Advances in jet dispensing for flat panel applications

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Abstract

As OLED manufacturing matures, it requires larger substrate processing. The larger substrates require higher dispensing throughput for UV sealants. Jetting the gaskets of seal materials has provided an increase in performance and dispensing capability. This paper describes the jetting process and deposition capability for applying the UV sealants.

1. Introduction

The strong consumer demand for televisions, cell phones, and other portable electronics continues to support projections for double digit flat panel display growth. As display manufactures are required to increase production numbers and yield, 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.

As manufacturers focus on increasing production line output for small format displays they have increased glass substrate sizes from Generation 2 to Generation 4. Figure 1 shows a generation 4 glass size with 899 typical sized gaskets. Using larger glass sizes with conventional dispensing technology will significantly increase the takt time for the seal dispensing process. This takt time increase will be especially acute when the manufacturing process employs ODF (one drop fill).

One of the obvious methods to increase production output for 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.

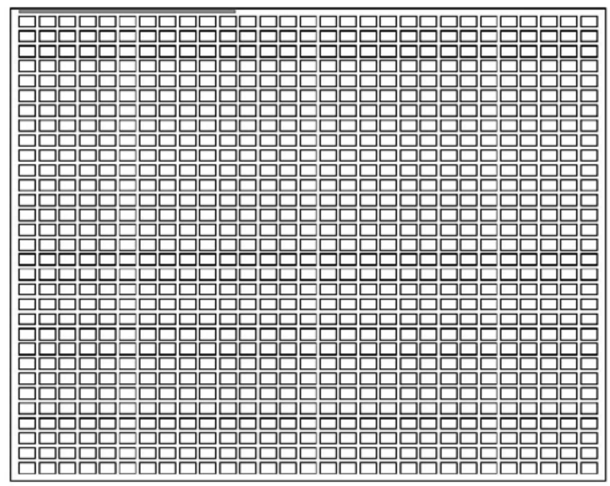


Figure 1- Gen 4 glass, 899 displays

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.

2. Jetting Benefits

The use of jetting fluid dispensing technology is gaining popularity in the manufacture of Flat Panel Displays (FPD). Jetting has demonstrated increased throughput, improved yields, and simpler setup for this industry.

Figure 2- Examples of a Jet Applicator (left) and an Auger Applicator (right)

Most of the throughput gains are realized from faster dispensing line speeds. The maximum velocity the jet can move while dispensing dots is not limited by the wetting of the fluid to the glass substrate as it is with needle dispensing. This is due to the different mechanism for separating fluid from the applicator. The jet uses droplet momentum and the needle uses the wetting adhesion. This also means that jetted lines can not exhibit the "roping" or "corner drag" failures associated with needle dispensing.

In addition to throughput improvements, jetting is a very robust process. If plasma cleaning of the glass substrate isn't consistent, needle dispensing will have yield excursions. The symptom can be observed as acceptable dispense quality in one region of a glass substrate but not in another. Since jetting is not affected by the glass to fluid adherence, jetting is immune to this failure.

Further, jetting is a digital instead of an analog process. This means the dots are dispensed in the correct position regardless of the speed or acceleration of the dispensing XYZ positioner. The issue of "pooling" fluid in the corner of a rectangular dispense pattern (as the machine decelerates, changes direction and accelerates) does not occur with jetting.

Finally, machine setup is simplified since the quality of the jetted dot is not affected by a wide variation in dispense gaps (1 mm). Local glass surface flatness, tooling planarity and height sense accuracy have no measurable affect on jet dispense quality. This removes a significant setup burden from machine operators especially when working through glove boxes.

3. Throughput Improvement

To measure the throughput improvement, five machine configurations were compared. This comparison was performed for a Generation 4 glass substrate with 899 UV seals as shown in Figure 1.

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:

— Dual Augers dispensing at 40 mm/sec
— Quad Augers dispensing at 40 mm/sec
— Single Jet dispensing at 100 mm/sec
— Dual Jets dispensing at 100 mm/sec
— Single Jet+ dispensing at 200 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.

One machine architecture (Jet+) was tested using "Strafing" a new dispense method to enhance throughput. The method dispenses all of the horizontal lines followed by the vertical lines. This eliminates a significant portion of time used to accelerate and decelerate that occurs when dispensing one seal at a time.

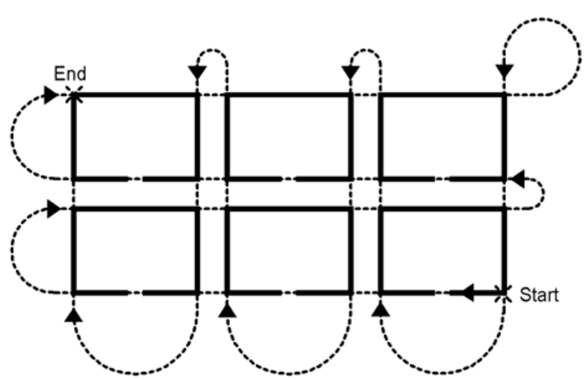


Figure 3- Strafing Pattern. Dotted lines indicate non-dispensing motion. The motion on straight lines is continuous between dispense and non-dispense segments.

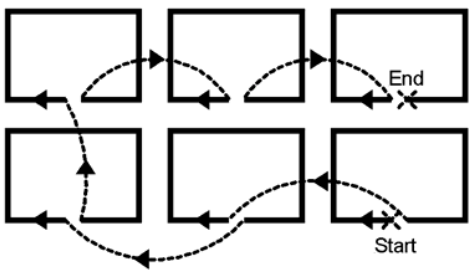


Figure 4- Traditional Dispensing Pattern. The machine accelerates and decelerates 4 times for each seal. Dotted lines indicate non-dispensing motion.

The result of the simulations is shown in Figure 5. That chart shows that a twin jet configuration is 30% faster than a quad needle configuration. In addition, a new jetting technology (referred to as Jet+) used with a strafing pattern yielded the fastest throughput in the comparison. This is significant since the setup, maintenance and complexity is much simpler for a single headed machine. Jetting is clearly an enabling technology for enhancing UV seal production rates.

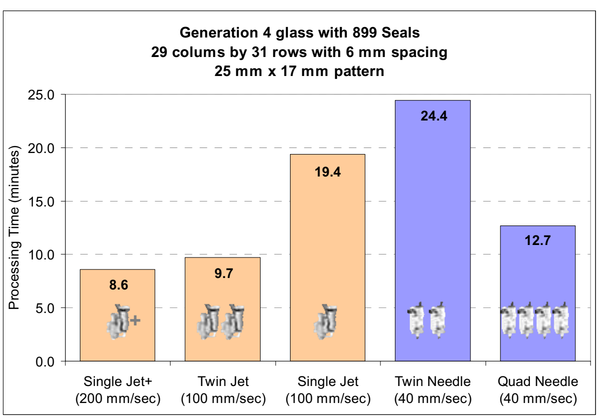


Figure 5- Processing Time (minutes)

4. Jetting Process Window

The jet enables a wider process window for 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 increase. Non-uniform plasma cleaning has no affect on the ability of the jet to deliver fluid to the surface.

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 the dispense height affects the quality of dispensed dots, a test was run dispensing 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).

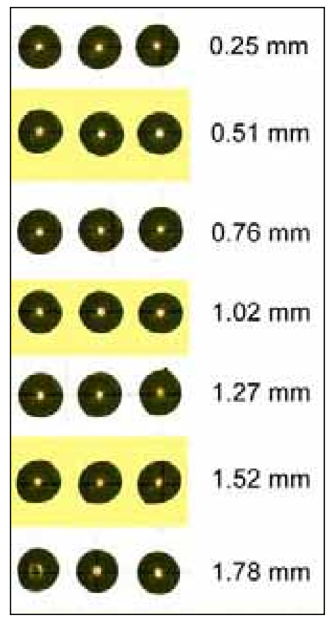


Figure 6- The column of numbers on the right indicate the dispense gap for each row of dots. The dot diameter is 0.45 mm.

As can be seen in Figure 6, 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 7- Picture of the dot profile from the dispense height test (0.45 mm diameter).

5. Process Control

Two methods have been introduced to improve quality control for jet dispensing. The first involves the usage of advanced materials to stabilize changes associated with part wear and the second involves automatic software control for dot weight.

Figure 8 shows changes in mass flow for traditional and improved jetting hardware as the jet is cycled with Nagase XNR 5570 over time. The graph of the traditional hardware suggests scheduling maintenance every three million cycles of usage. The graph for the new hardware suggests the maintenance interval can be extended more than three times that of the traditional. This magnitude of improvement and greater has been validated at several production sites in Asia, Europe and North America.

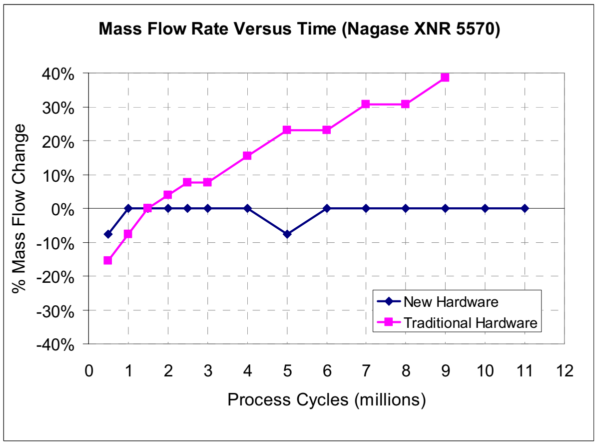


Figure 8- Changes in mass flow over time.

The second method, known as Calibrated Process Jetting (CPJ), enables the machine to automatically monitor the jet's mass flow rate and self adjust to compensate for a multitude of variations (viscosity, temperature, wear, pressure). The result of this technique is much higher precision for the total mass (volume) of fluid being dispensed. Volume accuracies better than 5% have been achieved.

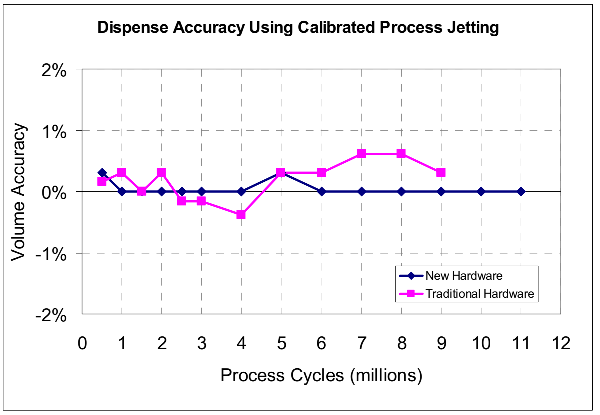


Figure 9- Results of mass flow process control.

Figure 9 shows the results when process control corrects for the mass flow variations seen in Figure 8. This allows a much longer interval between maintenance and a higher dispense accuracy.

There are alternate technologies to Calibrated Process Jetting that involve scanning the line as dispensed from an auger to control line height and width. These techniques rely on periodic scans of the line beads profile and some control line width by varying the speed of the auger. The amount of the line scanned, the bead's width tolerance, the bead's height tolerance and the control lag between the auger speed and bead width make this a much more complex and sensitive control process than CPJ.

6. 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 10. This sample also shows an interesting effect of leaving a small space at a corner to tighten the inner radius of the gasket.

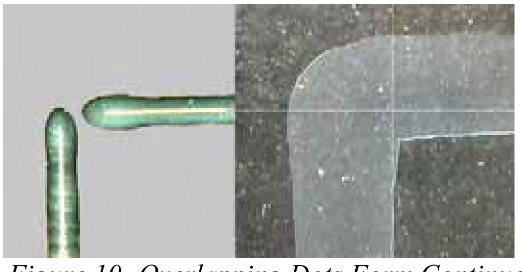
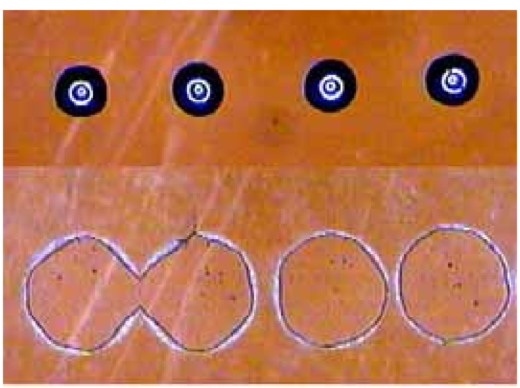


Figure 10- Overlapping Dots Form Continuous Lines

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.

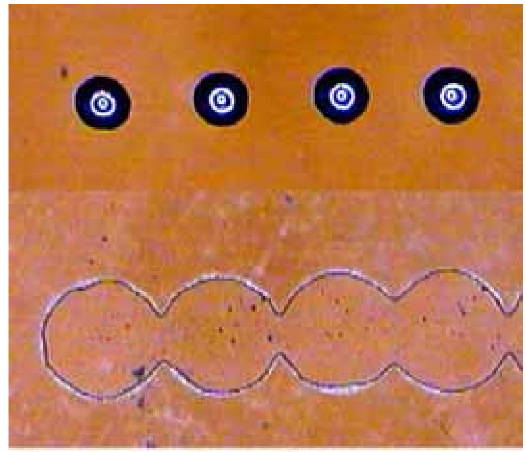
It is fairly easy to determine the minimum inter-dot spacing that will result in a continuous line. The dots spread as circles during the lamination process. So if the mass of the dot is known, its volume can be calculated. The volume is then used to calculate dot diameter at the lamination thickness.

A test was designed to visually study the dot flow patterns for a variety of inter-dot spacings. 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 11 through 14.



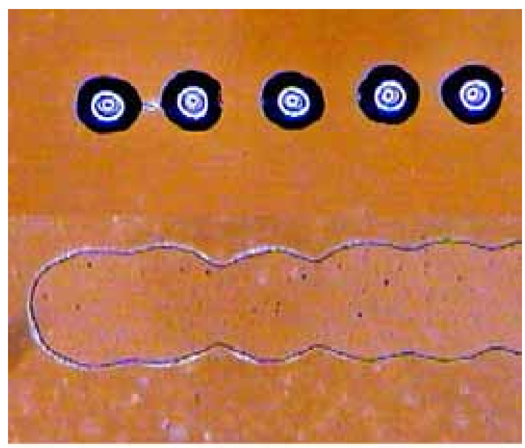
0.5 mm dia dots on 1.02 mm centers

Figure 11- The inter-dot spacing is so large the dots do not flow together under the weight of a glass slide.



0.5 mm dia dots on 0.89 mm centers

Figure 12- 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.



0.5 mm dia dots on 0.76 mm centers

Figure 13- the inter-dot spacing is close enough to form a basic line under the weight of a glass slide. There is some hint of the pitch of the dots in the scallops forming the line.

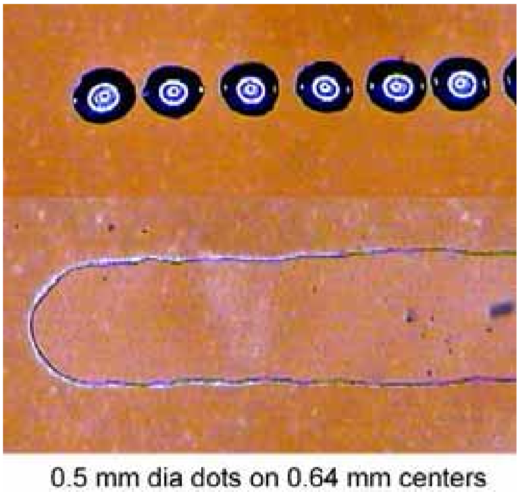


Figure 14- The inter-dot spacing is close enough to form a very nice looking line under the weight of a glass slide. There is no reflection of the dot pitch in the shape of the line.

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 11 through 13. The result shown in Figure 14 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 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.

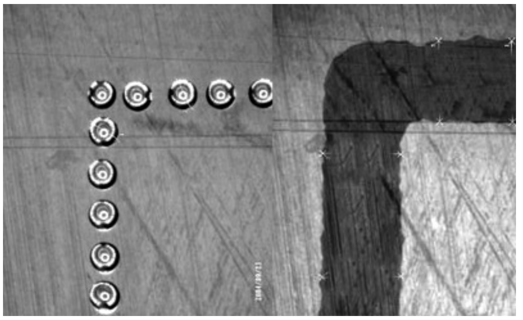


Figure 15- Dot placed at the corner

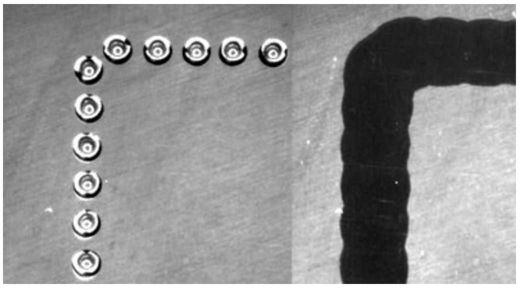


Figure 16- No dot placed at the corner.

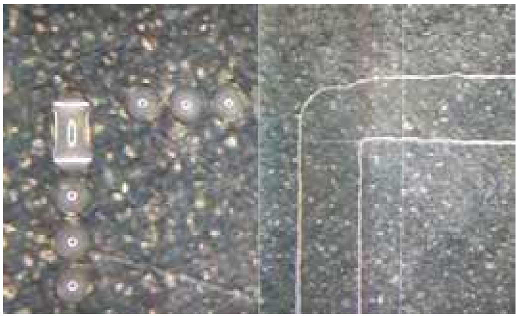


Figure 17- Skip a dot on one line leading to a corner.

8. 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 intolerable for needle dispensing. Also, the requirement for exacting 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.

9. References

[1] This paper is based on continuing research being preformed at Asymtek's facility.