Many LED manufacturers, such as OSRAM Opto Semiconductors, Lumileds, Everlite, and Nichia, are significantly betting on this package category, and the cost of manufacturing in this package is significantly lower than high power, and indeed the market is significantly large.

1.4.3 LED High-Power and Ultra-High-Power Packages

The high-power LED packages are those with input power in the range of 1–4 W, and ultra-high-power packages are those with input power greater than 4 W. Their driving current is greater than 350 mA, and biasing voltage is in the range of 1.5–3.5 V. Chip size is usually in the range of 600–2000 μm. They can have either single large like OSRAM OSONIQ® P 7070 chip or multiple large chip like OSRAM Duris® S8. Some packages have multi-small chips arranged in an array in one package, for example, OSRAM SOLERIQ® S9. There are many types of packages namely single large chip packages; some are multi-chip packages. The package substrate varies. Some are premolded leadframe, ceramic, and metal-core PCB. Figure 1.11 shows the different varieties of high-power and ultra-high-power LED packages for different applications. There is single large die package like OSLON from OSRAM, XLamp XM-L3 from CREE, and K2 from Lumileds. Multiple large die size in a package like OSTAR series of OSRAM. Small/medium-sized die array in a package from Luminus and OSRAM. And single or multi very large die in a single package of Luminus or OSRAM.

The emergence of high-power LEDs is mainly due to the inability of low-power or mid-power packages to handle heat dissipation. For example, if the input power of an LED is 1 W, with a chip of internal efficiency of 50%, the heat generated in the LED will be roughly 0.5 W. This heat has to be dissipated from the chip efficiently and quickly. Failing to do so, the chip will have a significant impact on brightness and package reliability, and its lifetime will deteriorate. In many cases, the LED failed spontaneously. Figure 1.12 shows the high-power LED PLCC package thermal management design. It has big heat slug (sink) that allows the heat from chip to drain into the heat sink. The big heat slug also plays a role as a good thermal capacitance reservoir.

Beside the PLCC package, there is also ceramic package in high-power LED products. In Figure 1.13, there is an example from OSRAM that shows the OSLON®Square ceramic package. The substrate of this package is usually aluminum nitride, but there are also some cases made of silicon carbide. The thermal conductivity of silicon carbide is higher than that of aluminium nitride. This is ideal for high-power LED. However, the price of silicon carbide is relatively higher than aluminium nitride.

The die is attached to this ceramic substrate. On top of the die, a phosphor layer was attached. It was encapsulated using clear silicone. This encapsulant usually forms an optic to collimate the light at a certain viewing angle.

The LED high-power packages evolved mainly for automotive applications in the mid-1990s, where high-brightness LED makes a significant market differentiation in terms of aesthetic values, clarity, and elegance that charms end users. Luxury car makers such as Mercedes, BMW, Audi, and others are capitalizing on these values

Figure 1.11 High-power LED packages with a variety of solutions. Source: Courtesy of ams OSRAM GmbH and Courtesy of Luminus, Inc.

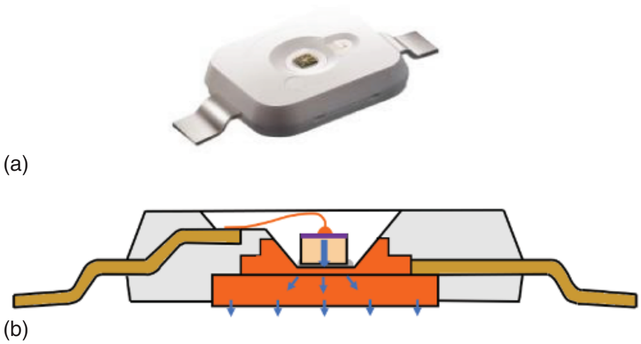

Figure 1.12 High-power LED PLCC package thermal management design: (a) Golden Dragon PLCC package. (b) Cross-sectional view of Golden Dragon PLCC package. Source: Courtesy of ams OSRAM GmbH.

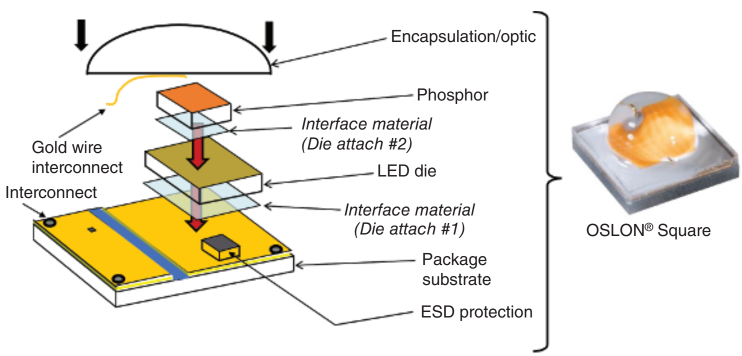

Figure 1.13 High-power LED package construction. Source: Courtesy of ams OSRAM Group.

to increase their sales. As a result, many of these large companies collaborated on research projects to develop new LED products that add value to end users. Some of the high-power packages that have evolved over the years are OSRAM Golden Dragon, Luxeon K2, Cree XLamp, Lumileds Rebel, OSRAM OSLON Square, OSRAM OSTAR, OSRAM OSLON Pure CSP, and SiP. Each is used for a specific application in the car, which will be further elaborated in a Chapter 2 and 4.

1.5 Summary

Light is one of the most essential elements for all living things. Humans mastered the science, technology, and engineering of artificial light over a period of time. This mastery has changed their lives and the course of evolution. The artificial light itself has evolved. The energy conversion efficiency of artificial lighting has changed from less than 1% to almost 80% in today's LED. The LED light has revolutionized human civilization. The LED application now covers almost every aspect of human life. The LED packaging plays a very important role to fit LEDs into all the applications that necessitate human wellbeing. It is the bridge between the LED chip and LED applications. The LED industry itself is still evolving. The LED's brightness increased as the need for high brightness increased. The LED packages evolved to support high brightness, where the package thermal management design was further perfected. The evolution further continues from single-component LED to a combined LED, sensor, IC, and passive component to a system packaging or system in a chip.

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