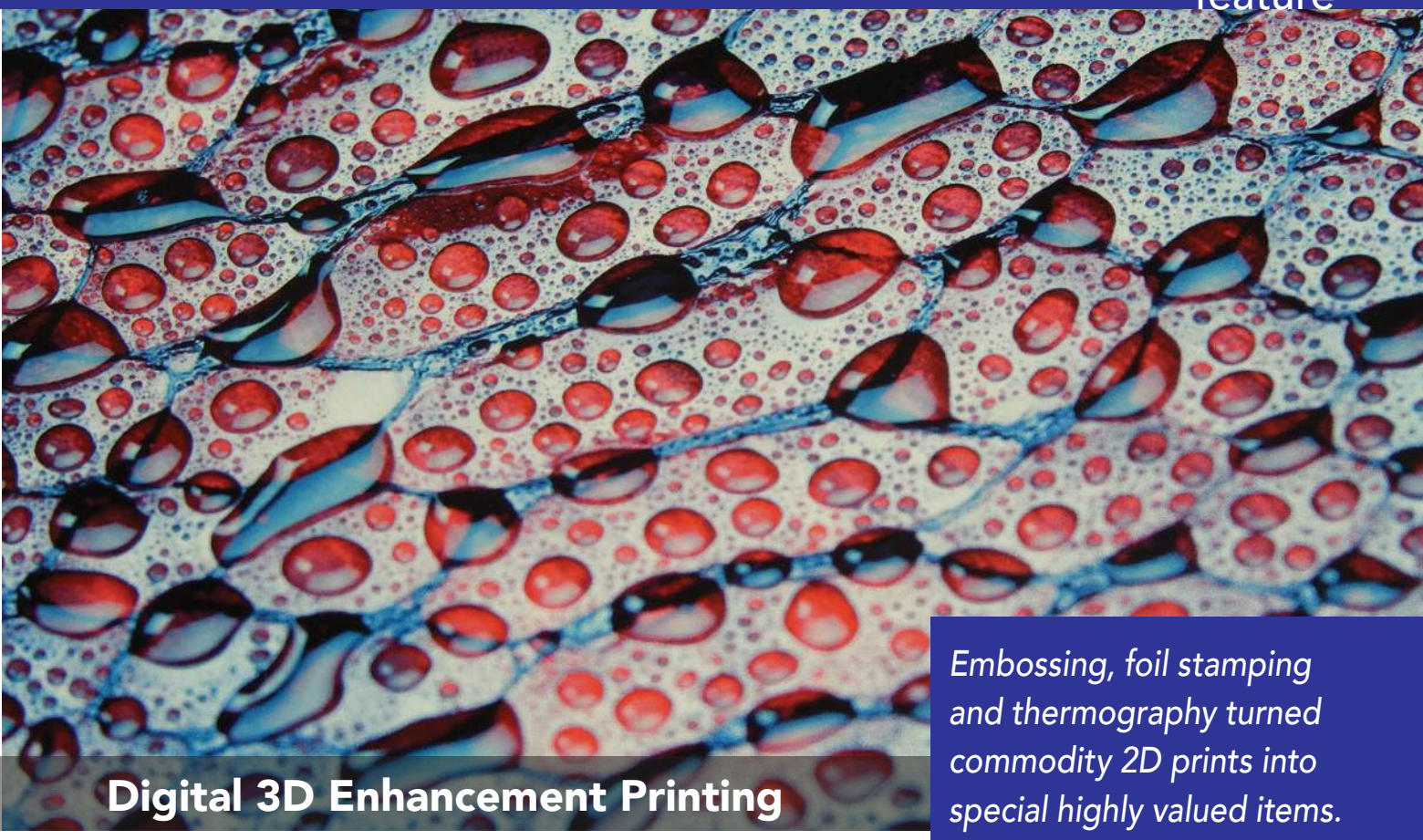


Digital 3D Enhancement Printing

Embossing, foil stamping and thermography turned commodity 2D prints into special highly valued items. Substrate manufacturers have produced high-value films and papers that provide attractive textures engaging the sense of touch. With the arrival of UV-curable printed inks and coatings almost four decades ago, very-high-gloss finishes and accents have also added the perception of high value to printed covers, documents and packaging.

Whether with a wax seal, embossed image or raised type, throughout much of history, adding dimension to documents has increased their perceived value and importance. As the Internet and desktop digital office printers reduced demand for some types of print and reduced other to lower value commodities, commercial printers sought new ways to increase their profit margins.

Advertisers and brand owners have long recognized that appealing to, and engaging customers through their multiple senses in addition to sight will engage their emotions and, if presented effectively, will stimulate a positive response to the brand and its products. Primarily, print advertising and packaging uses color and contrast to capture viewer attention visually. They can further increase customer attraction to product or service by adding the experience of one or more senses — auditory, olfactory, gustative or tactile to the visual. In our very competitive marketplaces, manufacturers and suppliers aiming to attract and hold customers' attention are increasingly turning to multi-sensory advertising, presentation and packaging to gain competitive advantage. In addition, some printing and digital enhancement methods offer attention-grabbing metallic and glitter effects.

3D enhancement adds a third dimension atop two-dimensional prints to increase the visual impact of the message and the perceived value of the printed item. It can also print design and texture elements that entice the viewer to touch the pattern. By stimulating the desire to touch an image, digital enhancement can increase the viewer's attention to and memory of the printed item. Digital enhancement can also print Braille that meets Americans with Disability Act (ADA) dimensional standards. Digital enhancement enables the printing of embossed images that can vary from one print to the next, and cost-effective short-run 3D enhancement. Digital 3D enhancement resides between 2D digital printing and 3D fabrication, aka Additive Manufacturing (AM). Like 2D printing, its primary task is graphic, albeit offering the potential for enhancing substrate structure and function. Like 3D fabrication, it is typically printed in multiple layers, but unlike it, 3D enhancement does not aim to produce objects thicker than a fraction of a millimeter.

Vince Cahill, President, VCE Solutions

How Inkjet 3D Enhancement Methods Produces Embossed Effect

Currently available 3D enhancement printing systems employ UV-curable ink. Most systems use LED curing or a combination of LED and Mercury bulb curing to polymerize the ink. Enhancement inkjet systems use printheads that can produce relatively large drops either through binary mode — as with the Dimatix Nova heads on the Scodix S-series printers — or through grayscale printheads, as with those on the Scodix Ultra, MGI JETvarnish UV, Roland, Mimaki, Direct Color Systems, Autobond and other systems. UV-LED-cured inks enable the printing of 3D layers that can be significantly thicker than achievable with solvent or aqueous-based inks. Systems that scan the printhead back and forth over the substrate or move the substrate back and forth under the printhead can add height with multiple layers of ink. Pinning or curing UV ink when it arrives at the substrate surface and has not had time to flow out will freeze the deposit at a greater height than if allowed to flow out. Columns of clear dots frozen on deposit will scatter light producing a matte to satin appearance. Subsequent clear layers allowed to flow atop and between the first layer of dots will also constrain the subsequent layer's outward edges, producing a gloss finish. Initial layers that are allowed to flow will produce a gloss finish on smooth substrates. While most 3D enhancement systems use clear varnish to produce embossed effects, Direct Color Systems and Dainippon Screen build their embossed effects using white and other print colors.

Other ways to deposit clear 3D coating on printed labels, tags and brand logos employ syringes, manual, peristaltic or gear pumps. Both manual and computer-controlled automated dispensing systems and production lines are available. Label makers have used these "doming" processes for both indoor and outdoor applications since 1997. Typically, doming deposits a clear bubble of urethane or urethane epoxy resin that flows out to the contours of the label. Clear urethanes used for doming are typically composed of a mixture of Polyol and Isocyanate that begin to cure exothermically when combined. The doming makes the label or tag water- and abrasion-proof, and resistant to fading and chemical exposure. Some flexible urethanes can contain mercury, which would make them unacceptable for some applications. Fast curing UV-cure urethanes are also available for doming printing for roll-to-roll processes, but these resins are more expensive than standard doming urethanes, and are prone to yellowing over time. Manufacturers of doming equipment include Development Associates, Inc. of North Kingston, Rhode Island, USA (www.daius.com); Mockridge International Ltd of Lancaster UK (www.mockridge.com); and Fluid Research Corporation of Tustin, California, USA (www.fluidresearch.com) among others.

Inkjet and other print methods can spot varnish with greater detail and can print a wealth of textures that doming cannot.

Market Applications

Applications for digital 3D enhancement have included enhancing, metallic, glitter and embossing effects for folding carton and other package prototyping, short-run packaging production, labels, publication covers, marketing brochures, direct mailings, catalogs, restaurant menus, photo books, albums, greeting cards, calendars, stationery, business cards, invitations and postcards.

A number of 3D enhancement printer manufacturers promote that their devices can print Braille. The US Government Department of Justice Americans with Disabilities Act (ADA) Standards require that Braille dot height be between 0.6 millimeters and 0.9 millimeters, i.e. 600 to 900 micrometers, and "have a domed or rounded shape." Multiple passes with the same inkjet printhead or multiple printheads would be necessary to print materials at a height and shape to satisfy these requirements.

3D Enhancement Printers

Three companies — Scodix, MGI and Roland — have pioneered the use of inkjet for digital enhancement with many others following with inkjet and other digital printing methods, including Dainippon Screen, Mimaki Engineering, Direct Color Systems and Autobond with inkjet and HP, Kodak, Xerox, and Canon with electrophotography.

Scodix Ltd is an Israeli company founded in 2007. It introduced its first inkjet enhancement press, the Scodix 1200, at IPEX 2010. It used the large-drop Fujifilm Dimatix Nova piezoelectric inkjet (PIJ) printheads to print UV-curable clear ink to a maximum resolution of 720 by 360 dpi and a maximum thickness of 250µm. The Scodix 1200 could enhance 550 A3 (500 by 707 millimeter/19.7 by 27.8 inches) sheets per hour. Scodix followed the 1200 with the S Series S75, S75 Pro, S52 and most recently the Scodix Ultra.

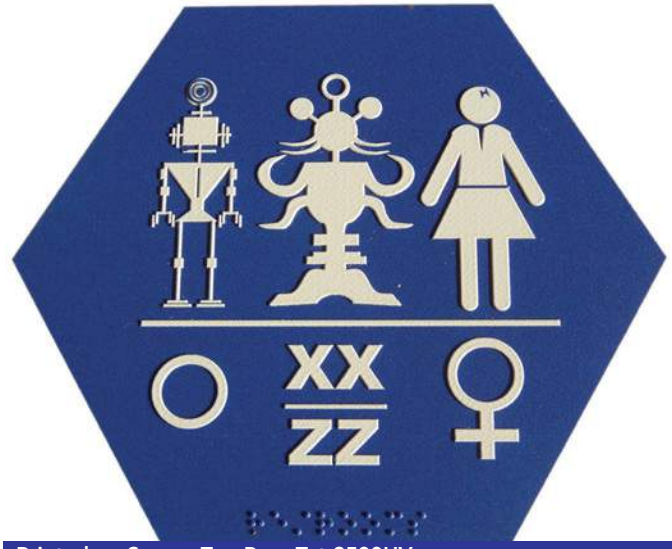
The Scodix S Series S75 can inkjet print B2+ sheets (530 by 750 millimeters/20.8 by 29.5 inches), while the S52 can handle sheets just under half that size, up to B3 format (530 by 353 millimeters/20.8 by 13.9 inches). All three of the S Series devices offer the Scodix

RSP™ registration system with two CCD cameras. Their maximum XY resolution is 2540 by 360 dpi and can print densities from one- to 100 percent. Their UV clear ink can produce a high gloss with up to 99 gloss units (GU). The Scodix Metallic™ can deliver a range of metallic colors. They can process paper with weights from 135 to 675 grams per meter squared or six to 30 point, and card stock up to 0.7 millimeters thick. They can produce printed elements up to 250 micrometers (0.25 millimeters) high.

The Ultra offers digital enhancement at production speeds of 1250 B2+ sheets per hour. It employs a full-width array of Ricoh Gen4L PIJ printheads. Its Scodix RSP™ sheet alignment system used 4 CCD cameras to ensure accurate 3D to 2D print registration. It includes a barcode reader for handling instructions for printing variable data and images. With the Ultra, Scodix has targeted the printing of folding carton packaging at production speeds.

Scodix also produces a "near" line inkjet glitter station, the Scodix Rainbow™, which can print glitter to the same or different locations on printed sheets.

Scodix offers inkjet-driven enhancing systems using robust and reliable printheads. They do not operate inline with 2D printing presses, and process sheets but not rolls. The Company recommends that substrates for use with the Scodix PolySENSE™ clear polymer have surface energy between 36 to 44 dynes per centimeter. Scodix achieves its 3D effects primarily with its clear polymer, but as mentioned above, it also offers glitter and metallic effects.



Printed on Screen TruePressTet 2500UV

MGI Digital Graphic Technology is a French company founded in 1982 with an office serving the Americas and the Caribbean located in Florida, and one

MGI JETvarnish 3D

Image courtesy of Scodix

Image courtesy of Direct Color Systems

Image courtesy of Direct Color Systems

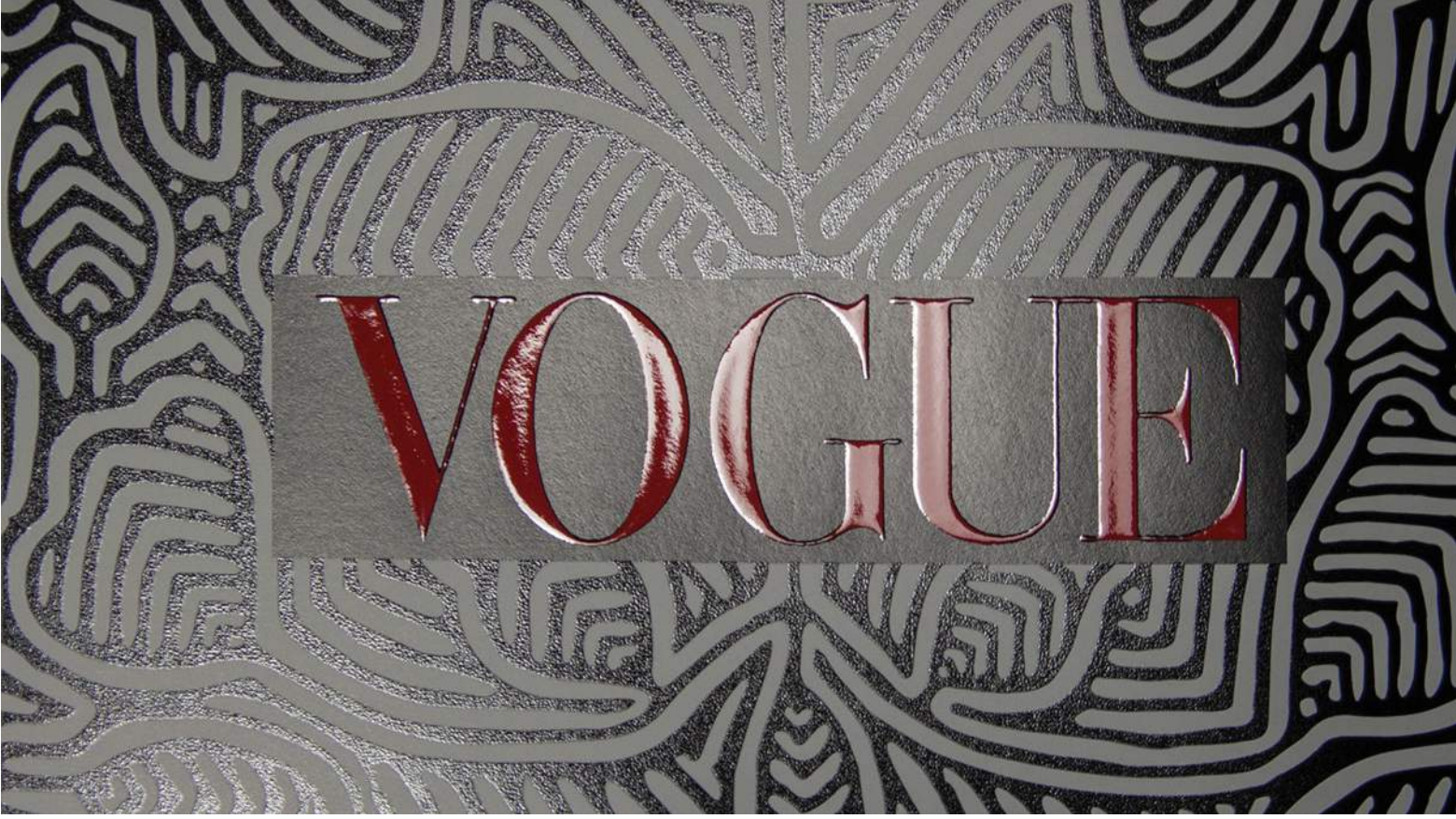
serving Asia Pacific in Singapore. MGI recently acquired CERADROP, a French manufacturer of industrial inkjet printers for printed electronics and photovoltaic cell printing and fabrication. It also acquired KÖRA-PACKMAT Maschinenbau GmbH, a German company producing film wrapping machines, material feeding and collating systems, ultrasonic sealing systems and digital print handling platforms. MGI is listed on the Euronext/NYSE as ALMDG.

MGI manufactures a range of digital printing, coating and finishing devices. Its JETvarnish 3D debuted at DRUPA 2008 and provides single-pass inkjet spot UV 3D enhancement for offset and digital prints. The Company reports throughput speeds of half a meter per second, i.e. up to 3,000 B2 sheets per hour. It offers an extended-format model printing 52 by 105 centimeters (20 by 42 inches) in addition to the standard format — 52 by 74 centimeters (20 by 29 inches). The JETvarnish 3D includes one or an optional two CCD cameras for optical detection of registration marks. It can print its UV clear coating with or without the 3D raise effect. It deposits from three to 100 micrometers of thickness with a single print bar, or up to 200 micrometers with its Twin two print bar option. It also offers variable data printing as an option.

MGI also offers its JETcard 3D for inkjet printing, personalizing, encoding and finishing pre-cut plastic cards with or without magnetic stripes or RFID tags. It can print four to eight UV-curable printed colors, spot or flood coat, 3D emboss, and read and write to magnetic stripes.

In addition to its 3D inkjet devices, MGI manufactures the Meteor DP8700 S & XL 2D color inkjet printers for printing paper, plastic and card stock, along with laminating, cutting, slitting, creasing, scoring and finishing solutions. MGI has invested in the growth side of the print market with its innovative and cost competitive product line. It claims to have the largest installed base of digital enhancement production lines.

Roland DG of Japan in September 2013 added the VersaUV LEF-20 to its line of bench-top UV printers, which includes the LEF-12 introduced in 2011. The LEF line joins the VersaUV LEC wide-format line of printer/cutters providing UV-LED curing and 3D enhancement, and the VersaUV LEJ-640 64-inch wide hybrid flatbed/roll-to-roll inkjet printer. The wide-format VersaUV LEC 300A, LEC 330 and 540 inkjet printer/cutter models can print CMYK plus white and clear, crease, 3D print emboss, varnish and contour cut. They have become essential tools for folding carton prototyping. They also provide short run and specialty labels,



membrane panel printing and pre-press proofing applications. Three-dimensional effects are only available with its ECO UV inks, for which it provides both matte and gloss clear in addition to CMYK colors. Roland's LED clear coat curing procedure enables a choice of gloss or matte finish. For a matte finish, the clear ink is deposited and UV cured at the same time. For gloss finish and a 3D embossed look, the inkjet deposits and cures a first layer then follows with a second layer without immediately curing to allow it to flow out producing a gloss finish. The printer then automatically returns to the print origin to begin the final UV curing process. Roland also offers its ECO UV-S inks for 2D applications requiring flexible prints, such as flexible packaging prototypes. Roland claims its ECO UV-S inks offer flexibility of up to 220 percent.

Roland employs six Epson DX4 PIJ printheads for the LEC 300A, 330 and 540, LEJ and LEF printers. Each head has two rows of 180 nozzles per row for 360 nozzles per head. Roland incorporated ink recirculation for its white ink channels. The Epson heads can produce grayscale high-resolution images and 3D effects printing clear with multi-pass scanning. The DX4 head is relatively old technology that is less robust and durable than heads used on the Scodix and MGI printers. A DX4 head also requires alignment with installed heads during replacement. DX4 heads, however, are less costly than the heads on the Scodix and MGI printers, and are readily available from third-party suppliers.

Mimaki Engineering Ltd. of Japan offers its UJF and JFX line of UV-LED inkjet printers that can also build multiple gloss layers to produce embossed-look 3D effects. The small-format UJF-3043FX and UJF-3042HG and medium-format UJF-6042 offer 3D embossed effects with LED UV curing on promotional products, novelties, cell phone covers, nameplates, business cards, book and album covers and small signs.

Dainippon Screen has demonstrated the printing of Braille signage with its Truepress Jet2500UV, building the image with multi-passing of its grayscale PIJ printheads printing CMYK, Lc, Lm and White.

X-JET and X2 from Inkcups Now (Danvers, Massachusetts) offer robust UV LED inkjet printers using Ricoh Gen4 grayscale printheads shooting seven, 14 and 21 picoliter drops. Inkcups Now targets the X-Jet as an industrial production printer primarily to the promotional products industry. The X-Jet mirrors the Mimaki UJF-706 except it uses UV-LED rather than the mercury bulb UV of the UJF-706. Inkcups Now does not promote the X-Jet or X2 as 3D enhancement printers, yet they appear to have the capability to perform 3D decoration.

Digital Color Systems (DCS) of Connecticut designs and manufactures thermal transfer and inkjet printing systems. The Company has focused on desktop to tabletop-sized formats for its product line. Its Direct Jet 1024UVHS and 1024UVMVP use Epson eight-ink channel printheads to deposit its Multisolve™ IR2 UV LED ink in CMYK colors plus clear and white. It supplies its UV ink in 200- and 500-milliliter bulk containers and offers automatic ink stirring for its white ink reservoir to prevent the settling of pigment. It recommends the addition of its adhesion promoter for printing on nonporous surfaces like metal, glass, ceramic and rubber.

DCS provides its ADA Sign Maker with Color Byte 9 software. Its software also enables extensive user control of print characteristics.

Emphasizing the profit potential of Braille printing, DCS CEO Blair Allen, said that its "1024UV printers can produce a six- by eight-inch ADA compliant sign in 220 seconds for a cost of $1.71." He also indicated that its Direct Jet systems have been able to deposit 0.020- to 0.030-inch (508 to 762 micrometers) thick layers with a single pass. DCS also offers compatible InkMark UV matte metal and acrylic substrates for use with its UV printers.

Autobond of the UK manufactures laminating equipment with inline UV LED cure inkjet spot varnishing systems

that can produce 3D effects atop the laminated film. The company offers B1, B2 and B3 format models, all using XAAR 1001 PIJ printheads, which offer 14 drop sizes. Autobond demonstrated its Mini 76 TH laminator/enhancement printer, which processes formats up to 30 by 41 inches, at Print 13 in Chicago.

Digital Production Printers Incorporating 3D Enhancement

Hewlett Packard has partnered with the TRESU Group to add its iCoat coater to operate inline with the HP Indigo 30000 liquid toner printer for post-print selective coating with both UV curable and aqueous chemistry. Scodix has also demonstrated its ability to 3D enhance HP Indigo output with embossing and metallic effects.

Kodak has added the choice of enhancing features to its dry toner electrophotography NexPress with its fifth inline imaging unit. These include dimensional dry ink, expanded gamut colors, red fluorescing dry ink, gold ink and a matte finish option in addition to inline UV curable coating for glossing.

Xerox now offers the Epic CTi-635 UV inline coater for use with its iGen4 color electrophotography printer and spot coating with flexo plate technology. It also offers the Rollem Jetslit for slitting, cutting, perforating and creasing; and the Stora Enso Gallop DC 58 buffering stacker and die cutter targeting short-run folding carton solutions for the high-end pharmaceutical packaging market.

Canon has added clear tone varnish and visual texture treatments ranging from subtle to bold for its color laser imagePress C1+II.

Mimaki UJF-6042

Direct Color Systems 1024 UV MVP

Conclusions

Applications for digital embossing and 3D effects on printed substrates are growing as these effects attract and engage customers in an increasingly competitive marketplace. Dimensional clear coating and doming also add durability to labels and brands. The growth of digital enhancement will likely continue for some time as it has proven its value and is in its early stages of development; it is far from saturating the market.

Also, new applications and functions for 3D print enhancement lie ahead as digital 3D enhancement provides a bridge between 2D print and 3D Additive Manufacturing. Printed 3D patterning can add structural strength and functional characteristics to printed surfaces. Combined with printed electronics and optics it can provide many new opportunities.

Vince Cahill is president of VCE solutions, which provides consulting services for Fortune 500 and other companies operating in the analog and digital printing and fabrication industries. He also was a principal in The Colorworks, in which he has a 35+ year career in specialty graphics. Cahill has served as CEO of Datametrics Corp., principal and technology developer for Newhill Technologies, as well as principal of Specialty Materials. He is a longtime volunteer with SGIA, serving on various committees. Cahill has contributed several articles to the SGIA Journal.

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