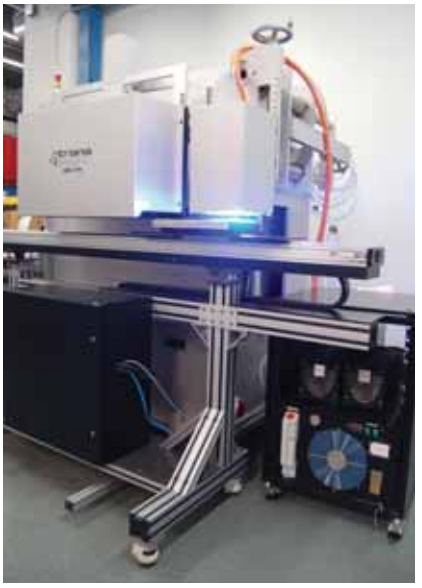
Variable Data Revolution Turns to UV Curing

By Paul Mills and Jennifer Heathcote

"Stop the presses!" Enabled by advances in UV curing, printers are moving old-fashioned screen and pad printing supplies to storage room shelves next to the carbon paper and Wite-Out®. Graphic arts has joined the electronic age and with it the ability to change what is being printed on-the-fly. This has created a sort of "variable data revolution," allowing inkjetting of high-quality images directly onto plastic parts. With no wraps, decals or labels, industrial inkjet printers equipped with UV curing can pop out beautiful finished parts—each bearing its own unique image at high speeds.

"Our business isn't making arc lamps or LED lamps. It's UV curing. The application should dictate the most appropriate technology. For some applications, that might be an arc lamp and for others an LED."



A compact, in-line industrial inkjet system. Parts are conveyed from left to right through printing and then curing stations.

This technological leap has liberated a market for applications ranging from short print runs to parts that need marking or coding for traceability and personalization. The underlying technology, drop-on-demand inkjet printing, has shattered the old print industry paradigms of large print runs driven by the high cost of time and materials required to change screens, plates, pads and other fixed resources. Now, a keystroke can print a thousand, dozen or single custom-decorated part(s).

"Digital inkjet systems using UV-curable inks are revolutionizing the cost structure of printing," says Sigi Knappik, new product development manager for ITW Trans Tech. Trans Tech has embraced the inkjet/UV approach to allow both new and existing customers to develop novel products and expand into new markets—from automotive parts requiring unique coding to medical devices needing traceability.

UV-LED sources are now finding their way into many commercial graphic arts and industrial applications. Here is high-speed, narrow-web printing.

"The question has changed from, 'what can we do?' to 'what do we want to do?'" said Chris DeMell, digital technical sales manager for Trans Tech. Their machines print directly onto plastic parts with no label, sticker or wrapper in a process analogous to painting with ink droplets. Each part passes under a digital inkjet head where the image is rapidly and very

accurately transferred to the part. UV curing is used during the ink application to freeze or "pin" jetted inks as they are applied to the surface. Pinning helps to precisely control drop gain (a measure of the spread of each ink droplet). Controlling the drop gain of each color improves resolution and produces sharper, crisper images. Next, the pinned ink is fully cured as quickly as it was applied using high-speed, UV-curing technology. In just seconds, parts go from bare substrate to beautifully printed pieces ready for packaging.

"UV curing is at the center of this process," said DeMell. "Not only does UV enable us to print at high speed with low heat, but the ability to optimize curing of our inks is critical to achieving the appearance required for higher resolution."

Trans Tech's pad printing machines have been used on many plastics decorating lines, but their business isn't pad printing—it's part decoration. "The UV inkjet machines give us another tool to help solve problems," added Knappik. "With our UV flatbed and in-line machines, our tool kit is bigger."

Not Your Grandfather's Inkjet

So you might ask, "what's so revolutionary about inkjet printing?" After all, you've had an inkjet printer in your home office for over a decade. Industrial inkjet technology is not your desktop printer variety of digital imaging. It provides image quality on par with some of the most demanding analog methods of printing.

In all likelihood, your home printer uses a print cartridge with a series of tiny chambers each containing a heater. A rapid pulse of electric current passing through this tiny heating element causes vaporization of the ink in the chamber to form a bubble. The increase in pressure propels a droplet of ink onto the paper. High-end digital inkjet heads differ in a few substantive ways. The modern piezoelectric print heads use a ceramic material that deforms when a small voltage is applied. The flexing of this material forces the ink droplet though the nozzle. Since no thermal vaporization is required, piezoelectric heads can be used with a wider range of ink formulations—including UV-curable inks. And with less sophisticated print heads (called binary print heads), either a drop of ink is printed or it's not. With more sophistication, printers can use grayscale print heads that actually deposit ink droplets made of much smaller sub-droplets. This allows the print head to deposit drops of varying sizes (typically just a few pico-liters, or a few trillionths of a liter—with each drop being about one-quarter the width of a single human hair.)

Digital inkjet heads can accurately and consistently produce and reproduce over 90 percent of any PMS color shade with apparent 1,000-dpi resolution. Printing isn't limited to paper substrates. These new machines can print dazzling images on metal, glass, plastic and other substrates with excellent adhesion and speeds that rival continuous inkjet printing at up to 16 inches per second. "These digital systems are designed for an industrial environment—robust, reliable and designed to operate continuously in a harsh manufacturing setting," said DeMell.

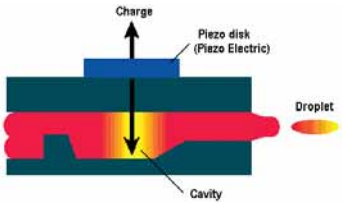
Depending on the printing system and product, customers may be able to uniquely mark 1,000 pieces in the time it previously took to print one piece with traditional printing methods. "This is only possible through the use of digital technology coupled with piezoelectric-based systems and UV curing," added DeMell.

The latest Trans Tech designs take UV curing a step further into the electronic age by employing solid-state, UV-LED technology. Until recently, the UV-curing lamps were compact, medium-pressure mercury lamps with high-speed shutter mechanisms. UV light-emitting diodes offer them a lot

The quality of inkjet images using the UV-cure process is as high as apparent 1,000 dpi in almost any PMS color.

Figure 1

Piezoelectric inkjet head



A modern piezoelectric inkjet head uses electronic pulses to rapidly and accurately deposit drops of various sizes onto the substrate.

of the same benefits that are driving LEDs as a replacement in other applications—much longer lifetimes, lower energy consumption, less heat, greater reliability and uniformity.

"There are some distinct parallels in our business philosophy," said Jennifer Heathcote, general manager for Integration Technology, a UK-based manufacturer of UV sources. "Our business isn't making arc lamps or LED lamps. It's UV curing. The application should dictate the most appropriate technology. For some applications, that might be an arc lamp and for others an LED."

For graphic arts, LED sources are rapidly gaining popularity since compact size and low-temperature substrates are driving the technology. For scanning head systems, the ease of integrating LED sources into tight quarters or mounting UV lamps onto moving carriages is a perfect fit for LED lamps. "UV is exciting technology," added DeMell. "We are big fans of UV curing because it provides a better and faster process. UV-LEDs may let us apply the advantages of UV to even more processes that require sources that are easy-to-integrate, safe and require features such as instant on-and-off capabilities for the process."

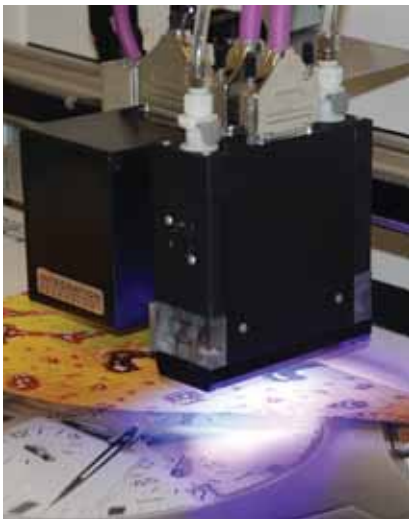
This has led to the development of direct-to-substrate digital inkjet equipment. One is a flatbed system designed with a scanning print head and UV-curing module design. This allows a wide range of parts to be cured, including multiple parts arranged in fixture trays while still providing the exacting registration needed for the highest quality imaging. This machine uses an arc lamp for curing. Another version is an in-line machine that supports materials up to 10 inches wide and processes parts at speeds up to 16 inches per second. Like its flatbed cousin, the in-line system supports printing with up to six inks (including white and clear) and is designed with solid-state, UV-LED curing technology.

A Twist to Digital Inkjet Printing

Bob Deets, founder and president of Scribe Inc., is adding his own twist to the digital inkjet technology. His company is developing systems that can jet UV-curable inks directly onto virtually any part, regardless of its geometry. That unique capability is helping to fill their lab with everything from coffee mugs to medical supplies, and from cosmetic containers to appliance parts.

To accomplish this feat, their system is designed to pick up parts with a robotic arm, position them accurately beneath the near-microscopic jets of a piezoelectric inkjet head that applies the image, and then move the printed part beneath a UV lamp that instantly cures the inks. A mistake of just .001 inch can mean a rejected part when jetting inks at 720 dots per inch onto a curved plastic surface.

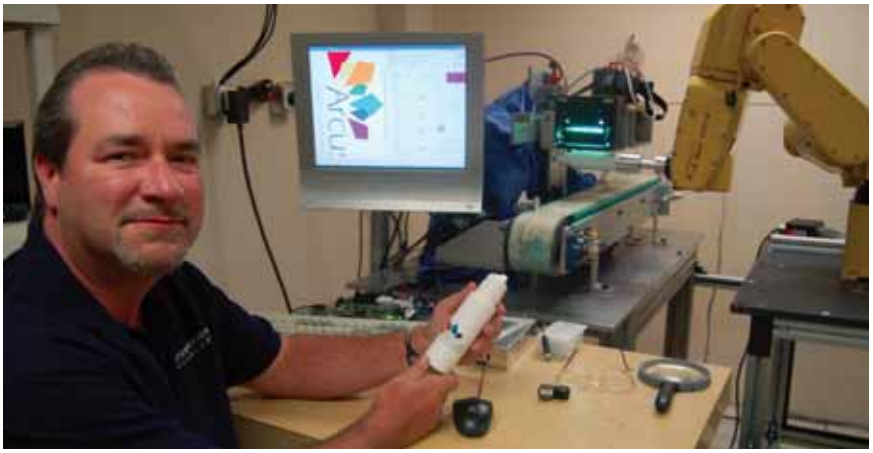
They have also developed technology to expand their capabilities in an already established plastics decorating business. Deets has worked in the plastics decorating field for nearly 25 years in an advertising specialties company that uses injection molds and decorates a wide range of novelty



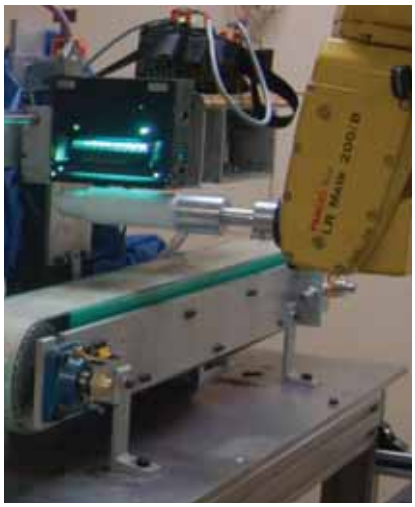
UV-LEDs are compact and have low voltage, making them an ideal source for applications where the UV source is attached to a moving carriage such as inkjet systems.

items. "We molded parts and decorated them using silk screening, pad printing and hot stamping, and ended up with storerooms full of tooling, dies and screens for the large-volume jobs we ran. We had to turn away customers who wanted small batches that we could not produce cost-effectively," said Deets. Digital inkjet printing solved two problems for his business—it cut the time and cost of developing the tooling needed for printing, and it provided a way to offer small-volume runs for custom-imprinted parts.

"We designed our first machines for our own use in the specialty printing



Three-dimensional shapes such as this shampoo bottle are easily decorated with robotic manipulation of the part under the print head and UV source.



The way "around" line-of-sight limitations of UV is, quite literally, to move the parts so all surfaces are exposed.

business," added Deets. "While we were building our own system, growth in variable-data applications was turning everybody's attention to the digital inkjet process and our development ran headlong into a world of uses that can take advantage of 3D inkjet printing technology."

Deets' company uses specialized software to "rip" images into coded instructions that allow multiple inkjet print heads to accurately shoot ink onto the part. Since each part is frequently unique, they have developed an extensive bag of tricks for adapting the process to different materials. But getting ink onto a part is just the beginning of the challenge.

Integration Technology Limited partnered with Scribe to understand how UV irradiance and energy density affects the shape and reproducibility of jetted inks. "We have learned it's not just the application of the ink that can make or break a beautiful image, but the curing profile of each droplet as well," said Glenn Sahlin, Scribe's technology manager. "We've found that UV curing gives us the needed precision to control drop gain and achieve the resolution they need."

Perhaps the most unique aspect of this technology is the ability to manipulate parts underneath inkjet print heads and UV lamps in such a way that printers can apply images to virtually any shaped part. "This includes six-axis electronic robots which allow us to apply inks to parts that were impossible to print with flat-line systems," explained Frank Pagano, Scribe's engineering manager. "The robot can pick up an odd-shaped part and place it in just the right spot for printing and curing. Controlling the motion of these parts under delicate print heads and UV lamps requires the extreme precision of a robot."

A leading cosmetics supplier wanted to custom imprint the name of each shade of makeup onto beautifully decorated cardboard boxes. Since there are dozens of possible labels, digital inkjet printing provided the ideal flexibility for their variable data printing needs. According to Pagano, this job could not have been done on a flat-line. Instead, they designed, tested and built a special box-printing machine that solved the problem.

The same sort of innovative thinking allowed Ameri-Vac (a medical supply manufacturer) to decorate vacuum canisters used in hospitals and healthcare facilities. To print markings on these cone-shaped containers, they used a robot with a specially designed end-of-arm tooling to move each canister rapidly from printing to curing stations. Ameri-Vac is now able to provide custom imprinted products to their customers, a feat that could never be achieved with the high setup and changeover costs of conventional printing.

Custom-decorated medical components like this canister are now cost-efficient to produce using industrial digital inkjet technology.

"We are especially excited about the fit of UV curing into our machinery," said Deets. "UV provides us with the speed and accuracy we need for a very complex printing task. And now we are exploring UV-LED sources that generate far less heat, and may let us work with thin-walled plastics and heat-sensitive foils our customers want to use in their products."

Benefits of UV Curing for Digital Inkjet

- **Image Quality:** UV-curable inks provide colors that are more vibrant and opaque than many solvent-based inks due to price control of droplet size.
- **Environmentally Friendly:** UV cure greatly reduces the use of harmful VOCs.
- **Flexibility:** The digital process can produce full color non-contact CMYK printing.
- **Durability:** UV inks can provide a thicker layer of ink on the substrate than most other digital print methods.
- **Cost Savings:** UV inkjet inks can increase productivity while reducing the expenses normally associated with solvent ink systems.

—Paul Mills is a marketing consultant for Integration Technology and Jennifer Heathcoate is general manager, North America, for Integration Technology in Chicago, Ill.