binay
Lighting Up The Future

WHY 5mm, 4-LED AND SMD SMALL-CHIP EPOXY-ENCAPSULATED LEDs ARE INAPPROPRIATE FOR HIGH POWER SOLID-STATE LIGHTING

Small-Chip Low-power LEDs (5mm, 4-leg and SMD packages) are NOT designed for use in illumination applications

Some suppliers are providing LED lights with 5mm (or 3mm, 4-leg or SMD) small-chip (low-power) epoxy-encapsulated LEDs, which were initially developed for indication use.

Such LED products are unsuitable for illumination applications, and will eventually fail – not immediately, but will gradually fade to zero intensity over a period of 12 to18 months. They will not last for anywhere even near the rated life.

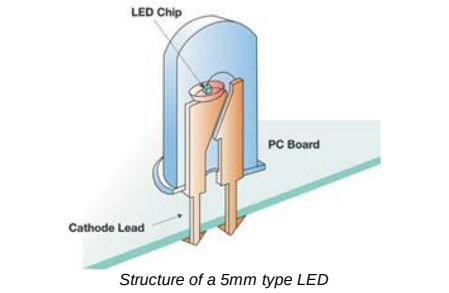
Luminaires made with such 5mm White LEDs do not last
Result: Loss of customer confidence in LED technology, which has tremendous benefits to offer

Even retrofit products made with power LEDs will have limited life, since conventional luminaires are not designed for the specific heat dissipation required at the power LED chip level

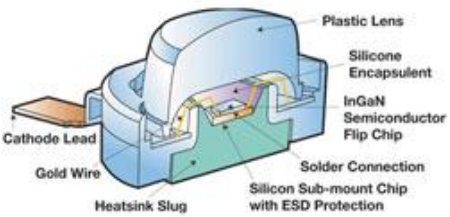
Epoxy-encapsulated LEDs are an older technology, where the LED chip is encapsulated by a transparent epoxy compound to isolate it from the environment. In this technology, the heat of the LED P-N junction is trapped inside. While some heat can be conducted out by the LED current lead-in wires, this is insufficient, resulting in a high P-N junction temperature.

A life test carried out by Lighting Research Centre of the USA (see graph below) shows that an epoxy-encapsulated small-chip white LED has a life of only 6,000 hours, as the heat generated at the chip junction cannot be transferred out through the thin lead-in wires of this package. (Lighting Research Centre is an independent research facility under the Rennsaeler Polytechnic Institute, New York, and has carried out a number of path-breaking studies in solid-state lighting.)

The reasons for such failure can be attributed to inadequate Thermal Management at the LED chip junction in the epoxy-encapsulated package, and are further enumerated as follows:

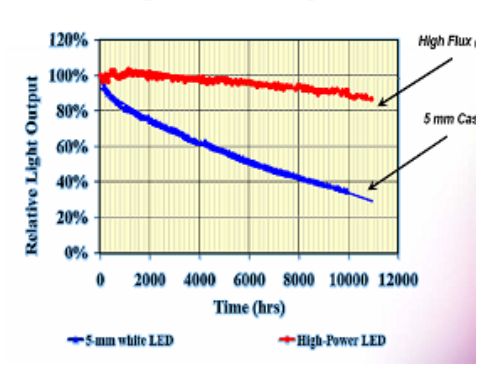


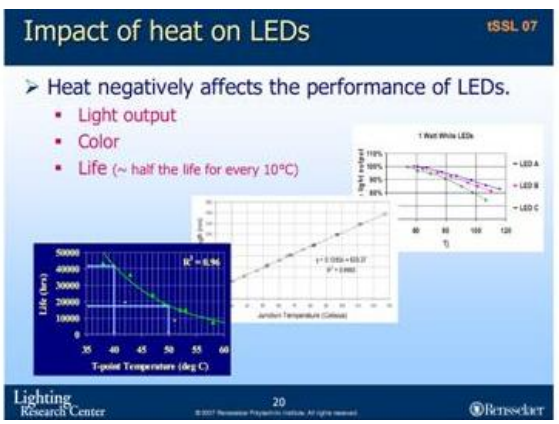
Structure of a 5mm type LED



Structure of a high-brightness LED
.Source: Lumileds™

- The long life of the LED is achieved by keeping the semiconductor P-N junction of the LED chip at as low a temperature as possible. This heat is generated when the current is forward biased and the active junction layer of the LED chip emits light, **and also generates heat**. This heat is not very apparent to exterior sensation (as it not radiated outwards), but will adversely affect the life of the LED chip; as such, it must be conducted away to the ambient environment by suitable thermal management. As can be seen from the graph alongside ('Long Term Degradation'), **a 10˚C rise in P-N junction temperature reduces the life of the LED chip by 50%**.
- White LEDs are made with blue InGaN LED chip, coated with a yellow phosphor to generate white light. The blue chip has a higher forward voltage drop, resulting in a higher wattage, and so contributes even more to heat generation.
- The epoxy resin encapsulation also becomes yellow with blue radiation, since it is an inefficient heat conductor.
- Furthermore, its rigidity does not permit any play in the bond wire during expansion and contraction when heated. This results in-wire bond stress, leading ultimately to LED failure.





…continued overleaf

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- Heat also tends to shift the emission wavelength from its highest point, resulting in lower light.

Improper thermal management is a major cause of failure of LED products the world over. This is more important for tropical countries such as India, where ambient temperature can rise to 55˚C during summer.

The upshot is a very short life – only 6,000 hours, as tested (and shown by the degradation graph) by the independent Lighting Research Centre**.** On the other hand, the bare power LED chip (as used by BINAY and by solid-state lighting manufacturers the world over), each running at 350mA (1.1 watts), and presently giving a lumen level of more than 110 lumens each – is shown in the graph as having very low light degradation, giving an ultimate life of 100,000 hours to 50% lumen degradation (L_{50}).

Light output is increased in Power LEDs, primarily by increasing the size of the chip to 1 sq. mm, and running at a higher current of 350mA (and above, up to 1.4A at present). Due to the generation of considerable heat (which, as explained above is very detrimental to the life of the LED), the encapsulant epoxy is replaced with high temperature-resistant silicone resin. A small copper slug is also placed below the LED chip to conduct away the heat. Apart from being a better conductor of heat, the silicone also permits the bonding wires to take up expansion and contraction (unlike epoxy, which is inflexible) when the LED chip is lighted and heats up from the ambient temperature to temperatures which may exceed 100°C.

Another solution is BINAY's LED Chip-on-Board (COB) solution, where the chip is directly mounted on a large mass of metal to quickly dissipate the heat generated, and non-yellowing silicone encapsulant is used to prevent light degradation. This is similar to the principle of the power LED; thus, our COB design enables us to keep the chip junction temperature just a few degrees above the ambient (in contrast to most other LED designs, in which the temperature is invariably much higher as there are several layers of packaging material in between).

Being LED manufacturers, we at BINAY have the ability and equipment to measure the chip junction temperature inside the chip and can therefore design products which will actively prevent thermal degradation.

It is abundantly clear that small-chip low-power LEDs (5mm, 3mm, 4-leg and SMD packages) are not designed for illumination, and will have a relatively short life if used for such applications as they cannot effectively remove the heat generated by the LED chip. For illumination applications, proper thermal management of the LED design is critically important, and power LEDs must be used.

BASIC REQUIREMENTS FOR A WELL-DESIGNED LED LUMINAIRE (IN ORDER TO ENSURE LONG LIFE)

The four major factors to be noted in a well-designed LED luminaire are (a) Quality of LED chip used (which must be of the highest luminous energy available) (b) Thermal Management of the LEDs (c) Optics, and (d) LED Driver construction.

(a) ***Luminous Efficiency:*** BINAY uses high-grade LED chips, avoiding uncertain Chinese makes. Of greatest importance in an LED-based luminaire is a high colour temperature of 6500°K (cool white) for the emitted light, as this contains more blue radiation, required to activate the night-time visibility 'RODs' of the human eye. Rods have maximum sensitivity at blue-green colour of 507nm wavelength, but are not sensitive to yellow or red; yellow and red colours serve to activate only the daytime 'CONEs' of the human eye, which are only useful for daytime visibility and have very little function in night-time visibility.

(b) ***Thermal Management:*** The LED is a solid-state device like a transistor, and heat is generated at the P-N junction of the LED chip. LED chip life is critically dependent on keeping the P-N junction cool, with good thermal transmission to the ambient (where the heat should be dissipated). The two major factors to be noted in power LED design are:

a. A 10% rise in P-N junction temperature decreases the LED chip life by 50%.
b. To dissipate one watt of heat requires 60 square cm. of surface area exposed to ambient air flow.

For proper heat dissipation, the thermal resistance to heat transfer must be minimised, with all surface junctions coated with heat-conducting silicone grease to avoid air gaps (as a gap of even 0.2mm results in high decrease in thermal transfer).

The LEDs in BINAY luminaires are exposed to the ambient air flow, since if they are enclosed, heat dissipation to the ambient will not take place. Appropriate sealing and ingress protection systems are provided to protect the electrical and optical systems of the luminaire from the environment.

It is important to examine the method of thermal management of any luminaire. Cast aluminium body construction is not beneficial to heat transfer, as it has lower heat transmission capability (on account of air entrapped in the metal during the casting process). In a standard box luminaire design, low-profile cast fins are sometimes provided for heat dissipation. Heat transfer may not be adequate with such designs, and this will result in reduction of the LED life in the long-term. (Evidence of a hot external body surface in an LED luminaire is an ideal guarantee of good heat transfer.)

(c) ***Optics:*** Power LEDs have a "lambertian" radiation pattern (obeying the cosine low), which results in very little light being radiated on the sides. BINAY's efforts are towards designing suitable LED light luminaires which will conform to the lighting requirement of dispersion, so as to cover the lighted ground area between adjacent fixtures.

(d) ***LED Driver:*** Power LEDs are constant current devices, and LED drivers are usually designed with switch mode power supplies (SMPS). This ensures that the output current remains steady, thus giving stable illumination despite variation over a wide range of input voltages (90V-260VAC).

The life of the LED Driver should also match that of the LED (50,000-100,000 hours). Components chosen must be highly over-rated, and provisions should be provided for power factor correction, short circuit protection, EMI/RFI filtering, and overload protection. The circuit design should be such that Driver efficiency is as high as possible.

For street lighting applications, BINAY's unique Eagle-Eye luminaire design ensures the optimisation of the above factors to ensure maximum performance. However, we also offer our lower-priced models in the conventional box type luminaire design.

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