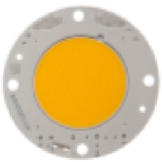
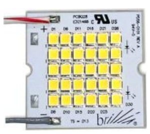
COB vs. POB

An Alternate LED Directional Point Light Source





Background

For LED lighting, the COB (chip on board) was created to address applications where the luminaire must provide a directional beam of light with consistently high quality color. Standard industry available optics are often used to shape the beam. Due to its design, the COB provides very pleasing and beautiful light. However, there are limitations and negative attributes inherent in the COB construction that this paper will address and provide an alternate construction POB (package on board) with improved performance, depending on the application.

Summary

This paper will review and compare differences between COB and POB technology, the main points are:

1. COB is preferred for use with off-the-shelf optics if a shaped (spot) beam pattern is desired whereas POB is superior in applications not requiring as critical of a shaped beam pattern.
2. POB achieve lower LED thermal junction temperatures than COB due to the superior thermal path from each individual LED “chip” to the heatsink.
3. POB deliver typically 15% higher efficacies than COB, mostly due to the superior thermal path from the LED “chip” to the heatsink.
4. POB maintains longer lifetime due to lower junction temperature, reducing higher cost of lighting maintenance, liability/frustration of application outages.
5. POB can provide lower cost and faster manufacturing time than COB, due to simpler design and utilization of standard components with higher economies of scale.
6. POB are available in wider range of color (CCT) and rendering (CRI) due to utilization of standard high volume manufactured components.

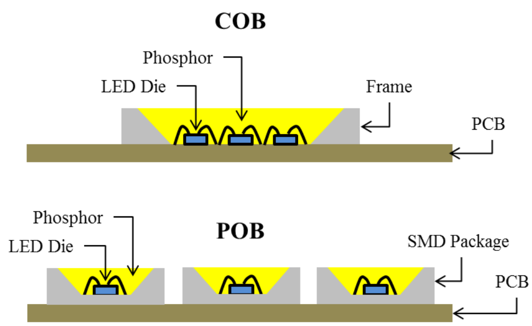
1220 South Wright Street, #B
Santa Ana, CA 92705
714.721.3255
www.forzlux.com

LED technology as of 2019

3mm LED *package*

LED (light emitting diode) **packages** (sometimes erroneously called **chips**) have been created in laboratory environments reaching efficacies of 300 LPW (lumens per watt). However, in mass production, the industry leading performance for high quality LED **SMD** (surface mount device) LED is achieved in 3mm LED packages such as shown at right. Efficacies are available up to 200 LPW for **cool white** and 150 LPW for **warm white**.[1] The term **chip** technically refers to the LED **die** which is about the size of a single piece of course ground black pepper. The theoretical limit of white LEDs is speculated at 300 LPW[2].

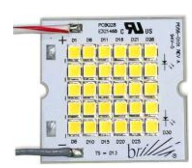
COB vs. POB Construction



The main difference is that COB employs multiple LED dies mounted directly to one printed circuit board (PCB), whereas POB utilizes one LED die in each SMD package with multiple packages mounted to one PCB. The difference is illustrated by the simple drawing on the right.

For COB, multiple quantities of LED dies are assembled directly onto a single PCB in parallel and series configurations to obtain a particular current and voltage combination. The individual LED dies (blue light emitting) are connected to the PCB with wire bonds, and then covered with a yellowish phosphor suspended in a gel material to produce white light. The PCB can utilize a circular frame or indentation to allow a radial pattern to hold the phosphor/gel.

A typical COB is show at right. This succeeds in emulating a light source such as incandescent or halogen lamp and is ideal for compatibility with standard reflector type lenses. One benefit of COB construction is higher LED die density or smaller **pitch**, meaning more light output can be placed in a smaller area. However, this can inhibit heat extraction and consequently create lower efficacy.



The POB is similar in materials and construction except each individual blue LED die is placed in its own SMD package, connected with wire bonds and then covered with phosphor/gel. Multiple SMD packages are soldered onto one PCB to create a POB. Most often **metal core printed circuit boards** (MCPCB) are used to more effectively couple the heat transfer out of the LED die[3]. Although the pitch of the LED die placement can be much greater on POB, the total PCB size can be relatively similar. A POB is shown at right using the same scale as the COB above. Note that the size is similar, though the individual LED **emitters** (the phosphor emission area) cover a larger area.

---

[1] Nichia Reference literature 2016.
[2] Yukio Narukawa et al (Nichia), September 8, 2010, *Journal of Physics*.
[3] Forzlux, US Patent 6,712,486 - Mounting Arrangement for Light Emitting Diodes.

1220 South Wright Street, #B
Santa Ana, CA 92705
714.721.3255
www.forzlux.com

The Effect of Heat on LED

As opposed to most conventional light sources, **HEAT** is the enemy of LED. When continuous current is applied to an LED some of the energy is released as light, but a large portion of the energy turns into wasted heat. An LED SMD package is tested for electrical and light properties by high speed robotic equipment at room **ambient Temperature** (Ta) of 25°C with pulsed current at typically 10 milliseconds (ten thousandths of a second). It is critical to note that this test does not subject the LED to continuous heating as it would experience in a luminaire (fixture) application. Nevertheless, the measurement technique is understood by and useful to experts in semiconductor manufacturing to calculate approximate application values. The LPW (efficacy) rating published with this pulsed test method is definitely NOT relevant to real world scenarios where the LED package will run continuous DC operation and at higher temperature due to current generated heating and most likely higher (surrounding) temperature ambient air (Ta).

Most LED SMD packages can be operated safely up to a maximum junction Temperature (Tj) of 120°C. Tj is a calculated temperature (not measured) of the LED die inside the SMD package. The actual thermal measurement is **Temperature solder-pad** (Ts) and made on the PCB **pad** next to the LED package. Industry standard LM-80 lifetime tests typically limit Ts to 105°C. The efficacy of a white LED typically decreases about 0.266 percent per °C[4]. For example, an LED rated at 161 LPW (pulsed at Ta = 25°C) running in continuous DC at Tj = 80°C (very typical real-world scenario) has a temperature rise of approximately 55°C x 0.266%. This decreases lumens by 15% and translates to a reduction from 161 to 137 LPW.

Multiple SMD LED packages located in close proximity create more heat and reduce efficacy. Therefore, when designing an LED **module**, it is best from a thermal consideration (and long-term life) to spread the SMD packages further away from each other. Unfortunately this increases module size and cost. For the purpose of this paper, the application requirement is a point source where the LED must be placed in close proximity. In general, the efficacy of a POB with 30 LED, compared to a standard LED module with 30 LED and 0.4" LED spacing, will be about 5% less.

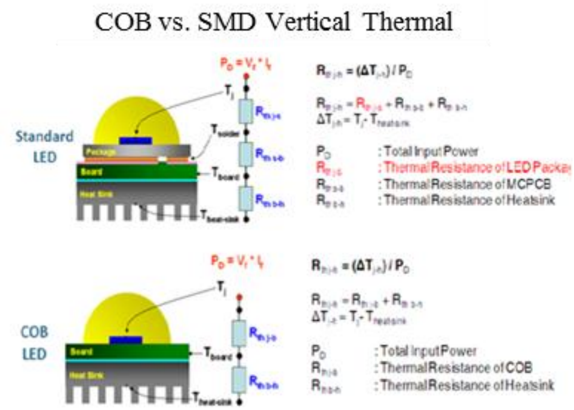
Standard LED module with 30 LED and 0.4" spacing

POB with 30 LED

[4] Typical Nichia LED specification, ambient temperature vs. relative luminous flux.

1220 South Wright Street, #B
Santa Ana, CA 92705
714.721.3255
www.forzlux.com

For a COB, the Tj is a less accurate value (calculation) because the Ts measurement point is further away from the center die to the outside of the COB. COB publications exist that suggest the Tj will be lower due to the reduction of vertical layers under the LED as shown at right.



While partially true, thermal conduction for SMD LED is not only vertical, in fact it is mostly horizontal. Contrary to intuitive understanding, the type of cooling which an LED die requires is not convection (air cooling). Air is one of the worst thermally conducting elements. For an LED die, the heat must be pulled away in millionths of a second (nanoseconds) at the molecular level. Air cooling takes too long and is not even considered at the semiconductor level. Heat can only be extracted this rapidly by a highly thermally conductive material such as copper which is typically the top layer conductor on a PCB. In layman's terms, heat is like water, it will take the lowest path of resistance or it will "run faster" through a more thermally conductive surface. Therefore, while the COB may extract heat faster vertically, each die inside the COB is handicapped in horizontal heat extraction compared to POB. Each LED die generates heat inside the COB and the center die(s) have the longest distance to horizontally extract heat. The die at the outside edge of the COB can extract heat faster so they will run cooler. Basically, each little "heater" does not have the optimum path to extract heat. A well-known real-world illustration of this thermal phenomenon is that a single 100W power supply runs hotter than two separate 50W power supplies in an enclosed environment such as a gasketed fixture or metal box.

This thermal phenomenon is evident when examining SMD vs. COB manufactured by the same LED manufacturer. SMD exhibit higher efficacies than COB. Nichia flagship SMD NFSx757G boasts 185 LPW[5], see blue highlight. By comparison, Nichia highest efficacy COB is 163 LPW which is 13.5% lower efficacy. Remember that these are pulse tested values and cannot be applied directly to real-world conditions.

NFSx757G

3.0 x 3.0 x 0.65mm

Ts=25°C

	Item	Unit	5,000K, Ra≥70 NFSW757G spec.	3,000K, Ra≥80 NFSL757G spec.
Rated	Forward Current	mA	65	65
	Forward Voltage	V	2.88	2.88
	Luminous Flux	lm	34.6	30.1
	Luminous Efficacy	lm/W	185	161
	Thermal Resistance	°C/W	13	13

NTCxS024B

15 x 12 x 2mm (Emitting ϕ: 6.7mm)

Tc=25°C

	Item	Unit	5,000K NTCWS024B spec.	3,000K, Ra≥80 NTCLS024B spec.
Rated	Forward Current	mA	135	135
	Forward Voltage	V	36.3	36.3
	Luminous Flux	lm	800	705
	Luminous Efficacy	lm/W	163	144
	Thermal Resistance	°C/W	3.0	3.0

To determine the true efficacy difference in real-world thermal conditions between COB and POB, it is critical to review data from packaged parts (not the **chip/die**) tested with continuous DC and properly mounted onto heatsinks and at elevated temperatures.

[5] Nichia Lighting LED Portfolio 2016

Bridgelux manufactures the Vero® series of COB which is widely used in the general lighting industry. Below is a condensed version of the latest Bridgelux Vero®18 Product Data Sheet[6]. The Vero®18 is 30W and 1.43" diameter. The performance shown is for 5000K CCT, typically the highest efficacy (LPW), at 80CRI. Bridgelux specifications are realistic with measurements taken with COB mounted on a typical heatsink at 85°C **case Temperature** (Tc) which represents real-world conditions. See note #9 below. The efficacy at 5000K is 125LPW.

Table 2: Selection Guide, Stabilized DC Performance (T_c - 85°C) [8,9]

Part Number	Nominal CCT[1] (K)	CRI[2]	Nominal Drive Current[3] (mA)	Typical DC Flux T_c = 85°C (lm)	Minimum DC Flux[10] T_c = 85°C (lm)	Typical V_f (V)	Typical Power (W)	Typical Efficacy (lm/W)
BXRC-50E4000-F-24	5000	80	1050	3762	3329	28.6	30.0	125

8. Typical stabilized DC performance values are provided as reference only and are not a guarantee of performance.
9. Typical performance is estimated based on operation under DC (direct current) with LED array mounted onto a heat sink with thermal interface material and the case temperature maintained at 85°C. Based on Bridgelux test setup, values may vary depending on the thermal design of the luminaire and/or the exposed environment to which the product is subjected.

Forzlux manufactures POB which are a viable option to COB, especially if lenses are not required. Forzlux also provides realistic data by taking measurements stabilized on a heatsink with similar Ts values. Below is a condensed version of the latest Forzlux BB30VK Product Data Sheet[7]. The BB30VK is similar power and size to Vero®18, 31.5W and 1.38" square. The performance is shown for the same 5000K, 80CRI. The power consumption is 5% higher, however the light output (lumens) is 20% higher. This is due to 15% higher efficacy of 144LPW.

Performance Characteristics, Table 1

Data from laboratory test measurements, actual results may vary.

Part Number	Designed to Replace	Nominal CCT (Kelvin)	Minimum CRI	Nominal Light Output @1050mA (Lumens)	Nominal Power Consumption @1050mA (WDC)	Nominal Module Efficacy (DC LPW)
BB30VK-50-80-01	Metal Halide	5000	80	4,529	31.5	144

The superior efficacy of the POB is due to faster heat extraction. Each SMD is mounted on a heavy copper trace which then has a highly thermally conductive horizontal path to the outside of the POB to evacuate heat rapidly and transfer this heat to the heatsink. For about the same power and size, the POB in real-world conditions can deliver about 15% higher efficacy than COB. This benefit can be used to lower the power while maintaining the same lumens, resulting in lower Tj and longer life. Alternatively, the higher efficacy can provide more light output at the same power for critical applications requiring the most delivered foot candles.

---

[6] Bridgelux Vero®18 Product Data Sheet, DS32, 09/2015.
[7] Forzlux BB30VK Product Data Sheet, May 2019.

1220 South Wright Street, #B
Santa Ana, CA 92705
714.721.3255
www.forzlux.com

COB vs. POB performance of CCT and CRI

This paper assumes the reader understands the lighting terms **CCT** (Correlated Color Temperature), **CRI** (Color Rendering Index) and **MacAdam Ellipse**. The COB has the highest potential for consistent quality of CCT and CRI. This is because the multiple blue LED die are all covered with the same phosphor suspended in a gel material as explained earlier herein. This is predicated on the assumption that each blue LED die in the COB are tightly **binned** (term for testing and selecting LED die with tight distribution of electrical and light values) and the phosphor is from the same manufacturing lot. Otherwise, COB from lot-to-lot may not measure the same CCT and CRI. POB have the potential for less consistency and quality of CCT and CRI. However, the SMD packages used on POB are produced in much higher volume than COB and can be high-speed robotically binned to tight CCT and CRI tolerances. For critical architectural or retail lighting applications where variance in lighting color is not acceptable, lighting designers specify consistency values of 2 to 3 MacAdam Ellipses. Utilizing the latest LED die/phosphor technology as of this paper, both COB and POB are available with consistent CCT and 2 to 3 MacAdam Ellipses. COB and POB are also both available with CRI of 90 minimum for requirements such as California's Title 24. Warm white POB now have typical values of 95CRI and are available up to 97CRI minimum. This makes them virtually indistinguishable from incandescent and halogen (100CRI) light sources in their ability to render colors accurately.

The SMD packaged LED is manufactured in higher volume than COB and therefore is also available in a wider variety of CCT and CRI. COB is typically only available in the standard **ANSI** (American National Standards Institute) CCT bins of 2700K through 5000K. However, POB are available in non-ANSI warmer CCT from 2000K to 2500K. These warmer colors are ideal for emulating HPS (high pressure sodium), dimmed incandescent, candles and even amber light. Although beautiful warm white LED sources have been available for years, due to low cost commoditization (i.e. LED flashlights, low quality LED landscape) much of the general public considers LED light to be blue or green hue and not attractive. Designers are now taking advantage of these warmer, more traditional and historic colors to maintain pleasing legacy appearance and aesthetics.

2000K POB Wallpack

1220 South Wright Street, #B
Santa Ana, CA 92705
714.721.3255
www.forzlux.com

COB vs. POB Optical Issues

COB is superior for use with standard industry available lenses (optics) to shape the light beam. COB allows for a smaller lens because of the radial phosphor configuration. However, that same benefit of smaller size is exactly what causes the penalty of reduced thermal transfer and therefore reduced efficacy examined herein. POB is recommended for applications not requiring critically matched optics where higher efficacy, lower temperatures, longer life and possibly lower cost are desired. POB can be the only existing solution when warmer/lower CCT than 2700K is required. When POB is used with industry standard optics with reflective material, the multiple SMD packages of the POB may project multiple **striations** (lines of light) which are not visually pleasing. For an exterior flood fixture such as a wallpack which is not designed to be decorative, this may be a moot point. However, custom optics and/or optics coated with white diffusing material can mitigate and/or eliminate this problem.

COB with low profile optic

Conclusions and Recommendations

COB provides very pleasing and beautiful light and is recommended for use with off-the-shelf optics if a shaped (spot) beam pattern is desired. POB are recommended for flood applications not requiring a critical or tight beam. POB achieves lower LED temperatures due to the superior thermal path from each individual LED to the heatsink. This results in typically 15% higher efficacies which provides longer lifetime. POB are available in a wider range of CCT and can be lower cost and faster to manufacture.

1220 South Wright Street, #B
Santa Ana, CA 92705
714.721.3255
www.forzlux.com