Precision Needle Dispensing—Get to the Point!

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Precision micro-volume dispensing of adhesives, encapsulants, solder and other materials demands highly accurate and repeatable material volume control, shape and positioning. Successful dispensing hinges upon inter-related design factors, including needle shape, pump technology and system platform.

Micro-dispensing is the process of dispensing small volumes (~ 0.010 inch, 0.254 mm or 10 mils or less, in diameter) of solder paste; electrically and thermally conductive adhesives; clear, optical-grade adhesives; or other materials with consistent precision and repeatability.

Key factors in micro-dispensing include how precisely and consistently the pump system meters and delivers materials and how well the needlemaker minimizes the part's restricted-flow area.

Before selecting a micro-dispense solution, ask some simple questions:

- Is the application high volume?
- Are dispense quantities small volumes on tight pitches?
- Are needles replaced frequently because of damage?
- Are they cleaned/reused?
- Is clogging a frequent problem?
- Does the application require a "foot" to establish a consistent height above the surface?

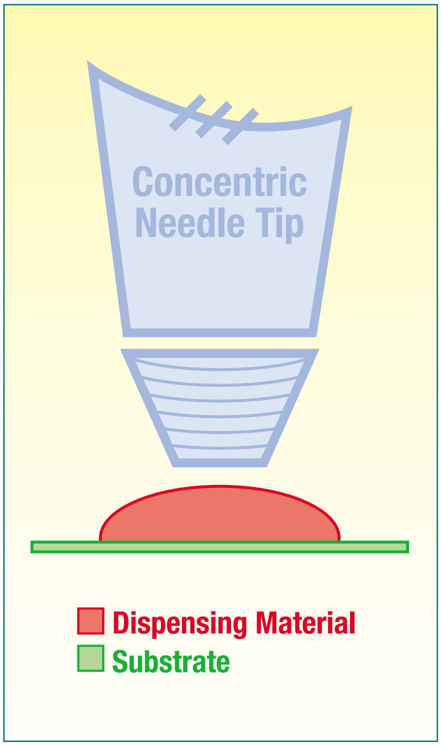

Figure 1. Concentric ring needle

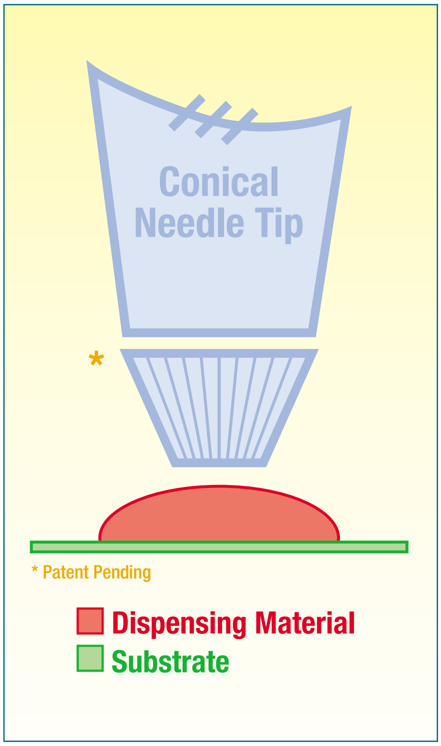

Figure 2. Conical needle

All of these questions point to the critical role that needles play in precision dispensing.

Not all needles, we should emphasize, are created equal.

Needlemakers can minimize the restricted flow area by shortening the circular flow area length (tightest internal diameter or I.D.) of medical-grade tubing needles, or by using a significantly different needle design that is a machined, one-piece construction.

The latter's smoother internal needle shape and contours actually improve dynamic fluid flow characteristics by reducing turbulence at the critical material exit point.

Tubing needles can be shortened to reduce restricted-flow area, but little else can be done to improve their dynamic flow by minimizing inherent tube roughness.

Why? Typically, tubing is made by tightly rolling sheet metal to form a butt joint, which is then seam welded. (This can be visualized by making a fist and peering through the irregular finger opening.) The outer surfaces stretch smooth while the inner surfaces are compressed, resulting in a series of ridges/crevices running the length of the tubing that are prone to accumulating material.

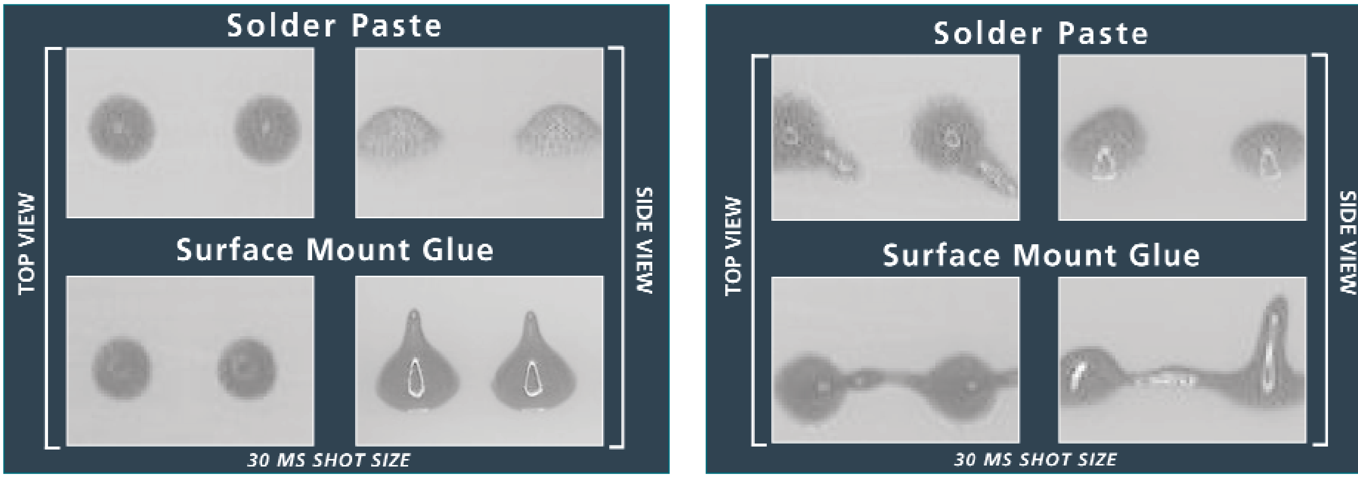

Figure 3. Dispense pattern differences, especially with adhesives, chamfered (left), non-chamfered (right).

Design Alternative

Tubing needles work well for gross volume dispensing but are not up to micro-dispensing tasks. One sophisticated design alternative to tubing is the precision-machined, one-piece, solid stainless steel needles. These needles work well for high-density assembly and packaging micro-dispensing. A conical-ground needle is far less likely to accumulate material than concentric ring shapes (Figures 1 and 2).

The one-piece design's unique smooth machined internal surfaces and small material exit conical tip provide the least amount of surface interference as the material flows through the needle, allowing more precise material flow and placement.

The machined interior promotes a smooth, spiral material flow. The machined needle's restricted area is minimal—typically 0.025 inch (0.635 mm) versus a tubing needle's 0.25 inch (6.35 mm) length, an order of magnitude difference.

Moreover, machined-needle I.D. tolerances differ significantly. For example, 25 gauge (0.010 inch or 0.254 mm) machined-needle tolerances are ± 0.0002 inch (±0.005 mm) versus typical tubing tolerances of +0.001 inch (0.0254 mm) to -0.0005 inch (0.127 mm), a potential 10% variation.

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Another frequently overlooked design factor is the needle's exterior smoothness and chamfering at the needle tip. These attributes are crucial because depositions from non-chamfered needles can result in dispensed material shape variations and volume variations, and may even encourage exterior material accumulations, unacceptable for critical packaging applications.

Chamfered tips reduce the surface tension between any needle—tubing or machined—and the material, which reduces the likelihood that material will stick to the tip.

This tip style also minimizes the risk that tailing or bridging will occur when the needle lifts from the dispensed material (Figure 3).

Needle Wear and Tear

Some production realities can negatively impact dispense machine uptimes and increase maintenance requirements.

Solder pastes and conductive adhesives contain spheres or flakes. Back pressure buildup, especially in tubing needles, may be enough to force the flux-suspended solder spheres to compact and fuse, thus blocking the needle.

Conductive adhesives contain solid metal flakes that can wedge in the tubing's irregular internal ridges. These flakes may lead to needle clogging because high pump backpressures can compact the trapped flakes.

Figure 4. Needle cleaning kit.

Figure 5. A precision-controlled auger pump.

Recently, most dispense materials were solder pastes, adhesives and encapsulants used in relatively large volumes for die attach, encapsulation or IC underfill. Now, however, optical-grade transparent materials are increasingly being employed in photonic packaging operations.

Photonic Components

Emerging mainstream applications include “window/lens” formation for photonic components, such as VCSELs (vertical cavity surface emitting lasers) arrays in BGA package formats and BGA light-detector arrays. Both share standard BGA I/O pitches and may use some of the I/O locations as laser-light exit ports or laser-light detector ports.

VCSELs manufactured with standard wafer fabrication techniques in chip form also contain electrical I/Os for data and power interconnects.

Maintenance Required

Needle clogging is a potential problem with tubing needles when dispensing small volumes. The irregular internal tubing surfaces are prone to internal material accumulations. These accumulations lead to buildup over time and degrade the quality and consistency of dispensed dots.

If the tubing is relatively rough, cleaning it thoroughly is problematic. Relatively inexpensive tubing needles are most often replaced when they clog or become badly worn.

Adhesives, solder pastes (and other dispensed materials) adhere by design, which suggests that anything that these materials touch should be routinely cleaned—or replaced. Cleaning kits for the needle’s interior and exterior that are effective with many vendors’ needles are shown in Figure 4.

Cleaning techniques vary with needle design, but careful mechanical clearing of the passages with fine wires is effective. IPA (isopropyl alcohol) is useful for soaking, wiping or brushing surfaces to remove residues. Some solvents may dissolve tubing-style needle assemblies.

motor. Low-pressure air maintains a steady flow of the material into the pump. When microdispensing, most auger pumps are challenged. To begin a dispense cycle, the pump motor is ramped up, followed by ramping down at end of cycle. Each time, a slight delay occurs as the motor reaches its maximum rpm velocity point, and again as it slows down to zero.

Since time/pressure and piston pumps are unsuitable for micro-dispensing, improved auger accuracy offers a solution. A precision-controlled auger pump (shown in Figure 5), is programmable, and augments the brushless DC servo motor with an encoder to precisely control rotation. An encoder provides 57,000 counts per revolution; i.e., a single 360° turn of the auger has 57,000 portions of a revolution to ensure accuracy and repeatability.

A programmed dispense signal provides a direct and specific point-to-point indexed rotation of the auger while regulating speed, thus precisely controlling the quantity dispensed.

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Selecting a Pump System

Many dispense-pump configurations are available. They range from simple time/pressure and positive displacement to rotary auger configurations with many variations.

Time/pressure pumps use pulsed high-pressure air to provide force on a plunger, thus moving the material through a needle.

Rotary auger pumps use an Archimedian screw turning in a cartridge (or sleeve) to push the material through the pump. In some cases, the pump uses an electromagnetic clutch to engage and disengage the constant-speed DC screw

Not Just ICs Anymore

Precise micro-dispensing is not optional when assembling conventional ICs with photonic devices, using transparent optical-grade materials.

Devices such as BGA-packaged VCSELs, corresponding detector arrays, mechanical MEMS/MOEMS, including micro- and nano-scale switchable mirror arrays, require advanced, needle designs (Figure 6).

As dimensions inevitably shrink with inherently fragile compound-semiconductor photonic devices, the needed level of precision increases.

To date, most photonic and MEMS/MOEMS devices have been expensive

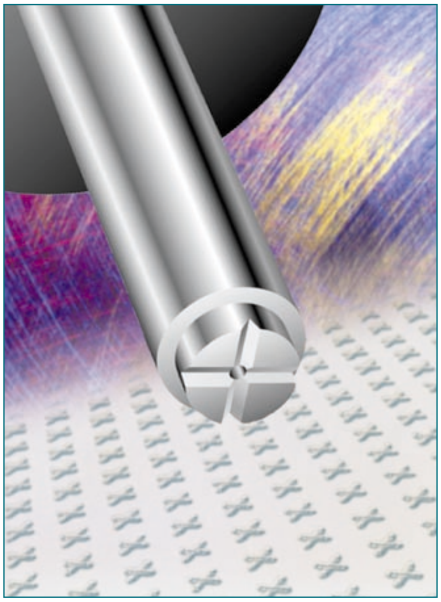

Figure 6. X-form tip needle used for conductive epoxy die attach application.

and assembled manually. That is changing, however, as the need for automating opto-electronic assembly becomes obvious.

Component manufacturers must improve dispense accuracy and precision while maintaining productivity. Using proven IC-like processes, such as micro-dispensing, will enable highly-automated photonic device "die" attach, alignment and window/lens formation to move forward.

With manufacturing costs always an issue, selecting a micro-dispensing needle system that meets both today's and tomorrow's needs is a sound investment.

Conclusion

Some higher-volume material dispensing applications are forgiving. If encapsulation height variations or excess dispensed materials do not affect functionality, most dispense needle systems are acceptable.

If the dispensed shape, however, must be in the 0.010 inch (0.254 mm) or smaller diameter range (or if exceptionally uniform, point-to-point, repeatable positioning is needed), select the more robust, precise and controllable micro-dispense needles and systems for the long haul.

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Mr. Fugere founded DL Technology in Haverhill, Mass., in 1999. Earlier, he was New Product Development Manager at Speedline Technologies' CAMALOT Systems. During his 22 years at CAMALOT, Mr. Fugere was also responsible for field service, project management and customer training. He is a toolmaker by trade and has more than 30 years experience in the electronics assembly industry.
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