LED LAMP

Definitions

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Solid state lighting (SSL) refers to a type of lighting that utilizes **light-emitting diodes (LEDs)**, organic light-emitting diodes (OLED), or polymer light-emitting diodes (PLED) as sources of illumination rather than electrical filaments or gas.

Basics

A **light-emitting-diode lamp** is a solid-state lamp that uses light-emitting diodes (LEDs) as the source of light. Since the light output of individual light-emitting diodes is small compared to incandescent and compact fluorescent lamps, multiple diodes are used together. LED lamps can be made interchangeable with other types. Most LED lamps must also include internal circuits to operate from standard AC voltage. LED lamps offer long life and high efficiency, but initial costs are higher than those of fluorescent lamps.

General purpose lighting requires white light. LEDs by nature emit light in a very small band of wavelengths, producing strongly colored light. The color is characteristic of the energy bandgap of the semiconductor material used to make the LED. To create white light from LEDs requires either mixing light from red, green, and blue LEDs, or using a phosphor to convert some of the light to other colors.

The first method (RGB-LEDs) uses multiple LED chips each emitting a different wavelength in close proximity to create the broad white light spectrum. The advantage of this method is the fact that one can adjust the intensities of each LED to "tune" the character of the light emitted. The major disadvantage is the high manufacturing cost, which is probably most important in commercial success.

The second method, phosphor converted LEDs (pcLEDs) uses a single short wavelength LED (usually blue or ultraviolet) in combination with a phosphor, which absorbs a portion of the blue light and emits a broader spectrum of white light. (The mechanism is similar to the way a fluorescent lamp produces white light from a UV-illuminated phosphor.) The major advantage here is the low cost, while the disadvantage is the inability to fine tune the character of the light without completely changing the phosphor layer. So while this will not yield high CRI (color rendering index) values without sacrificing some other performance property, the low cost and adequate performance makes it the most suitable technology for general lighting today.

To be useful as a light source for a room, a number of LEDs must be placed close together in a lamp to add their illuminating effects. This is because an individual LED produces only a small amount of light, thereby limiting its effectiveness as a replacement light source. If white LEDs are used, their arrangement is not critical for color balance. When using the color-mixing method, it is more difficult to generate equivalent brightness when compared to using white LEDs in a similar lamp size. Furthermore, degradation of different LEDs at various times in a color-mixed lamp can lead to an uneven color output. LED lamps usually consist of clusters of LEDs in a housing with both driver electronics, a heat sink and optics.

In 2008, SSL (Solid-State Lighting) technology advanced to the point that Sentry Equipment Corporation in Oconomowoc, Wisconsin, USA, was able to light its new factory almost entirely with LEDs, both interior and exterior. Although the initial cost was three times more than a traditional mixture of incandescent and fluorescent bulbs, the extra cost will be repaid within two years from electricity savings, and the bulbs should not need replacement for 20 years.

Application

LED lamps are used for both general lighting and special purpose lighting. Where colored light is required, LEDs come in multiple colors, which are produced without the need for filters. This improves the energy efficiency over a white light source that generates all colors of light then discards some of the visible energy in a filter.

White-light light-emitting diode lamps have the characteristics of long life expectancy and relatively low energy consumption. The LED sources are compact, which gives flexibility in designing lighting fixtures and good control over the distribution of light with small reflectors or lenses. LED lamps have no glass tubes to break, and their internal parts are rigidly supported, making them resistant to vibration and impact. With proper driver electronics design, an LED lamp can be made dimmable over a wide range; there is no minimum current needed to sustain lamp operation. LEDs using the color-mixing principle can produce a wide range of colors by changing the proportions of light generated in each primary color. This allows full color mixing in lamps with LEDs of different colors. LED lamps contain no mercury.

However, some current models are not compatible with standard dimmers. It is not currently economical to produce high levels of lighting. As a result, current LED screw-in light bulbs offer either low levels of light at a moderate cost, or moderate levels of light at a high cost. In contrast to other lighting technologies, LED light tends to be directional. This is a disadvantage for most general lighting applications, but can be an advantage for spot or flood lighting.

Current users

The world's first mass-installation of LED lighting is in the Manapakkam, Chennai office of the Indian IT company iGate. It spent Rs. 37 lakh (U$80,000) to light up 57,000 sq feet of office space. The company expects the LED lighting to completely pay for itself within 5 years, due to its energy efficiency being superior to Tubelight and Compact fluorescent lamp.

Using LED lamps on household AC power

Main article: LED circuit

A single LED is a low-voltage solid state device and cannot be directly operated on household AC current without some circuit to control current flow through the lamp. A series resistor could be used to limit current, but this is inefficient since most of the applied voltage would be wasted on the resistor. A single series string would minimize dropper losses, but one LED failure would extinguish the whole string.

Paralleled strings increase reliability. In practice usually 3 strings or more are used.

Lamp sizes and bases

LED lamps intended to be interchangeable with incandescent lamps are made in standard light bulb shapes, such as an Edison screw base, an MR16 shape with a bi-pin base, or a GU5.3 (Bipin cap) or GU10 (bayonet socket). LED lamps are made in low voltage (typically 12 V halogen-like) varieties and replacements for regular AC (e.g. 120 or 240 VAC) lighting. Currently the latter are less widely available but this is changing rapidly.

The LED light bulb

As of 2010, only a few LED light bulb options are available as replacements for the ordinary household incandescent or compact fluorescent light bulb. One drawback of the existing LED bulbs is that they offer limited brightness, with the brightest bulbs equivalent to a 45-60 W incandescent bulb. Most LED bulbs are not able to be dimmed, and their brightness retains some directionality. The bulbs are also expensive, costing $40–50 per bulb, whereas the ordinary incandescent bulb costs less than a dollar. However, these bulbs are slightly more power efficient than the compact fluorescent bulbs and offer extraordinary lifespans of 30,000 or more hours. An LED light bulb can be expected to last 25–30 years under normal use. LED bulbs will not dim over time and they are mercury free, unlike the compact fluorescent bulbs. Recent research has made bulbs available with a variety of color characteristics, much like the incandescent bulb. With the savings in energy and maintenance costs, these bulbs can be attractive. It is expected that with additional development and growing popularity, the cost of these bulbs will eventually decline.

Fluorescent tubes with modern electronic ballasts commonly average 50 to 67 lumens/W overall. Most compact fluorescents rated at 13 W or more with integral electronic ballasts achieve about 60 lumens/W, comparable to the LED bulb. A 60 W incandescent bulb offers about 850 lumens, or 14 lumens/W.

Several companies offer LED lamps for general lighting purposes. The C. Crane Company has a product called "Geobulb". The GeoBulb II uses only 7.5 W (59 lumens/W). In October 2009, the GeoBulb II was superseded by the GeoBulb-3 which is brighter and longer lasting.The company also offers wedge-base lamps for replacement in low voltage fixtures. In the Netherlands, a company called Lemnis Lighting offers a dimmable LED lamp called Pharox. The company Eternleds Inc. offers a bulb called HydraLux-4 which uses liquid cooling of the LED chips.

Comparison to other lighting technologies

See luminous efficacy for an efficiency chart comparing various technologies.

- Incandescent lamps (light bulbs) create light by running current through a resistive filament, thereby heating the filament to a very high temperature so that it glows and produces visible light. A broad range of visible frequencies are naturally produced, yielding a pleasing warm yellow or white color quality. Incandescent light however, is highly inefficient, as approximately 98% of the energy input is emitted as heat. A 100 W light bulb produces about 1,700 lumens, about 17 lumens/W. Incandescent lamps are relatively inexpensive to produce. The typical lifespan of an AC incandescent lamp is around 1,000 hours They work well with dimmers. Most existing light fixtures are designed for the size and shape of these traditional bulbs.

- Fluorescent lamps (light bulbs) work by passing electricity through mercury vapor, which in turn produces ultraviolet light. The ultraviolet light is then absorbed by a phosphor coating inside the lamp, causing it to glow, or fluoresce. While the heat generated by a fluorescent lamp is much less than its incandescent counterpart, energy is still lost in generating the ultraviolet light and converting this light into visible light. If the lamp breaks, exposure to mercury can occur. Linear fluorescent lamps are typically five to six times the cost of equivalent incandescent lamps but have life spans around 10,000 and 20,000 hours. Lifetime varies from 1,200 hours to 20,000 hours for compact fluorescent lamps. Most fluorescent lamps are not compatible with dimmers. Those with "iron" ballasts flicker at 100 or 120 Hz, and are less efficient. The latest T8-sized triphosphate fluorescent lamps produced by Osram, Philips, Crompton and others have a life expectancy greater than 50,000 hours, if coupled with a warm start electronic ballast. The efficiency of these new lamps approaches 100 lumens/W.

Research and development

US Department of Energy

In May 2008, the United States Department of Energy (DOE) announced details of the Bright Tomorrow Lighting Prize competition. The L Prize is the first government-sponsored technology competition designed to spur lighting manufacturers to develop high quality, high efficiency solid-state lighting products to replace the common light bulb. The competition will award cash prizes, and may also lead to opportunities for federal purchasing agreements, utility programs, and other incentives for winning products.

The Energy Independence and Security Act (EISA) of 2007 authorizes DOE to establish the Bright Tomorrow Lighting Prize competition. The legislation challenges industry to develop replacement technologies for the most commonly used and inefficient products, 60 W incandescent lamps and PAR 38 halogen lamps. The L Prize specifies technical requirements for these two competition categories. Lighting products meeting the competition requirements would consume just 17% of the energy used by most incandescent lamps in use today. A future L Prize program announcement will call for development of a new “21st Century Lamp,” as authorized in the legislation.

The EISA legislation establishes basic requirements and prize amounts for each category. The legislation authorizes up to $20 million in cash prizes. On September 24, 2009 the DOE announced that Philips was the first to submit lamps in the catogory to replace the of the standard 60 W A-19 "Edison" light bulb.

National Institute of Standards and Technology

In June 2008, scientists at the National Institute of Standards and Technology (NIST) announced the first two standards for solid-state lighting in the United States. These standards detail the color specifications of LED lamps and LED light fixtures, and the test methods that manufacturers should use when testing these solid-state lighting products for total light output, energy consumption and chromaticity, or color quality.

The Illuminating Engineering Society of North America (IESNA) published a documentary **standard LM-79**, which describes the methods for testing solid-state lighting products for their light output (lumens), energy efficiency (lumens per watt) and chromaticity.

The solid-state lights being studied are intended for general illumination, but white lights used today vary greatly in chromaticity, or specific shade of white. The American National Standards Institute (ANSI) published the **standard C78.377-2008**, which specifies the recommended color ranges for solid-state lighting products using cool to warm white LEDs with various correlated color temperatures.

DOE launched the Energy Star program for solid-state lighting products in 2008. NIST scientists assisted DOE by providing research, technical details and comments for the Energy Star specifications. The Energy Star certification assures consumers that products save energy and are high quality and also serves as an incentive for manufacturers to provide energy-saving products for consumers.

Other venues

Philips Lighting has ceased research on compact fluorescents, and is devoting the bulk of its R.& D. budget, 5 percent of the company's global lighting revenue, to solid-state lighting.

In January 2009, it was reported that researchers at Cambridge University had developed an LED bulb that costs £2 (about $3 U.S.), is 12 times as energy efficient as a tungsten bulb, and lasts for 100,000 hours.

Remaining problems

The current manufacturing process of white LEDs has not matured enough for them to be produced at low enough cost for widespread use. There are multiple manufacturing hurdles that must be overcome. The process used to deposit the active semiconductor layers of the LED must be improved to increase yields and manufacturing throughput. Problems with phosphors, which are needed for their ability to emit a broader wavelength spectrum of light, have also been an issue. In particular, the inability to tune the absorption and emission, and inflexibility of form have been issues in taking advantage of the phosphors spectral capabilities.

More apparent to the end user, however, is the low Color Rendering Index (CRI) of current LEDs. The current generation of LEDs, which employs mostly blue LED chip + yellow phosphor, has a CRI around 70, which is too low for widespread use in indoor lighting. (CRI is used to measure how accurately a lighting source renders the color of objects when compared to sunlight. Sunlight is defined to have a CRI of 100, while white fluorescent lamps have CRI varying from the 50s to 98.) Better CRI LEDs are more expensive, and more research and development is needed to reduce costs.

Variations of CCT (color correlated temperature) at different viewing angles present another obstacle against widespread use of white LED. It has been shown that CCT variations can exceed 500 K, which is clearly noticeable by human observer, who is normally capable of distinguishing CCT differences of 50 to 100 K in range from 2000 K to 6000 K, which is the range of CCT variations of daylight.

LEDs also have limited temperature tolerance and falling efficiency as temperature rises. This limits the total LED power that can practically be fitted into lamps that physically replace existing filament & compact fluorescent types. R&D is needed to improve thermal characteristics. Thermal management of high-power LEDs is a significant factor in design of lighting equipment.

The long life of solid-state lighting products, expected to be about 50 times the most common incandescent bulbs, poses a problem for bulb makers, whose current customers buy frequent replacements.