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Introduction

Ink Jet printing and UV-curing technologies have developed in parallel. Manufacturers have integrated ink jet print heads, printing mechanisms, UV-curable inks and UV curing systems to address a number of industrial printing needs. The Marking and Coding Industry has employed ink jet printed UV-curable inks to decorate the sheathing of wire and fiber optic cable, automotive hoses and packaging. Currently, manufacturers of graphic arts printing systems are adopting UV-curable inks for use with ink jet printing. Analog printing equipment manufacturers also are adding UV-curable ink jet printing to analog printing processes to combine digital printing's ability to print variable information with the high speed and quality capabilities of analog printing. Ink jet and UV-curing are now building layers of photopolymers for rapid prototyping. These developments and initial market demand for these new systems presage the growth of UV-curable ink jet printing for sign and industrial applications. The requirements and limitations of ink jet technologies continue to present challenges for its successful application of UV-curing, but advances in UV-curable ink chemistry are satisfying the requirements of ink jet technology and market applications.

Early Developments

The development of radiation curing of polymers parallels the development of ink jet and other digital printing technologies.

Ink Jet Origins - Although one could point to experimental ink jet recording devices as early as Lord Kelvin's patent for an ink jet "Receiving or Recording Instruments for Electric Telegraphers" in 1867 [1] and other patents prior to 1951, it was in that year that Siemens produced the first commercial ink jet recorder based on Elmquist's patent.

Photopolymer Origins - The 1950's also saw initial research into the photopolymer precursors of UV curing chemistry. The 1960's witnessed further development of photopolymer chemistry and ink jet printing. During that decade major chemical companies, such as Dupont, W.R. Grace, and Celanese developed photopolymer technology. They applied it primarily for making printing plates. PPG developed electron beam and UV curing for photopolymers for curing coatings for wood and composite substrates.

Early Ink Jet Developments - In 1966, Teletype developed the Intronic deflected jet continuous ink jet printer. In 1968, Swedish scientists, Hertz and others, developed a high-resolution continuous ink jet technology that eventually found application for color proofing of publication copy and fabric designs. Richard Sweet of Stanford University proposed an ink jet imaging system for A.B. Dick. The company's Videograph Division used the Sweet and Cummings patent (1968) to develop the first commercially successful ink jet, which it introduced in June of 1969.

A.B. Dick placed one of these high-speed printing systems with a Milwaukee, Wisconsin brewer, which had been trying unsuccessfully to find a way to date and code its beverage cans to keep pace with its line production of 2,000 cans per minute. The Videograph ink jet met the brewer's requirements and so began the Digital Marking and Coding Industry. Videograph Division evolved to Videojet Systems International and in December of 1999 to the current Marconi Data Systems. Over the years other companies, such as Imaje, Domino, and Trident, have offered their own continuous and piezoelectric drop-on-demand ink jet systems to satisfy the growing needs of this market.

UV-curing and Ink Jet - A number of these companies developed UV curable ink systems for their ink jet printing systems to address customer demands. These included challenging applications that required rapid processing, abrasion and chemical resistance, long messages, and difficult to print irregular surfaces. Industry employed digital ink jet systems to print UV curable inks onto automotive hoses, jacketed wire, bundled optical fibers and packaging. Most marking and coding applications, however, employed fast-drying solvent-based inks. The current Marking and Coding Industry currently sells over $2 billion in printing systems and consumables per year, but only a small portion of which involves UV curable inks. Ink jet marking and coding applications include the coding of cans, bottle and other packaging, bar code printing of packages and labels, data printing, and cable marking. Another beverage company, Coors, began decorating their beer cans using offset lithography and UV curable inks and varnishes. Today billions of beverage cans are marked with ink jet coding and some labeled with UV inks.

During the 1990's, the manufacturers of UV-curable inks continued to improve their products and increase market share over solvent-based inks. UV-curable inks became the chemistry of choice for screen printing compact disks, chemical resistant signs and point of sale displays, offset printing covers for annual reports, high quality brochures, magazines, books and directories, and value-added packaging, flexograph and letterpress printing of high quality labels. Almost all of letterpress label printing of self-adhesive labels grew to employ UV-curing of its inks. UV lamps have now become standard equipment on multicolor web label presses.

In the late 1990s, thermal ink jet manufacturer, Canon, also explored the use of aqueous UV curable inks with its thermal Bubble-jet system. NOGUCHI and SHIMOMURA reported that the use of this UV-curable ink system improved print quality, fastness and drying speed for printing on paper.[4]

Why UV-Curing for Ink Jet Printing

The use of UV curable ink with analog printing methods, including flexography, gravure, offset and screen process, is growing at a rate that exceed the growth rates for the use of these processes. For example, "the total flexographic ink market for labels is projected to grow at 3% per annum, whilst UV-curing ink is growing at 17%."[5] The Printing Industry has been adopting UV-curing inks and coatings because they:

- Emit little to no VOC solvents reducing worker exposure to hazardous substances and environmental pollution
- Will not dry during print process before curing, but will dry almost instantly when cured
- Permit high production throughput rates
- Can produce the highest ink printed gloss available and high quality matte and satin finishes
- Offer a large variety of adhesives, clear coating and ancillary chemistries
- Produce durable abrasion and chemical resistant prints
- Provide consistent ink composition throughout the length of print runs without solvent loss
- Do not produce set-off using impact printing processes
- Are compatible with each other
- Use curing equipment that occupies much less space that conventional thermal drying conveyors
- Continue to improve

Ink manufacturers invest in UV-curable ink research and product development due to the Printing and Coating Industries' growing adoption of this technology. The US Environmental Protection Agency views UV-curable inks as a green technology that it deems preferable to conventional solvent-based ink systems. While many Air Quality Management Districts restrict and control the emissions of VOCs from solvent-based ink systems, solvent-less UV-curable systems are exempt from those restrictions and avoid their resulting costs. Continuing research and development produces continual improvement, which in turn results in product improvements and additional applications. This positive spiral along with the regulatory costs associated with solvent-based inks, continue to persuade printers and coaters to adopt UV-curing. In addition, UV-curable research has removed or reduced many of the objectionable characteristics of earlier UV-curable ink systems. Many newer formulations have reduced user allergic reaction incidents and objectionable odors in addition to providing improved ink film performance.

UV-curable inks, however, remain higher (approximately 2x) in material costs than most oil- and solvent-based inks, still require special handling procedures [5], and deposit a thicker ink film than most solvent-based inks that can interfere with desired print performance.

Despite the drawbacks associated with UV-curable chemistry, manufacturers of ink jet printing systems have sought UV-curable solutions to satisfy their customers' demands for the positive print characteristics that UV-curable technology could provide. UV-ink chemistry also solved one of ink jet's difficulties, the tendency of solvent-based inks to clog ink jet nozzle orifices when not continuously firing.

UV-Curable and Digital Printing: Current Developments

Ink jet piezoelectric print head manufacturers, XAAR and Spectra, have developed models of their print heads specifically for using UV-curable inks. Both SunJet (formerly Coates) and Sericol have developed inks for Spectra print head, while Sericol and others have developed inks with XAAR for its print systems. Flint recently offered a UV-curable ink jet ink set for Spectra print heads. Dupont, Lyson, Inkware, Avecia and other ink companies are also reportedly developing UV-curable ink systems for use with ink jet printing. Currently, almost every major manufacturer of ink jet printing equipment for graphic arts applications is developing systems for use with UV-curable inks.

A number of manufacturers of analog printing systems are marrying ink jets to their analog printers for supplying variable data printing.

Chromas Technologies and the **Digital Label Alliance** introduced their Argio 75SS ink jet printing system at Labelexpo 2000. Chromas designed the Argio 75SS to retrofit to a range of analog presses adding multi-color digital variable data capability. It uses Spectra print heads firing UV-curable color inks at 600 dpi with a print width up to 7.6 inches. Chromas reports that the Argio can print "almost any substrate at a speed of up to 100 ft/min."[9] Chromas offers the Argio in-line with its series of flexographic tag and label printers.

Heidelberg exhibited a high-speed piezo ink jet variable information printing system at Drupa. Spectra 600 dpi print heads delivered high-speed high-resolution one color UV-cured prints. It will be configured to add digital printing processing of variable data to offset presses. The Heidelberg developers indicated that they expect to have their system ready for market in 2002-2003.

In addition to the hybrid of ink jet and analog printers, a number of manufacturers have developed stand alone ink jet systems for use with UV-curable inks.

Barco Graphics debuted "the.factory" (pronounced the dot factory) in 2000. It uses the Xaarjet 500 drop on demand piezo grayscale print heads and is designed to print a maximum width of 63 cm on up to 65 cm wide material with at least four colors plus additional spot colors by increasing the number of color bars. It is reported capable of printing 800 square meters per hour with 8 gray levels and prints UV-curable inks. The system consists of a roll-to-roll material handling system with corona pretreatment for flexible plastics and UV-curing post-treatment. The system is designed to regularly purge and clean its print heads to prevent nozzle blockage and is designed for industrial printing applications.

The.factory uses Xaar's gray scale print heads that vary drop volume to produce different tints of ink. This also increases the apparent resolution to photographic quality.

Barco brings its extensive software and workstation experience to the design of this system. It comes with information management, variable data control and merging, job control, RIP, and color management software. Barco has yet to install production versions of the.factory. It reportedly is hoping to place five production units before the end of 2001.

Inca, a British integrator and equipment developer, debuted its Eagle 44 wide-format flatbed ink jet press at Drupa in May of 2000. This device marked the beginning of UV-curable printing for wide-format color printing. It featured Xaarjet 500 piezoelectric print heads and used Sericol four-color process CMYK UV-curable Uvijet digital inks. Inca recently exhibited a smaller Eagle-type device with Spectra piezo print heads. The current Xaarjet version prints both flexible and rigid substrates up to 40 mm thick and boards 96 in. x 53 in. from edge to edge that are held on a moving vacuum flatbed with pin registration. It can print up to 950 sq ft/hr at its lowest resolution 360 dpi poster mode, 600 sq ft/hr in a 360 dpi standard mode, 540 sq ft/hr at a 360 dpi HiQ (high quality) mode, and 300 sq ft/h at its highest resolution 720-dpi Backlit mode. Wasatch SoftRIP 4.3 software drives the Inca Digital Eagle 44. This Raster Image Processor (RIP) enables the use of other layout and image-editing programs, provides image tiling, and permits queuing and easy switching between print jobs.

The Sericol Uvijet ink uses automotive grade pigments that enable outdoor durability and extended light fastness. This ink system adheres to a variety of materials including standard cardboard and paper, plastic films, metals, wood and glass.

Sericol is distributing the Inca Eagle under the name Sericol Imaging. It claims that its instant ink UV-curing results in minimum dot gain, high print quality and color consistency over a range of materials. The Eagle has been operating at production sites in the UK. Sericol says that it will be launched in the US 4th Quarter 2001 and will be available for sale 1st Quarter 2002.

Durst created its Rho 160, Large Format Direct Digital Production Inkjet Printing Press for the commercial photographic and screen printing markets. It introduced the Rho 160 with Xaarjet 500 piezo print heads to produce four-color process images with UV-curable inks. It is reportedly discontinued its use of Xaar print heads and will offer the printer with Spectra print heads. This will increase its resolution to 600 dpi. Durst specially designed this device to print both uncoated roll media and rigid boards up to 160 cm / 62" wide and rigid material up to 40 mm / 1.58" thick. The Rho 160 can hold media rolls up to 400 m in length. Its Xaarjet version operates at a maximum output speed of 60 m^2 per hour at 360 dpi and at 40 m^2 per hour for greater image quality. Its Unix workstation includes the Durst Dice America Cheetah RIP. Its auto-spooling and monitoring features permit its unattended operation.

Zünd, a plotter manufacturer located in Altstätten, Switzerland, acquired Perfecta and assumed its digital printer sales for the Combiprint UV120-F for flatbed printing of rigid and flexible substrates up to 1.2 meters wide and ZÜND Combiprint 215R (roll to roll) for textile and flexible substrate printing up to 2.16 meters wide. Both devices use four Xaarjet 500 piezo ink jet print heads for printing CYMK four-color process images at 180 or 360 dpi resolution. They use in-line UV-curing lamps. Both use Sericol's Uvijet RB automotive grade pigmented inks.

L&P Digital Technologies, a Division of Leggett & Platt, introduced the Virtu MT, a wide format ink jet for printing roll-to-roll fabrics, vinyl and paper at DPI 2001 in April at Atlanta. It was originally designed to print quilt and mattress cover cloth. It employs eight bi-directional Spectra print heads producing up to 720 dpi and eight colors. It can produce 2250 square feet per hour with 100% coverage. Its introductory version uses UV-curable inks, which it developed with SunJet (Coates), the HueV ™ UV system. The company reports that HueV inks are durable outdoors up to one to two years depending on exposure intensity. The company supplies its UV-curable inks in collapsible and disposable five-liter containers to eliminate the worker skin contact exposure with the ink chemistry. It also plans to offer both solvent and water-based inks. The company has also announced that it will offer two other models of its Virtu line of digital printers. It will introduce the Virtu RS at SGIA 2001 in Anaheim in September. The Virtu RS will provide roll-to-roll processing for flexible materials or flatbed printing for rigid graphics substrates. L&P will offer a wider format model, the Virtu TX, by the end of 2001. It is designed for printing roll-to-roll for textiles and flatbed for signage.

L&P also supplies an array of software running under Windows NT. It provides continuous production information and job status that monitors the systems scheduling, printing and curing process. Its Virtu RIP manages up to eight colors.

Leggett and Platt through its L&P Digital Technologies Division developed its Virtu ink jet printing systems initially for the internal manufacturing functions of company divisions. It stepped in to satisfy its own needs for an industrial printer and realized it could provide the same solutions for other users.

Objet Geometries, an Aran Company of Rehovet, Israel developed a rapid prototyping device, the Objet Quadra, employing ink jet application of UV-curable polymers. It introduced the Quadra at Euromold 2000, Frankfurt, 29 November 2000 and is beta testing it at Eastman Kodak Company in Rochester, New York, Ford Motor Company in the UK, and at Aran's Rapid Prototyping Service Bureau in Israel.

The Quadra builds three-dimensional models employing ink jets with 1536 nozzles that deposit and UV-cure 20 micron layers of Objet's proprietary photopolymer. The system also deposits removable support materials that one can separate from the model mechanically. It prints 600 dpi on its x-axis, 300 dpi on its Y-axis and 1200 dpi on it Z-axis. It can build parts up to 270 x 300 x 200 mm (10.6" x 11.8" x 7.8").

Others

Other industrial and flatbed inkjet printing devices are available that can use UV-curing systems. Printers from Tampoprint, and Sias also use Xaarprint 500 piezo inkjets. Vutek offers systems with Spectra print heads. Dupont is offering its *Artistri™ Technology,* which includes Dupont ink chemistry, the Dupont Ink Jet 3210 Printer, a Vutek built system with Spectra heads for textile printing, and color management and system software. Aprion is planning to offer its printing systems with UV-curable capability in the near future.

Conclusions

Sign and screen printers are attempting to acquire ink jet printing with UV-inks. Some technical difficulties have delayed delivery of some systems, but production systems are currently operating at print establishments. The attractions of the combination are many. Ink jet printing device like those from Barco, Inca, Durst, Sias, Zund, Tampoprint or Leggett and Platt can:

- Eliminate the cost and time for making films, plates and screens and set up
- Print short-run and one-of-a-kind images economically
- Permit variable information printing and customization
- Can print for long term outdoor durable images
- Eliminate the cost and waste associated with lamination from many application

- Print a wide range of flexible substrates including paper, textile fabrics, banner materials, vinyl, polyester, polycarbonate and other plastics. The flatbed models can also print rigid substrates, such as rigid plastics, wood, glass, tile, metal, and foam and corrugated board.

One can expect UV-curable inks and ink jet multicolor printing to grow to supply an increasing part of the demand for P.O.P. advertising, display graphics, posters, signs, banners, rigid boards, outdoor graphics, exhibition and stage graphics, architectural graphics and murals, backlit displays, flags, fleet and vehicle graphics, bus shelters graphics and bus wraps. UV-curable inkjet inks are much less substrate dependent than water, oil and solvent-based ink jet inks. The Leggett and Platt example of using UV-curing for textile inks suggests additional possibilities for fixing and curing textile dyes and other colorants.

Hybrids of UV-curable ink jet and analog printing processes are also entering the market for high-speed label and commercial printing.

Ink jet printing coupled with UV-curing of polymers can also create three-dimensional objects for rapid prototyping and other applications.

The marriage of ink jet and UV-curing technologies is growing to meet the needs of commerce and industry. UV-curable technology is poised to repeat the rapid growth with ink jet printing that it produced with analog processes over the past two decades.

References and Sources

1. Jean Philippe STEFANINI, "Ink Jet For The Textile Industry", Toxot Science & Applications, Bourg les Valence, France, 1994, p.4

2. Jerome L. JOHNSON, "Principles of Non Impact Printing", Irvine, CA: Palatino Press , 1986

3. Hue P. LE, "Progress and Trends in Ink-jet Printing Technology", Journal of Imaging Science and Technology, Volume 42, Number 1, January/February 1998, p. 49-62

4. Hiromichi NOGUCHI, Canon Inc., "UV Curable, Aqueous Ink Jet Ink: Material Design and Performance for Digital Printing", Proceedings of IS&T's NIP 14 International Conference on Digital Printing Technologies, 1998, p. 107-110

5. Nigel CAIGER, "Industrial Application of UV-Curing Jet Inks", Rad Tech

6. Richard J. BAKER, "Practical Considerations for Using UV Reactive Inks in Piezo DOD Printheads", Proceedings of IS&T's NIP 15 International Conference on Digital Printing Technologies, 1999, p. 111-115

7. Nigel CAIGER, "Oxygen Inhibition Effects in UV-Curing Inkjet Inks", Proceedings of IS&T's NIP 15 International Conference on Digital Printing Technologies, 1999, p. 116-119

8. R.W. STOWE, "UV Processing of Digital Printing", Proceedings of IS&T's NIP 15 International Conference on Digital Printing Technologies, 1999, p. 306-309

9. Flexo Market News, February 14, 2001, Special Wednesday Edition, N.V. Business Publishers, Northbrook, IL 60062, p.3

Biography

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