

IESNA
Technical
Memorandum
on
Light Emitting
Diode (LED)
Sources
and
Systems

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Prepared by:
The IESNA Light Sources Committee



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Technical Memorandum on Light Emitting Diode (LED) Sources and Systems

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The IESNA Light Sources Committee

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Approved by the IESNA Board of Directors, April 11, 2005, as a Transaction of the Illuminating Engineering Society of North America.

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Published by the Illuminating Engineering Society of North America, 120 Wall Street, New York, New York 10005.

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Printed in the United States of America

ISBN # 0-87995-206-70

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Technical Memorandum on Light Emitting Diode (LED) Sources and Systems

FOREWORD

The purpose of this Technical Memorandum is to describe Light Emitting Diode (LED) sources and systems and to answer the most common questions that the lighting industry receives from the curious public. The authors, all members of the IESNA Light Sources Committee, represent a wide cross section of lighting disciplines – from LED-source, lamp, and luminaire manufacturers to lighting-controls producers.

While LEDs operate by converting electrical energy into light energy, this is the only similarity with other light sources in general use today. LEDs look different, are manufactured differently, and are handled differently than other light sources. For example, consumers cannot go to their local hardware store and purchase a replacement “LED lamp.”

LEDs are currently being used in advertising signs, keychain and full-power flashlights, exit signs, traffic signals, and vehicle signaling systems – literally hundreds of unique applications. Research by dozens of companies is underway to deploy LEDs even further. The ultimate goal is to move these special light sources into common usage for general lighting wherever applicable. Therefore, TM-16 will be updated from time to time to report on industry progress toward that end.

1.0 BRIEF HISTORY OF LEDS

1.1 Invention and Development

In 1962, Nick Holonyak of General Electric invented the first practical light-emitting diode operating in the red portion of the visible spectrum. Throughout the later 1960s and 1970s, further invention and development produced additional colors and enabled LEDs to become a readily available commercial product. **Figure 1** illustrates the advances made in LED technology from the 1960s to the year 2000.

1.2 Product Deployment

LEDs were initially deployed as indicators in electronic measurement devices, and later used in seven-segment alpha-numerics that became briefly popular in digital watches and other display applications during the early 1970s. Later, as output power and color

variation improved, LEDs were adapted into various other direct displays including traffic lights and automotive applications.

Most often associated with the LED is the classic T-1½ lamp “bullet shape” because early LEDs retained the outline of the indicator they replaced. Later, surface mount technology (SMT) packaging was adopted because it did not require a through-hole when used on printed circuit boards, and it provided better thermal transfer. As power levels increased, new high-flux packages were developed to handle the increased thermal loads.

2.0 TECHNOLOGY OF LEDS

2.1 How LEDs Work

Basically, LEDs are solid-state semiconductor devices that convert electrical energy into visible light. When certain elements (see **Figure 2**) are combined in specific configurations and electrical current is passed through them, photons (light) and heat are produced. The heart of LEDs, often called a “die” or “chip,” is composed of two semiconductor layers – an n-type layer that provides electrons and a p-type layer that provides holes for the electrons to fall into. The actual junction of the layers (called the p-n junction) is where electrons and holes are injected into an active region. When the electrons and holes recombine, photons (light) are created. The photons are emitted in a narrow spectrum around the energy band gap of the semiconductor material, corresponding to visible and near-UV wavelengths.

Customers can purchase LED products in many different forms since the devices are sold as separate dies or in packages. Engineers, specifiers, and buyers should be directly involved in the specification of the LEDs, drivers, thermal management technology, and other system components to assure that the end product (luminaire) has the performance and life required. Often thermal management, mechanical mounting, driver circuitry, controls, lenses, and optics are offered as an optimized lighting system package (see **Figure 3**).

2.2 Types of LEDs

Discrete LEDs may be sold as the die itself. However, most LEDs are purchased in a package which is a much more usable configuration for the luminaire manufacturer. **Figure 4** shows examples of five different LED packages on the market today and illustrates their approximate size.



2.3 Basic Characteristics

2.3.1 Materials. Assembled as an LED, phosphides and nitrides of aluminum, indium, and gallium produce light of different colors and efficacies. The two major material groups are the InGaP (indium-gallium phosphide) compounds, used to create red and amber, and the GaN (gallium nitride) compounds, used to create blue, cyan, and green. These LED materials can also generate infra-red and ultra-violet radiation outside the visible range.

2.3.2 Size. LED die sizes range from tenths of millimeters for small-signal devices to greater than a square millimeter for the power packages available today. By using multiple dies or groups of packaged LEDs, the light needed by the application can be obtained.

2.3.3 Energy Output. The output of an LED is dissipated as light and heat. The light is emitted from the LED die in all directions. Based on the shape of the die, the material from which it is constructed, and the package in which it is assembled, light from the surface of a packaged LED can be captured for use in a lighting system. Heat is not radiated (as it is with conventional lighting technology) but is retained in the LED package. Heat must be effectively conducted away from the die by the packaging materials or the device leads. Without proper thermal management, internally-generated heat can cause packaged LEDs to fail. No infra-red or ultra-violet energy is emitted in the beam of a visible LED.

2.3.4 Color. The color of an LED is determined by the dominant wavelength of the device. Typical single-wavelength LED output falls on the standard CIE chromaticity diagram as shown in **Figure 5**.

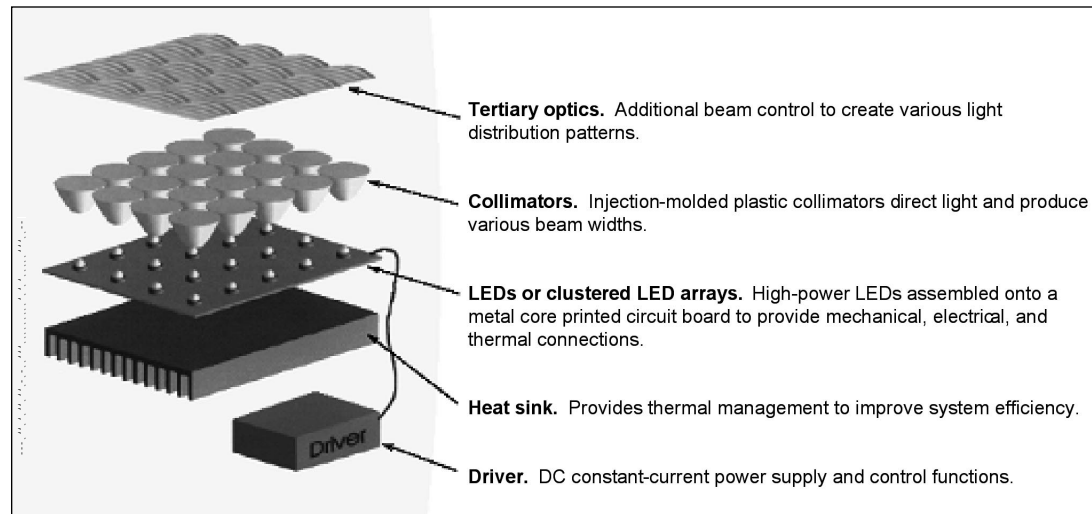


Figure 3. This typical packaged LED system contains multiple elements stacked together for optimum performance.

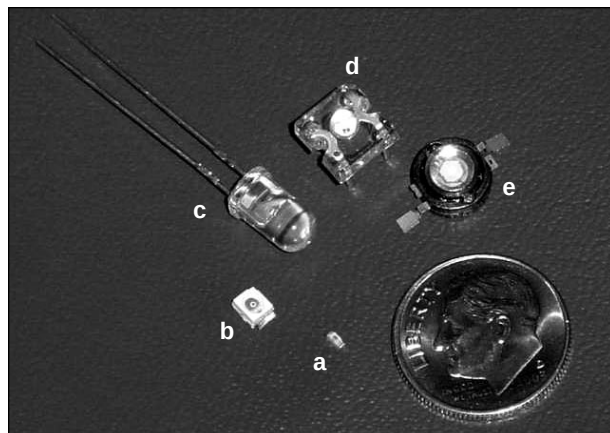


Figure 4: Common LED packages shown alongside a U.S. dime (17.9 mm diameter): (a) surface mount (<1 mm² area); (b) surface mount (~3 mm² area); (c) T-1½ lamp style (5 mm diameter), (d) super flux design (7.6 mm² area); and (e) high-flux power design (~8 mm diameter).

2.3.5 “White” LEDs. White light can be obtained from LEDs by any of the following three methods:

Color mixing: the primary light from three individual LEDs (red, green, and blue) is mixed together, creating white light (see **Figure 6** for an illustration of the color mixing principle).

Binary complementary wavelength conversion: a blue LED is complemented with a yellow phosphor and white light is created. Cool white LEDs (with a typical color temperature of 5500 K) are produced in this manner. By adding a secondary red phosphor, warm white LEDs (with a typical color temperature of 3200 K) are produced.

Ultra-violet wavelength conversion: a single ultra-violet LED is used to excite a tri-color phosphor, thus creating white light.