“Flat Panel Assembly using Jet Dispensing for Gasketing Applications”

Thomas Ratledge
Flat Panel Business Director
Asymtek

Floriana Suriawidjaja
Senior Member of Technical Staff
Asymtek

Ken Fukunaga
Lead Applications Engineer
Asymtek

Abstract
The consumer demand for televisions, cell phones, and other portable electronics is expected to increase for the next few years. This is fueling projections of double digit growth for flat panel displays. As display manufacturers are required to increase annual output, each process on the production line will be examined. One of the processes employed in the manufacture of OLED (organic light emitting diode) and TFT (thin film transistor) displays is dispensing gaskets of sealant material on glass substrates. This paper examines the use of jet dispensing technology to apply these seals and increase production line output for this process.

One of the other trends in flat panel production is the continual increase of glass substrate sizes. As manufacturers focus on increasing production line output they will also be shifting to larger glass substrate sizes. Many manufacturers have production lines based on Generation 2 glass substrates (370 x 470 mm) and are planning for Generation 3.5 glass substrates (620 x 750 mm). Using larger glass sizes with conventional dispensing technology will significantly increase the takt time for the sealing process.

Figure 1 shows a Generation 2 glass substrate with an array of 25 x 17 mm gaskets spaced by 6 mm in both x and y. Figure 2 shows the same array of gasket patterns on a Generation 3.5 glass substrate. The number of gaskets increases from 225 to 624 with the larger glass size; that is an increase of 270%.

One of the obvious methods to increase production output of the gasketing process, is to increase the dispense speed of the machine. The current industry standard for dispensing gasket material (UV Sealant) is needle dispensing using an auger pump. The maximum dispense speed in this type of system is limited by the rate of adherence of the fluid to the glass substrate. If the material is not allowed to wet, odd dispense patterns, skipping and poor corners can occur. In addition, needle dispensing requires a small dispense gap (typically 125 µm). Dynamically maintaining this gap across a large glass substrate is challenging for machine manufacturers as well as machine operators.

The goal of this paper is threefold. First, it will review the throughput differences between jet and needle dispensing UV Sealant material. Second, it will examine the wider process window that jetting enables. Finally, it will illustrate the process of forming lines from individual dots.

Conventional Dispensing Technology
Needle dispensing with an auger pump has been a staple of electronic assembly for many years. The auger allows a controlled flow of fluid to be developed that is precisely dispensed through a small needle. This device is very flexible as
changing the needle and the auger screw enables a very wide performance range.

**Figure 3- Typical Auger Pump with Needle**

For fine line dispensing applications, the auger pump requires an accurately controlled dispense gap. If the dispense gap is too large, the fluid bead will not properly wet to the substrate. This causes issues with gasket placement especially around start points, corners and end points. On the other hand if the dispense gap is too small, the flow of fluid will be impeded resulting in too little fluid being dispensed.

Further, the maximum needle dispense speed is constrained by the rate of material wetting to the substrate. If the material has not wetted sufficiently, it will stay attached to the needle rather than the substrate and ruin the dispense pattern. Wetting is a property of the fluid, the needle and the substrate. Plasma cleaners are often utilized to improve substrate surface wetting.

**DispenseJet Theory of Operation**

The DispenseJet ejects individual dots of fluid out of an orifice. While the end result is very similar to that of a commercial ink jet printer, this jet uses a different mechanism to produce dots. This mechanism was required as the materials in the electronics industry have much higher viscosities than printing inks.

The DispenseJet operates by using an electronic pulse to signal the request of dot. This signal turns on a pneumatic valve that allows pressurized air to lift a piston. Fluid fills in the cavity vacated by the piston. Then at a precise time interval, the electronics signals the pneumatic valve to release the air holding the piston. A spring returns the piston to its original position. This action displaces fluid and causes a dot of fluid to eject out of a nozzle.

There are many factors that influence the size of the ejected dot. These include the nozzle diameter, the shape of the internal cavity, stroke length, temperature and others. In order to make continuous lines or larger dots, the jet is often fired in rapid succession (>150 Hz) while moving or remaining at rest.
One of the interesting characteristics of the DispenseJet is its nondependence on substrate surface wetting forces. Droplets of fluid separate from the jet nozzle as the result of a tensile break from the momentum of the ejected droplet. The substrate surface wetness does not affect the dispensing process and hence, does not influence the maximum dispensing velocity. The only limitation on the maximum dispensing velocity is the desired density of dots and the maximum firing rate of the jet.

Figure 6- Momentum Separates Droplets

Gasket Dispensing Throughput
Two sample substrates were created in order to compare throughput between different dispensing technologies. These were based on Generation 2 and Generation 3.5 glass substrate sizes and utilize the same gasket pattern. Five different machine architectures were compared using both auger and jetting applicators.

Figure 7- Test Gasket Pattern

Each machine architecture was tested by creating a simulator with an Excel® spreadsheet to model machine throughput. The simulators were verified by programming both a needle and jetting pattern for Generation 2 glass on a single headed machine and measuring the actual throughput. In all cases the simulator matched the actual measurements within 3%.

The machine architectures compared include:
- Single auger dispensing at 25 mm/sec
- Dual augers dispensing at 25 mm/sec
- Quad augers dispensing at 25 mm/sec
- Single jet dispensing at 75 mm/sec
- Dual jets dispensing seals at 75 mm/sec

All tests were burdened with appropriate overhead for vision, height sensing and non-dispense moves. The test machine was assumed to have a maximum XY acceleration of 1g and a maximum Z acceleration of 2 g’s. The throughput numbers do not include load or unload time.

The test results for Generation 2 glass substrates showed the jet enabled much faster panel processing. A single jet exceeded the speed of a dual auger machine. A dual jet exceeded the throughput of a quad auger machine. Although the jet was able to dispense with a single height sense as compared to the normal sixteen height senses, the dispensing speed (75 mm/sec) enabled most of the throughput gain.

Figure 8- Throughput Comparison, Generation 2 Glass
The test results for Generation 4 glass substrates matched the results from the Generation 2 tests. Again, a single jet exceeded the speed of a dual auger machine and a dual jet exceeded the throughput of a quad auger machine. What was more interesting on this test was the takt time changes. A single jet machine was able to complete in 18 minutes what a single auger machine was able to complete in 46 minutes. This is a net time reduction of nearly 30 minutes.

Jetting Process Window

The jet enables a wider process window for both glass substrate cleaning as well as the dispense gap.

As mentioned earlier, the speed of the jetting process is not affected by the rate of fluid wetting to the substrate. While this is an advantage in speed, it is also an advantage in process control. Uniformly plasma cleaning glass to the same surface activation is difficult. It becomes more difficult as the substrate sizes increases. Non-uniform plasma cleaning has no affect on the ability of the jet to deliver fluid to the surface; see figure 6.

One of the tedious items to control when auger dispensing is the dispense gap. Dynamically maintaining a 125 µm dispense gap over 750 mm of machine travel is difficult. Maintaining this gap for two or more heads on the same machine increases the difficulty of machine setup and maintenance.

To determine how height affects the DispenseJet a test was run dispense dots at various heights. The dots were then examined for diameter and profile. Although typical jet usage utilizes dispense gaps of less than 1 mm, the test was run through 1.78 mm (70 mils).

It should be noted that 75 mm/sec is a conservative dispense speed for the jet. Many patterns have been dispensed at 100 mm/sec. The more conservative value represents good practice for production.
As can be seen in Figure 11, there is very little variation in dispense quality as the dispense gap varies. As the dispense gap exceeded 1 mm, some variation can be noted in the dot shapes. At a typical dispense height of 760 µm, variations of ±250 µm have no visible effect on the process. This simplifies machine setup and reduces process variation due to normal substrate variations.

![Figure 12 - Picture of the dot profile from the dispense height test (0.45 mm diameter).](image)

**Forming Lines from Dots**

The DispenseJet can dispense continuous lines of sealant material by adjusting the pitch of dots so they overlap or touch. In this case, the dots flow together forming a continuous line as shown in Figure 13. This sample also shows an interesting effect of leaving a small space at a corner to tighten the inner radius of the gasket.

![Figure 13 - Overlapping Dots Form Continuous Lines](image)

An alternate method of dispensing lines is to adjust the inter-dot pitch so the dots flow together during the lamination process. While this may seem unusual at first, as long as the pitch is close enough, the technique is successful. If the pitch is too large, the dots will never form a continuous line.

It is fairly easy to determine the minimum inter-dot spacing that will result in a continuous line. The dots spread as circles during the lamination process. So if the mass of the dot is known, its volume can be calculated. The volume is then used to calculate dot diameter at the lamination thickness.

A test was designed to visual study the dot flow patterns for a variety of inter-dot spacing. In this test several lines of dots were dispensed on a glass slide. Another glass slide was carefully placed on top of the dispensed dots. The weight of the slide was the only force compressing the dots. The inter-dot spacing was gradually reduced until a line of acceptable quality was formed. It should be noted that during the lamination process the final sealant thickness is likely much smaller than in these tests. The results of the tests are shown in Figures 14 through 17.

![Figure 14 - The inter-dot spacing is so large the dots do not flow together under the weight of a glass slide.](image)

![Figure 15 - The inter-dot spacing is just large enough to allow the dots to flow together under the weight of a glass slide. Note how the pitch of the dots matches the pitch of the line scallops.](image)
0.5 mm dia dots on 0.76 mm centers

Figure 16- the inter-dot spacing is close enough to form a reasonable line under the weight of a glass slide. There is some hint of the pitch of the dots in the scallops forming the line.

0.5 mm dia dots on 0.64 mm centers

Figure 17- The inter-dot spacing is close enough to form a very nice looking line under the weight of a glass slide. There is no reflection of the dot pitch in the shape of the line.

It was expected that all lines formed by dots would include a scallop pattern that matched the pitch of the dispensed dots. This can be seen in Figures 13 through 16. The result shown in Figure 17 was not expected. In this picture, it is not possible to detect the pitch of the dots in the compressed pattern. This suggests that there is a critical dot spacing that results in very high quality laminated line shapes.

Another test was done to study the effect of dot placement on the formation of corners. Needle dispensing often has issues forming tight internal radius on corners of gasket patterns. This is due to extra fluid being dispensed as the velocity changes (slows down) in the corner. The ability of the DispenseJet to dispense individual dots allows the amount of fluid and its placement to be varied in the corners.

The following figures, as well as Figure 13, illustrate the effect of different corner treatments on the final laminated line profile. These treatments show the effects of a dot at the corner, no dot in the corner, and a dot missing from a line leading to the corner. In all cases, dotted corners were able to avoid the excess fluid characteristic of needle dispensing.

Figure 18- Dot placed at the corner

Figure 19- No dot placed at the corner.

Figure 20- Skip a dot on one line leading to a corner.
Summary
This paper has defined the areas where jetting technology provides distinct advantages over conventional technology for dispensing gasket patterns for flat panel display manufacturing.

The throughput tests demonstrated the significant speed benefit of the DispenseJet. In all simulations, the output of a single jet dispenser significantly exceeded the output of two needle dispensers. As glass substrates increase in size, the jet affords significant benefits in raw takt time.

Additional tests also identified areas where the DispenseJet has a process window much wider than needle dispensing. There was no noticeable difference in jetted dispense quality as the dispense gap ranged in values unheard of for needle dispensing. Also, the requirement for uniform surface preparation of the glass substrate was shown to be unnecessary for jetting gaskets.

Finally, the process of forming lines from individual dots showed that dots do form lines. With optimized inter-dot spacing, the lines formed from dots are indistinguishable from needle dispensing. In fact, corner treatments appear to be another area where jetting is superior to needle dispensing.