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Detailed Overview Over the Book Chapters

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(1) Knowledge, expertise, and experience in a wide range of different fields is needed to compile the "inkjet system solutions" that allow successful development and implementation of inkjet technology in industrial applications.
Impossible for an individual to master all the required areas.
This "handbook of inkjet printing in industry" therefore compiles chapters written by experts from the various fields, and thus can serve as guidance when developing inkjet applications for use in the laboratory or on the manufacturing floor.
The sketch in Figure 1.1 gives an overview of the topics addressed in the handbook.
Basis for developing a successful application of inkjet printing in industry is knowledge and expertise in many technical areas as well as legal, ecological, or further fields.
Capabilities and limitations from the various fields must be assessed, interfaces and interactions be evaluated, and potentially tuned toward obtaining appropriate "inkjet system solutions" to enable specific inkjet printing applications and their implementation in industry.
The bi-directional arrows in Figure 1.1 should point out that on the one hand printheads, materials, and processes define the range of potential applications. On the other hand, "inkjet system solutions" are often application-driven, thus requiring further developments in materials, printhead, and process technology.
Inkjet printheads, inks, and substrates are three major players in an inkjet system, and their interaction and interfaces are essential.
Software provides flexibility in inkjet drop formation, image definition, error compensation, etc. Metrology techniques are essential to quantitatively evaluate capabilities and limitations. Pre- and post-processes enable the extension of capabilities of image, film, and pattern formation.

Inkjet Printing in Industry: Materials, Technologies, Systems, and Applications, First Edition.
Edited by Werner Zapka.

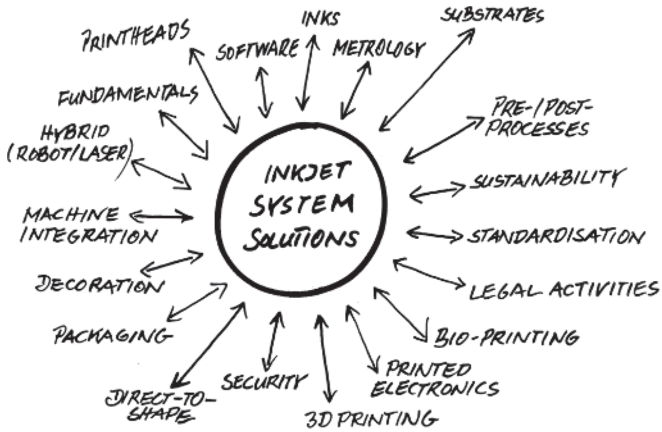

Figure 1.1 Topics that are covered in this handbook.

Sustainability is of ever higher importance. On the one hand the digital printing approach is of advantage, allowing "additive" instead of "subtractive" processing and thus saving material, resources and reducing waste. On the other hand, inkjet printed media are notorious for poor de-inking, thus causing problems in recycling. Therefore, de-inking performance should be considered in an inkjet system solution.

Standardization and legal aspects should also be addressed.

Machine integration is key and central to implementation of inkjet printing in industry. At this point, all hard- and software, processes, and materials are combined. If the specific application requires capabilities beyond inkjet printing alone, then hybrid solutions combining inkjet with laser, robots, or other technologies can extend the capabilities further.

Numerous applications of inkjet printing are already in use in laboratories and for manufacturing. The further extension of existing applications and the development of new applications will contribute to tougher specifications and higher requirement to the future "inkjet system solutions," which in turn will require further improvement and innovation from printhead, materials, and processes.

Inkjet technology remains an exciting field. Let's stay tuned in.

In the following, you find short summaries of each individual chapter in this handbook with the respective numbering in brackets for the table of content.

Fundamental Aspects

(2) S. Hoath addresses "wood grain", an important problem and issue of industrial inkjet printing, caused by aerodynamic effects when drops are jetted at high frequency and often at high print distance. In high detail the effects of drag and gravity forces, wakes and vortices, and of print distance on the motion of drops in air are described for single- and multi-nozzle jetting. Focus is laid on the

study of “wood grain” and approaches to minimize its effect on print quality. An extensive reference list invites for further reading.

(3) P. Smith presents an overview of the growing understanding of inkjet drop formation and jettability. With the Reynolds number, Weber number, and Ohnesorge number, the Z-number could be used as prediction whether an ink would print. Continuing work based on observations when and why the Z-number gave wrong prediction led to further understanding, like the Capillary number, to determine the jettability window of inkjet inks.

Pros and Cons of Inkjet Printing

(4) G. Hübner, I. Reinhold, W. Voit, O. Buergy, R. Askeland, John Corrall, and W. Zapka address the question whether digital inkjet printing or analogue printing techniques like screen printing should be used for a specific application. The technical capabilities and limitations of these technologies are outlined and supported by examples of processes and products from the respective techniques.

Inkjet Inks

(5) A. Kamyshny, E. Sowade, and S. Magdassi give an overview of inkjet ink and fundamentals of ink formulations. UV-inks have become dominant in inkjet printing and are therefore covered in detail.

(6) J. Baro and Ch. Fleckenstein review UV-curable alkenyl monomers and oligomers as the backbone chemistry of UV inkjet inks. The review starts with a historical background and formulation basics, and the description of radical photopolymerization and radical stability. Thereafter, in very high detail, the performance profiles and application characteristics of the following classes are covered in high detail: UV-curable alkenyl monomers and oligomers; water-compatible UV-curable alkenyl monomers and oligomers, as well as product innovations and technology perspectives of new UV-curable alkenyl monomers and oligomers. The review is supported by an extensive reference list.

(7) K. Dietliker and Z. Li give a highly detailed review of UV-photoinitiators for inkjet applications. Focus is on photoinitiators for radical curing, with type I, type II and bifunctional photoinitiators, and their respective classes. Specifically, photoinitiators for low-migration UV inks for food packaging are covered, focusing on photoinitiators for UV-LED curing. The development of water-based UV photoinitiators for UV-LED curing with their advantages for environment and safety is described. Cationic photoinitiators are addressed. An extensive reference list covers the field of UV photoinitiators.

(8) M. Graindourze describes UV-inkjet inks and their various applications in industrial inkjet printing. Advantages of free radical and cationic UV ink types

are described, as well as the UV-curing processes and the required match between each UV ink and curing process. The production process of UV inks and their applications are outlined with a focus on low-migration UV inks for food and pharmaceutical packaging.

(9) Th. Paul focuses on UV-inks for label printing as used in Labelfire 340, a hybrid label-converting system. General aspects of ink development are presented, specifically of the selection of white and color inks and the pigments' effect on ink viscosity. Ink stability and test methods are addressed and failure mechanisms like thermal polymerization or ink aggregation are outlined, as well as test methods for control of performance after UV-curing like substrate adhesion and shrinkage. Regulatory requirements for inks for indirect food contact are addressed.

(10) D. Illsley and N. Caiger describe EB-inks and mechanism of EB-curing, focusing on free radical polymerization and crosslinking of polymers. The key technical differences of EB and UV curing are outlined. Raw material selection for EB inks is discussed, as well as the EB-curing process and relating factors together with materials enhancing EB curing. Water-based EB-curing inks are addressed as well.

(11) Ming Xu presents dye sublimation inkjet inks as used in direct printing and specifically in transfer printing. Advantages are presented like no need for pre-treatments, and eye-appealing colors as for decoration printing onto textiles and garment. Typical sublimation inks, transfer media, and substrates are outlined, and the process engineering aspects of transfer printing covered in detail. Finally transfer printing is compared with direct printing, and an outlook given on future developments.

(12) A. Martinez and B. Rudersdorf describe the properties, the formulation, and preparation of ceramic inks, digital glues, and coatings as used for inkjet printing in the tile industry or related applications. Requirements for the inkjet printhead and print process are addressed.

(13) G. Promis, T. Villwock, and B. Carnes present security inks for authentication and tracking, focusing on magnetic nano particle MICR inks and on INKcrypt® with custom functionalized DNA. Various application areas are described as well as the ink security levels, which relate to the difficulty of identifying reproduction (counterfeit) or fraudulent manipulation (tampering).

(14) F. de la Vega and co-authors give an overview of the formulation and the manufacturing of nano-particle metal inks for prototyping and mass production of printed electronic devices.

(15) Ch. Boeffel, M. Gensler, and A. Wedel present the successful formulation of inks and the processes for printing functional organic electronic devices like OLED-displays, organic solar cells POV, and quantum dot QD-displays. Further development toward higher resolution QD-displays is addressed as well.

(16) J. Ortiz covers legal aspects of the formulation of inks for the regulated market of food packaging that require stringent component purity selection, manufacturing process control, quality system management, and change control. The US and EU regulatory regimes are described. Food packaging as a system is addressed, with details on the substrate barrier performance and guidance on

ink formulation chemistry. The importance of the ink chemist and regulatory team relationship is described as key part of the ink development framework.

(17) A. Fischer draws attention to de-inking of inkjet printed media. Though a well-known problem, it is often neglected in application development. The issues, with and the capabilities of de-inking processes as needed for successful recycling of media, are described.

Inkjet Printhead Technology

(18) J. Przybyla and S. Simske give an overview about continuous CIJ, piezo-, and thermal TIJ inkjet printheads with focus on Hewlett Packard's TIJ printhead technology, including a case study on HP's page wide XL printer series, as well as HP's printhead and process technologies for 3D printing.

(19) A. Tomotake describes the technical details of Konica Minolta's bulk- and thin-film PZT printheads. Focus is on features like ink-through flow and Parylenecoating; a stainless-steel nozzle plate and velocity and volume compensation per nozzle is meant for high-precision applications like display manufacturing. See also KM's print results at high distance in G. Hübner's chapter.

(20) B. Paulson presents Fujifilm Dimatix's approach to inkjet system development and an overview of Dimatix's bulk piezo and MEMS printheads, together with an overview of application areas.

(21) A. Condie and J. Brühnal explain Xaar's bulk piezo printhead technology with focus on shear-mode operation with chevron architecture and ink throughflow at the nozzle, providing improved ink latency and capability to print higher-viscosity inks.

(22) A. Eranpurwala gives insight in Seiko Epson's printhead development with consecutive improvements leading to the Seiko RC1536 printhead. A study of printing at high print distances is included.

(23) K. Taira, M. Shimosato, and K. Adachi provide an overview over ToshibaTec's development of their inkjet printhead portfolio, including printheads featuring, e.g. drop volume compensation, and ink-throughflow; the latter allowing jetting of high-viscosity inks.

(24) T. Roetker explains Memjet's printhead architecture in detail. Present thermal inkjet MEMS printheads feature very high nozzle count for page wide printing at very high print resolution; silicon nozzle plates and high drop velocity provide high dot placement (see also Memjet's print results at high distance in G. Huebner's chapter). Memjet's future mechanical MEMS technology is outlined.

Substrates

(25) T. Wiegel, L. Parthier, U. Peuchert describe in detail different glass materials regarding their physical/chemical characteristics. Focus is laid on measurement of surface properties and on pre-treatment of glass surfaces like cleaning or modification of surface energy before inkjet printing.

(26) P. le Galudec shares his experience on coating substrates to match ink performance and to meet user requirements, covering the various issues, demands, and solutions posed in development and manufacturing of the various substrates from office paper and films, to fine art paper and outdoor signage and displays.

(27) W.A. Schmidt, E. Martorana, and M. Jocher cover paper and paper-based substrates for industrial inkjet printing. Bulk and surface properties are addressed that affect inkjet printing. Various types of coated paper are described with focus on sublimation paper as used for transfer printing.

Metrology

(28) T. Tuladhar presents in high detail various techniques to measure the complex rheology of inks, and he correlates the results with the jetting behavior. Such correlation can be used to predict jetting performance, thus to select promising ink candidates, monitor batch-to-batch variations in ink manufacturing, and more.

(29) W.D. Bachalo introduces the phase Doppler interferometry (PDI) technique for the measurement of inkjet droplet size, velocity, and trajectory. Features are high measurement accuracy of drop size and velocity and very high data rates. A detailed description of the operating principle of PDI is provided together with results obtained from a turnkey PDI system specifically designed for inkjet measurement applications.

(30) Y. Kipman, P. Best, and K. Pucci present Image Xperts' drop watcher technology and print quality analysis. Stroboscopic image capturing and image analysis for measurement of drop velocity and volume is described as well as detection of jetting defects. A print station can be combined to assess various print quality defects.

(31) J.E. Holmes and E.S. Betton outline automated measurement techniques as essential part of the product development cycle. In a sequence of tests the essential components (printheads, inks, and substrates) are tested, the integration tests compared with the expected performance, and system tests are carried out.

(32) I. Trachanas outlines the process and tools for print quality control of single-pass printers, focusing on color density unevenness and white lines. The process involves calibration of the tools, then Heidelberger's color density measurement and compensation, and the detection and compensation of malfunctioning nozzles.

(33) J. Baro covers the complex topic of precise and reproducible measurement of UV radiation in UV inkjet techniques. He introduces radiometric terminology, then details the various UV radiation sources and the physics of UV light absorption, before describing practical measurement techniques.

(34) H. Wijshoff describes sensing methods to control printhead performance. Failure mechanisms like nozzle inconsistency, nozzle plate wetting, and the causes

for satellite formation and generation of air bubbles are explained together with optical measurement techniques. More sophisticated sensing techniques like acoustic sensing and nozzles with built-in capacitive sensors provide info on phenomena before the drop formation as a basis for feed forward control.

Pre/Post Processes

(35) M. Theiler's overview provides the understanding of UV curing of UV inkjet inks as required for successful implementation of UV curing units into printing machines with focus on UV-LED sources. The physics of the UV curing process is covered in detail followed by process development for different application areas from commercial to food, and pharma application with their different technical and regulatory requirements.

(36) E. Sowade, P. Öhme, and A. Schoenfeld describe chemical priming for inkjet printing of textiles. An overview about the existing digital textile printing processes is given discussing the requirements of priming for textiles, the nature of different textiles, the textile–colorant interactions, and different methods of how to apply the primer. Finally, ecological aspects and concepts for the reduction of primer chemistry and for energy consumption are addressed.

(37) D. Korzec, C. Little, A. Werkmann, and E. Brandes cover in detail the processes and tools for plasma pre-treatment of surfaces enabling quality inkjet printing, with brief plasma treatments to adjust the surface free energy for control of dot gain, print quality and adhesion, or prolonged plasma treatments for removing organic residues, for surface roughening or other chemical changes.

(38) Ch. Beechey and D. Johnson focus on UV arc lamps for curing of UV inks, after a detailed comparison of advantages and disadvantages of various methods of generating UV radiation. Features of UV arc lamps are presented, the main ones the high-power irradiance, the broad spectrum facilitating adjustment with the ink absorption spectrum and low cost.

(39) D. Exner focuses on UV-LED for curing of UV inkjet inks, with detailed description of the technology components of the UV-LED lamp system. LED-light sources for the spectral regimes UV-A to UV-C are covered as well as markets and applications, together with advice for careful choice and adequate integration of UV-LED lamps.

(40) R. Mehnert presents UV Direct Cure for curing of UV inks without photoinitiator additives by using acrylate molecules as internal photoinitiators when irradiated below 220 nm. Suitable low-wavelength UV lamps are described together with processing details and comparable curing results as with EB curing. With even shorter wavelength xenon excimer sources surface matting can be achieved, and by combining UV-curing with xenon excimer irradiation product with soft-touch surfaces can be manufactured.

(41) M. Fischer and M. Baines promote e-beam curing for inkjet printing in industry. The chemistry of the curing process is described together with the important EB irradiation parameters. Various types of EB equipment used in industry are

presented including equipment for inkjet printing. Advantages of EB curing vs. other techniques are shown, e.g. regarding environment and food packaging, as well as the ability to cure even coatings and adhesives.

(42) M. Ishikawa, S. Matsui, and M. Sachsenhauser start with an overview about EB curing as used in industrial inkjet printing including a comparison with UV-curing, before focusing on the installation and operation of EB irradiation systems. Beyond conventional EB sources the chapter describes the ultra-low energy ULEB sources, which are specifically suited for thin film curing as used in inkjet printing.

(43) K. Bär gives a detailed description of IR-based drying systems for use in inkjet printing. The physics of heat transfer mechanisms is explained to distinguish IR-drying from convection- and conduction-based drying systems. Emission spectra of various IR-sources are shown as well as spectral properties of various substrate materials and inks, crucial for the heat transfer. Thermal drying and curing processes are compared with focus on conventional IR- and NIR-curing, supported by several application cases.

(44) V. Akhavan, K. Schroder, T. Veit, and S. Farnsworth present NovaCentrix's photonic curing equipment and process for fast thermal processing of films. The machine operation is explained with the main features of pulse shaping and feedback control. The issue of fast in situ thermometry during the process is addressed. Present applications in printed electronics are described with an outlook at potential future multilayer functional flexible hybrid electronics.

Software/Data

(45) O. Luedtke, J. Seguda, and Th. Kirschner describe color management software with a historical look at RIP, Postscript, and PDF. Color measurement and analysis are addressed, as well as color management for the conversion of absolute and device-dependent color for the various industrial applications with their specific materials and requirements, like packaging, textile, decoration, ceramic or tile printing. An outlook is given on 2.5D printing where color management enables inkjet printing varnish pattern high enough to create a visible and tactile structure on top of the print.

(46) S. Simske outlines the data created for industrial printing, including security printing, with focus on the latter, which requires mass serialization, with unique printed marks associated with each item for authentication purposes.

Machine Integration

(47) D. Volk, D. Hahn, C. Wenzler, and K. Keller describe Notion System's approach to inkjet printing of solder masks on printed circuit boards. Advantages as well as technical challenges are addressed. The selection of the various components like materials, printheads, processes, data handling, and maintenance as needed for machine integration is described and exemplified in the n-jet solder mask printer for industrial production of PCBs.

(48) J. Corrall provides a very detailed and extensive description of machine integration based on IIJ's long year experience. After an assessment of the customer's requirements the technical concerns are identified and addressed, from the choice of the ink and printhead to application dependent print reliability and print quality as well as printhead life. Color management and workflow, safety and maintenance are covered, and an integration example is presented.

(49) W. Eve, N. Campbell, and S. Wilson share Inca's long experience in system integration for inkjet applications in industry. They cover single-, multi-pass, and scanning architectures, describe the key issues of ink delivery systems like pressure- and temperature-control as well as motion systems with encoders and system software and data path. Guidelines are given on system design for the compensation of various shortcomings of printhead and motion system.

(50) C. Brinkmeyer presents Hymmen's Jupiter Digital Printing Line for single-pass inkjet printing of décor, e.g. for the laminate flooring industry. The machine concept addressing the various technical challenges is explained in detail. A case study describes Hymmen's digital lacquer embossing to produce haptic surfaces appropriate for flooring or furniture.

(51) T. Mizutani, T. Takabayashi, M. Obata, and T. Sugaya describe Konica Minolta's Accuriojet KM-1 sheet fed digital inkjet press, specifically explaining the features of image quality and print reliability. High image quality is achieved by a phase-change UV ink and a pinning process, and gloss by optimized halftone screen patterning. Nozzle compensation and banding correction are outlined as well as in-line sensing of missing lines (streaks) to enable on-time compensation and thus print reliability.

Printed Electronics

(52) Th. Rohland, S. Sauva, J. Schinke, Ch. Kaiser compare analog and digital printing specifically for printed electronics. Focus is laid on analog techniques, mainly screen and flexographic printing. The considerations for the choice of the ink and the printing techniques are outlined for several device examples from printed electronics, and decision criteria for analog or inkjet printing are discussed.

(53) J. Keck, K. Gläser, D. Juric, W. Eberhardt, and A. Zimmermann describe process development of digital printing of functional pattern and devices using metal nano inks jetted with inkjet or aerosol printheads. Process parameters from the printing and pre/post-processing are assessed, and the performance of thermal sintering, photonic curing, and laser sintering is compared. Several techniques for electrically connecting the printed pattern are presented together with a number of examples of printed functional devices like heaters and sensors.

(54) J. Wolf and M. Kennert explain why Würth Elektronik chose inkjet over screen or other printing techniques for printing legend and solder masks. Legend printing on FP4, metal, or solder resist could be achieved combining inkjet printing with pre-treatment and UV-pinning processes. Inkjet printing

of solder masks showed several advantages over screen printing to produce solder masks of adjustable low layer thickness and edge definition. Processes to produce rigid and flexible solder masks are presented as well as an automated system based on Notion System's n-Jet solder mask printer (see D. Volk et al.).

Inkjet + Robot

(55) D. Fechtig addresses the combination of inkjet printing and robotics for direct-to-shape printing. Printing of decoration and functional pattern on a variety of substrates like shoes, glass, textiles is demonstrated, together with a detailed description of Profactor's Robojet 6-axis system printing up to four colors or functional materials with the robot moving the printheads. A perspective of future developments is given.

(56) B. Buck describes robot-based Direct-to-Shape printing for seamless partial or full coverage of 3D object. Requirements for the printing process, the printing process unit, the handling system, and the data flow are explained together with a discussion of the workflow architecture. As an industrial example Heidelberger's Omnifire 1000 is presented, a 6-axis robot that moves the object under fixed printheads.

(57) R. Trip, O. Bürgy, and W. Zapka evaluate the performance of an inkjet printhead mounted on a 6-axis robot. Drop formation and printing were studied with stroboscopic observation and printing during motion with various accelerations and printing into various directions including upwards. Ink through flow capability of the Xaar 1003 GS6 printhead used appeared to be essential for the capability to jet under accelerated motion. However, limitations by excessive pressure fluctuations require clever design of the ink supply system and selection of process parameters.

(58) D. Vogel and D. Tipura present the MABI robots as suitable for combination with inkjet printing in direct-to-shape printing applications, specifically for moving the inkjet printhead. The control algorithm, calibration, and compensation strategies provide high accuracy, stiffness, and repeatability through out the whole movement. The latter results in the high path control as is essential for inkjet printing.

3D Printing

(59) N. Hopkinson and P.J. Smith give a short overview of processes for 3D printing/additive manufacturing. They explain inkjet technology as an enabler in 3D printing by way of the inkjet-based selective sintering/fusion process. A description of the high-speed sintering machine is given together with examples of printed parts and an outlook for future development.

(60) L. Schranzhofer outlines the integration of printed electronics into 3D printing with the example of structural electronics. Based on an overview of materials, printing technologies, and pre/post-processes for printed electronics, how bottom-up and top-down structural electronic devices can be produced by different printing techniques including inkjet printing is described.

(61) J.W. Stasiak, D. Champion, U. Yadati, and T. Weber present Hewlett Packard's Metal Jet printing as an extension of HP Multi Jet Fusion technology. The materials, printheads, and processes involved are described, as well as the advantages of Metal Jet over conventional metal injection molding. Present use of HP Metal Jet in automotive and medical industry is mentioned and an outlook of future industrial applications is given.

(62) E. Beckert describes the process and capabilities of inkjet printing of 3D optical objects and devices, fulfilling the stringent requirements on bulk material transmission and homogeneity as well as surface shape and roughness. The advantages of inkjet printing provide freedom of design and functionality. The material selection and the process are presented together with printed objects. An extensive outlook covers the many potential applications including multi-material functional 3D devices.

(63) H. Mathea and F. Löbermann describe dpp's serial 3D production tool with a rotating platform as a new method to increase the productivity of additive manufacturing systems. The constantly rotating platform enables high productivity components. Apart from inkjet printheads, levelers, and UV curing there is space for further process units and the machine can be combined with pick-and-place robots for integration jobs. Process details and applications are presented.

(64) S. Beetz presents a user's view of 3D printing in the automotive industry with focus on experience gained with the OBJET 100 machine with 8 inkjet printheads. The printing and related processes are described together with data format and quality assurance. An extensive number of 3D functional or multicolor objects are AQ9 shown, and Table 63.7 with material properties offers specific use for application development.

Bio-printing

(65) J.W. Stasiak, J.D. White, and R. Wenger address several aspects of inkjet-based bio-printing. An overview of earlier work is presented with thermal inkjet printing of bio-fluids including fluids containing cells and proteins. Inkjet-based chemical synthesis for optimization and screening of chemical reactions is further described. A third topic is inkjet-based bio-fabrication of 3D functional human tissue, where the stringent requirements, and the concept and workflow of tissue engineering are addressed.

Case Examples, Direct-to-Shape, Security, Packaging

(66) J. Przybyla, J. Kearns and A. Veis give an overview of the market of printed corrugated media, and about inkjet press priorities and needs. They then focus on HP's C500 direct to corrugate press and on HP's T1190 s corrugated liner preprint press, where they detail on the digital front end, the printheads and printbar configuration, media handling, inks and finishing. They address the issue of missing nozzles by way of redundancy and nozzle health tests.

(67) A. Lyashenko, R.Weikl, Z. Rozsnyai, and J. Regensburger describe DEKRON's direct-to-shape printing technology for bottles and containers. Inks and specifically the complex preparations of glass and plastic bottles are covered in detail including pre-treatments for enabling inkjet printing. Print data preparation as well as the print and drying processes are addressed.

(68) J. Geerinckx presents UNILIN's approach for high-volume digital printing of laminates. Key advantages of inkjet printing of décor paper are outlined, as well as the selection of technical components like inkjet printer and printhead, substrate, ink, and primer. Another focus is laid on the various test procedures. The importance of licensed IP is mentioned, and a comparison of cost of inkjet vs. gravure printing is presented with favorable result for inkjet.

(69) F. Peinze explains Bundesdruckerei's approach to polycarbonate-based personalization methods for security documents. The choice for polycarbonate is explained as well as the process sequence, which includes the tight control of all inkjet printhead process parameters to guarantee the color gamut. A specific feature is the usage of satellites as part of image formation, which requires complex inks and tight control of drop formation. An overview of present and future applications is given.

Printing Strategies

(70) S. Simske proposes "tessellation and recombination" for optimizing processes and procedures relating to inkjet printing. Existing or concepted production processes should be de-composed into individual steps or sub-processes, then suitable inkjet printing methods be added, and all together be re-composed into a final process, where the introduced inkjet printing process added value, simplified the total process, or saved cost. The method is here applied, e.g. security printing and additive manufacturing.

Standardization

(71) S. Hoath draws attention to the need for standardization of inkjet printing equipment, and focuses on jetting and printing performance. Optical in flight measurement techniques for drop velocity, drop volume, and drop jetting direction are explained in high detail together with the reporting of errors

and uncertainties. For the measurement of droplet placement a procedure is proposed for consideration as standard, which includes choice of media and the measurement method with tight control of the listed process parameters; such should be adopted for presenting data in publications or data sheets.

Regulatory Requirements, Legal Aspects

(72) M. Thompson and J. Woods give guidance to manufacturers of inks and printing systems to provide their products complying with the statutory regulatory requirements and further assuring safety of customers and everyone in contact with the product during manufacturing and in the supply chain. Regulation of toxicological evaluations, chemical inventories, and equipment is described together methods for risk assessment. Regulation in food packaging is detailed for various world locations. Environmental protection is a further topic as well as communication of risk.

Ecological Aspects, Sustainability

(73) M. Has presents a methodology to assess the most important contributors to the carbon and energy footprints involved in industrial production system, exemplified by a comparison of the value chains and eco footprints of printing on paper, on self-adhesive labels, or printing direct-to-shape is elaborated in detail.

Patents

(74) A. Strevens points at patents as a most valuable source of information on technical developments and trends. In this chapter he covers technical inventions and applications in inkjet printing in high detail, and gives advice on extracting valuable knowledge from patent reports or using services, e.g. for screening and filtering the worldwide patent databases.

(75) J. Geerinckx and N. Tack advise on the twofold purpose of patents, as protection against un-licensed exploitation and using licensing to generate income. Several aspects of licensing are addressed, like cross-licensing, proactive licensing, or reactive licensing in case of infringement. Focus is laid on Unilin's proactive licensing approach with examples of Unilin's patents on digital printing equipment, materials, and processes.