Understanding LEDs and LED Lighting

What's SSL lighting?

SSL is short for Solid State Lighting. Most of us come into direct contact with light-emitting diodes (LEDs) every day. LED is a solid-state technology. This means there are no glass bulbs, no pressurized gases, no toxic chemicals and no burning filaments. They work by flowing electrical energy through a semi-conductor.

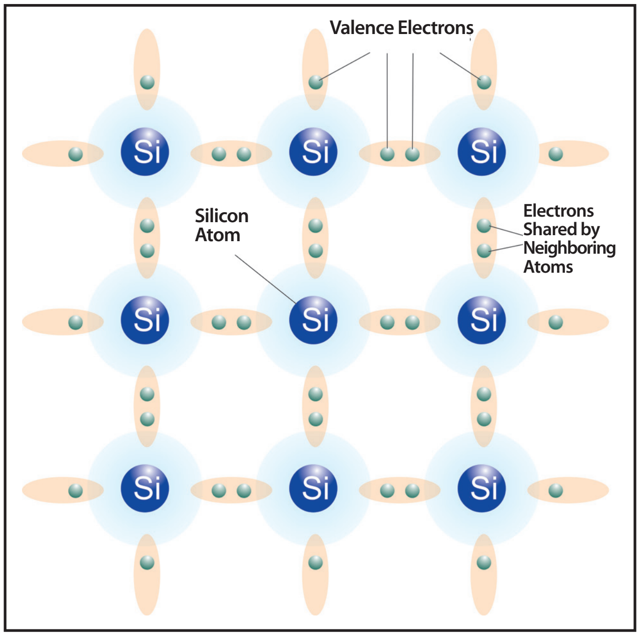
Used as indicators in automotive dashboards, numeric displays on consumer electronic devices, or as low power flashlights, LEDs have been perceived as low output, monochromatic light sources. Not surprising considering that for many years, there were no advancements in LED technology and very little changes in lighting technology overall. In recent years, LED technology has completely changed by reinventing the light bulb and the way we think about lighting in general. This was not really possible prior to the technological revolution of the '90s and the rapid advancement of semiconductors. The same advancements that spurred the computer to reach dizzying levels of efficiency have done the same for the LED. Just as computers have become faster and cheaper, LED lights have become brighter, smaller, less expensive, and more sophisticated.

Today, there is little debate over the effectiveness of LED lamps vs. traditional incandescent bulbs. With up to eight times greater efficiencies than traditional incandescent bulbs and easily conquering those of fluorescent lamps, LEDs are becoming preferred light sources for today's lighting community. According to the U.S. Department of Energy, "No other lighting technology offers the Department and our nation so much potential to save energy and enhance the quality of our building environments."

Where does LED light come from?

LEDs are solid-state (P-N junction semiconductor) devices that convert electrical energy directly into light by a process called electroluminescence.

We will try to explain, in layman terms, what makes LED the light source of the future. To better understand LEDs, we have to start with an explanation of what is a basic diode.



It all starts with silicon. This is the same silicon that is the main element in sand and quartz. Silicon has four "free" electrons in the outermost shell of an atom. Valence electrons, as they are scientifically called, dictate the electrical and chemical nature of every solid matter. Valence electrons in base substrates share covalent bonds with their neighbors.

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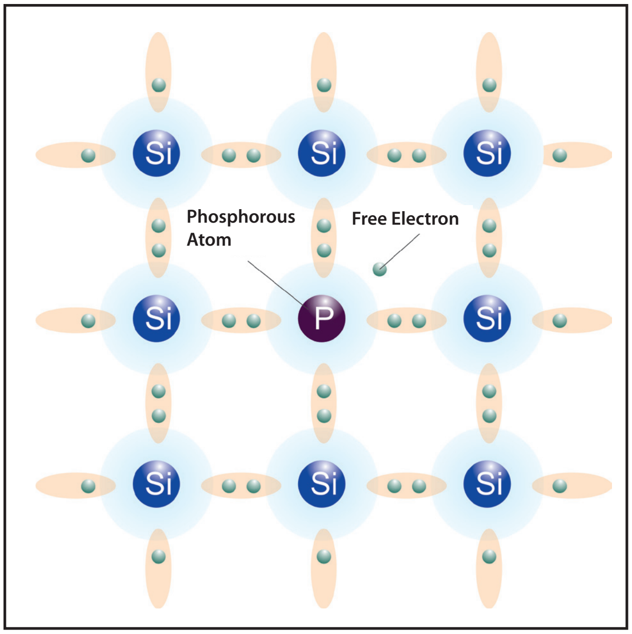
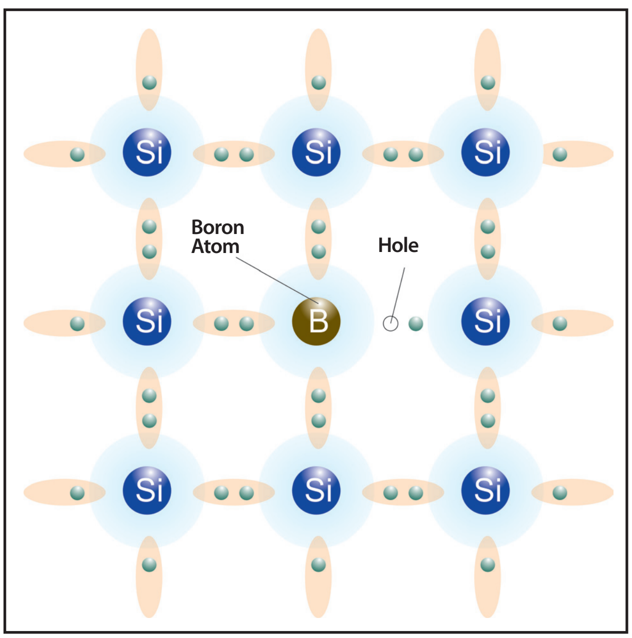
By adding a small amount of impurities to silicon, you can change its behavior and turn it into a conductor. An N-type (negative) impurity is an element with five "free" outer electrons so they're out of place when they get into the substrate lattice.



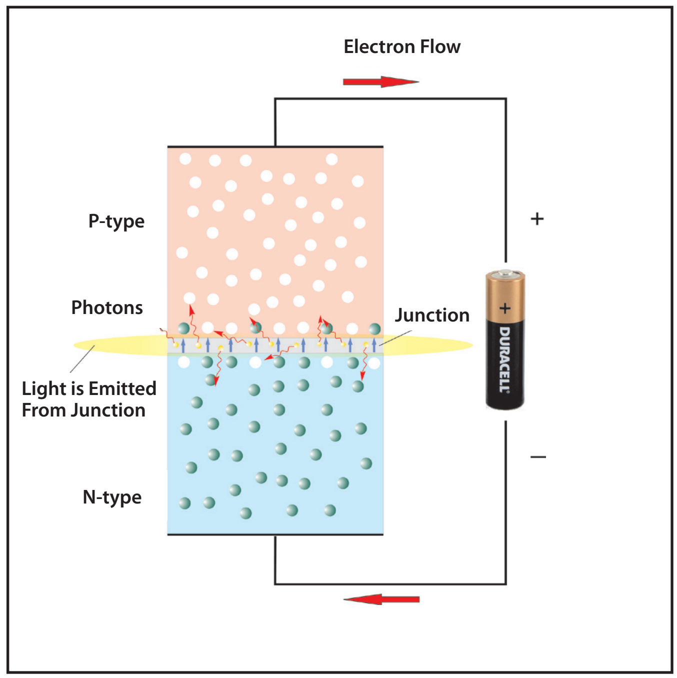
The fifth electron has nothing to bond to, so it's free to move around. A P-type (positive) impurity is an element with three "free" outer electrons. The absence of a fourth electron creates a "hole".



A hole happily accepts an electron from a neighbor, moving it from hole to hole. By introducing N or P type impurities into silicon, we change the electrical behavior of the substrate from a perfect insulator to a conductor called a semiconductor.

Sandwiching N-type and P-type semiconductors together creates a device called a diode. When you connect such a device to an electrical energy source, a very interesting phenomenon occurs.

By connecting a positive battery terminal to the N-type side of the diode and a negative terminal to the P-type side of the diode, electrons and holes near the junction will repel from each other. Although N-type and P-type elements by itself are conductors, the diode connected in reverse does not conduct any electricity. On the other side, if we connect a positive battery terminal to the P-type side of the diode and a negative to the N-side, free electrons in the N-type semiconductor will be repelled (pushed) away from the negative terminal, and holes in the P-type will be repelled away from the positive terminal. In the junction region electrons will cross from the negative side to the positive side filling the holes.



So where is the light coming from? Well, crossing the border comes with a hefty price tag. During the jump (scientifically called recombination) an electron looses a portion of its energy. In a regular diode, this energy is emitted in the form of heat. By utilizing specific N and P type semiconductors such as gallium phosphide (GaP), this energy "weight loss" produces photons (light) instead of heat. The amount of energy lost defines the color of the light. For example red is a low energy light and blue is a high energy light.

Why are color LEDs much more vibrant?

LED emits color in a very narrow spectrum. As we mentioned before, once the electron crosses the junction between the N-type and P-type semiconductors, it releases a very specific amount of energy. Think of it as paying a crossing toll where electrons producing blue photons must always pay a quarter and use only quarters.

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"Red" electrons have to pay a dime and use only dimes. In contrast, an incandescent lamp produces a much wider color spectrum (though less vibrant) because it can pay its toll in a variety of denominations. So for their $0.25 toll, incandescent lamps can use dimes, pennies or quarters. A very good example of color purity is found in Christmas lights. LED based decorations will be significantly more vibrant.

How are white LEDs created?

As strange as it may sound, white light does not exist. What is perceived as white light is actually a combination of red, blue and green. White LEDs can be created in two different ways. Less common is a combination of green, blue and red LED chips. The most common way is a combination of a blue LED chip and a phosphorous coating. In this process, called fluorescence, a blue photon is absorbed by the phosphorous coating which triggers the emission of a less energetic photon (red, green). Different phosphorous coatings will produce different hues of white color – warm white, natural white, cool white, etc.

Are LEDs cool light sources?

A common misconception is that LEDs do not produce any heat. In fact they do. Electrons crossing the P-N junction produce not only photons, but also heat. It is very important to thermally manage LED devices because heat decreases the efficiency and lifespan of the LED. Compare it to an athlete. If you are running in an un-breathable jersey you overheat very easily and your performance goes down. If you run for a longer time, you may hurt yourself. It makes sense then, that a cooler environment, increases the athlete's efficiency and performance. LED light sources produce dramatically less heat than conventional incandescent lamps, however, the heat output needs to be thermally managed to achieve optimum efficiency. There are many LED lamps on the market with improper or no thermal management of junction heat. Such LED lamps will experience a very dramatic intensity decrease and a very short life span.

What is the main difference between incandescent and LED light sources?

Traditional incandescent lights contain a filament that's heated until it emits light. This process is called incandescence. The hotter the filament, the more light the lamp produces. Efficiency of an incandescent lamp is less than 5%, which means 95% of the energy is wasted in the form of heat. Filament in an incandescent light is fragile and burns out or breaks relatively easy. Its life span is generally less than 3000 hours.

What is the main difference between a fluorescent and LED light source?

Fluorescent lamps generate light by a high voltage arc passing through mercury vapor. The arc generates high energy ultraviolet light that is absorbed by a phosphor coating inside the lamp, causing it to glow, or fluoresce. Every fluorescent lamp contains highly poisonous mercury, so if the lamp breaks, the surrounding environment will be exposed to it. Linear fluorescents have life spans of approximately 10,000 to 20,000 hours. Compact fluorescent (CFL) life span varies from 1,200 to 20,000 hours.

I heard that LED life is over 100,000 hours. Is it true?

No, it is not. LEDs may go over 100,000 hours, but only in perfect laboratory conditions. Real life environments are substantially different. Before we answer the lifespan question, let's first define what lifespan of an LED really means. In traditional incandescent lamps, lifespan is defined as a time to the point where 50% of all sampled lamps will go defective. LED is very different. If designed properly, LEDs will work for decades without catastrophic failure. However, the light output will slowly decrease. New industry standards define LED lifespan as a time where luminous intensity reaches 70% of its initial value.

As we mentioned before, the lifespan of the LED depends on thermal management of the LED lamp and/or system. With proper thermal management, smaller lamps like the GU10 will easily reach 30,000 hours and larger lamps (PAR30, street lights, etc.) will go beyond the 50,000 hour mark. Compared to the 2,000 hours lifespan of incandescent lamps or 10,000 hours of compact fluorescents, LEDs are the very clear winners.

Aren't all LEDs the same?

No. LEDs, LED lamps, and LED lighting systems are quite different in design and quality. A good LED lamp or system design is much more efficient than incandescent or compact fluorescent lighting. Unfortunately, most LED lighting available for consumers today is of marginal quality and expensive. Poorly designed luminaries can be relatively inefficient, fail, or deliver poor light characteristics.

Are LED lamps dimmable?

Properly designed LED lamps and/or systems are fully dimmable. However, there are many LED lamps on the market without dimming capabilities that may lead to shortened lifespans. It is important to mention that dimming characteristics of LED lamps are different compared to incandescent. Usually the slope of LED dimming is much steeper.

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Does turning an LED lamp on and off shorten its lifespan?

No. Unlike fluorescent light sources (compact or linear), LED light sources are "switch" friendly. Turning them on and off extends their lifespan. A fluorescent lamp's lifespan will be dramatically shortened if turned on and off.

Why do white LED light sources have such a blue hue?

White LED light sources should not have a blue hue unless it is purposely designed in such a way. Some LED systems, for example parking lot lights, are designed to have a blue hue mainly because modern security cameras are more sensitive to bluish white (cooler white). However, a bluish hue is usually a sign of an improperly designed system. If you exceed the maximum power an LED can handle, or if the LED thermal management is designed improperly, an LED light will slowly turn to the blue spectrum. A good example is found in many LED based flashlights. LEDs within flashlights are overdriven on purpose and thermal management is usually very basic in order to make them more affordable. Overdriving will increase intensity but lifespan goes down to under 3,000 hours. Even so, 3,000 hours is still 30 times more than an incandescent counterpart.

I do not like the quality of light generated by fluorescent light sources. Are LEDs different?

Definitely. LED light sources generate much more pleasant and vibrant light. However, color-rendering properties are not as good as incandescents, especially in the red spectrum.

How efficient are white LEDs?

LED light sources are extremely efficient. Today's best commercially available LED sources can generate close to 90 lumens per watt. Incandescent lamps are typically 10 to 12 lumens per watt, halogen lamps 20 to 25, and fluorescent lamps 40 to 60.

Will LED lighting become more efficient over time?

Yes. Even today we are experimenting with LEDs that are generating close to 150 lumens per watt. We can expect to see such LED light sources on the market within the next 5 years.

Who is Once Innovations™?

A fast growing Minnesota company that's changing the world. Pure and simple, Once Innovations™ designs LED lighting that's better for people and the world they live in.

Products from Once Innovations™ are affordable, made from recycled material, use less energy to make, ship and use, do not contain dangerous mercury or rare metals, last longer, and feature packaging that is reusable and biodegradable.

Visit onceinnovations.com

New products will be on the market soon. Go to onceinnovations.com to find out when and where you'll be able to purchase quality LED lighting for residential, commercial, and municipal applications. While online, sign up for email alerts regarding new products and developments.

LED advantages

- **No abrupt burnout like incandescent bulbs**
- **On/off cycling doesn't diminish lifespan as with CFLs**
- **Instant on; no warm up time needed as in HID lamps**
- **Produce greater light per watt than incandescent bulbs**
- **Easily dimmed**
- **Have a usable life 30 to 50 times longer than incandescent bulbs and 3 to 5 times longer than CFLs**
- **Do not contain dangerous mercury, unlike CFLs**
- **Very small size gives them more design options**
- **Solid-state components make them shock resistant and virtually unbreakable**
- **Deliver efficient directional light, unlike incandescent bulbs and CFLs**

If you are interested in LED residential, commercial, or municipal lighting, please call or email Once Innovations™.

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