Dispensing for LEDs: Tighter control through jetting

Jetting systems can save time, labor and expense with clear-cut silicone dispensing.

by Akira Morita, Nordson ASYMTEK

The white LED market has been emerging rapidly in the past few years and its growth prospect is quite bright for the future. The largest market driver is display backlighting for TVs, notebook PCs and monitors. Illumination LED also has gotten strong attention as incandescent lamps are being phased out. In this market, LED companies are aiming for tight CIE, or bins, as the most important differentiator regardless of end-application. Silicone phosphor dispensing is critical for LED color quality, and therefore tight CIE. Until recently, silicone phosphor dispensing was done with a needle dispenser; however, jet dispensing is also being used now. Although using a jet instead of a needle dispenser is a relatively new process for silicone phosphor, jetting technology itself has been around for over 20 years and offers many advantages. Many of the problems incurred in silicone phosphor cavity fill can be solved, and costs reduced, with automated dispensing systems developed for LED applications.

Many companies are facing difficulties controlling CIE tightly because of the many variables that contribute to CIE tightness: LED chip quality, phosphor quality, phosphor amount, phosphor deposition structure, and production equipment stability. These variables are not easy to control because of patents, supply limitations, and immature technologies. In terms of phosphor deposition structure, however, silicone phosphor cavity encapsulation has become the widely accepted technology. In this process, silicone phosphor is dispensed into a cavity with LED chips placed in the cavity bottom. The cavities are arranged in arrays in a lead frame structure.

Because the deposition of the silicone phosphor has to be extremely precise, many companies currently rely on frequent CIE inspection and adjustments to the equipment during the manufacturing process to meet CIE specifications. Feedback frequency is sometimes measured every 10 lead frames, each of which has hundreds of cavities. A typical inspection method measures CIE soon after silicone phosphor dispensing. That data is then used to adjust the fluid pressure on the dispensers. For example, if CIE data shifts to the yellow side, less fluid pressure would deposit less silicone phosphor in the cavities, resulting in the targeted CIE. However, by focusing mainly on the dispensing feedback, attention is taken from many of the other variables and reliance placed on inspection of tight CIE LEDs, which is an expensive and time consuming

What's CIE?

The International Commission on Illumination (usually abbreviated CIE for its French name, Commission internationale de l'éclairage) is the international authority on light, illumination, color, and color spaces and its CIE 1931 XYZ color space was one of the first mathematically defined color spaces. Bin coding is a method of describing the specifications of an LED in a short and simple way. The code consists of 4 parts: the flux rating, tint, Vf (forward voltage), and color. The goal in LED manufacturing is to achieve a targeted white color LED. Depositing the exact amount of silicone phosphor needed in the cavity that holds the LED helps to tightly control the CIE, or color balance, of the LED.

Figure 1: *Needle dispensing.*

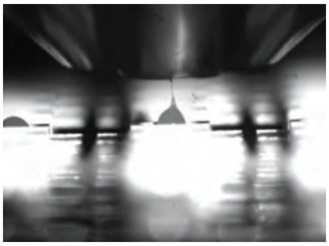

Figure 2: *Jet dispensing with active nozzle technology.*

procedure. In light of this, fluid dispensers are the most important piece of process equipment in determining CIE.

Obviously, LED companies have to decrease LED costs while producing tight CIE LEDs. Applying tightly controlled materials and equipment to the production is a much better way to reduce costs than frequent inspections. If the system used to dispense the phosphor provides a high level of fluid weight accuracy and consistency, LEDs have a better chance of maintaining tighter CIE and inspection frequency can be decreased.

Advantages of jet dispensing

Silicone is a tough fluid to dispense because it is very sticky. With needle dispensers, long retraction movement is required to cut off the silicone tail (see **figure 1**). This is time consuming. Nordson ASYMTEK experienced the same issue when it first developed its jet technology. As a solution, they developed "active nozzle technology" for silicone clear-cut-off dispensing without long retraction. The active nozzle technology helps jet dispensing with by adding additional energies to the breakpoint. .

Active nozzle technology uses a jet instead of a needle, offering many benefits (see **figure 2**). Multiple shots can be jetted into a cavity much quicker than with a needle and are better than a single large shot for achieving weight accuracy and consistency of the fluid in the cavities. Multiple shots converge with a smaller tolerance than the tolerance of a single larger shot, and tighter tolerance contributes to tighter CIE LEDs. Long silicone tails that result from needle dispensing often lay down or over sideways. Not only are they a mess, but they, too, contribute to an inaccurate measure of silicone in the cavities. Jetting systems can save time, labor, and expense with clear-cut silicone dispensing.

Faster shot rate increases production throughput with higher units per hour (UPH), lowering production costs. One LED manufacturer achieved greater than 20,000 UPH for 5630 cavity lead frames with one jet and dual lanes using Nordson ASYMTEK's automated jet dispensing system designed for LED manufacturing. Rates as high as 24,000 UPH have been demonstrated in labs.

Phosphor settling in silicone is another challenge for dispensing, a phenomenon that depends on the material combination. Smaller phosphor particles in a higher viscosity medium don't have this challenge, but larger particles in a lower viscosity medium settle easily. An agitation system on the dispenser can alleviate settling. Several types of agitation systems are available with more being developed for use with a variety of material sets.

Advanced calibrated process jetting

Silicone phosphor fluid changes its viscosity over time because of curing, room temperature changes, and/or other factory variables. These changes seriously affect the accuracy of the weight of the phosphor being dispensed and the consistency. Advanced calibrated process jetting (CPJ+) software and support tools, such as an integrated scale on a platform, have recently been developed for LED applications to automatically adjust dispensing conditions to meet a user's targeted weight tolerance.

Users can set up calibration ranges (maximum and minimum) for dispensing parameters such as on time and off time. Dispense weight and tolerance targets also are input into the system. The system then performs an automatic calibration using the sample being dispensed on the scale and determines the optimal dispensing conditions to meet the targets. When calibration is complete, the system starts LED dispensing production over the cavity lead frames. It periodically adjusts the dispensing parameters to make the shot weight meet the target. Tight tolerances are maintained throughout the dispense cycle and dynamic processes, such as fluid viscosity, and any changes to nozzle or dot size, are stabilized.

The basic algorithm of CPJ+ is to maintain dispensing weight accuracy over tens of thousands of LEDs. The software is so precise it can change the volume of dots. After initial set-up by the operators, the system performs a patented dispensing (jetting) operation autonomously until the fluid syringe is empty (see **figure 3**).

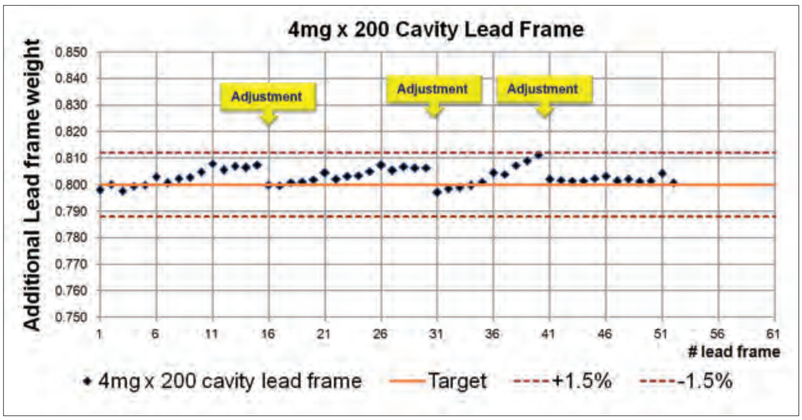

Figure 3: *Dispensing weight adjustment with CPJ+.*

Multiple heads vs single head

Another challenge of manual operations is the set up and adjustment of multiple heads on a dispensing machine. It is often thought that having a dispenser with multiple heads (whether using air-over or auger valves) will speed the dispensing process, especially for an application such as LEDs where volumes are extremely high and throughput is a critical factor. Some companies are using 8 needle heads with the goal of achieving a throughput of 10,000 UPH.

Although multiple heads might work in theory, benefits in speed are lost in set-up time and diminished product consistency, reliability, and quality. Imagine what it takes to set up and adjust the operation of 8 needle heads on a machine compared to just one head. Operators have to set up all the heads so they are in the same position and condition. They each need to dispense the same amount of fluid at the same viscosity and have to maintain the same speed and operate in unison. If one clogs or stops, the whole process has to shut down. For each feedback step, each needle has to be manually adjusted.

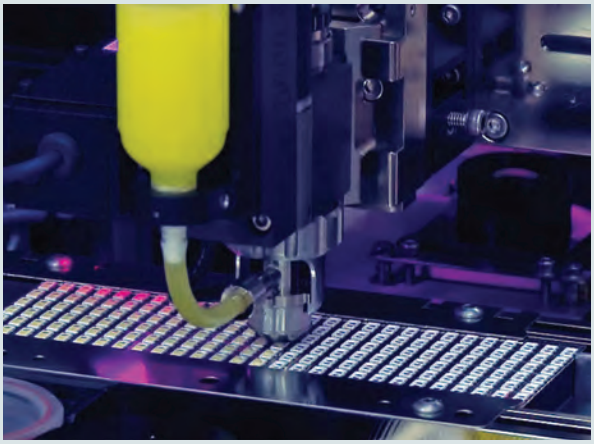

Figure 4: *Single jet operation.*

The combination of manual operation and multiple heads makes LED production extremely complex and results in longer down time and less accuracy. Using a single jet can achieve double the UPH of 8 needles, but with a much higher level of consistency of the dispensed silicone phosphor (see **figure 4**).

Without CPJ+, LED companies need to check CIE or dispensing weight frequently and adjust dispensing conditions manually. This manual operation interrupts the production process and is prone to human errors. Especially when compared to automatic system operation a nd closed-loop feedback, the manual feedback operation is much less accurate and consistent. Many backlight LED companies are presently building production capacities of hundreds of millions of LEDs per month. Human error, wasted time caused by frequent inspections and interruptions, and poor accuracy and consistency are huge quality and cost issues in these large scale productions.

Cost of ownership

Many LED companies compare dispensing machines by system price per UPH ($/UPH) for investment consideration. This is a simple and quick way for a brief comparison, but it doesn't give an accurate investment comparison because it doesn't include comparisons in yield, down-time, floor space, labor, consumables, equipment lifetime, and so on.

For an accurate comparison, a cost of ownership (CoO) model is a better guide because the model includes all the costs incurred (such as the ones just mentioned) to calculate lifetime costs per one LED (costs/piece). Using a cost calculator, it was found that systems that seemed more expensive at the time of purchase actually cost 30 percent less cost/piece than a dispenser with a lower purchase price and multiple heads. That is because yield is a major factor in the calculation. By increasing yield by even one percent, a tremendous savings can be realized.

Summary

LED companies are strongly seeking advanced technologies and equipment for tighter CIE LEDs and lower cost production. A silicone phosphor automated jet dispensing system with active nozzle technology, agitators, calibrated process jetting, and single valve jet dispensing is an easy-to-use, cost effective solution for dispensing phosphor for LED encapsulation. Such a system provides very tight fluid weight consistency for LED applications, resulting in tight CIE LED production without downtime or the need for expensive inspection and frequent feedback. It minimizes one of the most important variables in the LED manufacturing process, enabling focus on other variables necessary for process improvement. While dispensing results and throughput are improved, using a jet dispensing system also can lower cost of ownership. EM

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