校建筑、光源与照明等相关专业的研究生和本专科学生教材。

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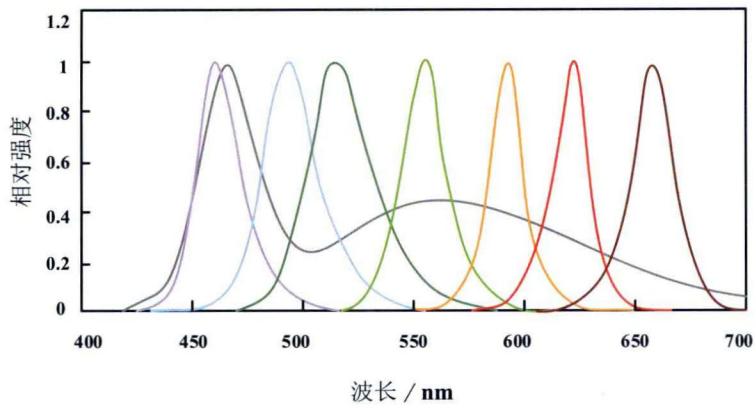


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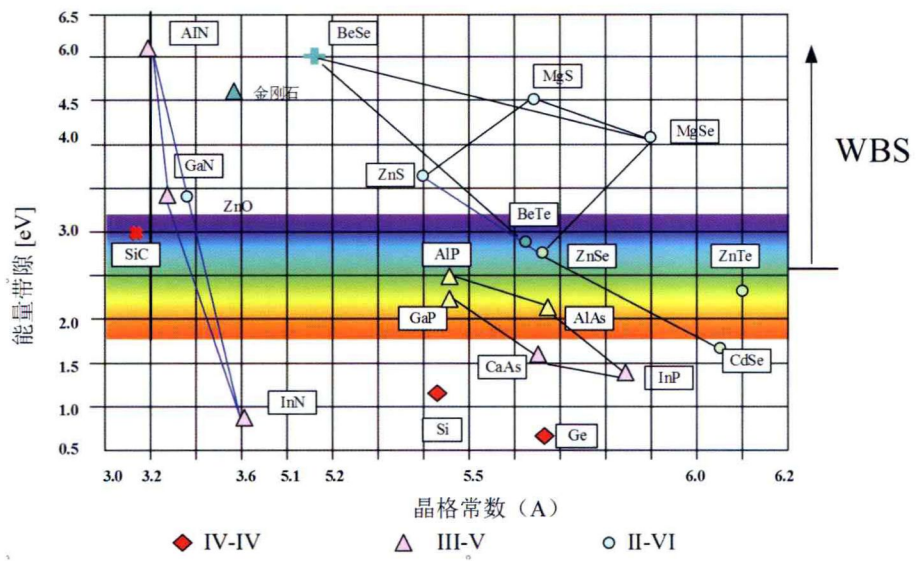


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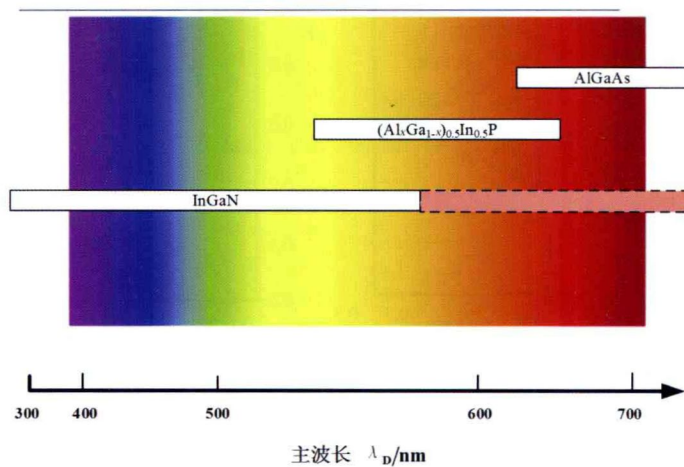


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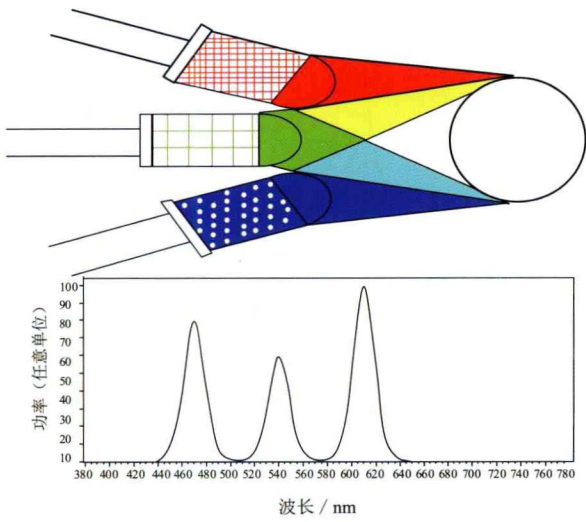


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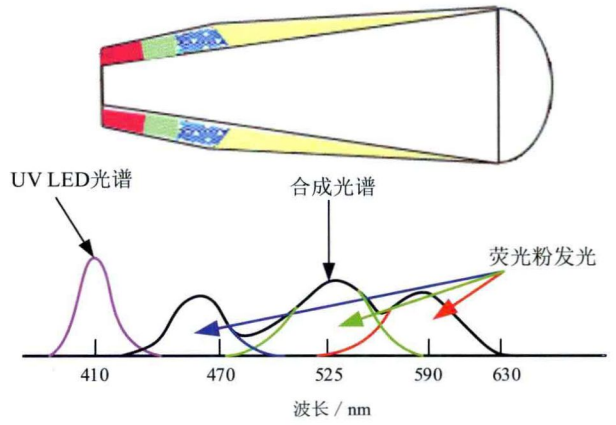


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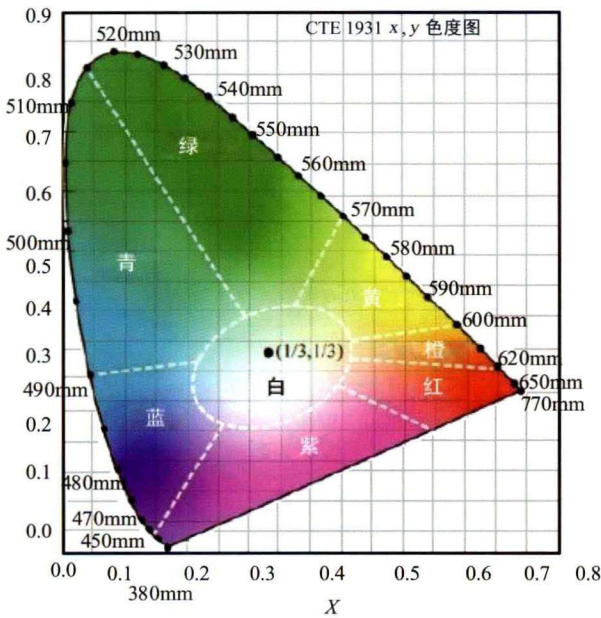


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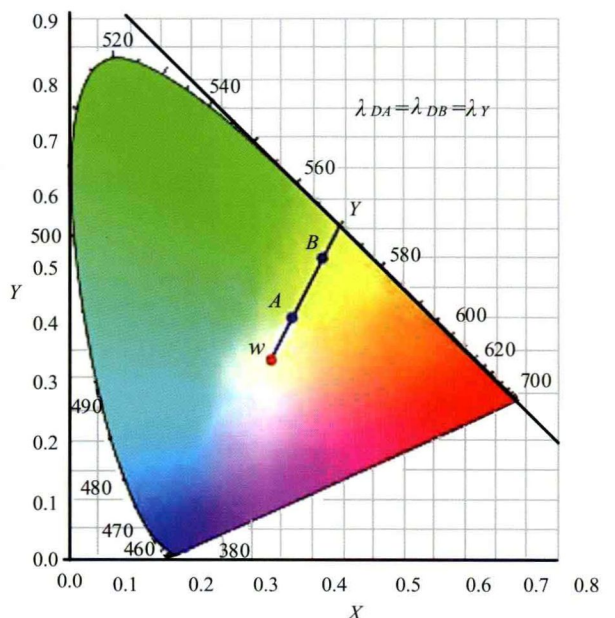


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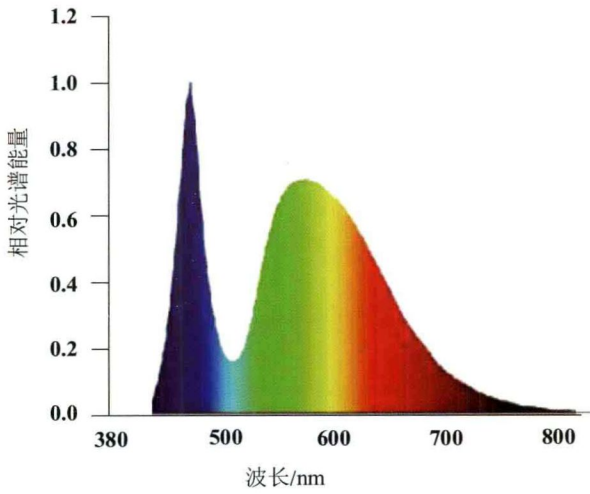


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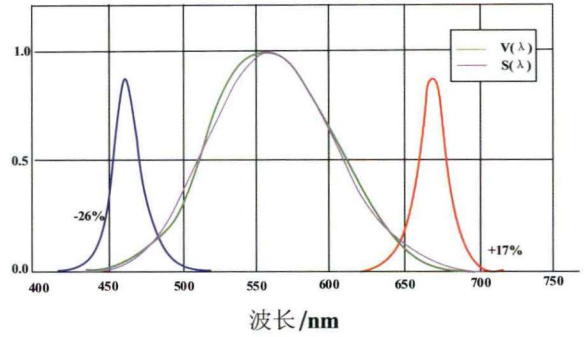


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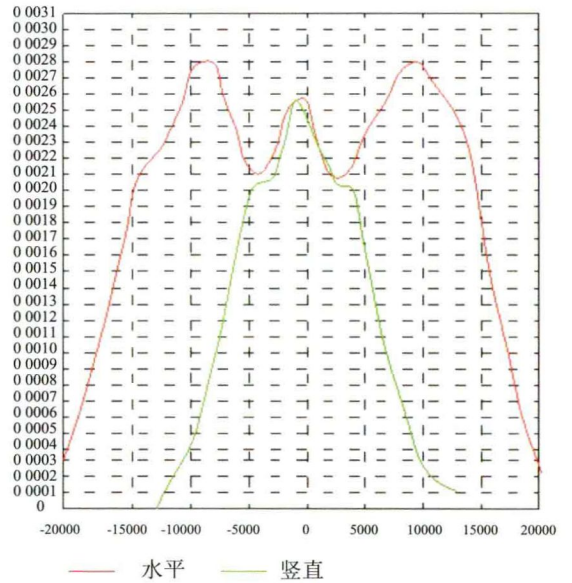
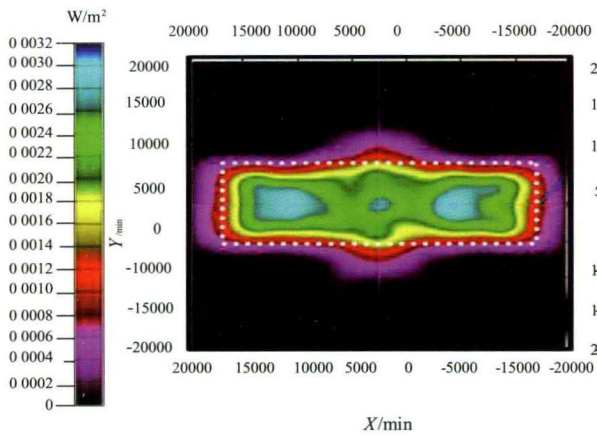


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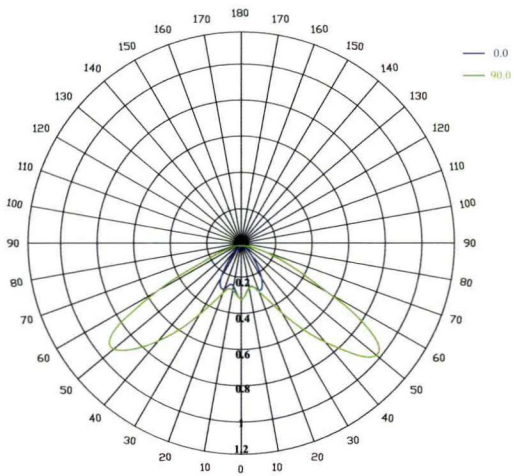


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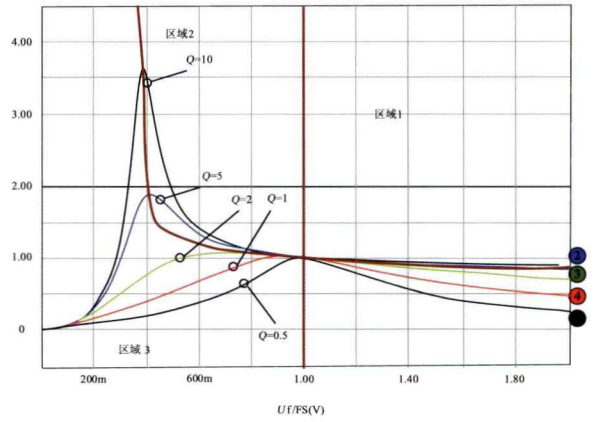


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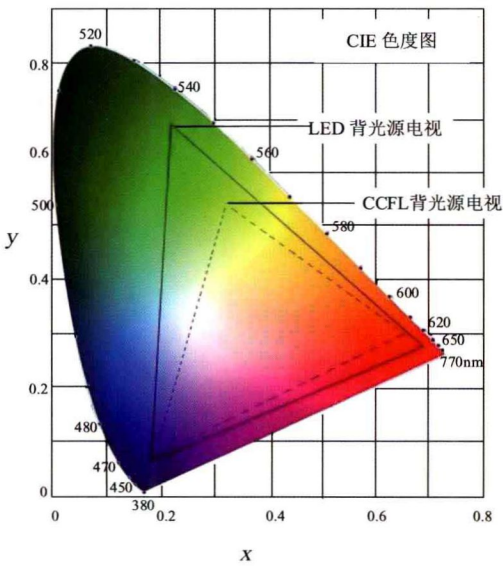


图15.6 RGB LED方法比CCFL有更大的色域

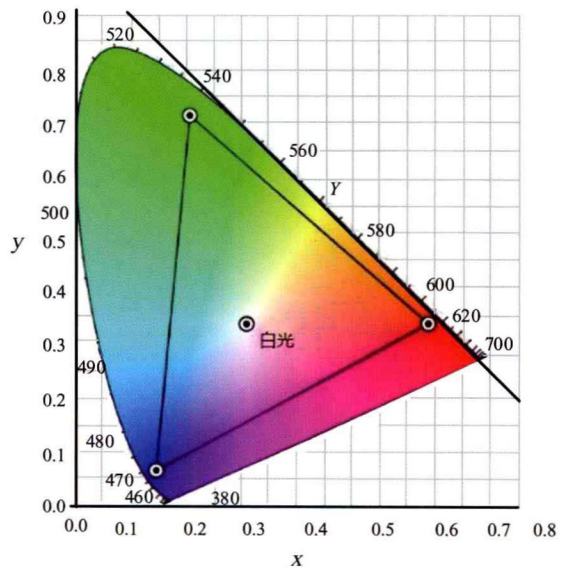


图16.2 CIE三刺激值函数  $x(\lambda)$ 、 $y(\lambda)$ 、 $z(\lambda)$

# First Foreword (序一)

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The emergence of high-brightness light-emitting diode (HB-LED) white light source technology, made possible by the development of blue LEDs in the 1990s, is an exemplar of disruptive technology introduction. Its promise and potential for delivering low-cost, high efficiency illumination sources, with much improved life-cycle costs (LCC) compared to incumbent technologies, is being realized and it is on course to become the dominant lighting technology in the majority of major lighting sectors, i. e. , residential, retail, commercial and industrial.

The importance of HB-LED technology does not derive simply from its advantages as an energy efficient and cost effective alternative to the established thermal and plasma light source technologies, widely referred to now as “legacy” lighting. It is important also because of at least two of its other major characteristics. Firstly, LEDs are simple electronic circuit components enabling them to be incorporated into complex multi-sensor, multi-function, addressable lighting systems, i. e. , a basis for “intelligent” lighting. Secondly, multi-LED systems, with or without the assistance of phosphors, make it possible to realize spectral power distributions (SPDs) of almost arbitrary profile in the near-uv, visible and near-ir regions. In the visible region this latter characteristic makes it possible, for example, to dynamically control the colour temperature of a lit internal space to mimic the diurnal behaviour of daylight. Importantly, the ability to design the SPD of sources is highlighting a need for much greater understanding of the interaction of living systems with light, for example, as it relates to human health or to plant growth.

Such issues and opportunities deriving from the characteristics of HB-LED technology have created a rich, diverse and rapidly growing area of lighting-related research worldwide to help guide the further, decades long, development of the technology and its applications, including its many non-lighting applications. HB-LED technology may be said to have emerged from its revolutionary development phase to become today an established alternative lighting technology, albeit with a long development path ahead to reach its full potential.

This timely and valuable book by Professor Liu Muqing and colleagues from the Institute for Electric Light Sources at Fudan University, made available to me as a machine translation from the original Chinese, takes the opportunity to review the technology as it transitions from revolutionary to evolutionary phases of development. The book provides in-depth, accessible descriptions of the major constituent parts of LED modules and their underlying design principles, of the driver and control technologies, and of device performance metrol-



ogy. The book describes also several of the major application areas of HB-LEDs, including non-lighting applications. As highlighted in the Foreword by Secretary General Wu Ling, Professor Liu and his colleagues have made significant contributions to LED-lighting applications in China. They have achieved also international recognition because of the LED-related research they have presented to major international conferences on lighting science and technology over several decades.

The perspective the book provides ensures that it will become a valuable learning and reference resource for: students beginning a career in lighting and related technologies; experienced lighting professionals, including designers and specifiers, who wish to deepen their knowledge of this increasingly important element of their daily work; newcomers to lighting; and anyone with a scientific/technical background with an interest in technological developments, intrigued by the high public/legislative/commercial profile of HB-LED-based solid state lighting (SSL) .

China is playing a most important role in the development of HB-LED lighting systems both in respect of its world leading productive capacity and, increasingly, in respect of its national research and development activities. I expect this book, and future editions updated as the technology progresses, to be very well received by the Chinese lighting community.



**Robin Devonshire**

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Chair, International Scientific Committee, LS Symposia (国际光源科技研讨会, 学术委员会主席)

# 序二

人类的照明技术一直在进步，作为照明物质基础的电光源经历了热辐射光源、气体放电光源等发展历程，已经开始步入固态光源时代。LED 作为固态照明的主要光源，是照明领域近年来发展的最大亮点，受到国际特别是科技较为发达的政府与产业界的高度重视。一方面技术的进步使 LED 光效等性能指标快速提高，另一方面性能的快速提高也成就了价格的下降并进入了各种照明市场。中国从 2003 年开始，通过“十五”、“十一五”、“十二五”计划，在科技部、发改委等部委及地方政府的持续支持下，LED 技术发展日新月异，产业规模持续扩大，其科技与产业等方面都在国际上占有一席之地。

本书对 LED 产业链的上游材料与芯片、中游封装及下游应用都进行了介绍，特别是下游 LED 应用技术，更为详细，包括 LED 应用的关键技术及主要应用领域等；书中也包含了作者的一些观点与近年来的研究成果。

本书作者来自复旦大学电光源研究所，这是一个在传统照明领域为我国做出重大贡献的研究机构，近年来在 LED 应用领域也取得了很多创新性成果。其中主要作者刘木清作为科技部“十一五”863 专家参与了相关国家科技计划的制订，为推动我国 LED 应用技术的发展做出了积极的贡献。如书中介绍的上海长江隧道 LED 照明应用，是目前世界上最大的单个 LED 隧道照明工程，对业界产生了很大影响，基于该隧道的技术规范已成为国家半导体照明工程研发及产业联盟的技术标准。

中国是照明大国，目前 LED 产业及应用规模也是全球最大的，特别是从事 LED 技术及相关产业的人员众多，希望这本书能够对 LED 照明研发和应用的业内人士及对此感兴趣的相关人员提供可供借鉴的参考。

国家半导体照明工程研发及产业联盟秘书长



2013 年 6 月

# 前言

20世纪90年代LED在蓝光LED技术上的突破以来，LED技术受到世界上科技发达国家的高度重视，通过各自的国家科技计划推动LED的发展。在这种情况下，LED无论从技术与产业的角度都获得很大的发展，并且还在快速发展之中。目前LED已经成为照明的重要光源并且在不久的将来有望成为主流光源，同时LED的特点也诞生出许多传统光源不能实现的应用领域，特别是LED的非视觉应用。因此，我国大专院校很多相关的专业都从事LED知识的讲授，各地都有很多科研机构进行LED的相关科研工作，进行LED生产或应用的企业更是非常多。鉴于此，本书对LED相关的主要环节进行介绍，试图使读者对LED有较深入的了解。

全书按照LED产业链的主线进行编写，试图从LED的原理、材料、芯片、封装、应用等阐述LED。全书分为16章，第1章电光源综述，介绍光源的历史并对LED与传统光源进行比较；第2章介绍LED的发光原理；第3章介绍LED的材料体系；第4章介绍LED的光取出；第5章介绍LED的芯片制造技术；第6章介绍LED的封装技术；第7章介绍白光LED；第8章介绍LED的器件的性能；第9章介绍LED光及热特性的测试；第10~12章分别介绍LED应用技术三个重要方面，即光学设计、驱动技术与散热技术；第13、14章分别介绍用于普通照明的中小功率、大功率LED灯具；第15章介绍LED的信号显示与背光应用；第16章介绍LED的非视觉应用。

本书可作为大专院校建筑、光源与照明等相关专业的研究生和本专科学学生教材，也可以作为光源照明和建筑行业的工程师及相关爱好者的参考书。

本书由复旦大学电光源研究所几位老师与研究生共同编写，其中刘木清多年在复旦大学进行“LED及其应用技术”课程的讲授，并长期在LED应用技术领域进行科研工作，相关的多个科研成果在书中有表述。崔旭高负责第2、3、4、5章的大部分编写工作；江磊负责第11章编写；刘颖负责第6章的编写，其余章节与内容由刘木清负责编写。全书由刘木清、高维惜统稿。

感谢韩凯、甘媛媛、顾鑫等同学在编写过程中的帮助。另外，特别要感谢复旦大学客座教授、国际电光源委员会主席 Devonshire 博士为本书作序、编写英文目录，感谢 Devonshire 博士及复旦大学客座教授、CIE 前主席 Van Bommel 先生对本书多个问题的讨论。

由于编者水平有限，书中试图涉及LED直接相关的各个领域，而这些领域跨度很大，因此疏漏之处在所难免。同时LED目前仍然处于高速发展阶段，许多内容处于不断的更新之中。鉴于此，书中如有疑问或不当部分，请联系 [mqliu@fudan.edu.cn](mailto:mqliu@fudan.edu.cn)。

编者  
2013年6月

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