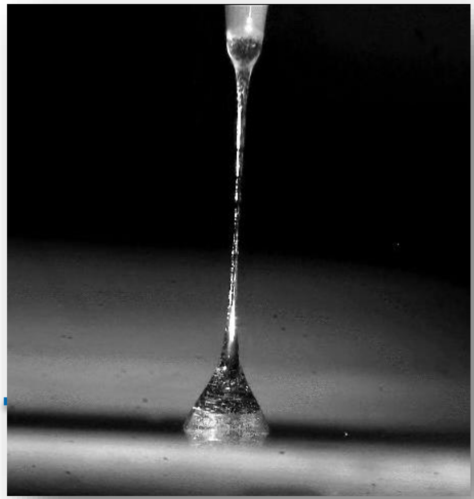
Dispensing Solutions for the LED Industry



Dispensing Solutions for the LED Industry

By Akira Morita

Introduction

LED lighting is popular because many governments ban incandescent bulbs to save energy and carbon dioxide, especially for general lighting. In the automotive industry LEDs are being used because they save energy and costs, especially with the migration to hybrid cars and electric vehicles, and because the flexible LED light shape creates cool designs. These applications have created a need for more precise and accurate fluid dispensing as well as the dispensing of some fluids that require special attention. These dispensing applications must take into account

- CIE value
- Heat dissipation
- LED life
- Power savings
- Production costs

People think switching to LED lighting is an up-front investment because it is much more expensive than other lights, such as incandescent and florescent, but LEDs should last for a much longer time, like more than 10 years, and their power consumption is much less. Therefore, the technologies that enable LEDS to save more power, have a longer life, and lower their production costs are important.

CIE value relates to the clarity and color of the product. People prefer to see a warm color which is similar to an incandescent light rather than a cool color like a florescent light in factories. People have a pretty good sense of distinguishing color differences with the naked eye, so the CIE specification is quite tight: many LED manufacturers require “1 bin” for the specification. See Figure 1.

Heat dissipation technologies at the package and board assembly levels play a key role in extending LED life. This is because heat dissipation reduces the LED’s junction temperature. The lower the junction temperature the longer the life. In addition, LED designers try to find the best way to extract as much light as possible to save power: the more efficient the light emission the less input power. Reduction in cost also contributes directly to making the investment equation better.

Typical Package Types and Dispensing Applications

LED packages vary according to the end-application and cost constraints. Typical package types include

- cavity encapsulation
- flip chip with phosphor attachment
- remote phosphor

Each of these packages has different dispensing applications.

Cavity encapsulation is the most popular package because of its long history, fewer patent constraints, simple structure, material availability, and technology as well as lower cost. The package needs silicone phosphor cavity encapsulation dispensing. The amount of phosphor in the cavity is the key to controlling CIE. The color depends on the consistency of the volume of the dispensed mixture. Changing the volume of the fluid considerably changes the color, so the dispensing operation to fill the cavity with phosphor silicone has to be very precise and consistent.
There are three major ways to get consistent dispensing:

- a jetting valve with controlled process jetting (CPJ+),
- a displacement valve
- an auger valve with mass flow control.

A jetting valve with CPJ+ is a sophisticated method which strikes a balance between getting an outstanding rate of units per hour (UPH) and good dispensing consistency. In CPJ+, the automated dispensing equipment measures the weight of the dot size and compensates for changes by recalibrating and adjusting the fluid volume as the viscosity of the fluid changes or the fluid changes because of expansion. The jetting valve can achieve 18,000 UPH for a 3014 plastic leaded chip carrier (PLCC) package and +/-1.5% weight consistency by dot weight calibration with periodic monitoring. **See Figure 1: Lead frame weight.**

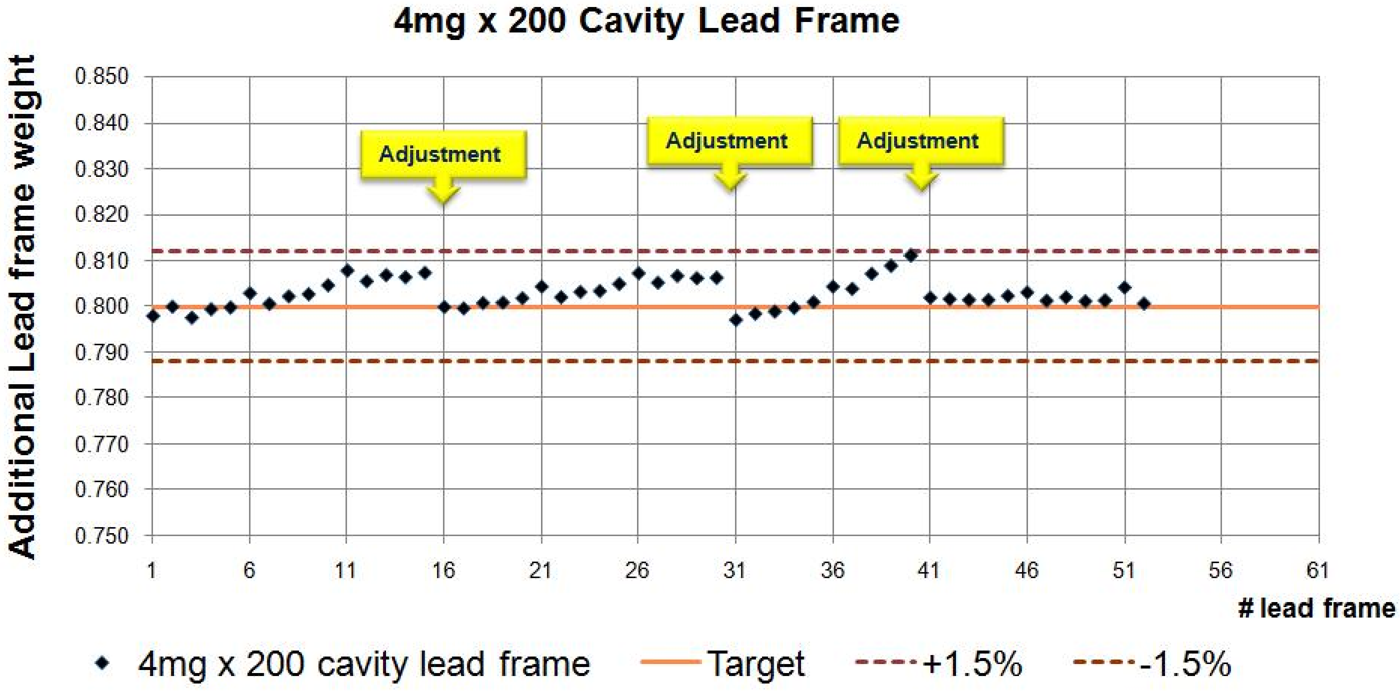


Figure 1: Lead frame weight.

A displacement valve has the best weight consistency because its piston and cylinder structure provide volume measurement capability, but its UPH is a slow 8,000. An auger valve provides 8,000 UPH and a little less weight consistency even with mass flow control. Cavity encapsulation packages are produced in billions of units a year, therefore the balance between consistency and productivity is important.

Flip chip with phosphor plate attachment has a better performance package than cavity encapsulation because it has better heat dissipation, more emission extraction, a better power supply. Because of its higher performance, it is often used for applications where performance is more critical, such as in automotive head lamps. This package type requires several dispensing operations such as underfill, reflection material dispensing, adhesive dispensing for plate attachment, and silicone casting. Underfill plays an important role in dissipating heat from the LED chip to the package substrate, thus providing a better heat path between the chip and substrate. The underfill material is usually silicone because of its heat resistance. When dispensing underfill, a jetting valve is most commonly used because the fluid has to be placed extremely close to the die, get into very tight, hard-to-reach places, the volume of dispensed fluids is small, and it has to be dispensed accurately.

Thermal interface material (TIM) dispensing is important for heat dissipation although all LED package types are applicable. The material is applied between the LED package and the LED lamp substrate to transfer the heat from the package to the lamp and ultimately to the fixture. Many of the TIM materials are silicone.

Reflection material dispensing is done around the LED chip to prevent light from coming out of the side wall of the LED. Titanium oxide (TiO2), which is a high viscosity material, is commonly used. The dispenser needs to have excellent location and placement accuracy because the dispenser has to negotiate LED chips as small as <300 µm x 300 µm to avoid contaminating the top die while filling the gap between the chip and wall. Dispensing location accuracy such as +/-40 µm plays a key role for dispensing. Auger and jetting valves are available for this application depending on the viscosity and UPH requirement.

Adhesive dispensing is required for phosphor plate attachment. In this package, adhesive is dispensed on the top of the LED chip and a phosphor plate is then die bonded to that. The material dispensed is usually silicone. A consistent weight is important to avoid fluid bleeding or lessening the adhesion.

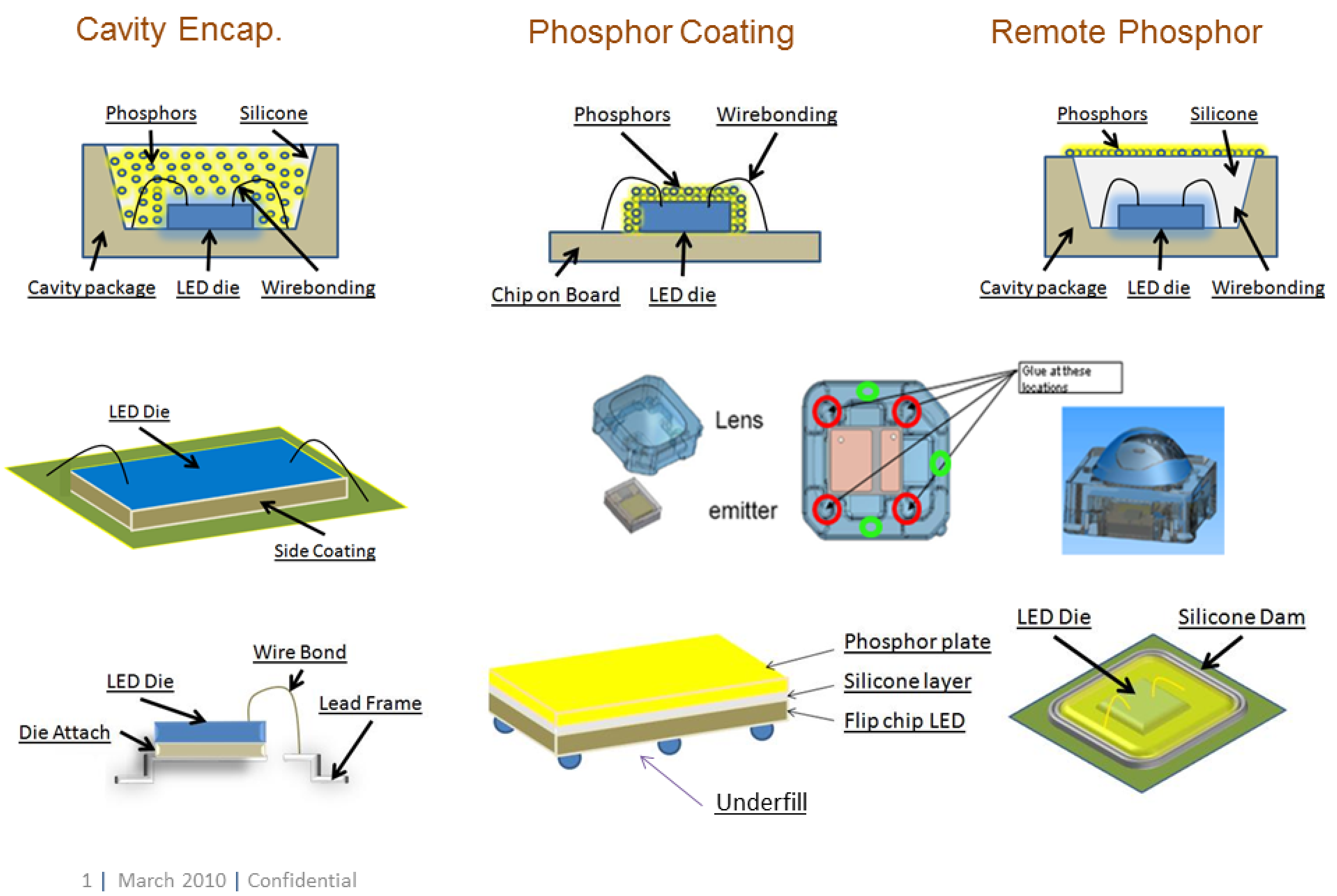


Figure 2: LED Dispensing Applications.

Silicone casting is used to cover an LED chip with an exposed phosphor layer. In other words, the phosphor surface needs to be protected after phosphor plate attachment. Pure silicone is dispensed on the surface.

Remote phosphor is the latest package technology and has better light emission extraction than the others because of its unique structure. A space is created between the LED chip and phosphor to avoid yellow light and heat generated from the phosphor from being absorbed by the chip. The space between the chip and phosphor is filled with silicone by pure silicone dispensing. In a flip chip package, reflection material is dispensed for the same reason. The space gap is sometimes defined by the amount of silicone dispensed, therefore in silicone dispensing consistency is a key requirement.

Silicone Dispensing Challenges

As you can easily see in the package descriptions above, silicone dispensing is quite popular in LED packaging. However, dispensing silicone is quite challenging. The silicone is stringy and leaves a long tail that has to be cut (see Figure 2). If it is not cut cleanly and quickly, a long trail of fluid lays down next to the part instead of going into the cavity. The amount of silicone dispensed is precisely measured because the fluid volume plays a key role in the way the LED performs. If all the fluid doesn't go into the cavity or place where it's intended, then the amount of fluid won't be accurate and performance will suffer. Not only is it messy, but in a tightly packed assembly that tail overlaps into the next package altering the volume in that LED. For every LED manufactured to be the same, a consistent amount of fluid has to be dispensed.

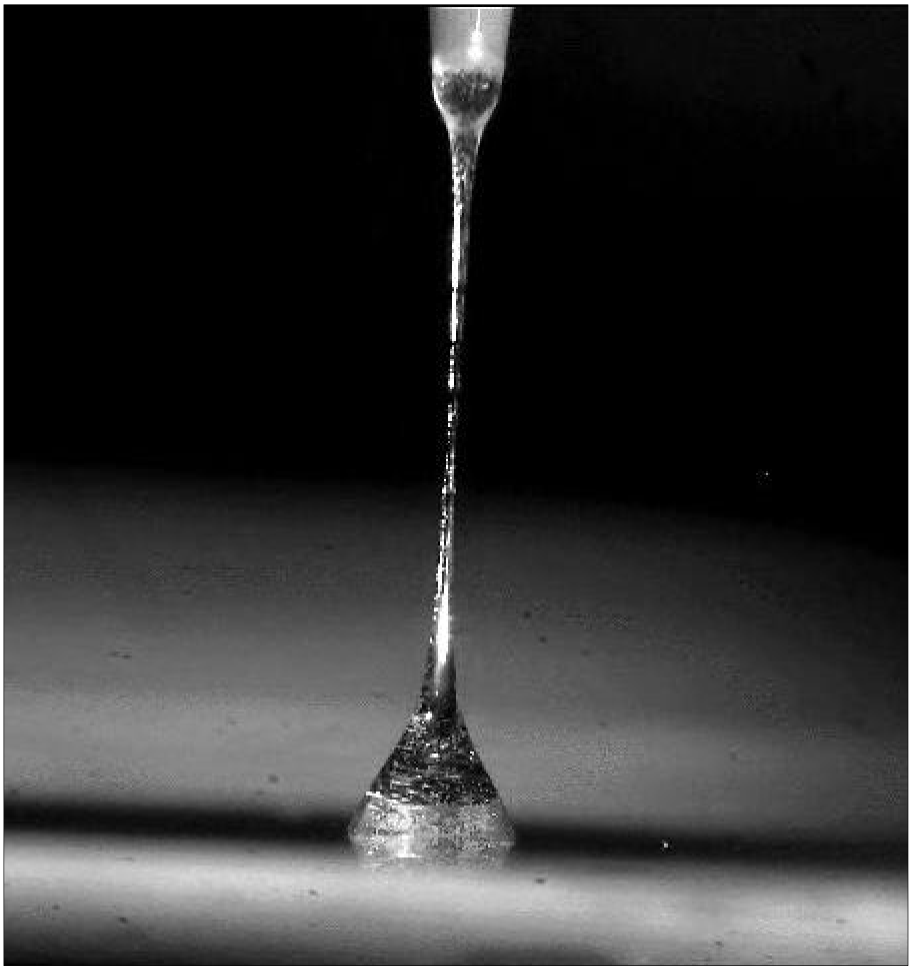


Figure 3: Silicone Dispensing

Z-retraction is the key movement used to cut the silicone tail, but there is a distinct difference between the z-retraction of needle and jetting valves. A needle requires a long retraction in the z-axis. Jetting, on the other hand, needs a short one. Jetting has a unique technology that uses a valve with an active nozzle to easily make the cut. It requires only a tenth of the retraction that a needle does. The retraction is actually very time consuming and often accounts for a considerable percent of dispensing time. Therefore, using a jet vs. a needle not only helps solve the tail problem, but it significantly contributes to improvement in units per hour.

Conclusion

LEDs are becoming more commonplace in all aspects of our life so manufacturers will need to find the most cost effective way to produce them in large quantities while optimizing their color, performance, and product life. There are many manufacturing challenges because their packages are small, they are tightly packed with components, silicone is not easy to work with, and they need to be manufactured with precision, accuracy, and consistency. Fluid dispensing plays an important part in many aspects of LED manufacturing. Because fluid dispensing has been an important component of microelectronic packaging and manufacturing for many years, the equipment, processes, and capabilities are already available and proven. Fluid dispensing equipment manufacturers will continue to innovate and adapt their equipment and processes to play a vital role in the manufacture of LEDS.

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