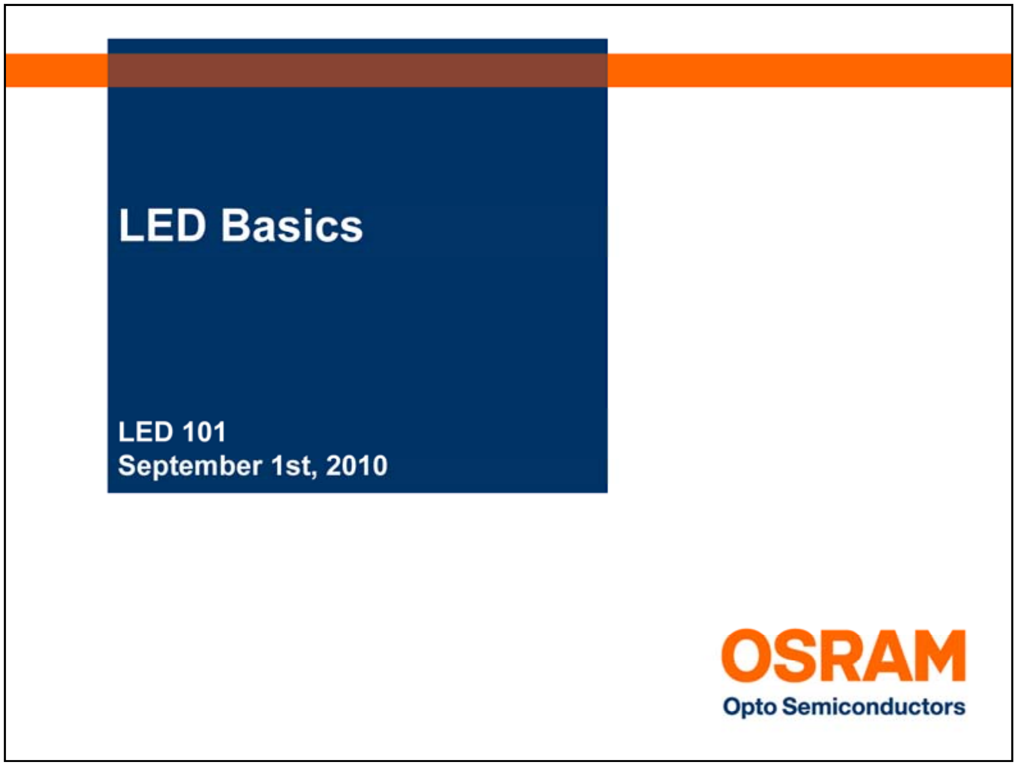
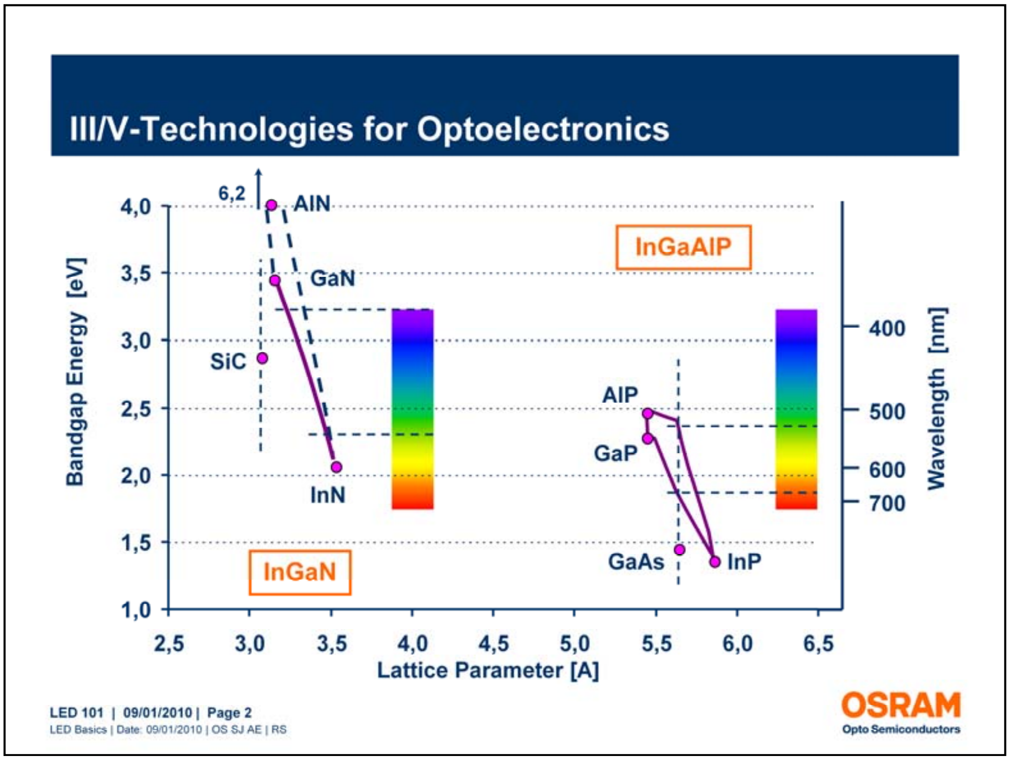


Hello and Welcome to this presentation on LED Basics. In this presentation we will look at a few topics in semiconductor lighting such as light generation from a semiconductor material, LED chip technology, structure of an LED, creating white light in an LED package, and finally some definitions of CCT and CRI.

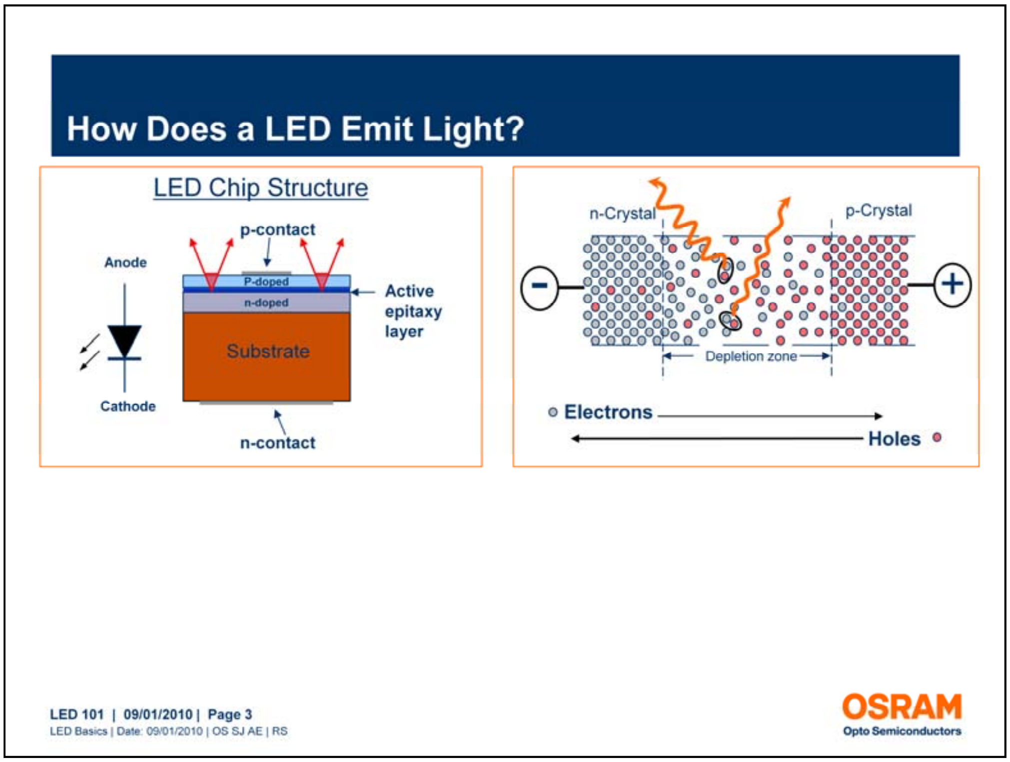


This graph shows the band-gap energies and corresponding wavelengths for two major semiconductor materials used for LEDs today.

InGaN (*indium gallium nitride*) is used for violet, blue, and green LEDs.

Where as InGaAlP (indium gallium aluminum phosphide) is used for green, yellow, orange, and red LEDs.

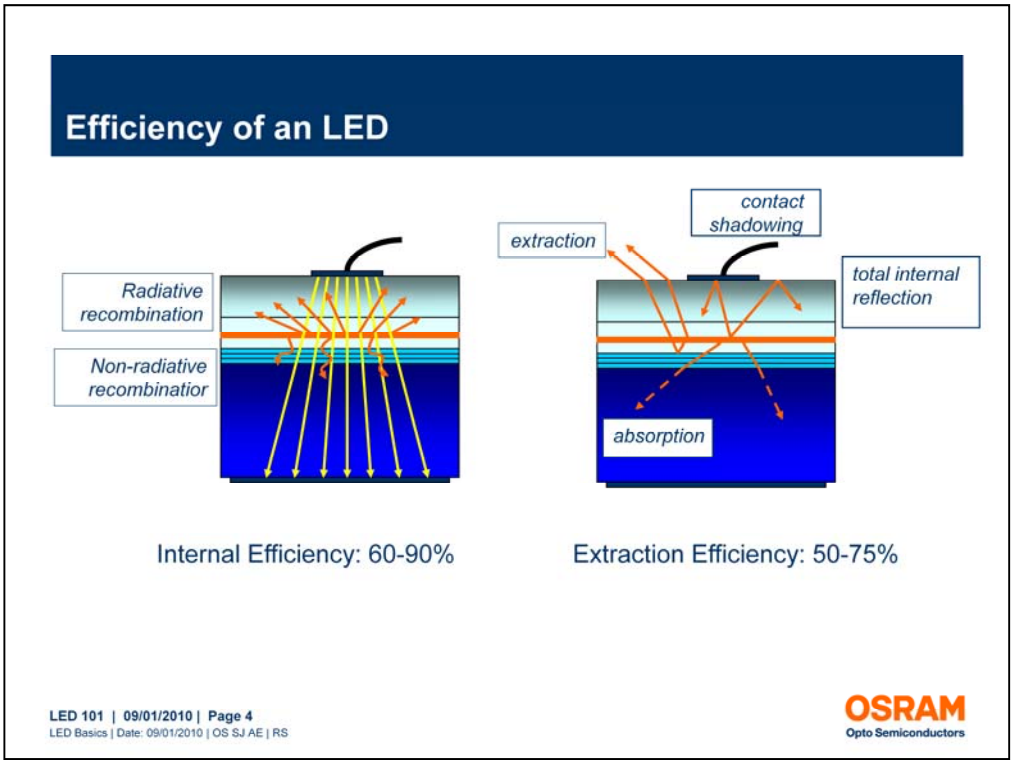
The wavelength of light, or its color, is determined by the light's energy. The energy of a light particle (photon) emitted by an LED is equivalent to the band gap of the semiconductor material used for the LED, which is an intrinsic feature of the semiconductor material used. Manufacturing an LED with a designated wavelength is all about engineering the semiconductor materials and their band-gaps.



LEDs are semiconductor diodes or electronic devices, that permit current to flow in only one direction. The diode is formed by bringing two slightly different materials together to form a PN junction.

In a PN junction, the N side contains negative charge carriers, that is electrons, and the P side contains positive charge carriers, that is holes, which indicate the absence of electrons.

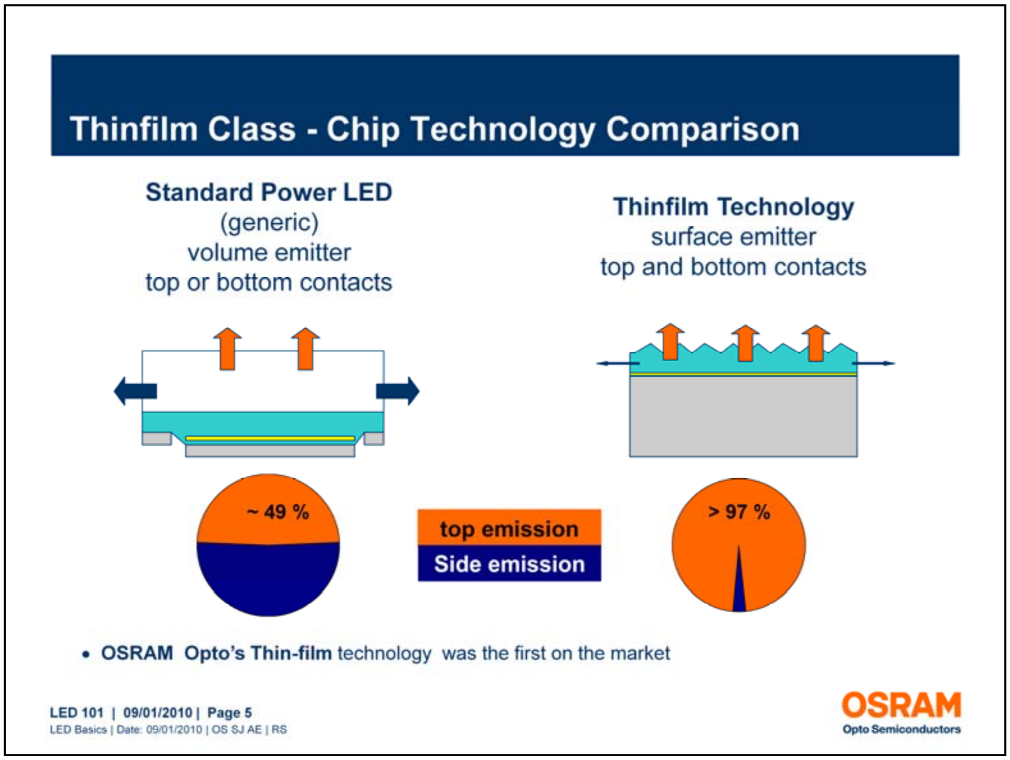
When a forward voltage is applied to the PN junction electrons move from the N side towards the P side and holes move from the P side towards the N side and combined in the depletion zone between these regions. Some of these recombination's are radiative in which energy is released in the form of light.



The non-radiative recombination's occurring in the PN junction result in heat being generated in the semiconductor material. The ratio of the radiative to non-radiative recombination's in the PN junction determine the total efficency of the LED.

Some of the light is lost within the semiconductor material due to effects such as total internal reflection, absorption, and shadowing of contacts etc.., resulting in only a certain portion of the light exiting the package. This is the extraction efficiency of the LED.

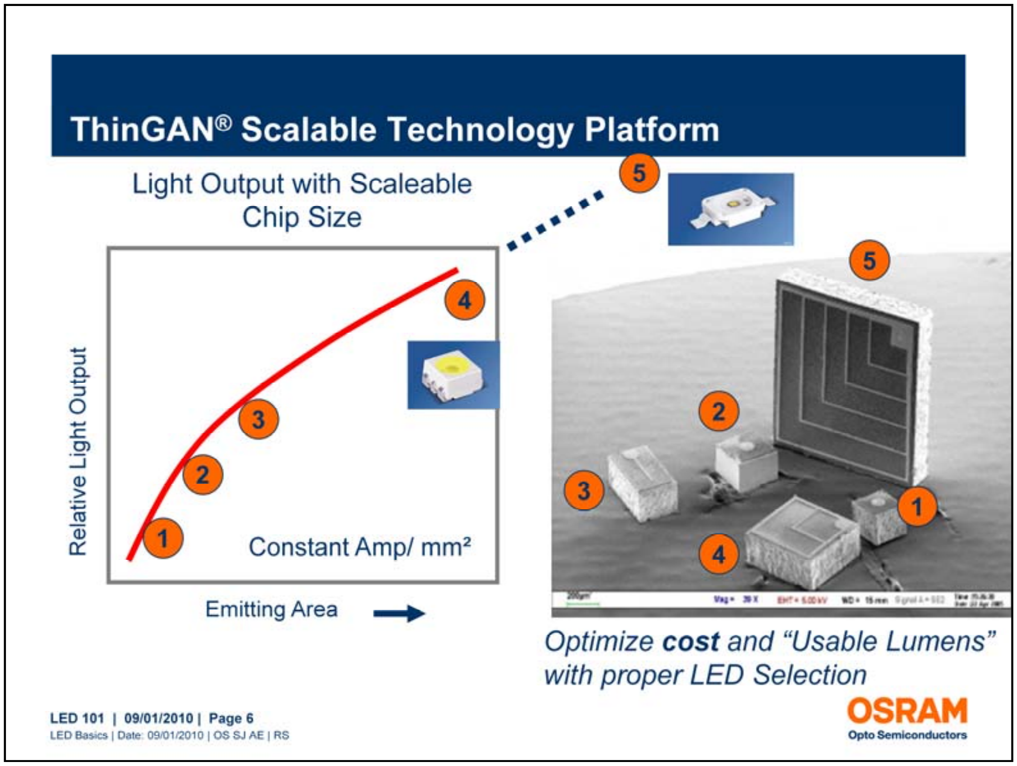
To improve the overall efficiency of an LED package it important to improve both the internal and extraction efficiency of the LED.



The first generation of Power LEDs from OSRAM Opto Semiconductors were volume emitters with top and bottom contacts. These LED packages had a top emission of ~49% resulting in almost 50% light lost within the package.

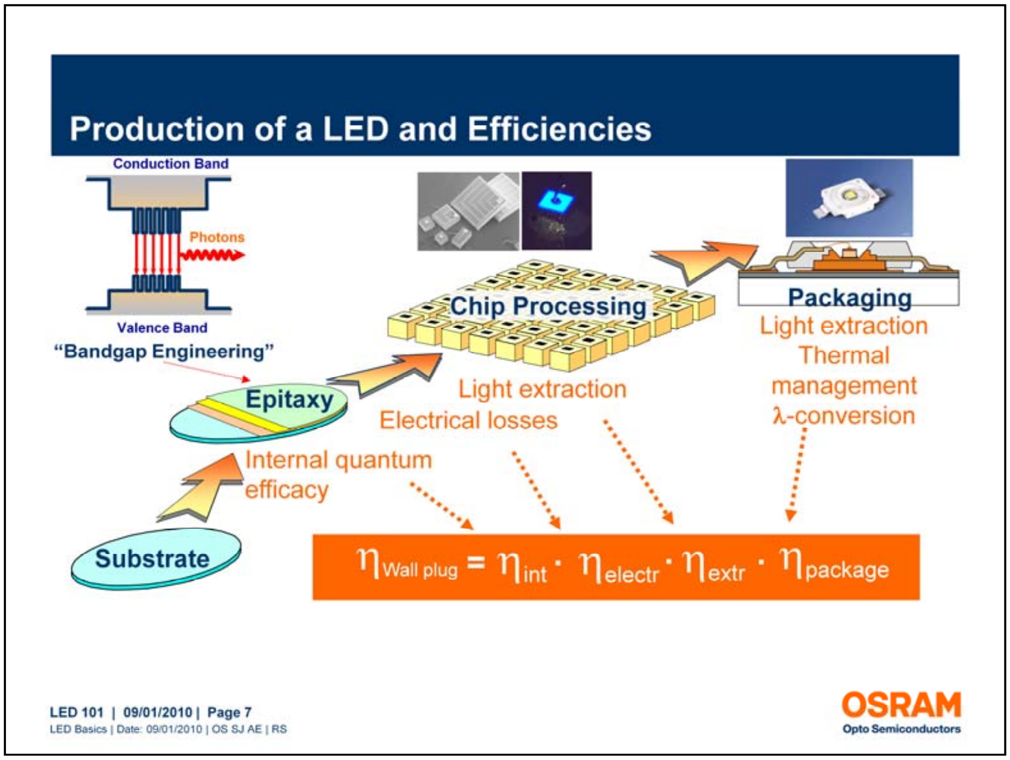
Subsequent advances in semiconductor technology have resulted in improved efficiencies.

OSRAM Opto Semiconductors Thin-Film technology was the first surface emitter which resulted in greater than 97% of the light being emitted from the top surface of the semiconductor chip.



The ThinFilm or ThinGaN technology is scalable with the chip size. The relative light output from the semiconductor chip increases almost linearly with the emitting area.

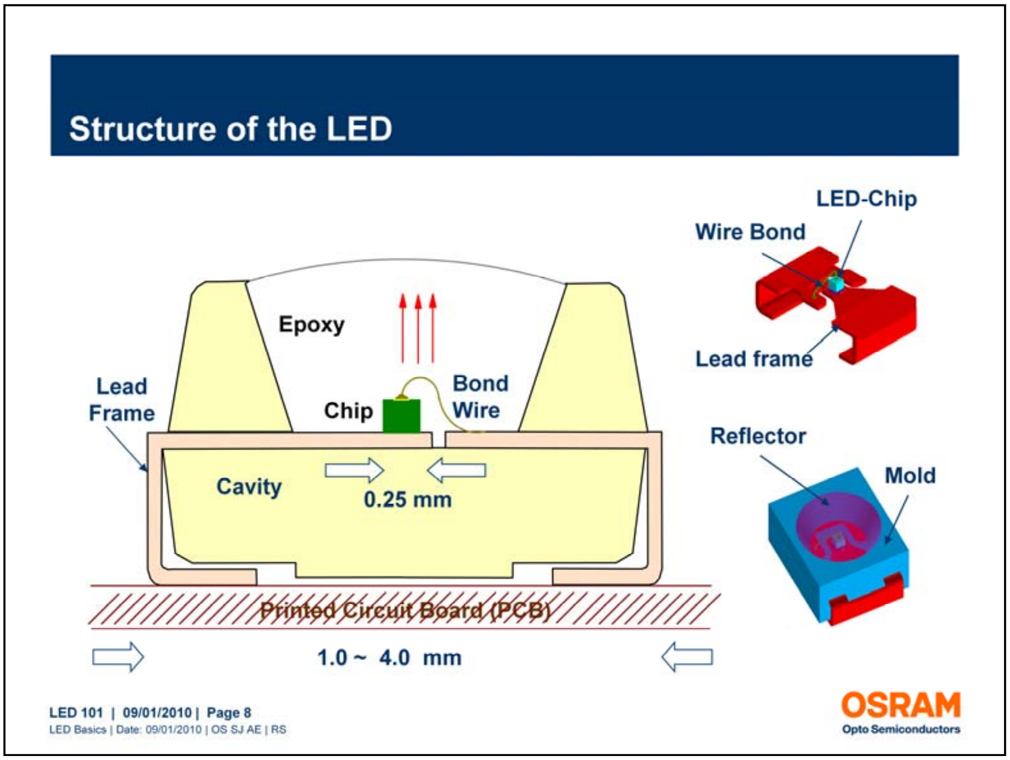
This enables optimization of the usable lumens and cost with the appropriate chip size.



To further improve the overall efficiency of the LED, optimization is required in all value added steps beginning from substrate through the package.

To fabricate an LED, we start with a substrate on which several Epitaxy layers are grown atom by atom. After various chip processing steps, the entire wafer is diced into single chips also known as dyes.

Finally the small semiconductor chip is assembled into a package for mechanical protection and electrical, optical, and thermal interface. To approve the overall efficiency of the LEDs each of these manufacturing steps needs to be optimized.

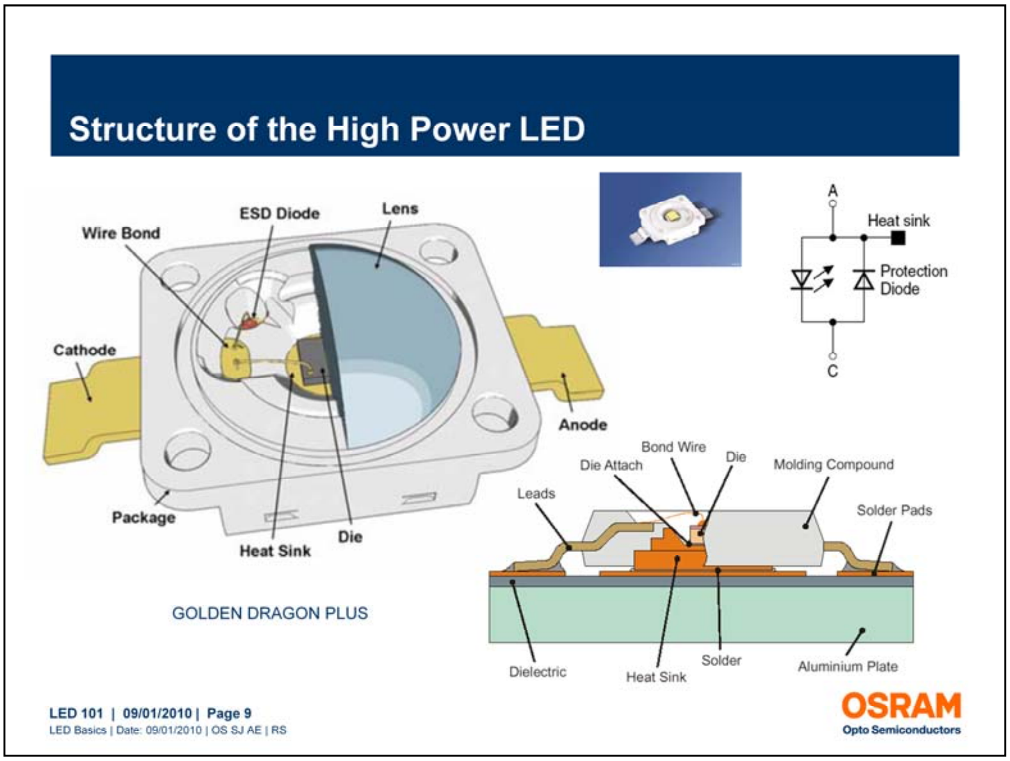


The image shows the construction of an LED package. Within a cavity of the LED is a semiconductor chip mounted onto a lead frame, which is housed in a premould package.

The leadframe acts a thermal path to dissipate the heat from the semiconductor chip and also serves as the electrical and mechanical interface to the Printed Circuit Board.

A gold wire bond is used to connect the top side of the chip to the leadframe.

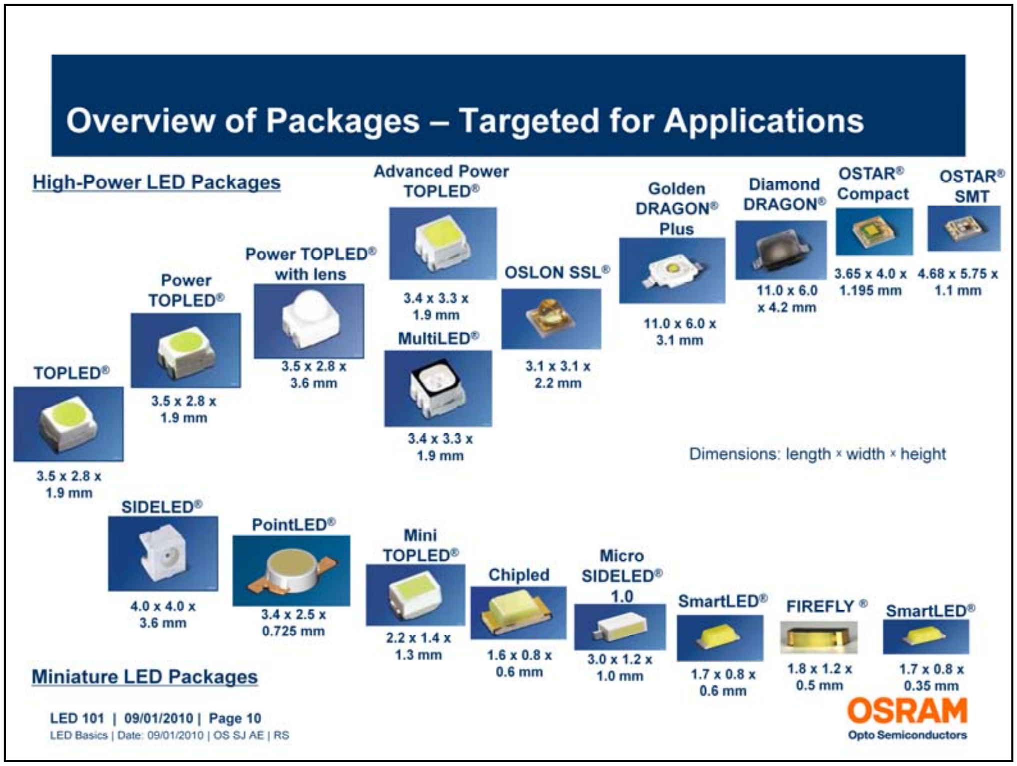
The cavity is filled with epoxy resin and serves as reflector to extract the maximum amount of light out of the package.



This image depicts the construction of a high powered LED package; the Golden DRAGON Plus.

The light source of the Golden DRAGON Plus is a highly efficient semiconductor dye, mounted directly on a integrated heat sink in a premould package.

The silicone encapsulant in the package is formed into a lens which optimizes efficiency by allowing more of the generated light to be extracted from the package.



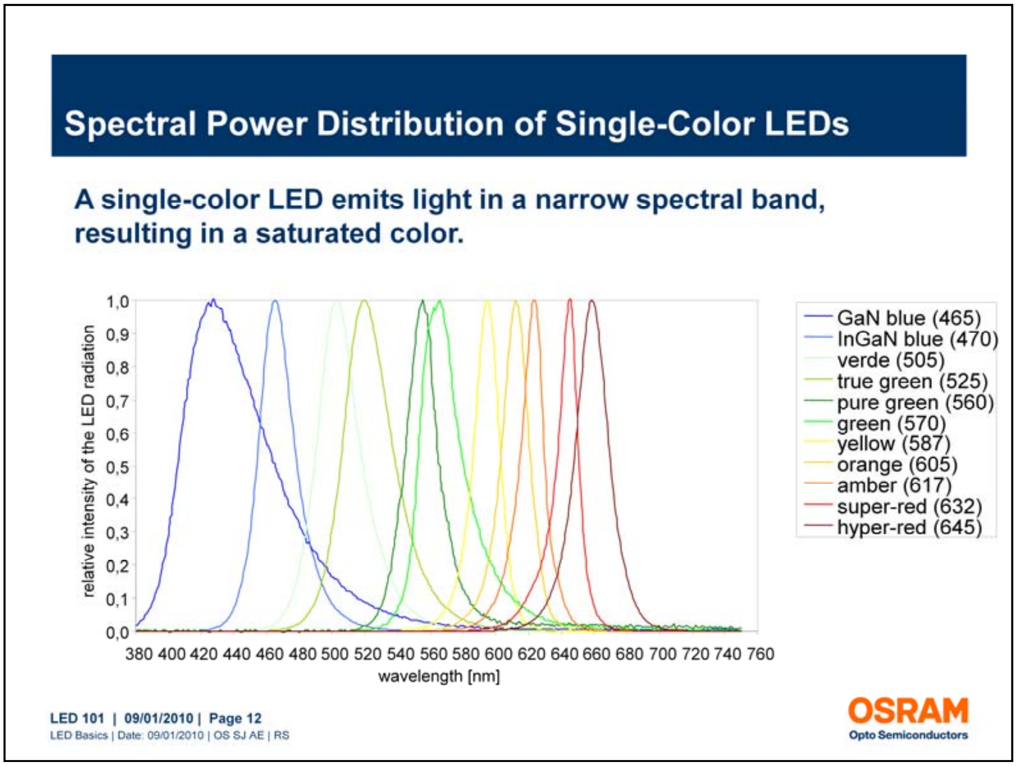
OSRAM Opto Semiconductors offers a wide surface mount product portfolio featuring miniature, standard, and high powered LEDs.

The miniature portfolio features low powered LEDs with small package sizes.

The standard portfolio features the TOPLED, one of the longest running surface mount technology LED packages available on the market.

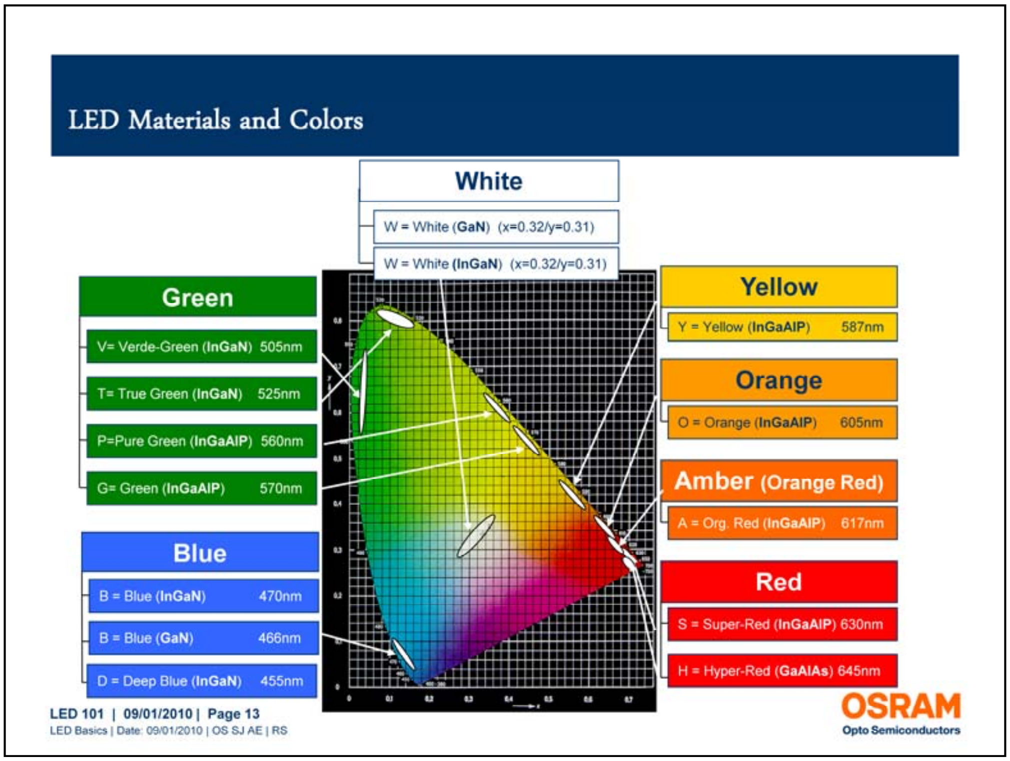
The high powered product portfolio features the DRAGON and OSLON family of products.

Various LED parameters are used to quantify the performance of the LED. These include optical, thermal, and electrical quantities.

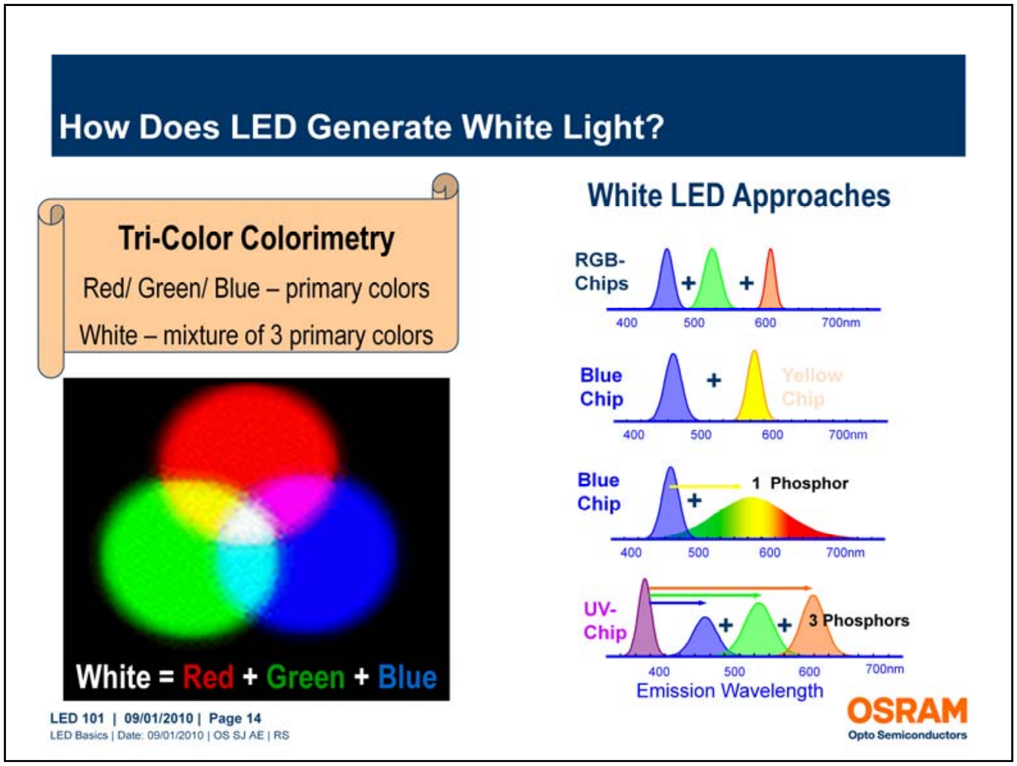


A monochromatic or a single color LED emits light in a narrow spectral band. The Spectral Power Distribution is a representation of the radiant power emitted by a light source as a function of wavelength. The semiconducting material used in an LED determines its wavelength or color of light.

As mentioned earlier, InGaN (*indium gallium nitride*) and InGaAlP (indium gallium aluminum phosphide) are the two primary semiconductor materials and slight changes in the composition of these alloys changes the color of the emitted light.



The image shows the various colors produced with different composition of alloys on a CIE 1931 color chart.



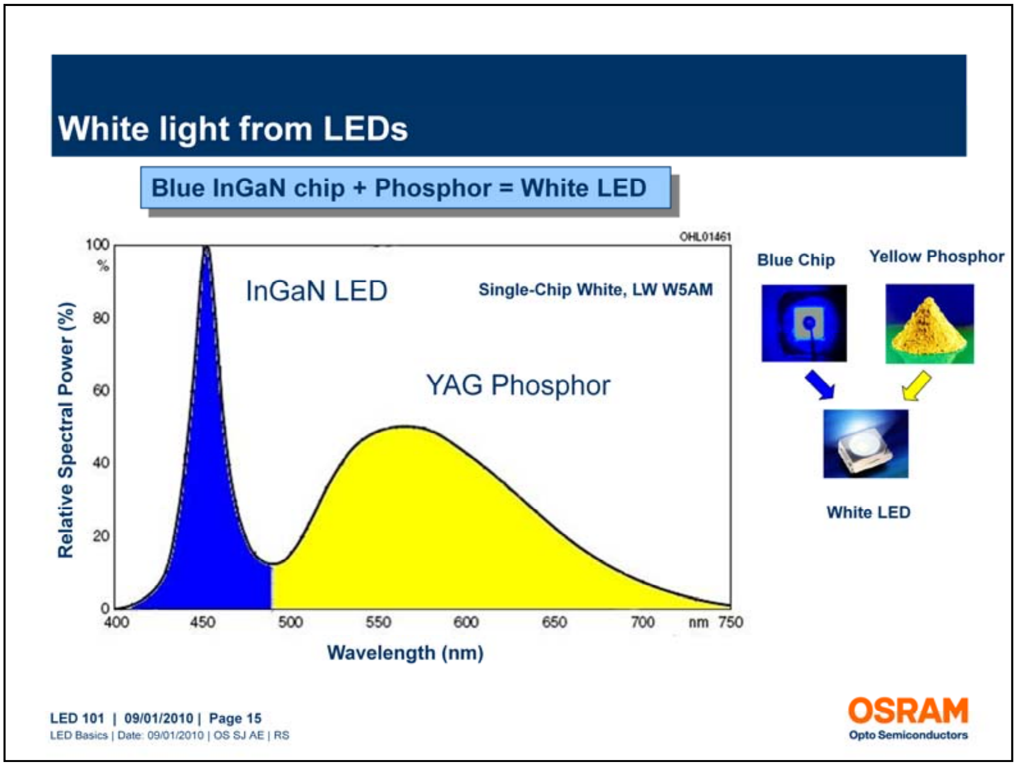
Apart from monochromatic LEDs, white LEDs are used in a number of applications.

One approach to generating white light utilizes a combination of three primary colors: red, green, and blue LEDs.

Another approach is to use blue and yellow LED chip together in a certain ratio in sum to produce white light.

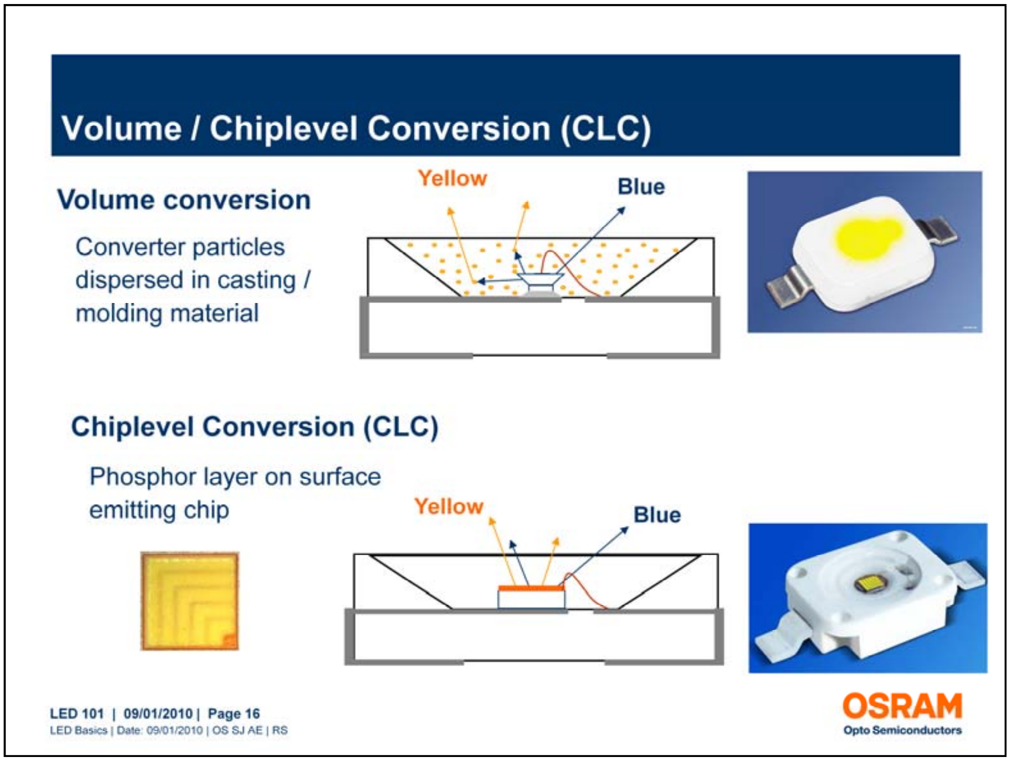
Third approach would be to use a blue chip and a yellow phosphor to generate white light.

Or by utilizing an ultraviolet (UV) LED to excite - red, green, and blue phosphors.



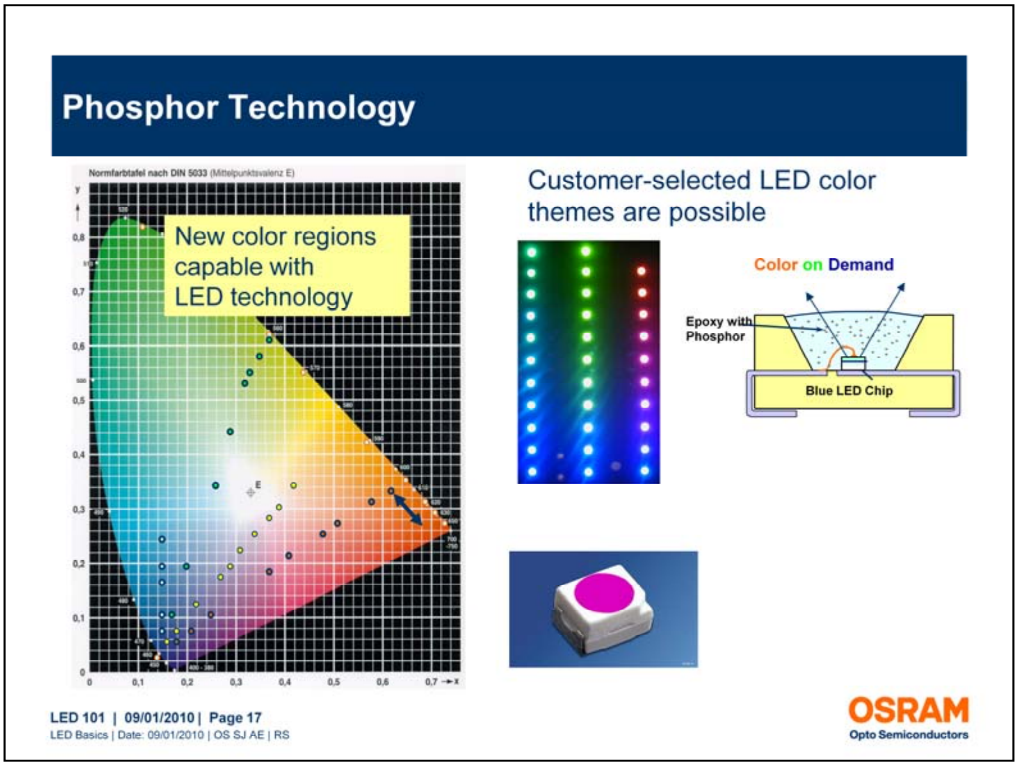
The most widely used approach to create a white LED is to use a blue LED chip combined with the phosphor.

The phosphor layer absorbs a portion of the blue light and emits light at longer wavelengths. The phosphor concentration defines how much of the blue light is converted.

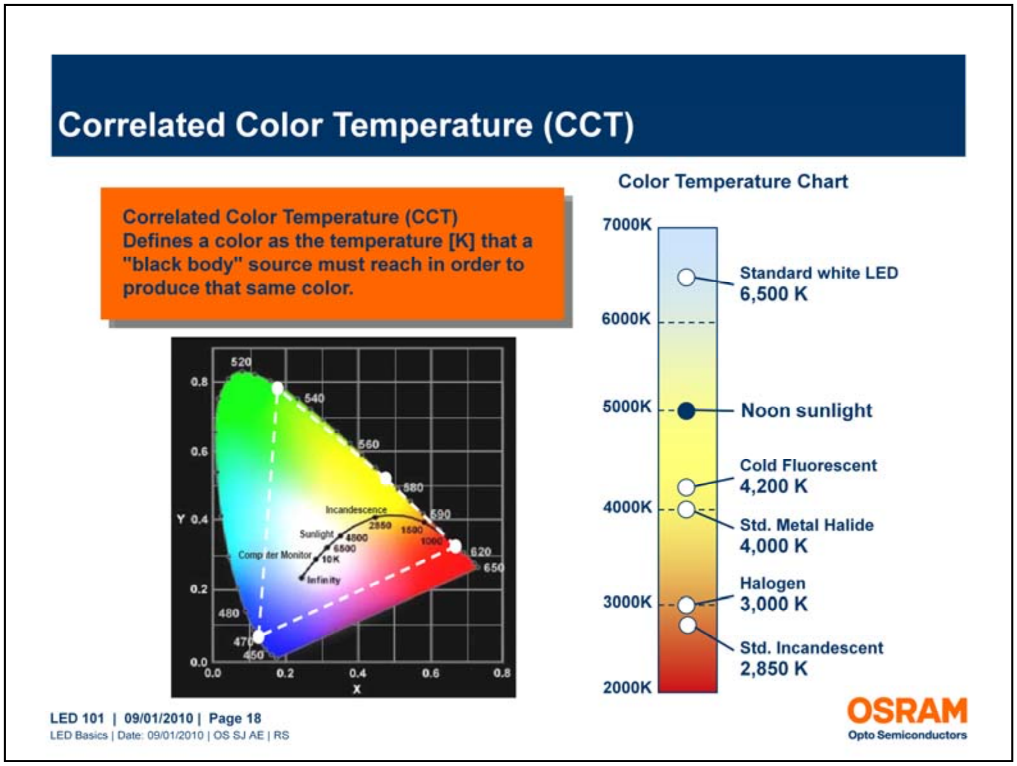


Volume conversion involves the dispensing of phosphor particles into the transparent molding material.

An alternate method is chip level conversion in which a phosphor layer is placed on top of the LED chip. The advantages of chip level conversion include: better color homogeneity, high luminance, and less color variation over angle.

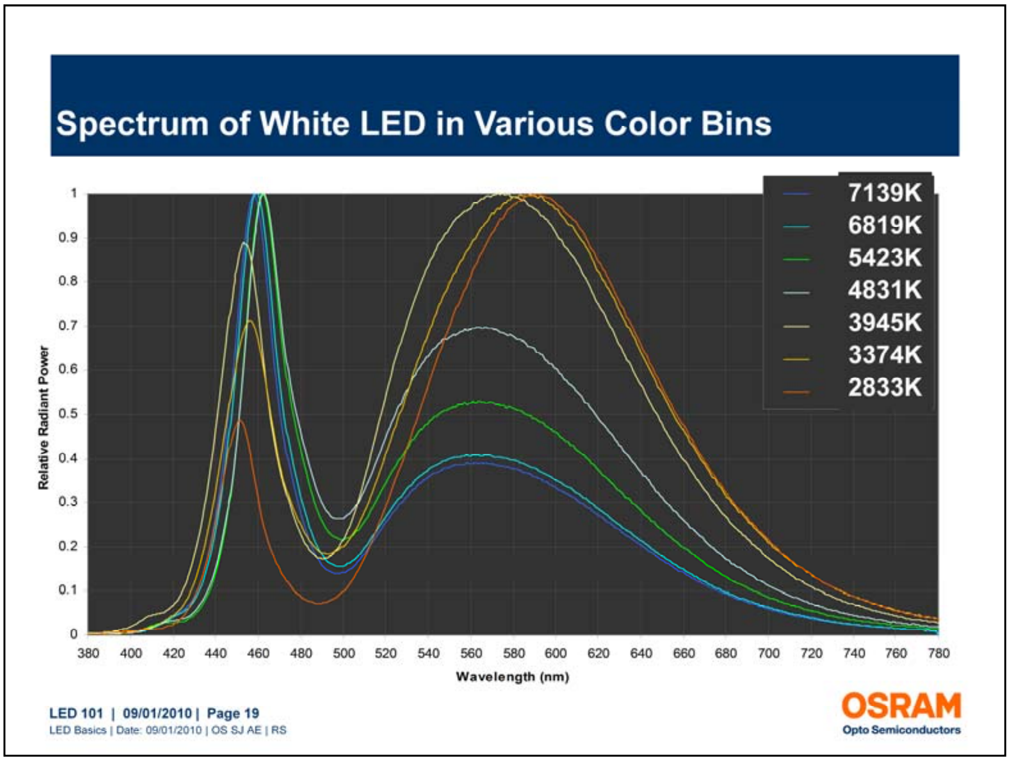


In addition to white light, new color regions can be achieved by employing different phosphors.



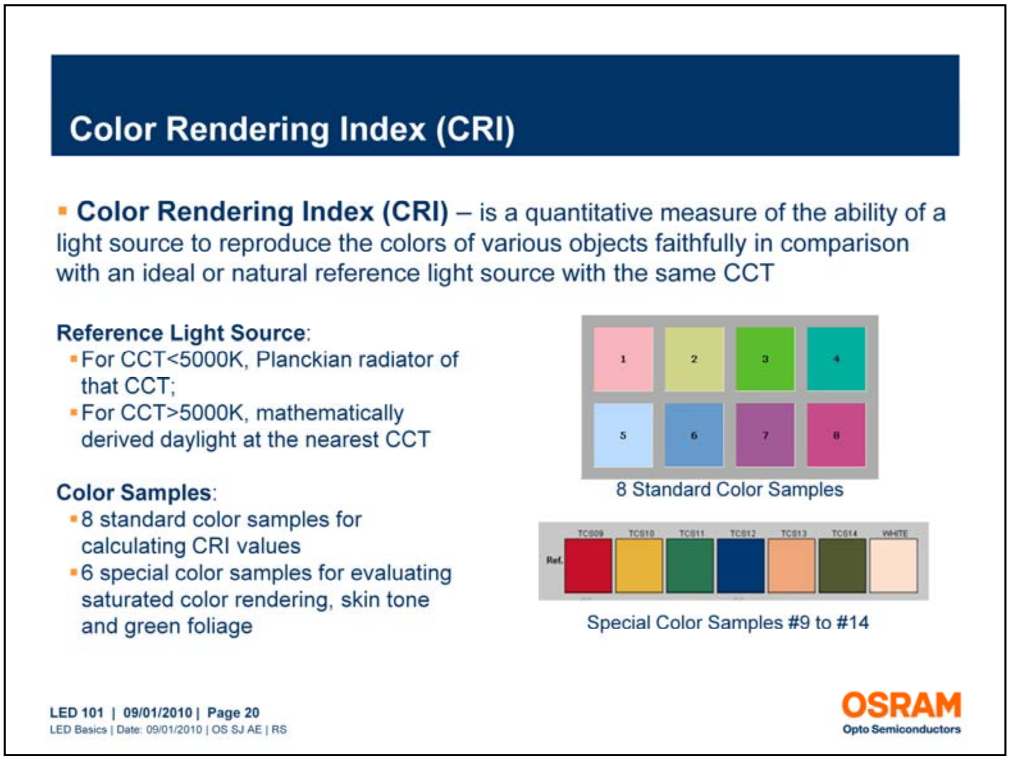
The Correlated Color Temperature (CCT) is the temperature at which a blackbody radiator and illumination source appear to match. It is usually specified in degrees Kelvin.

The CCT for a light source gives a good indication of the lamps general appearance, but does not give information on its' spectral power distribution. Therefore two lamps may appear to be the same color, but their effects on object colors may be quite different. Examples of CCT of some common light sources are shown on the figure on the right.



This image shows the spectrum for various CCT's of white LEDs.

By changing the phosphor content it is possible to achieve different color temperatures of white light.



The *Color Rendering Index (CRI)* is a measure of a light source's lighting quality. It's an index rating commonly used to represent how well a light source renders the colors of objects that it illuminates.

For a CRI value of 100, the maximum value, the colors of objects can be expected to be seen as they would appear under an incandescent or daylight spectrum of the same CCT.

Eight standard color samples are used for calculating CRI values. Six additional color samples are used for evaluating rendering of saturated colors, skin tone, and green foliage.

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