FCS3280

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Energy Efficient Homes: Introduction to LED Lighting[1]

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Quick Facts

- LED lights are very small, extremely durable, and can be manufactured in a variety of colors and forms.
- They have the potential to be more energy efficient and last far longer than most current lighting technologies.
- They are considered environmentally friendly, since they contain no mercury, and the visible light applications for home or business do not emit infrared (IR) or ultraviolet (UV) light.
- They produce very little heat; and, their lifetime is not affected by frequent on/off switching.
- The cost of materials needed to make LED lighting has plummeted in the past several years. Although LEDs remain more expensive that their counterparts, their prices are steadily declining.

Terms to Help You Get Started

- **LED** Light Emitting Diode
- **SSL** Solid State Lighting, a general term for semiconductors that convert electricity into light
- **Semiconductors** Solid materials that possess electrical conductivity
- **Diode** A simple semiconductor device
- **CFL** Compact Fluorescent Lamp (lamp is the lighting industry's term for bulb)
- **CRI** Color Rendering Index, a measure of how a standard series of colors appear under a light source, compared to a reference light source (daylight or incandescent light); CRI is measured on a scale of 0 to 100, with 100 being identical to the reference light source
- **CCT** Correlated Color Temperature, a measure of the color appearance of a light source; CCT is measured in degrees Kelvin (K), the absolute temperature scale; white light products

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commonly range from “warm white” (2700K) to “cool white” (5000K)

- **RGB** Red-Green-Blue, the three primary colors of light
- **White light** Not an actual “color”, but rather a combination of all wavelengths in the visible spectrum of light

What are LEDs?

Light Emitting Diodes (LEDs) are part of a comparatively new class of lighting called Solid State Lighting (SSL). Unlike incandescent or compact fluorescent lamps (CFLs), LEDs are small electronic components that convert electricity into light.

LEDs are already being used in a variety of applications:

- Status lights on electronic devices of all kinds
- Flashlights
- Decorative lighting strings (both indoor and outdoor)
- Auto headlamps
- Traffic lights
- Outdoor lighting fixtures for parking lots, streets and parks
- Architectural lighting
- Retail display lighting
- Desk and task lights
- Home lighting applications such as recessed down-lights, and under-cabinet lights

LED applications allow for extraordinary flexibility in lighting design with regard to color, brightness, size, shape, and distribution. There is even a fabric with LEDs incorporated into the weave—imagine t-shirts with designs that change shape and color, or a sofa in an airline terminal with a digital clock displayed across its cushions!

However, in terms of general lighting—that is, general illumination using white light—quality and efficiency can vary greatly from product to product. The U.S. Department of Energy lists several reasons:

- **The technology is new**: LED technology is developing fast; new generations of LED devices appear every 4 to 6 months. Last year's LED light may well be outdated by now, with newer models providing better quality light more efficiently.
- **The technology is different**: Because LEDs are completely different from traditional lighting sources, new standards and testing procedures have just been implemented by the ENERGY STAR® program (a collaborative effort of the U.S. Department of Energy and the Environmental Protection Agency) as of June 2008 in the interest of making it easier for consumers to compare products.
- **Everyone's learning**: Because LEDs can be sensitive to some thermal and electrical conditions, manufacturers are racing to develop fixtures or components that are LED compatible in multiple applications.

Ongoing research in LED lighting is happening right now all around the world. Governments and private industry are extremely interested in LEDs both because of their great adaptability in design, and because of the potential energy savings that LED lighting offers. LED lighting will revolutionize home, office, retail, and architectural lighting in the coming years—and that includes general white-light illumination.

How do they work?

LEDs differ from traditional light sources in the way they produce light. In an incandescent lamp, a tungsten filament is heated by electric current until it glows, emitting light. In a fluorescent lamp, an electric current causes the gas inside the tube to emit ultraviolet (UV) radiation, which strikes the phosphor coating on the inside of the glass, causing it to emit visible light.

An LED, on the other hand, is a *semiconductor diode*, a device that allows current to flow in only one direction. It's made of a chip of semiconducting material treated to create a structure called a p-n (positive-negative) junction. The positive side contains excess positive charge ("holes," indicating the absence of electrons) while the negative side contains excess negative charge (electrons).

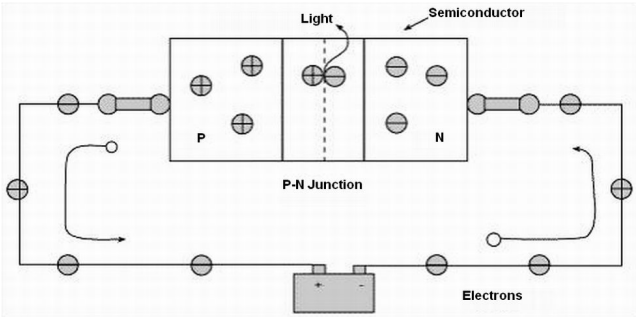

Figure 1. PN junction image from NLPIP Lighting Answers, Vol. 7, Issue 3, May 2003 *http://www.lrc.rpi.edu/programs/NLPIP/lightingAnswers/led/whatIsAnLED.asp#* Credits: Image courtesy of: Lighting Research Center, Rensselaer Polytechnic Institute

When current is applied, the negatively-charged electrons move toward the positive side, and the positively-charged “holes” move toward the negative side. At the junction, the electrons and holes combine. As this occurs, energy is released in the form of light that is emitted by the LED.

Depending on the alloy used to make the semiconductor, the light emitted by the LED can range through the colors of the rainbow: red, orange, yellow, green, and blue. "White" light is created by combining the light from red, green, and blue (RGB) LEDs, or by coating a blue LED with yellow phosphor.

How does the light produced by LEDs compare to that of incandescents?

White light is a combination of all wavelengths in the visible spectrum. Incandescent lamps inherently produce white light. LEDs do not. They emit light in a very narrow range of the spectrum, producing nearly monochromatic light—the color depending on the materials used to create the LED. “White light LEDs” are created in two different ways: phosphor conversion or RGB. In phosphor conversion, a blue LED is coated with a yellow phosphor, resulting in light which appears white to the eye. This method is lower in cost than the RGB approach. Phosphor converted chips are manufactured in large quantities in forms that are integrated into lighting fixtures.

In the RGB method, white light is produced by mixing the light from multiple red, green, and blue LEDs; sometimes amber is added to enhance the quality of the light. This results in great flexibility in the possible “shades” of white light produced, but is technically more demanding to manufacture, and thus more expensive at this juncture. RGB systems are generally found in custom-designed architectural lighting.

Light quality is indicated by two measurements, *correlated color temperature* (CCT) and the *color rendering index* (CRI).

CCT is that aspect of light that people refer to when they talk about “cold” fluorescent lighting; such lighting has a *high* CCT. CCT is measured in “Kelvins”; cool white light is 5000K while warm white light has a *low* CCT at about 2700K. Until recently, most white light LEDs had very high CCTs, often above 5000K, but warm white LEDs are now available. They are less efficient than cool white LEDs, but are comparitively efficient as CFLs.

The CRI is a measure of how color appears when illuminated by a light source, compared to reference sources such as incandescent light or daylight. A CRI of 100 is identical to the reference source, so the higher the CRI the better. Everyone has experienced the dull colors and washed-out faces resulting from old-style fluorescent tube lighting, which had a CRI ranging from 50 to 60. Phosphor-converted warm white LEDs are now being produced that are claimed to have a CRI of 80, a value most people find quite acceptable. Others exceeding 90 have also been reported.

The CRI, however, has been found to be inaccurate for white light RGB LEDs and there is controversy in the industry as to the reliability of the rating for other lighting types as well, so a new measurement system is under development.

LED technology is changing quickly; white light LEDs producing high-quality light will be commonplace in the next few years.

Are they energy efficient?

It depends. The best white light LED lamps can meet or exceed the efficiency of compact fluorescent lamps—but many LEDs currently on the market do not. LEDs are sensitive to temperature and electrical conditions, and LED fixtures must be carefully designed to take this into account; many manufacturers are not yet experienced in such design. However, research and development in this area is very active, and new generations of LED devices that are more energy efficient will be appearing on the market within a few years. The U.S. Department of Energy states, “The energy efficiency of LEDs is expected to rival the most efficient white light sources by 2010.”

Are they an economical choice for home lighting?

Currently, good quality LED products are fairly expensive, compared to standard lighting. But costs are coming down—in 2007, they were roughly one-seventh of costs in 2001—and it's expected that LEDs will be competitive within a few years.

What about ENERGY STAR®?

The ENERGY STAR® Web site states, “Solid-State Lighting (SSL) is the future of lighting, and thanks in part to ENERGY STAR, it'll be here faster than you think. The ENERGY STAR label on SSL luminaires will provide consumers with the confidence that these products meet efficiency and performance criteria established by DOE in collaboration with industry stakeholders. With test procedures being finalized, the ENERGY STAR SSL program is on schedule to launch September 30, 2008. ENERGY STAR is focusing on lighting applications and products for which the technology has advanced to a point where performance is equal to or better than traditional efficient lighting technologies based on light output, luminaire efficacy and cost. The focus on quality will go a long way to ensure that consumers have a good experience with this new technology.” Visit the ENERGY STAR Web site at http://www.energystar.gov or the Building Technologies Program site at http://www1.eere.energy.gov/buildings/ssl/ for more information.

Summary

LEDs for general illumination currently may be considered the “Not Quite Ready for Prime Time” player in the home and office lighting field. But stay tuned—they're improving quickly. Once industry and ENERGY STAR® standards are fully in place, consumers will be able to comparison shop for LED white lights the way they now do for incandescent and compact fluorescent lights, choosing the lamps and fixtures that give them the combination of light quality and energy efficiency they're looking for. LEDs are already available for multiple applications in and around the home—from landscape and walkway lighting to holiday lighting, and even ambient lighting in hard to reach places where the long life of LEDs is a real asset—and the future is looking brighter every day.

References and Resources

- *Using LEDs for General Illumination* http://www.netl.doe.gov/ssl/usingLeds/index.htm
- *Solid State Lighting Luminaires* http://www.energystar.gov/index.cfm?c=new_specs.ssl_luminaires
- *LEDs* http://www.lrc.rpi.edu/researchAreas/leds.asp
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