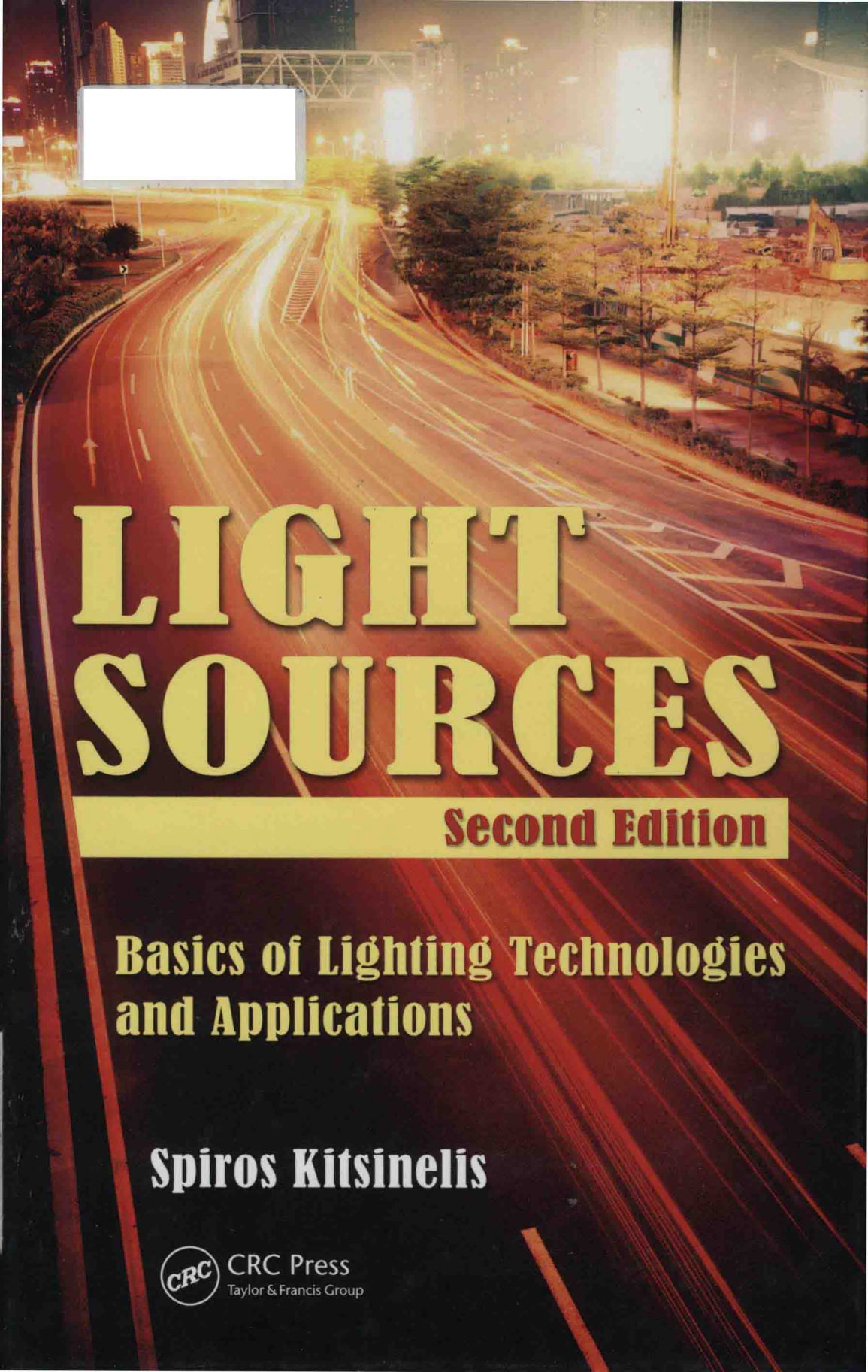
LIGHT SOURCES
Second Edition
Basics of Lighting Technologies and Applications
Spiros Kitsinelis
CRC Press
Taylor & Francis Group

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Dedicated to my son Christos…the light of my life!

Prologue

The spread of electricity and the development of power grids that began with Thomas Edison changed the way we illuminate our lives and created a new industry. The present book, just like its first edition, provides an overview of the three main technologies that gave birth to the numerous families of products one can find in the market today. Electrical *incandescence*, electrical *gas discharges*, and semiconductor *light-emitting diodes* are those three dominant technologies that have lighted our world for more than a century.

This second edition not only provides updates on the scientific and technological developments of existing and new light sources but also expands on the topic of applications. Different lamp technologies are characterized based on a large number of parameters that need to be taken into account before making a choice; but in this book, the selections and proposals for various applications are based mainly on the "quality" of light, which basically means the *color/wavelength* of the light, the *color rendering index* of the source, and in the case of white light—the *color temperature*. In some cases, other parameters such as the luminous flux or the lifetime may play a role.

This book will assist lighting engineers design the most appropriate environments for people with various needs and professions. Health professionals will be able to create the appropriate visual environment for people with different medical conditions, thus improving the quality of life for many groups of citizens. The book will also serve as a guide for authorities who have to choose the correct technology for cost-effective lighting schemes in order to increase the security and aesthetics of communities. Finally, it will help the ordinary citizen decide which technology will suit him or her the best at home or at work.

Other Sources

This book is an overview of all the main technologies and important families of light sources that have dominated the market and our lives since the end of the 19th century. It is not, however, an exhaustive list of all the available commercial products. There is no point in trying to keep up with all the special characteristics of new products, which change rapidly, and this type of update would be better served by the catalogs of all the major companies.

The photographic material in this book comes from three main sources:

- The author's own collection
- The Museum of Electric Lamp Technology (J.D. Hooker, http://www.lamptech.co.uk)
- Wikimedia Commons (http://commons.wikimedia.org)

The reader will find references at the end of the chapters regarding specific research results, but the general information presented throughout this book is based on the following two important sources:

- *Lamps and Lighting*, 4th Edition, by J.R. Coaton and A.M. Marsden, 1996, London: Routledge/Taylor & Francis Group
- *Electric Discharge Lamps*, by John Waymouth, 1971, Cambridge: MIT Press

More information and publications on lighting design and standards can be acquired from a number of professional organizations such as:

The *International Commission on Illumination* (CIE), which is an international authority and standard defining organization on color and lighting. CIE publishes widely used standard metrics such as various CIE color spaces and the color rendering index (http://cie.co.at).

The *Illuminating Engineering Society of North America* (IESNA) publishes lighting guidelines, standards, and handbooks (http://www.ies.org).

The *International Association of Lighting Designers* (IALD) is an organization that focuses on the advancement of lighting design education and the recognition of independent professional lighting designers (http://www.iald.org).

The *Professional Lighting Designers Association* (PLDA) is an organization focused on the promotion of the profession of architectural lighting design (www.pld-c.com).

About the Author

Spiros Kitsinelis, Ph.D., is a researcher whose focus is on the development of novel and energy efficient light sources and on the communication of this science to a broader audience. He earned his master's and Ph.D. degrees in chemistry from the University of Sheffield in England for his research and development of pulse-operated low-pressure plasma light sources in the High Temperature Science Laboratories. He continued his research as a postdoctoral fellow at Ehime University in Japan in the Department of Electrical and Electronic Engineering. Dr. Kitsinelis held the position of project leader at Philips Lighting Central Development Lighting in the Netherlands, and continued his research and development of the next generation of plasma light sources for the Physics

Department of the National Technical University of Athens, Greece. After a respite from research when he served as a chemical engineer for the armed forces, he acted as the National Contact Point for Energy at the National Documentation Centre of the National Research Foundation of Greece; set up the electronic periodical *Science and Technology of Light Sources* (*SATeLightS*); and later worked as a researcher at Paul Sabatier University in Toulouse, France.

Dr. Kitsinelis is the author of a number of scientific publications, has attended many international conferences, and is the cocreator of a number of patents in the field of light sources. His science communication activities include books, television and radio shows, science film festivals, and articles in popular magazines. His latest academic position was that of associate professor at Ehime University in Japan. His personal Web site contains more details at: www.the-nightlab.com.

Dr. Kitsinelis has previously published two books with CRC Press/Taylor & Francis: *Light Sources: Technologies and Applications,* First Edition (2010), and *The Right Light: Matching Technologies to Needs and Applications* (2012).

Acknowledgments

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Introduction

Humanity has to deal with two main issues regarding energy. The first is the availability of nonsustainable energy sources and whether the global demand for energy can be met. This is due to energy source depletion in certain parts of the world or due to geopolitical factors, and in any case, the impact to the global economy is substantial. The second issue is one that deals with the environmental changes of the planet and the impact these changes have on our lives. The burning of fossil fuels as the most common energy generation mechanism results in the formation and emission of carbon dioxide as a byproduct, which is one of the gases responsible for the greenhouse effect.

Considering that humans are using about a fifth of the world's generated electric energy for lighting applications [1,2], it is easy to appreciate the importance of light source technologies both from an economic perspective and from an environmental standpoint. Light sources and lighting not only represent an economic market of billions of dollars but the consumption of energy for lighting is responsible for the generation of millions of tons of CO_2 gas annually.

Furthermore, light is vital and light sources play an indispensable role in daily life. The quality of life, including aspects such as health and urban security related to traffic and crime prevention, depend on light and its quality. Of course, the use of light sources is not limited to general lighting, but also to a range of other applications that require emissions in the ultraviolet and infrared part of the electromagnetic spectrum, such as sterilization, health science, aesthetic medicine, art conservation, food processing, and sterilization of hospitals or water, to name a few.

Efforts to create light at will, as well as to understand its nature, started thousands of years ago with the use of fire. Over time, the burning of wood was replaced by the burning of oil and later, in the 18th century, by the burning of gas. The harnessing of electricity and its use brought about a revolution not only in the way we live our lives but also in the way we light our lives. Electric lighting

technologies have been with us since the middle of the 19th century and have been evolving ever since. The first technology, incandescence of a filament, was due to the efforts of people such as Heinrich Gobel in the middle of the 19th century, and Joseph Swan and Thomas Edison a few years later. The second technology, electrical discharge through gas, became widespread in the beginning of the 19th century thanks to Humphry Davy. The third technology, the use of diodes resulting from developments in the semiconductor field, was born much later in the middle of the 20th century, once again revolutionizing the field of lighting.

When Isaac Newton analyzed white light into its constituent colors in the middle of the 17th century, explaining the formation of rainbows, he did not discount the magic of this phenomenon but opened the door to another magical world that had to do with the nature of light. Even though since the time of the ancient Greek philosophers, questions regarding the way the human eye functions and the nature of light continue to tantalize scientists. Today, after centuries of experiments and scientific disputes, certain ideas and theories have been proven and become universally accepted. Some of the basic properties of light will be discussed in Chapter 1.

References

1. European Commission, Directorate-General for Energy and Transport (2007). EU energy and transport in figures. Statistical Pocketbook 2007/2008. http//ec.europa.eu/dgs/energy_transport/figures/pocketbook/doc/ 2007/2007_pocketbook_all_en.pdf.
2. International Energy Agency (2006). *Light's Labour's Lost: Policies for Energy-Efficient Lighting.* http://www.iea.org/publications/freepublications/publication/light2006.pdf.

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