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Revisiting Underfill: Your Handbook

Current Applications, Tips, Tools, and Popular Equipment Options and Upgrades

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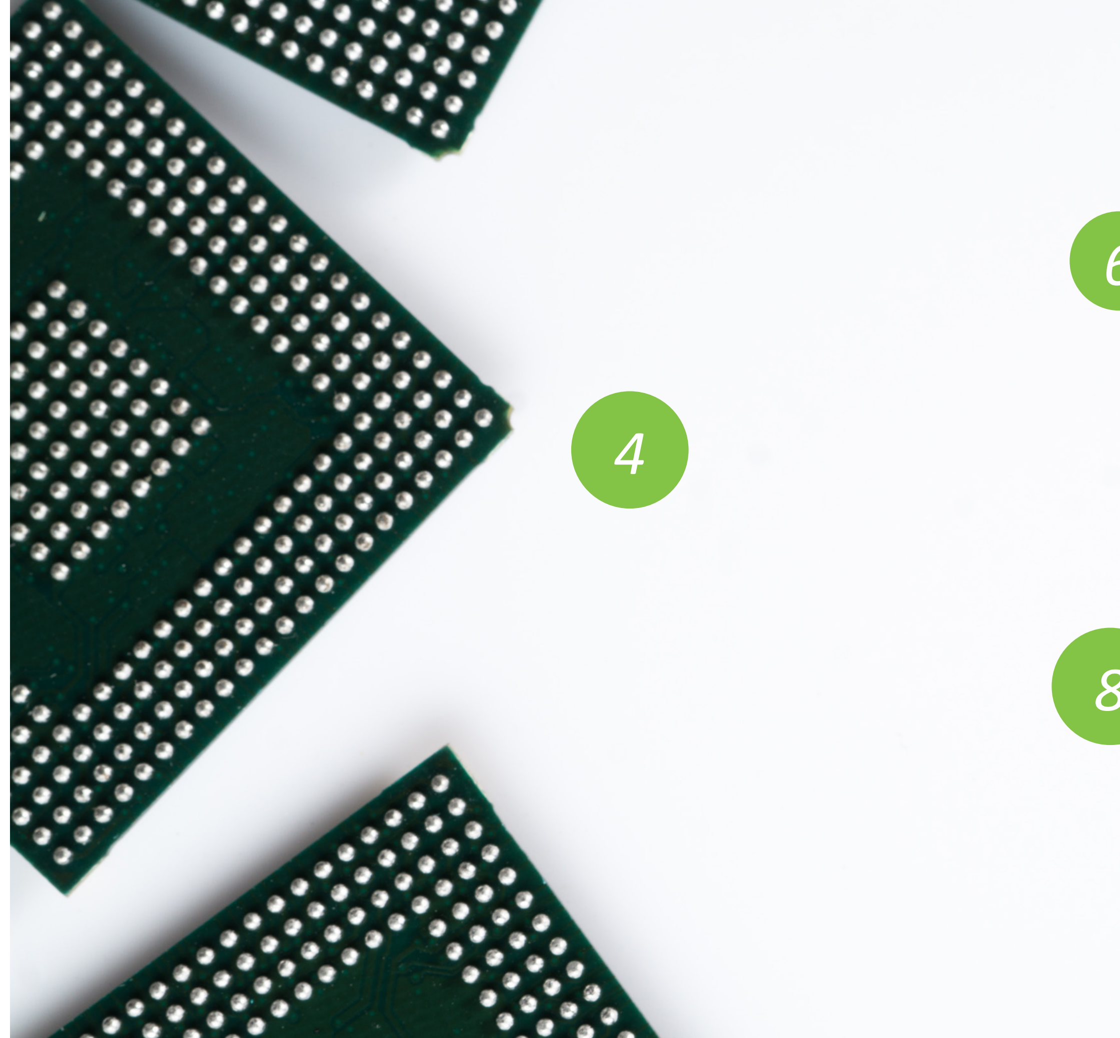

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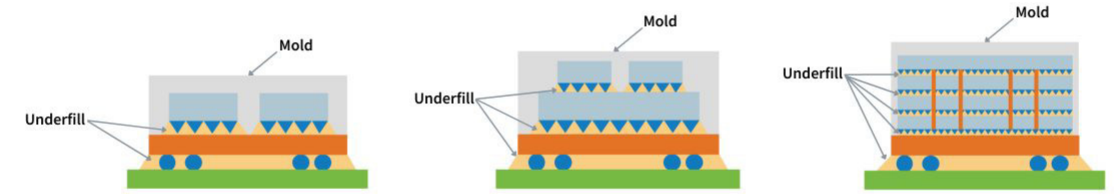

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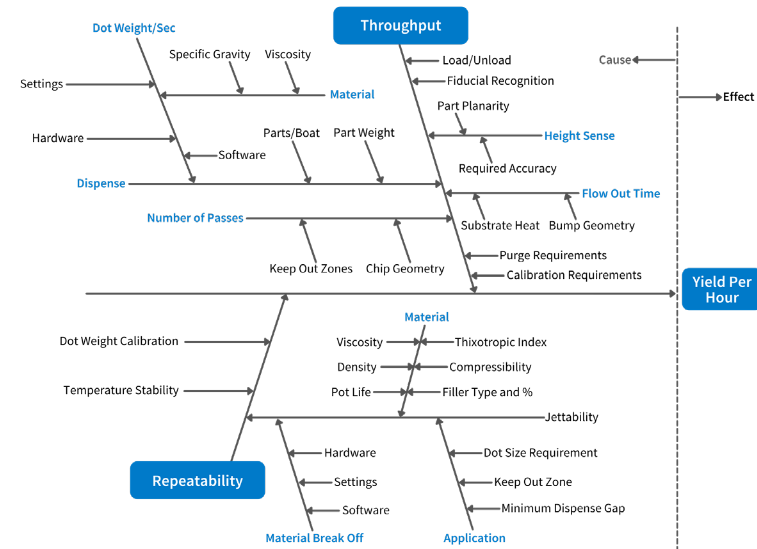

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UNDERFILL *evolution*

Reviewing current applications and revisting the fundamentals.

What is underfill?

Underfill is an epoxy material that fills gaps between a chip and its carrier or a finished package and the PCB substrate. Underfill protects electronic products from shock, drop, and vibration and reduces the strain on fragile solder ball connections caused by the difference in thermal expansion between the silicon chip and carrier (two unlike materials).

Capillary Underfill

In capillary underfill applications, a precise volume of underfill material is dispensed along the side of a chip or package to flow underneath through capillary action, filling air gaps around solder balls that connect chip packages to the PCB or stacked chips in multi-chip packages.

No-Flow Underfill

No-flow underfill materials, sometimes used for underfilling, are deposited on the substrate before a chip or package is attached and reflowed.

Molded underfill

Molded underfill is another approach that involves using resin to fill gaps between the chip and substrate.

Without underfill, the life expectancy of a product would be significantly reduced due to the cracking of interconnects.

Underfill is applied at the following stages of the manufacturing process to improve reliability.

- Wafer Level
- Panel Level
- Board Level

IN THE BEGINNING AND BEYOND

Solder ball interconnect technology was invented by IBM engineers in the early 1960s resulting in the still widely used flip-chip technology, also known as the controlled collapse chip connection (C4). Reference.

The technology is still going strong, keeping up with evolving methods, including 2.5D and 3D packaging.

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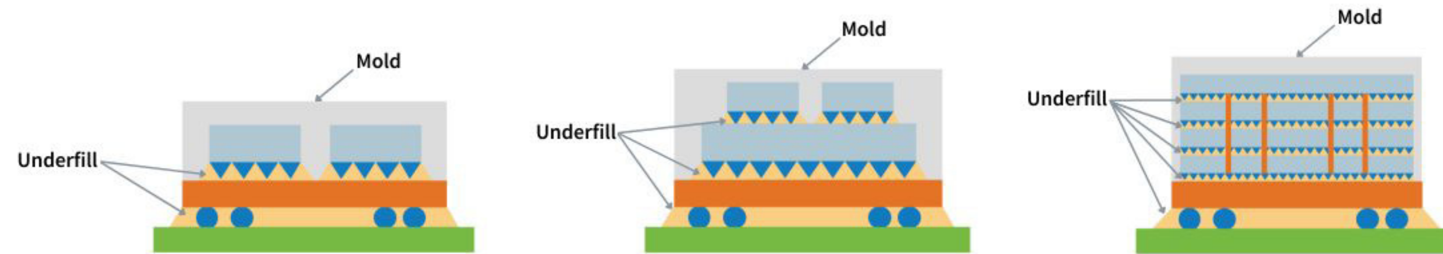
Wafer and Panel Level

Underfill is applied within flip-chip, 2D, 2.5D, 3D, and other packaging architectures at the individual substrate, wafer, and panel level. Wafer and panel level applications continue to gain in popularity because they deliver significant cost reductions. Chip-on-wafer (CoW) architecture reduces production costs by continually shrinking and increasing the chip population on wafers, bringing the gap between chips down to a few hundred microns. At the same time, bump heights underneath the chips are reduced down to tens of microns for small form factors. Despite these tight geometries, large volumes of underfill must be cleanly delivered between chips and flow under them to encapsulate solder bump connections. Precise, consistent, and advanced UPH results are paramount.

Wafer-Level Packaging (WLP) generally encompasses different integration approaches that require underfill, such as fan-in/fan-out, chip-first/chip-last, and a range of other packaging types. WLP is the cornerstone of heterogeneous integration (HI), which includes wafer-level system-in-package (SiP) architectures, 2D, 2.5D, and 3D integrated circuit (IC) stacks, and, most recently, chiplet architecture applications.

Board Level

At the board level, underfill is applied between finished packages and the PCB. The smaller form factors and the increased component population continue to shrink keep-out-zone (KOZ) dimensions between CSP/BGA and other board components. Dispensing accuracy thus becomes more important to minimize KOZ and deliver underfill fluid as close to the package as possible without landing on top or wicking off to neighboring components.



CAPILLARY VS. MOLDED UNDERFILL

Capillary underfill offers important advantages over molded underfill for high-performance computing devices, including CPU, GPU, and AI processors in datacenter, autonomous driving, and mobile devices with AI capability. These devices run under critical situations, and their physical size is large to support their range of functionality and advanced performance. Capillary underfill offers these advantages:

- **A long application history and many years of reliability data. With so much field data, it's easier for engineers to manage and control the capillary underfill process to prevent potential reliability issues such as voids.**
- **Better underfill penetration for larger chips with more complex and large bump layouts.**

The Underfill Process

Understanding how fluid flows and the best delivery method to assist flow is critical to a successful process.

Application Development

When developing an application, Nordson applications engineers can help you:

1. Establish the dispense volume.
2. Select the optimal dispense pattern: L or I
3. Determine the number of passes to dispense the required volume while balancing UPH requirements.

Process Steps

1. Convey and heat the substrate.
2. Find chip or package edges.
3. Perform height sensing.
4. Dispense.

Essential Process Controls

- Heating and staging controls ensure preheat stability to keep target flow out times in range.
- Vision system controls ensure fiducials and edges are located consistently and accurately.
- Dispensing controls ensure volumetric repeatability within the shot size range.

ASYMTEK PRODUCTS SUPPORT:

- System-in-Package (SiP)
- Integrated Passive Device (IPD)
- Redistribution Layer (RDL)
- Chip-on-Wafer (CoW)
- Chip-on-Wafer-on-Substrate (CoWos)
- Package-on-Package (PoP)
- Fan-Out Wafer Level Packaging (FOWLP)
- PCB/Flex circuit
- Organic substrate
- Ball Grid Array (BGA)
- Chip Scale Package (CSP)
- Flip-chip
- Controlled Collapse Chip Connection (C4)
- Edge or corner bond partial underfill
- No-flow underfill and jetting encapsulation

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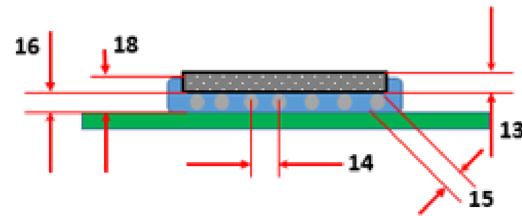
Process Tips & TOOLS

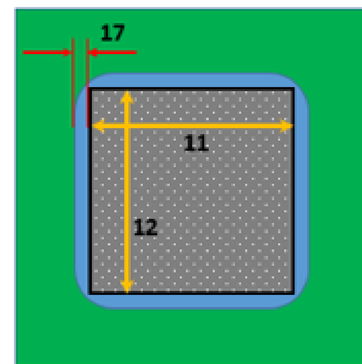
Underfill Volume and Tolerance Calculator

Use the underfill calculator to determine target dispense volumes and tolerances based on chip dimensions. The calculator provides English and Metric units.

What you'll need:

- Die length and tolerance
- Die width and tolerance
- Die thickness and tolerance
- The number of I/Os or pitch
- C4 connection diameter
- Underfill gap
- Fillet width and tolerance
- Minimum fillet height as a percentage of the die thickness
- The specific gravity of the fluid
- Epoxy contact angle at the flow temperature





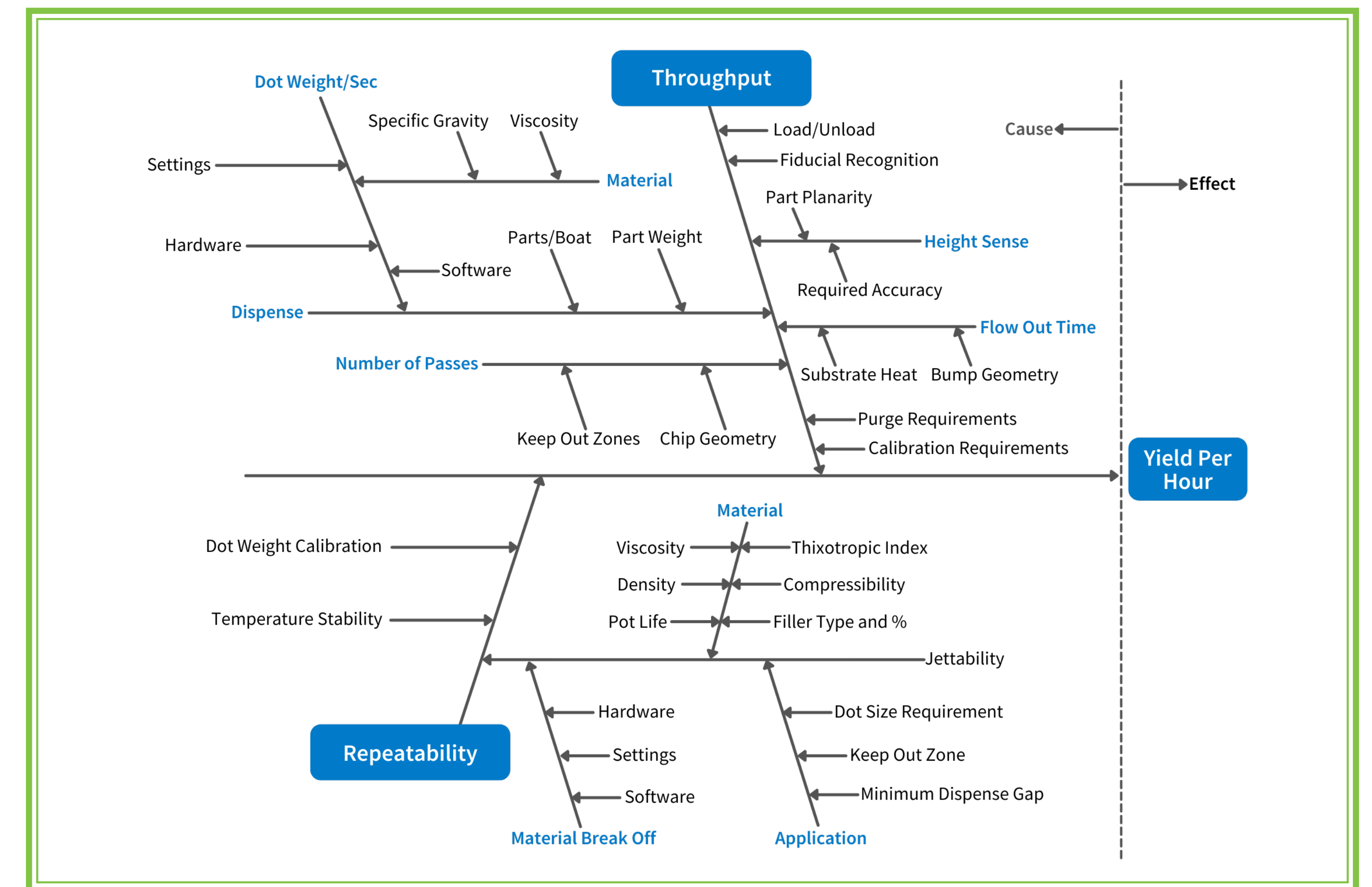
Download the Calculator

Instructions and the dimension sketch reference shown here are included in the calculator tool.

Understanding Cause and Effect in the Underfill Process

Throughput and repeatability are two significant areas that impact yield in an underfill dispensing application. Each area has several causes and sub-causes that affect the process.

Refer to the following diagram to gain insight into the underfill process. If you need assistance resolving a yield issue, contact us at any time, and our applications engineers will identify the cause of the issue and develop a solution for you.



Is your dispensing equipment right for your underfill process?

Is your underfill process meeting current process requirements, reaching UPH and yield goals, and accommodating future dispensing needs?

If not, it's time to assess your requirements, weigh your options, and create a new underfill solution.

As we shift to an increasingly digital world, the need for new technologies such as 5G infrastructure, server networks, mobile and IoT devices, cloud computing, autonomous driving, financial tech, and more is intensifying. And that means you have new manufacturing challenges to solve. We understand that, and we're here to help you bring those technologies to life.

The following pages highlight several dispensing platforms, essential process controls, and our premier piezo-jet, which are ideal for underfill applications.

With over 35 years of experience, we offer the right equipment and process controls to accelerate your process.

Reach out to your local sales representative at any time to request a budgetary quote or to get additional information about our solutions. We look forward to hearing from you.

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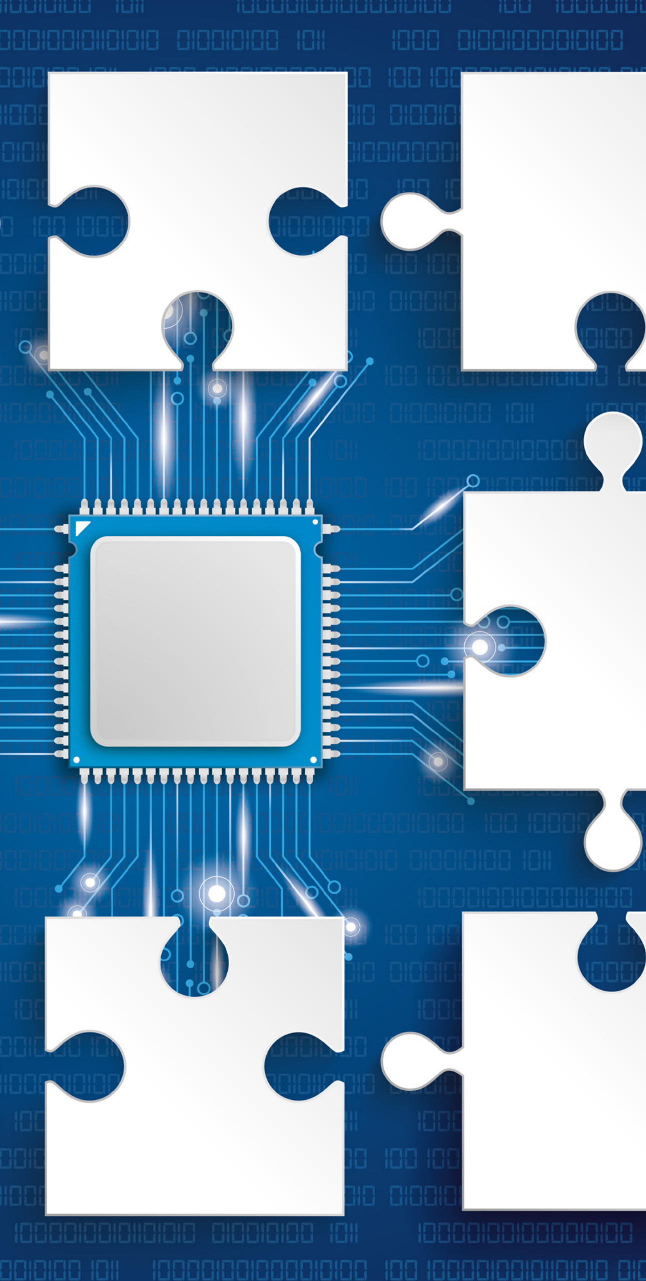

Dual Simultaneous Jetting

Run two IntelliJet Jetting Systems on the dual-valve-ready Vantage or Forte Series dispensing platforms. With dual-simultaneous dispensing, two identical valves dispense repeated patterns of the same fluid simultaneously.

Dual-simultaneous jetting is ideally suited for applications with multi-up, panelized, or patterned parts with consistent spacing.

Dispense time is at least 2X faster with dual-simultaneous dispensing when compared to single-jet dispensing, resulting in higher units per hour without having to purchase an additional dispensing system.

Vantage Series

Learn More

The Vantage Series is our most advanced system for leading-edge semiconductor packaging and electromechanical and PCB assembly. Vantage offers unparalleled dispensing with the IntelliJet Jetting System, Canvas® software, and a larger dispense area to handle wafers, panels, and large PCBs or arrays.

- Dual-head dispensing
- Patented* real-time skew correction
- Stream widths < 175 µm
- Wafer-level line paths of < 1.5 nL
- Closed-loop process control

Forte Series

Learn More

The Forte Series offers exceptional fluid dispensing productivity and accuracy for high-volume PCB, flex circuit, MEMs, and electromechanical assembly.

- Forte MAX dual-valve jetting
- IntelliJet Jetting System
- Patented* real-time skew correction
- 1.5 G point-to-point acceleration
- Space-saving footprint
- Canvas software
- Closed-loop process control

Spectrum ll

Learn More

The world-class Spectrum II fluid dispensing system is designed for semiconductor packaging, MEMs, and PCB assembly.

- IntelliJet Jetting System
- Consistent quality and reliability
- Ideal for high board density
- Minimal wet-out distances
- Highly scalable, modular design
- Fluidmove® software
- Closed-loop process control

Calibrated Process Jetting

Fluid viscosity and dispense weight vary with time and temperature. Closed-loop process controls remove dependence upon an operator to make appropriate adjustments as changes occur.

There are two methods of Calibrated Process Jetting (CPJ):

Standard CPJ

The standard CPJ software feature maintains volumetric repeatability for closed-loop process control and automatically compensates for changes in fluid viscosity. With this process control, the dispensing platform automatically measures the mass per dot and compares it to the set min/max values to maintain a constant dispensed weight per part (Patent #5906682).

CPJ+

CPJ+ adjusts pressure to maintain constant mass per dot. The feature automatically compensates for both fluid viscosity changes over time as well as batch-to-batch variations. CPJ+ increases dispense accuracy, delivering higher yields and ensuring consistent Takt time for improved process capability (CpK).

Fids-on-the-Fly

The Fids-on-the-Fly software feature calculates a spline travel path based on the programmed fiducial locations in the dispense program.

After the fiducial path is calculated, image capture is performed at maximum acceleration and velocity without stopping.

Fids-on-the-Fly software uses a high-speed digital camera that operates at 60 frames per second. High-intensity on-axis LED lighting enables reliable fiducial capture for even the most demanding applications.

*Nordson US Patents 9,707,584; 10,150,131; 10,737,286 and other patents pending.

Continuous Path Motion Control

Continuous Path Motion Control is ideal for line dispensing on component arrays when underfill dispensing and discrete encapsulation are required. It accommodates various configurations and is designed to enable continuous motion dispensing at high speeds when parts are small and close together in an array. Instead of stopping to move between components, backtracking, ramping up to speed, dispensing, and decelerating, the jet maintains a continuous speed and direction throughout the process.

Fluidmove Software

Fluidmove software offers multiple layers of process control and an array of features for the Spectrum ll fluid dispensing system.

Canvas Software

Canvas software features a graphical programming interface that simplifies programming tasks and provides powerful insight and process control. Canvas software is offered on the Vantage and Forte Series fluid dispensing systems. Canvas includes well-known, reliable Fluidmove software features such as Fids-on-the-Fly, Calibrated Process Jetting, and Continuous Path Motion Control.

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Advanced semiconductor dispensing applications require a combination of speed and precision to achieve maximum throughput and yield.

The piezo-driven IntelliJet Jetting System with ReadiSet® Jet Cartridge is the world's premier high-frequency jet for achieving consistent, precise dispensing of a wide variety of fluids, with ultra-fast jetting speeds up to 1.8 million dots per hour and a maximum frequency of 1000 Hz.

Quickly advance UPH by adding a second IntelliJet to your Vantage or Forte Series dispensing platform.

The IntelliJet offers:

- Dual-simultaneous jetting on the Vantage, Forte, and Spectrum ll Series dispensing platforms.
- ReadiSet Jet Cartridge for quick, easy cleaning and replacement – saves time and money.
- Market-leading piezo stack longevity and warranty with actuator reliability lasting up to six times longer than other jets on the market.
- Integrated self-calibration adjusts for consumable wear and setup-to-setup variations for consistent performance.
- An advanced valve design built on decades of jetting experience across a wide range of applications

IntelliJet valves and ReadiSet jet cartridges are covered by US Patents 9,346,075; 9,808,826 and 10,646,893 and other patents granted or pending in the US, Asia, and Europe.

Learn More

Advanced Underfill Jetting

ReadiSet Jet Cartridge

The Readiset Jet cartridge separates easily into two parts for cleaning in an ultrasonic bath with solvent or IPA to deliver effortless, cost-effective maintenance. A wide range of cartridge sizes are available for 0.5 nL to 300 nL dot sizes.

STANDARD READISET JET CARTRIDGE

Form fits function with the 2-piece ReadiSet Jet Cartridge that features a fully visible fluid path, is ultrasonic compatible, and offers easy access for efficient day-to-day cleaning.

Replace entire cartridges, entire sub-assemblies, or piece parts as needed.

READISET JET CARTRIDGE WITH STINGER TIP

The ReadiSet Jet Cartridge with stinger tip includes all the benefits of the standard cartridge and improves access to substrates in the z-axis, reduces satellites, and is compatible with tilt and rotate.

Save on maintenance cost with the efficient nozzle design that lets you replace just the nozzle tip — separate from the lower assembly.

Your Representative Has All the Details

Contact us today for a budgetary quote. A member of our applications team will work directly with you to understand your application, assist with equipment selection, and set up and run your application demo.

We offer exemplary service and commitment to your success.

Discover how our underfill solutions and outstanding application and support teams can optimize your process.

We've earned the confidence of the world's largest electronics companies to support their high-volume dispensing processes.

Join our dispensing community, and let us help you succeed.

Contact Us

Visit our website or contact us. We have several global locations to serve you.

North America
Asia Pacific
EMEA

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