Enabling Advanced Assembly and Packaging with Automated Dispensing

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Abstract
Today's automated dispensing for electronics manufacturing is a complex and precise process in order to meet the challenges posed by ever more demanding assembly and component technology requirements. Dedicated dispenser technology is key to success in meeting challenging applications in a production environment with precision and repeatability. The major components that comprise a dispenser will be described, with a view toward understanding the importance of each; the result will illustrate how these sub-systems combine to create high-volume dispensing platforms. Real world examples with data substantiating the speed and accuracy obtained for some of the most common advanced dispensing applications in the market will be demonstrated such as high speed surface mount adhesive, wafer level Underfill and shield edge interconnects.

Introduction

A dispense application is most simply defined as placing a controlled amount of material in a desired location. In reality, however, automated dispensing of electronic materials in a production environment is a complex and highly-controlled, repeatable process. Automated dispensers are tasked with accurately and consistently depositing a wide range of materials in a host of demanding applications ranging from SMT assembly to advanced component packaging and semiconductor manufacturing, and certainly in many industrial applications well outside of the electronics industry.

Examples of challenging applications include dispensing sub-250μm solder paste dots, 0402 SMA dots at >45000DPH, or precise flux control for optical applications. Automated dispensers are required to be flexible enough to accommodate different process requirements with ever-narrowing process windows and increasing throughput requirements. In order to achieve accurate, high speed dispensing, a dispenser must be constructed from first principles with dispensing in mind; i.e., adding a pump to a gantry system with a trigger signal is no longer a viable solution, especially for today's challenging applications.

Global consumer electronics sales have more than doubled in less than eight years in large part due to the growth of smartphones, tablets and ultrabooks. All of these products have in common a reduced form factor and weight to enable portability. To achieve this size and weight minimization, the electronics industry relies on "wet" processes that reduce weight, add robustness, and enhance reliability of the products. Due to the continuous reduction in form factor and the higher quantities of products that need to be made, a 'ground-up' approach must be taken when designing and engineering a dispenser capable of maintaining the high degree of wet dispense accuracy required for these processes.

Importance of a Stable Gantry System

A robust gantry system is key to achieving speed and accuracy for the dispenser's moving elements. The gantry must be able to carry all the required equipment: camera, lighting, pumps, sensors, Z-axis stage and potentially other components while moving at a high speed, and it must be able to stop very quickly without vibrating. Vibration adversely affects accuracy regardless of speed. Eliminating vibration from the system (damping) quickly is the key to enabling maximum accuracy at high speeds with minimal settling times **(Figure 1).**

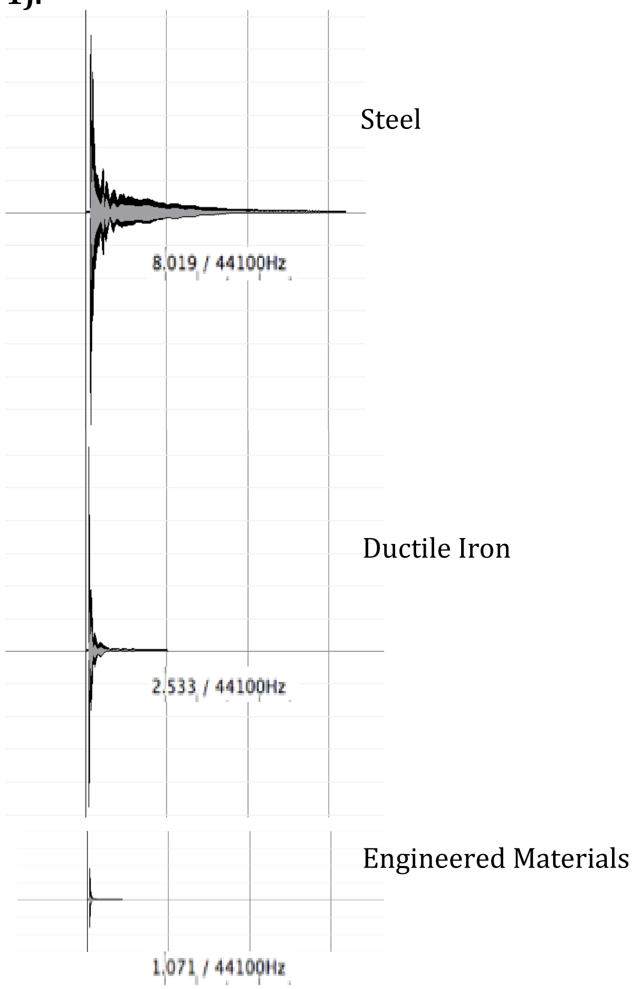


Figure 1: Damping Effect of Various Gantry Composition Materials

The motion control hardware that is chosen for installation on the frame, in addition to the gantry frame materials (as seen in **Figure 1**) is critical to providing accuracy at high speeds; and precision sub-micron encoders are required to obtain accurate positional feedback throughout the length of travel. Point-to-point positional accuracy is extremely important for dispensing discrete dots, for example, and also, dynamic in-motion accuracy is crucial for accurate line dispensing. This is the primary difference between a system with an integrated pump or valve, and a system designed specifically to be a dispenser. The dedicated dispenser system will be designed specifically and only for high accuracy, high speed production dispensing. It is focused on dispensing and no other functionality.

Role of the Vision System

The dispenser's vision system must be able to capture, process and feed back visual data at a high rate. This will minimize dead time and allow the gantry to be in constant motion, directly impacting and maximizing the dispenser's overall throughput.

The lenses used to magnify the camera images will determine the overall field of view and basic resolution of the vision system. Calibration routines calculate a pixel-to-micron ratio that is used by the gantry system to accurately place the camera and the dispense head. The more repeatable the calibration result, the more repeatable the dispense process will be **(Figure 2).**

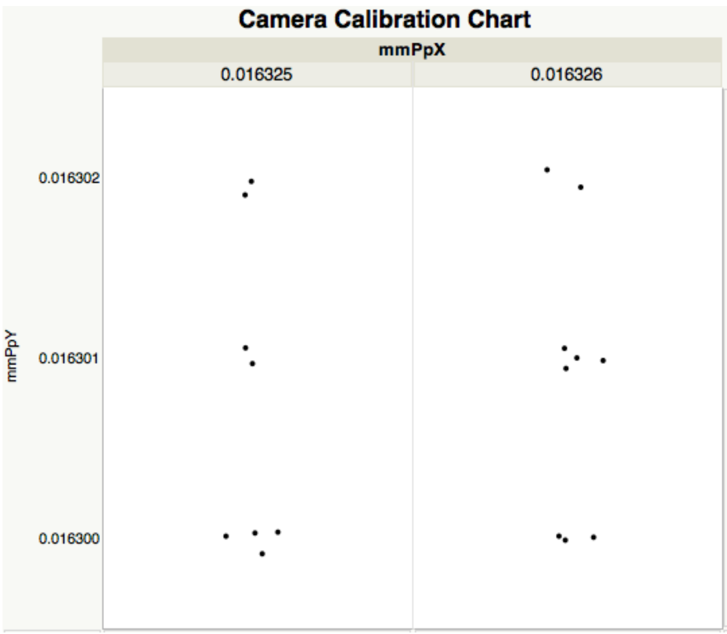


Figure 2: Camera calibration results (sub-micron accuracy)

Dispense Tools
There are many different mechanisms that the dispensing machine may use to deposit fluids, and although they are commonly referred to as 'pumps', that term is of course an over-simplification. There are several basic types of dispense tools, and each configuration or design has its own unique array of benefits for certain types of materials, even though many different material deposition tools can dispense the same materials.

Time/Pressure: A syringe containing the material to be dispensed is directly fitted with a needle. Air pressure is toggled on to promote the flow of material out of the needle and toggled off to stop the flow of material. This method can be used with almost all materials. The drawback is the low throughput for processes that require many on/off sequences, which makes this a good tool for R&D but rarely used in volume production.

Auger Valve/Pump: A syringe containing material is fitted to a chamber, usually through a disposable tube. There is a screw or auger inside the chamber that rotates to dose the material in a controlled manner. Compared to time/pressure systems, this pump enables higher throughput with better material control, and in similar fashion to time/pressure, can be used with almost all materials.

Positive Displacement Pump: This pump is also known as a volumetric or piston pump. There is usually a single port or dual port chamber into which the material is fed from a syringe. Once the chamber is filled with the dispense material, a piston pushes or compresses that material at a controlled rate to dispense. Since the piston and chamber are tightly coupled, the volume displaced is consistent regardless of viscosity. There are two noticeable drawbacks to positive displacement pumps; first, they are ideal for Newtonian fluids, but have difficulty controlling non-Newtonian fluids; and secondly, since a chamber needs to be filled before dispensing, it cannot run continuous dispense applications that require large volumes.

Spray Valve: For applications that require selective area coatings of certain low viscosity materials such as flux and coatings, spray valves are used. The materials are atomized using an air stream at the exit of a pressurized fluid path that converge at the nozzle forming a fine spray, another method is by the activation of ultrasonic transducers close to the nozzle tip to disperse the stream of material resulting in fine spray. The spray pattern can further be controlled through variation of the atomization source, fluid pressure or the addition of an external air sheath to focus the atomized material. Spray valves enable wider area coverage than nozzle dispense and offer good material deposition uniformity; a common effect is rough line edge definition that is a result of the random nature of atomized particles.

Jet Valve: Jet valves are mainly used for applications requiring small and precise quantities of material deposited within a target area. Material is ejected from a nozzle by the impact force exerted by a piston contacting a seat, a piezoelectric exciting a diaphragm or any similar method that creates a single drop of material on demand. Many materials can be jetted with very high repeatability; material rheology is key to determine the capability of the jet to perform more so than material viscosity alone. Pneumatic jets tend to operate in the range of 200-300Hz with new piezoelectric jets capable of operating at 600Hz. Jets have widely become the material deposition method of choice for microelectronics packaging and assembly.

Stream Pump: These pumps are a hybrid, a combination of a positive displacement pump and a jet valve. They possess very similar small shot characteristics and fast cycle rates as jet valves, but do not require contacting a seat to eject the material, and operate on the positive displacement principle of filling a chamber with material and ejecting it by means of piston displacement. Due to this fact that contacting a seat is not required to dispense, these pumps work well with materials that tend to coin within jets such as solder paste. Besides not contacting a seat the other major differentiator between a Stream pump and a Jet valve is that volumetric displacement enables a larger amount of material to be deposited per single cycle allowing this technology to dispense in a single cycle what a jet valve would require several cycles to achieve at a given location.

Given the differences between dispense tool capability and method of operation, the common factors taken into consideration for valve/pump/jet selection are as follows: material rheology, throughput requirement, target dispense weight, and process window (**Table 1**).

	Time/ Pressure	Auger	Positive Displacement	Spray	JET	Stream
Underfill	X	X	X		X	X
Sealant	X	X	X			
Dam+Fill	X	X	X			
Surface Mount Adhesive	X	X	X		X	X
Solder Paste	X	X	X			X
Thermal Interface Material	X	X	X			
Conformal Coatings				X		
Silver Epoxy	X	X	X		X	X
Flux	X			X	X	X
LED (phosphor)	X		X		X	

Table 1: Common dispense tools for some materials

What separates a Dispenser from an automated Cartesian System with an on/off signal is the way it is capable of controlling different pumps, jets and valves. The key to precise controls is not only via dedicated hardware channels, the software is the key components that enable the different dispensing mechanisms to perform to peak capabilities in conjunction with the gantry system and vision. This is especially noticeable when dynamic dispensing control during high-speed gantry motion is required to enable high throughput in advanced packaging and assembly applications.

System Calibration

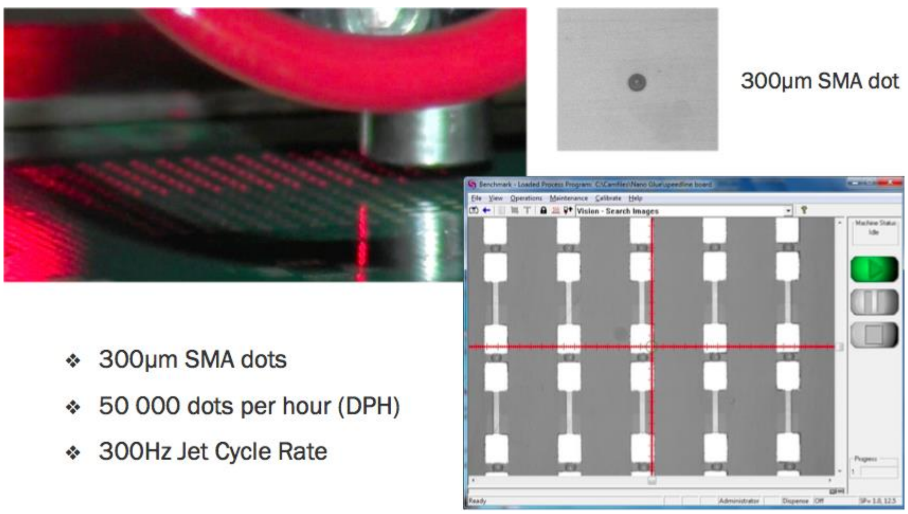
To minimize the tolerance stack-up of the major sub-assemblies within a dispenser a well designed "calibration station" is required. This sub-assembly ties all major components of a dispenser together and enables the coordinated function between different dispense tool setups. Automated system calibration routines eliminate human interaction and therefore eliminate a process variable that can introduce errors into the equipment accuracy.

Integrated System (Dispense Applications)

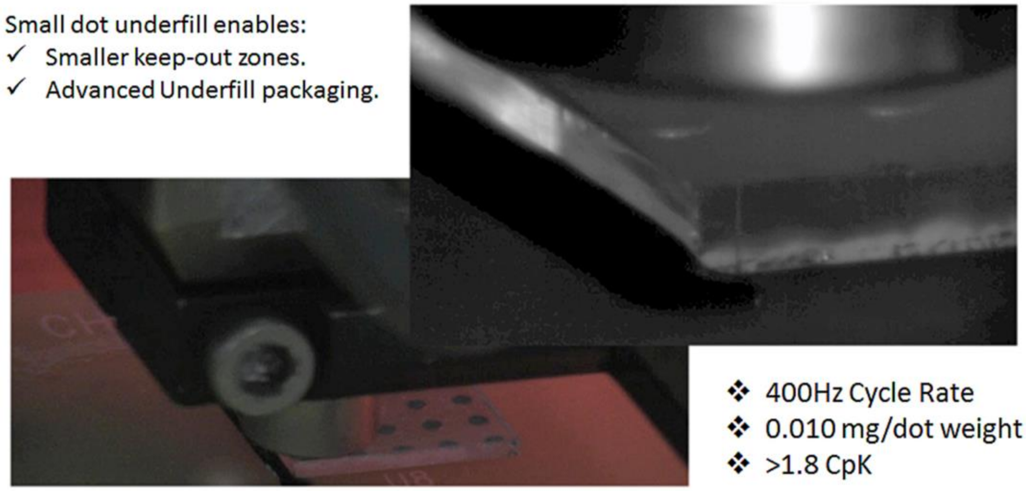
Once the gantry system, vision system and valve/pump/jet have been set up through a calibration routine, the final step is to prove the capability of performing complex dispensing applications and determine the maximum speed at which the process can be executed within given accuracy specifications.

Three common dispensing applications that present challenges when running at high throughputs are outlined below, with the resulting solution and enabling factor(s) for reference:

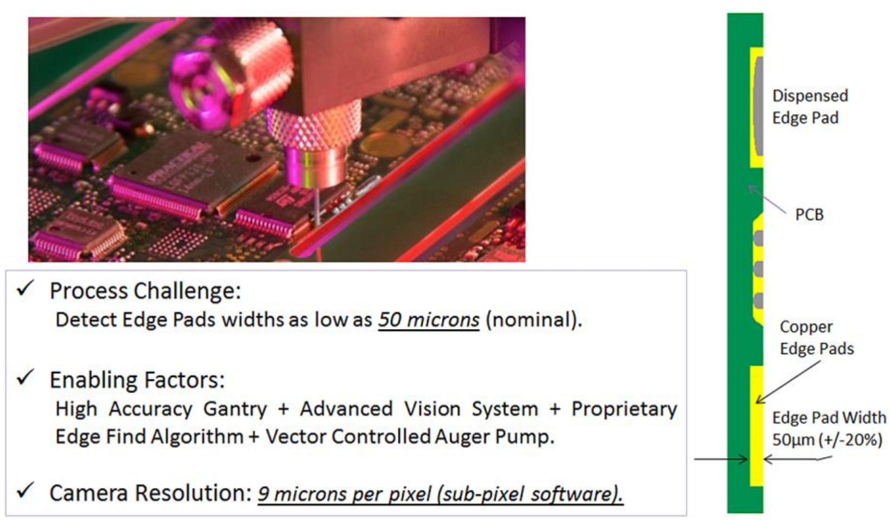
High Speed Surface Mount Adhesive (SMA):
A JET type pump is the preferred tool for dispensing SMA for 0402 type components and larger. This is because the high cycle rate and small dot capability of a JET enables many discrete SMA dots to be placed rapidly. By coupling a piezo controlled JET with a high-speed gantry, a dispenser can accurately place 50 000 dots per hour of SMA. These enables higher production throughputs due to faster overall dispense rates.



Wafer Level Underfill (Advanced Underfill):
Wafer level Underfill applications require precise dot placement so as to not have the underfill flow to undesired locations. The gantry system is key in keeping a tight positional accuracy, typically <50um in these applications. By leveraging the rapid cycle rate (400Hz) of a piezo type JET pump you can dispense small dots at a 10ug/dot weight enabling a high resolution dispense process that does not create overflow of the underfill above the die or to adjacent components.



Shield Edge Interconnect (SEI):
Novel applications such as SEI require that the vision system function with precise algorithms that can find very small pads typically 50um at the edge of substrates at uneven contrast ratios. By coupling an accurate gantry, the vision system and a closed loop controlled Auger Pump a precise bead of conductive material can be dispensed on the small target pads enabling a physical electromagnetic interference (EMI) shield connection at the edge of the board eliminating the need to grounding planes within board. The result is more real estate for functional components within the board and robust EMI performance.



Conclusion
In order to enable advanced assembly and packaging processes, the dispense system used must be designed 'from the ground up'. Each sub-assembly has a specific function that contributes to the overall speed and accuracy of a system for performing a given application. In particular, the valve of pump technology employed coupled within a closed loop system thanks to a calibration routine achieves all the desired targets of wet dispense accuracy, throughput, and process window at optimum rates.

References

David Watkins, "Connected CE Devices Global Market Forecast", July 27, 2012, www.strategyanalytics.com

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