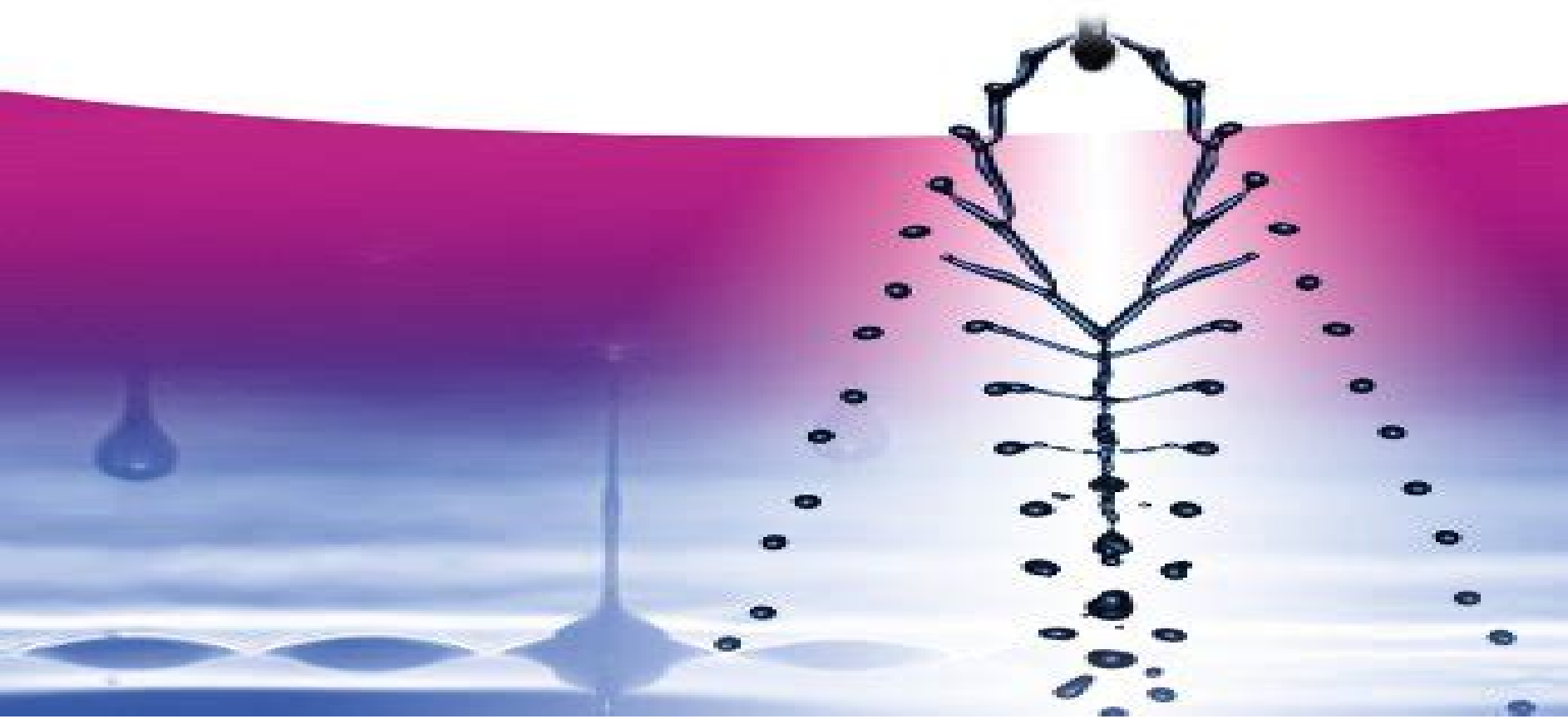


Edited by Stephen D. Hoath

# Fundamentals of Inkjet Printing

The Science of Inkjet and Droplets



# **Fundamentals Inkjet Printing Science Droplets Ebook**

**Patrick Galliker, Dimosthenis  
Poulikakos (Mechanical engineer,  
Greece, United States), Vahid  
Sandoghdar (Chimiste.)**

## **Fundamentals Inkjet Printing Science Droplets Ebook:**

**Fundamentals of Inkjet Printing** Stephen D. Hoath, 2015-12-14 From droplet formation to final applications this practical book presents the subject in a comprehensive and clear form using only content derived from the latest published results Starting at the very beginning the topic of fluid mechanics is explained allowing for a suitable regime for printing inks to subsequently be selected There then follows a discussion on different print head types and how to form droplets covering the behavior of droplets in flight and upon impact with the substrate as well as the droplet's wetting and drying behavior at the substrate Commonly observed effects such as the coffee ring effect are included as well as printing in the third dimension The book concludes with a look at what the future holds As a unique feature worked examples both at the practical and simulation level as well as case studies are included As a result students and engineers in R D will come to fully understand the complete process of inkjet printing

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**Inkjet Technology for Digital Fabrication** Ian M. Hutchings, Graham D. Martin, 2012-12-26 Whilst inkjet technology is well established on home and small office desktops and is now having increasing impact in commercial printing it can also be used to deposit materials other than ink as individual droplets at a microscopic scale This allows metals ceramics polymers and biological materials including living cells to be patterned on to substrates under precise digital control This approach offers huge potential advantages for manufacturing since inkjet methods can be used to generate structures and functions which cannot be attained in other ways Beginning with an overview of the fundamentals this book covers the key components for example piezoelectric print heads and fluids for inkjet printing and the processes involved It goes on to describe specific applications e g MEMS printed circuits active and passive electronics biopolymers and living cells and additive manufacturing Detailed case studies are included on flat panel OLED displays RFID radio frequency identification manufacturing and tissue engineering while a comprehensive examination of the current technologies and future directions of inkjet technology completes the coverage With contributions from both academic researchers and leading names in the industry Inkjet Technology for Digital Fabrication is a comprehensive resource for technical development engineers researchers and students in inkjet technology and system development and

will also appeal to researchers in chemistry physics engineering materials science and electronics      *Science and Engineering of Droplets*: Huimin Liu,1999-12-31 This is the first book to encompass the fundamental phenomenon principles and processes of discrete droplets of both normal liquids and melts It provides the reader with the science and engineering of discrete droplets and provides researchers scientists and engineers with the latest developments in the field The book begins with a systematic review of various processes and techniques along with their applications and associations with materials systems This is followed by a description of the phenomena and principles in droplet processes Correlations calculations and numerical modeling of the droplet processes provide insight into the effects of process parameters on droplet properties for optimization of atomizer design Droplets are found in the areas of metallurgy materials automotive aerospace medicine food processing agriculture and power generation and encountered in a huge range of engineering applications      3D Bioprinting Ibrahim Tarik Ozbolat,2016-11-21 3D Bioprinting Fundamentals Principles and Applications provides the latest information on the fundamentals principles physics and applications of 3D bioprinting It contains descriptions of the various bioprinting processes and technologies used in additive biomanufacturing of tissue constructs tissues and organs using living cells The increasing availability and decreasing costs of 3D printing technologies are driving its use to meet medical needs and this book provides an overview of these technologies and their integration Each chapter discusses current limitations on the relevant technology giving future perspectives Professor Ozbolat has pulled together expertise from the fields of bioprinting tissue engineering tissue fabrication and 3D printing in his inclusive table of contents Topics covered include raw materials processes machine technology products applications and limitations The information in this book will help bioengineers tissue and manufacturing engineers and medical doctors understand the features of each bioprinting process as well as bioink and bioprinter types In addition the book presents tactics that can be used to select the appropriate process for a given application such as tissue engineering and regenerative medicine transplantation clinics or pharmaceuticals Describes all aspects of the bioprinting process from bioink processing through design for bioprinting bioprinting techniques bioprinter technologies organ printing applications and future trends Provides a detailed description of each bioprinting technique with an in depth understanding of its process modeling underlying physics and characteristics suitable bioink and cell types printed and major accomplishments achieved thus far Explains organ printing technology in detail with a step by step roadmap for the 3D bioprinting of organs from isolating stem cells to the post transplantation of organs Presents tactics that can be used to select the appropriate process for a given application such as tissue engineering and regenerative medicine transplantation clinics or pharmaceuticals      **Reactive Inkjet Printing** Patrick J. Smith,Aoife Morrin,2017-11-27 A comprehensive overview of the technique and its use in fabricating functional materials for health and energy applications      **Optimization of Ink Drop Formation by Polymeric Addition in DOD Inkjet Printing** Mingming Guo,2012      **Smart Multifunctional Nano-inks** Ram K. Gupta,Tuan Anh Nguyen,2022-10-26 Smart Multifunctional Nano inks

Fundamentals and Emerging Applications covers nano inks and how they can be used in inkjet printers for printing complex circuitry on flexible substrates or as a paste for 3D printers. Microstructures can be 3D printed using nano inks in a combination of high resolution plasma printing and subsequent rotogravure printing. In addition, smart multifunctional nano inks are not only required for the electronic but also in other applications such as for secure inks for currency and in immigration documents. This book focuses on fundamental design concepts, promising applications and future challenges of nano inks in various areas such as optoelectronics, energy, security and biomedical fields. The current challenge for the successful industrial application of nano inks is in the preparation of a stable dispersion of advanced materials for nano inks. The functionalization, synthesizing and theoretical modeling provide the solution for most of the current issues but there are still remaining challenges which are covered in this comprehensive resource. Outlines the major nanomaterials used in the manufacture of smart nano inks. Provides information on the major industrial applications of nano inks. Assesses the major challenges of using nano inks in a cost effective way and on an industrial scale.

### **Printing on Polymers** Joanna

Izdebska-Podsiadły, Sabu Thomas, 2015-09-24. *Printing on Polymers: Fundamentals and Applications* is the first authoritative reference covering the most important developments in the field of printing on polymers, their composites, nanocomposites and gels. The book examines the current state of the art and new challenges in the formulation of inks, surface activation of polymer surfaces and various methods of printing. The book equips engineers and materials scientists with the tools required to select the correct method, assess the quality of the result, reduce costs and keep up to date with regulations and environmental concerns. Choosing the correct way of decorating a particular polymer is an important part of the production process. Although printing on polymeric substrates can have desired positive effects, there can be problems associated with various decorating techniques. Physical, chemical and thermal interactions can cause problems such as cracking, peeling or dulling. Safety, environmental sustainability and cost are also significant factors which need to be considered. With contributions from leading researchers from industry, academia and private research institutions, this book serves as a one stop reference for this field, from print ink manufacture to polymer surface modification and characterization and from printing methods to applications and end of life issues. Enables engineers to select the correct decoration method for each material and application, assess print quality and reduce costs. Increases familiarity with the terminology, tests, processes, techniques and regulations of printing on plastic, which reduces the risk of adverse reactions such as cracking, peeling or dulling of the print. Addresses the issues of environmental impact and cost when printing on polymeric substrates. Features contributions from leading researchers from industry, academia and private research institutions.

**Printing Materials** R. C. Thompson, 1998. *Numerical Simulation of Droplet Formation for Piezoelectric Inkjet Printing*, 2012. *Droplet Deposition in Solid Ink Printing* Ri Li, 2008. Introduced in 1991, solid ink color printing technology is widely used in the office printing, prepress proofing and wide format color printing markets. Ink droplets are first deposited on a rotating drum and then

transferred to paper to reproduce images with high print quality The objective of this thesis is to develop scientific knowledge of ink droplet deposition which is needed for precise image buildup on the drum surface The first problem studied in the thesis is droplet formation from the printhead with varied working voltages and jetting frequencies Attention is paid to the formation of satellite droplets the contraction of ligaments and the startup of high frequency jetting The jetting conditions for obtaining consistent droplet generation with satellites are determined A theoretical model is developed to predict the lifetime of ligaments The second problem we studied is the deposition of single droplets on solid surfaces The surface texture and final shape of deposited droplets are correlated with impact conditions which include printhead temperature substrate temperature distance from printhead to substrate and the type of substrate surface An analytical model is developed to evaluate the interaction of oscillation and viscous damping in the droplet during impact The third problem covered in the thesis is the deposition of multiple ink droplets on the drum surface Interaction between droplets causes drawback effect which degrades print quality We define a parameter to quantify the drawback effect with varied deposition conditions A simple model is provided to predict conditions for making continuous lines based on the results of two ink droplets deposition To understand the hydrodynamics in causing drawback effect a series of experiments using large liquid droplets are carried out Focus is put on the evolution of spread length and dynamics of contact line Correlations for maximum and minimum spread lengths are developed which are used to reveal the cause of drawback effect in the deposition of ink droplets

**Material Interactions and Self-assembly in Inkjet Printing** Karam Nashwan Al-Milaji, 2019 Inkjet printing has attracted much attention in recent years as a versatile manufacturing tool suitable for printing functional materials This facile low cost printing technique with high throughput and accuracy is considered promising for a wide range of applications including but not limited to optical and electronic devices sensors solar cells biochips and displays The performance of such functional devices is significantly influenced by the deposit morphology and printing resolution Therefore fabrication functional devices with precise footprints by inkjet printing requires deep understanding of ink properties material interactions and material self assembly In conventional inkjet printing process where sessile droplets are directly printed on substrates particle depositions are usually associated with the well known undesirable coffee ring effect due to the high solvent evaporation rate at the edges of the printed droplets Such particle accumulation phenomenon in vicinity of the three phase contact lines of sessile droplets is considered detrimental to inkjet printing applications This study investigates the material interactions and self assembly of colloidal inks in inkjet printing applications at different length scales The potential of inkjet printing has been exploited through employing the dual droplet inkjet printing of colloidal particles to investigate the self assembly of colloidal nanoparticles at the air liquid interface and at the three phase contact line of sessile droplets which provide better understanding of the particle deposition morphologies after solvent evaporation Different from conventional inkjet printing the dual droplet printing involves jetting wetting droplets containing colloidal

nanoparticles dispersed in solvents with high vapor pressure over supporting droplets composed of water only. By tuning the surface tensions and controlling the jetting parameters of the jetted droplets, monolayers with closely packed deposition of colloidal nanoparticles are demonstrated. Various solutions are proposed to totally suppress or mitigate the coffee ring effect in inkjet printing applications through tuning the pH value of the supporting droplets in the dual droplet inkjet printing to control the multibody interactions, i.e. particle-particle interface and particle-substrate interactions, or by applying magnetic field to direct the self-assembly of colloidal particles in conventional inkjet printing. In addition, the influence of various forces such as drag force, van der Waals force, electrotactic force, and capillary force on the particle deposition and assembly in vicinity of the three-phase contact line area were investigated for both the conventional and dual droplet inkjet printing techniques. Finally, fabrication of functional devices such as stretchable conductors have also been demonstrated by inkjet printing of silver nanowires into elastomer substrate where the viscous liquid elastomer layer shaped the printed silver wire lines into tens of micrometers in diameter. The silver nanowires align along the printing direction during solvent evaporation, resulting in wires with good mechanical stability and electrical performance. The printing techniques and the outcomes presented in this study can be harnessed in engineering and manufacturing a wide range of technological applications ranging from high performance optical and electronic devices to stretchable conductors and sensors.

The Chemistry of Inkjet Inks Shlomo Magdassi, 2009. Modern printing is based on digitizing information and then representing it on a substrate such as paper pixel by pixel. One of the most common methods of digital printing is through inkjet printers. The process of inkjet printing is very complicated and the ink used must meet certain chemical and physicochemical requirements including those related to storage stability, jetting performance, color management, wetting, and adhesion on substrates. Obviously, these requirements, which represent different scientific disciplines such as colloid chemistry, chemical engineering, and physics, indicate the need for an interdisciplinary book that will cover all aspects of making and utilizing inkjet inks. This book provides basic and essential information on the important parameters which determine ink performance. It covers not only the conventional use of inkjet technology on graphic applications but also the extension of this method to print various functional materials such as the use of conductive inks to print light emitting diodes (LEDs) and three-dimensional structures. Thus, the book will serve a large community: industrial chemists who deal with ink formulations and synthesis of chemicals for inks; chemical engineers and physicists who deal with the rheological and flow properties of inks; and researchers in academic institutes who seek to develop novel applications based on inkjet printing of new materials.

*New Frontiers of Functional Printing* Patrick Galliker, Dimosthenis Poulikakos (Mechanical engineer, Greece, United States), Vahid Sandoghdar (Chimiste.), 2013. *Fluid Characterisation and Drop Impact in Inkjet Printing for Organic Semiconductor Devices* Sungjune Jung, 2011. An inkjet printer can deposit a very small volume of liquid with high positional accuracy, high speed, and low cost. As a maskless, non-contact, additive patterning method, inkjet printing technology is

increasingly being explored as an alternative to lithography etching and vapour deposition processes to pattern electrical conductors and thin films with applications in printed electronic devices The functional inks used in many of the applications involve non linear viscoelasticity and their behaviours in the context of inkjet printing have not been fully understood This thesis aims to characterise Newtonian and non Newtonian properties of inkjet fluids and identify the key parameters affecting drop impact and spreading processes Various fluid characterisation techniques such as the filament stretching rheometer and piezoelectric axial vibrator are explored We propose an experimental method to assess the jettability of non Newtonian inkjet fluids without using an inkjet print head The oblique collision of two continuous liquid jets leads to the formation of a thin oval liquid sheet bounded by a thicker rim which disintegrates into ligaments and droplets Under certain conditions the flow structure exhibits a remarkably symmetrical fishbone pattern composed of a regular succession of longitudinal ligaments and droplets Good correlation was found between the maximum included angle of the fishbone pattern and the maximum ligament length in the jetting experiments which suggests that a test based on oblique impinging jets may be useful in the development of fluids for ink jet printing High speed imaging is used to analyse the impact and spreading of sub 30  $\mu\text{m}$  drops of diethyl phthalate or polystyrene solutions in diethyl phthalate on to smooth glass surfaces with controlled wettability at speeds from 3 to 8  $\text{m s}^{-1}$  under conditions representative of drop on demand inkjet printing Data on drop height and spreading diameter are generated with high time and spatial resolution over eight orders of magnitude in timescale The effects of fluid viscosity and elasticity which significantly affect jetting performance are negligible throughout the whole deposition process with no significant difference between spreading curves The values of the fluid surface tension and the substrate wettability also have no effect on the kinematic spreading or relaxation phases but a marked influence on the wetting phase in terms of the speed of expansion of the contact diameter and the final spreading factor

### **The Role of Evaporation and Particle Self-assembly on Deposition Morphologies of Inkjet-printed Drops** Dong-Ook Kim, 2019

Inkjet printing is a powerful tool in various applications from printable electronics to biomaterials due to its low cost compatibility with a wide range of ink materials and accurate deposition of droplets in the micron diameter range In this work the dynamics of the contact line and deposition of inkjet printed drops are investigated to develop the fundamental understandings of the transport phenomena and improve inkjet printing techniques by controlling final deposition morphologies Compared to their spherical counterparts ellipsoidal particles experience stronger adsorption energy to the drop surface where the anisotropy induced deformation of the liquid air interface leads to much greater capillary attractions between particles Using inkjet printed colloidal drops of varying drop size particle concentration and particle aspect ratio we demonstrate how the suppression of the coffee ring is not only a function of the particle anisotropy but rather a competition between the propensity for particles to assemble at the drop surface via capillary interactions and the evaporation driven particle motion to the contact line When the capillary force the hydrodynamic force 1 ellipsoids on the drop surface form a



coherent network inhibiting their migration to the drop contact line and the coffee ring effect is suppressed whereas when the capillary force the hydrodynamic force     **Printing Materials** Bob Thompson, 2004

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