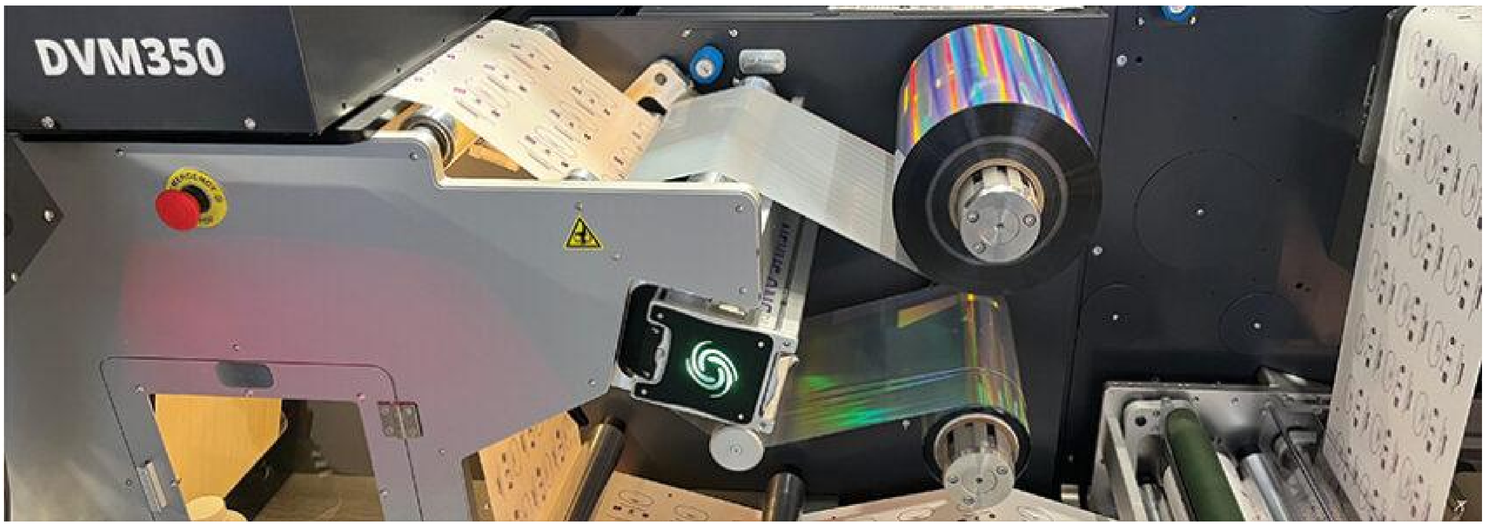
Expanding Applications

UV and UV LED Curing Advance for Digital Print



by Cassandra Balentine

UV curing for digital print is evolving fast across industrial, packaging, and décor applications. The role of UV curing technology expands to support the continued adoption of digital industrial printing—from decoration to manufacturing.

Above: Excelitas recently introduced the Phoseon Nexus II UV LED curing platform for flexographic printing with advanced monitoring capabilities and improved system reliability.

UV and UV LED curing technologies are essential components of modern digital inkjet printing. Today, nearly all major inkjet platforms rely on UV LED systems for curing.

Short-run, variable, and personalized packaging and décor applications demand curing systems capable of rapid job changeover, low waste, and flexible production—key attributes of digital manufacturing, suggests Peter Lin, CEO, IUV.

UV Evolution

The role of UV curing technology in digital printing is shifting from an "auxiliary drying process" to a "core engine of value creation," according to Lin.

Before 2015, UV curing primarily served as a faster alternative to infrared or hot-air drying, valued for its "quick-dry" capability.

After 2020, the introduction of UV LED reduced the curing window to under 0.2 seconds, while printhead line speeds continued to climb—making the curing and ink segments the key limiting factors for productivity.

By 2025, with continuous breakthroughs in functional inks and resins—such as conductive, insulating, three-dimensional (3D) texture, or micro-encapsulated fragrance materials, UV curing has transformed into a material modification stage—where cross linking directly determines material performance. "Curing has thus advanced from a supporting process to the core of material and process innovation," shares Lin.

Digital printing expands beyond simple color reproduction into 3D texturing, spot varnish, braille, and direct writing of RFID antennas, where Lin says UV curing plays a role in both forming and functionalizing the printed layer.

Shift to LED

The move to UV LED is growing along with demands for digital print, including a noticeable move from traditional mercury UV to LED technology. "Today, almost all digital printing has transitioned from traditional mercury UV arc lamps to UV LED technology because of all the benefits," notes Stacy Hoge, marketing manager, Excelitas.

Sustainability requirements are one driver for UV LED adoption as many major brands require environmentally sustainable processes from printers and converters. "These requirements significantly impact the developments for UV curing technology. The environmental benefits of UV LED curing are numerous. With traditional UV curing processes, the tremendous heat associated with mercury UV lamps requires a lot of electricity to operate. Upgrading to UV LED curing can reduce energy bills up to 85 percent overnight with return on investment (ROI) in well under one year," offers Hoge.

Chris Davis, director of sales, Hoenle Americas Inc., agrees, stating that UV curing is environmentally friendly, sustainable, and completely solvent free. "Over 20 years of use in digital printing, UV curing has evolved into an established and integral technology that is now indispensable in many production processes."

Flexographic/digital integration is also making an impact on the adoption of UV LED curing in the digital, industrial print space. “Integrating flexographic and digital into one system is becoming a common trend in the printing industry, with supporting UV curing systems for both processes. Hybrid industrial printing systems combine flexographic analog printing with inkjet on a single-pass production line. This setup leverages the benefits offered by both printing technologies. A combined flexographic digital printing system gives printers two production tools in virtually the same footprint. UV LED curing easily supports both digital and flexographic processes, offering one technology for the whole print flow,” explains Davis.

The consumption of UV LED inks is steadily increasing in digital print, as conventional UV systems are increasingly replaced by UV LED technology. As a result, UV LED digital printing is becoming a “firmly established and indispensable complement to water-based printing processes. UV applications demonstrate their particular strengths wherever high ink durability, fast processing, brilliant colors, or printing on non-absorbent substrates is required,” notes Davis.

UV ink manufacturers continue to improve ink properties—including price, processability, and reactivity—to make an even broader range of applications economically viable. “This is especially relevant since UV inks are currently around five to eight times more expensive than water-based inks. Further improvements are expected through more efficient UV and UV LED systems. In close cooperation with machine and ink manufacturers, ongoing work is carried out on existing and new UV applications,” says Davis.

Mark VandenBosch, technical sales, IST America, points out that the rapid adoption of UV-curable inks, especially those formulated with 100 percent solids, reflects a critical industry shift. “These ink formulations enable the deposition of small, well-defined dots without the volume loss or dot gain associated with evaporative drying.”

In many high-resolution systems, including those from OEMs, a dual-stage approach is used—an LED lamp is placed immediately after jetting to partially “gel” the ink. “This pre-gelling step locks the dot geometry in place, preserving image sharpness and fine detail before a final full-cure step downstream. This approach is particularly important for achieving high-quality output at speeds now expected of industrial digital systems,” explains VandenBosch.

Latest Advancements

We see many advancements in UV/UV LED curing that support digital print.

Higher energy utilization across nearly all UV technologies, and especially in UV LED, enables significantly greater overall efficiency, says Davis. “In addition to this, the switchability of UV LED systems provides a crucial lever for improving energy efficiency even further.”

In low-migration applications such as package printing, more efficient inks and varnishes with reduced migration risks open up new possibilities. “We offer the optimal UV and UV LED curing solutions to support these applications,” shares Davis.

New ink formulations increasingly focus on low volatile organic compounds, low migration, and recyclable materials, aligning with the principles of a circular economy, shares Lin.

Recent developments in UV curing systems are increasingly influenced by the demands of durable goods and complex packaging formats. “For instance, while LED curing offers efficiency and lower heat profiles, many digital press manufacturers, particularly those in packaging and label markets, continue to specify traditional arc UV for final curing stages,” explains VandenBosch.

VandenBosch says the reason is technical, arc UV systems emit a broader spectrum that includes UV-C wavelengths, which contribute to cross linking at the surface level. This deeper and more complete polymerization translates to increased surface hardness and better resistance to abrasion, chemicals, and scuffing, key requirements for packaging and industrial applications.

This performance advantage has also led finishing equipment manufacturers to integrate arc UV stations for varnish curing and overprint protection. “These systems support embellishment effects such as cast and cure or foil applications, where reliable, high-density cure is critical to final quality,” shares VandenBosch.

For the décor sector, brilliant colors, high resistance levels, and customized designs such as digitally structured products in the wood-based materials industry are achievable only with precisely tailored UV technology. “For this reason, we focus not only on UV curing systems themselves but also on developing new UV applications in close collaboration with our partners, creating tangible added value for customers,” shares Davis.

The advantages of UV LED technology are particularly clear in manufacturing environments. This includes switchability, compact system size, and ozone-free operation. “This allows not only paints, inks, and varnishes to be cured inline, but also UV adhesives, all within a minimal footprint,” notes Davis.

Curing technology is evolving from standalone light sources to modular, networked process units that integrate seamlessly into digital production environments, says Lin. Smart UV systems now leverage process data analytics, predictive maintenance, and real-time adaptive control, transforming curing into an intelligent and connected manufacturing function.

Hoge notices increased automation and the employment of smart machines and smart factories with informed data helping to produce goods more efficiently and productively across the value chain. “By collecting more data from the factory floor and combining that with other operational data, a smart factory can achieve information transparency and better decisions.”

Customers require process control via real-time monitoring of UV LED curing lamps to better support Industry 4.0 manufacturing. “Many of them run ‘dark factories’ that have no lights or no humans during processing, so 24/7 remote performance monitoring is key. Even in facilities with human operators, customers want to be notified about curing issues immediately,” says Hoge.

Lin believes modern UV systems deliver higher output, greater dose intensity, and faster curing cycles, supporting high-speed printing and manufacturing, while compact modular designs allow more flexible installation, shorter setup times, and reduced downtime.

As artificial intelligence advances, it is able to better track ROI, including cost savings, efficiency gains, and environmental impact for printers. “It will also be able to give some guidance on the best technologies to use for printers,” suggests Hoge.

Requirements on the Move

Curing requirements change as digital print moves into industrial areas beyond paper-based products.
Also, as digital printing expands into industrial and decorative applications, substrate diversity presents new curing challenges. “Filmic materials, which are widely used in consumer goods and flexible packaging, often require enhanced adhesion and surface hardness. UV inks generally outperform water-based or solvent-based inks in these areas, offering both higher gloss and greater durability,” states VandenBosch.

Higher durability and functional requirements come into play. “Industrial products often require more than surface curing; they demand scratch resistance, chemical resistance, weatherability, or specific functionalities—conductivity, anti-fouling, and antimicrobial properties. Curing systems must ensure high cross linking, mechanical performance, and chemical stability to meet industrial standards,” offers Lin.

Increased press speeds also require more power from the UV curing light source. “Having enough power is crucial to the curing process. This is where peak irradiance and energy density (dose) come into play. A minimum threshold of irradiance is needed to start the polymerization process, and then a dwell time of dose is needed to finish the curing process. Both high irradiance and energy density are required for a successful cure,” explains Hoge.

Davis says digital printing with UV today relies almost entirely on UV LED inks, whereas conventional UV inks were previously common. "UV LED technology has now reached sufficiently high peak intensity levels, meaning that further development is focused less on increasing peak intensity and more on achieving a higher overall UV dose. This is accomplished through wider emission windows in UV LED systems, resulting in greater energy input. This trend is particularly evident when printing on closed or non-porous substrates. At the same time, the reactivity of inks and varnishes has generally improved."

Expanding Applications

The adoption of digital print encourages advancements in UV and UV LED curing technologies and inks to support more substrates and applications.

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