# Applications of the SUSS PiXDRO LP50 inkjet printer with Fujifilm Dimatix cartridge (DMC) print heads in research and development


## Abstract

In this white paper we highlight the value of combining the SUSS (PiXDRO) LP50 inkjet printer with the Fujifilm Dimatix cartridge (DMC) made possible by the adapter kit of JB Instruments GmbH. We refer to more than thirty scientific publications featuring the combined use of the LP50 and the DMC. You will find inspiring examples for complex technology developments most of them featuring a carefully balanced development of suitable materials, process technologies and functionality optimization accompanied by thorough characterization. It ranges from energy conversion devices e.g advanced solar cells, OLDEs, via soft and flexible printed electronics, a large variety of sensors (acoustic to X-ray) all the way to medical substances being printed on contact lenses for personalized drug delivery.


## Introduction

The SUSS LP50 inkjet printer with PiXDRO technology is a highly versatile and precise inkjet printing system that can be used with a large variety of print heads for research and development purposes. Especially the possibility of using the Fujifilm Dimatix cartridge (DMC) with that printer opens up a large field of activities. The low-cost cartridge can be filled with up to 1.5 ml of printing ink but also much smaller amounts of material can be tested effectively. The adapter kit developed and produced by JB Instruments GmbH allows to connect the printer and the cartridge.

Functional inkjet printing is always strongly linked to substantial materials and process development or at least to ink development. The DMC cartridge allows to do this at low cost and quickly with low amounts of material (few ml are enough for many printing tests) as the small ink reservoir is directly connected to the print head resulting in practically no materials loss in piping etc. In case a material or process parameter leads to clogging or loss of the cartridge it can be easily replaced at low cost as the small DMC is equipped only with 16 (in the newer versions of the SAMBA-DMC only 12) nozzles and is especially designed to facilitate R&D while being compatible to industrial products allowing scalability of the R&D results. The LP50 printer allows a very convenient waveform design and the PiXDRO Dropview system supports the process of finding the ideal material and printing parameters. During printing the high precision of the machine and the possibility of using its advanced alignment function enable to combine inkjet printing with other technologies in order to realize complete devices with new functions. As inkjet is one technology element amongst others needed to create such desired functionality it is mandatory that this step can be carried out with highest precision, reliability and reproducibility.

## Solar Cells and other energy conversion devices

In solar cells research especially in the currently very hot topic of perovskite solar cells researchers are exploring inkjet printing as a technology to create different parts of the cell [Hat22][Hat21a]][Scha21] [Roh21] and[Ver20]. Also the silicon based solar cells are constantly improving and for the metallization of solar cells with passivated contacts, which are a feature of all highest efficiency silicon solar cells, type new metallization schemes are required and inkjetting of metal particle loaded inks is a future option here [ScJ19][ScJ20]. As Silver is represents a considerable cost factor in silicon solar cells it is important to explore the use of alternative materials like copper. In their research Hatt and coworkers applied inkjet printing to prepare solar cell surfaces for subsequent copper plating [Hat21b]. Alternatively, Wehmeier et al. directly print even silicon inks to form highly localized and aligned passivated contacts to simplify the POLO approach and to form advanced interdigitated back contact solar cells (IBC) [Weh21]. The possibility to operate the LP50 within a glovebox allows the group to apply the pyrophoric ink in inert atmosphere.

Rosa and coworkers present research on the synthesis of ceramic nano particles using continuous hydrothermal synthesis (CHS). In the second step they created inks for inkjet printing see [Ros19] and [Ros19b]. Interestingly they focused on YSZ and NiO nanoparticles used in electrodes for fuel cells and electrolyser research and development.

**Displays and smart windows**

OLEDs (organic light emitting diode) are very interesting for display applications. It is tempting to try to process these systems using Drop-on-Demand inkjet systems circumventing lithography steps that come with a whole lot of additional processing steps. Especially when it comes to research and development a quick way to evaluate materials performance is using inkjet direct deposition [Mer19]. But the possibility to create a light source by inkjet printing can also be used for totally different applications as for lab-on-a-chip systems as some of them need light sources to be functional [Shu17].

Further display oriented activities are published by Jin et al. The group realized smart window displays using inkjet-printed PMMA based micro etching masks for plasma treatment processes on PDMS substrates [Jin22].

**Printed electronics and sensor applications**

In complex systems like soft or flexible electronics, optoelectronic systems, or biodegradable electronic systems like electrochromic displays above mentioned combination of a disposable very precise and small volume print head combined with the high performance and high precision printing platform the PiXDRO LP50 (former Meyer Burger now SUSS) is of very high value [Mik20] [Pie20] [Schl21]. The additive nature of the printing process simplifies processing as complex and possibly incompatible masking steps usually required for patterning can be omitted.

Bolat and coworkers published work on the preparation of thin film transistors using inkjet printing with resolutions up to 400 dpi. AlOx and YAlOx dielectrics were inkjet-printed using LP50 inkjet printer with Dimatix cartridges. To avoid pinholes two layers were printed which requires precise mechanical repositioning of the printhead [Bol20, Bol22].

Schubert et al. published work on printed flexible and stretchable electronics as e.g. is needed for electronic components to be attached to skin for monitoring or other purposes [ScM18][ScM18b]. In their work they printed silver as well as platinum particle-based inks using inkjet. To achieve high electronic conductivities without introducing too much heat they explored flash lamp annealing (FLA) and high-power diode laser processing. This way sufficient conductivities can be achieved without damaging the polymer-based substrate.

As for printed electronics also paper and other uneven or porous substrates may become relevant it is important to understand the impact of the substrate structure and the process on the properties of the resulting electronic component. This was demonstrated impressively by Zikulnig et al. who used van der Pow structures to quantitatively analyze the sheet resistance of inkjet printed silver layers on paper substrates [Zik20].

Strobel et al. demonstrate the realization of inkjet printed organic photodiodes (OPD) aiming to create lightweight flexible wearable electronics able to communicate via optical signals [Str20]. Wavelength selective heterojunction photodetectors allow color dependent signal processing. In their work they inkjet printed the PIF:NFA active layer on an inkjet-printed electron extraction ZnO layer.

As a further example Cirelli and coworkers are developing components for micro sized molecular sensing arrays that could detect various substances in the ambient. Their research requires to precisely deposit very small amounts of liquid sensing substances on a predefined grid to establish the sensing array a challenge that they solved applying inkjet technology. In this work the PiXDRO drop analysis software tool (ADA) was used to understand the printing behavior of the complex materials under investigation. Furthermore, precise optical alignment was needed as printing had to be precisely aligned to the sensor substrate [Cir19].

Regarding printed magnetoelectronics Gupta et al. published work on scalable partly inkjet printed sensor arrays. Inkjet (silver dispersion-based ink) was used to realize the metallization schemes on large A4 sized PET substrates creating arrays of 7x20 GMR sensors (GMR giant magnetoresistance) [Gup22].

Inkjet printed acoustic sensor networks for structural health monitoring are presented by Liao and coworkers [Lia21]. The applied ink was based on carbon black and polyvinyl pyrrolidone (denoted hereinafter by CB/ PVP) dissolved in NMP and was adjusted to fit the rheological properties required for inkjet printing. Sensor network geometries were easily varied due to the digital nature of inkjet printing.

X-Ray detectors based on inkjet printed layers of triple cation perovskite (TCP) are demonstrated by Mescher et al. [Mes20]. The sensors feature a high sensitivity and are mechanically flexible as due to the reduced process temperatures PEN (polyethylene naphthalate) substrates could be used.

Buchheit et al. create hybrid dielectric layers for soft and printed electronics using inkjet printing of hybrid inks consisting of a polymer matrix with filler particles to increase the overall dielectric constant. The group succeeded demonstrating an inkjet printed capacitor with core-shell particles in the hybrid dielectric [Buc21].

When transparent electronically conducting layers are required PEDOT:PSS (a polymer based on a mix of two ionomers that allow to carry positive and negative charge) is often used. In a recent publication Donaldson and coworkers apply inkjet printing (also using an LP50 with a JB Instruments integration module to allow the usage of Dimatix cartridges printheads) [Don21]. They not only print the transparent PEDOT:PSS electrode but also deposit silver nano particle layers with inkjet to form silver bondpads for interconnection of the generated microelectrodes. The authors mention that using inkjet patterning instead of lithography or electroplating facilitates the research on multimodal neuroscience as electrodes with various geometries can be easily fabricated.

Transparent electrodes can also be formed based transparent conducting oxides (TCO). These materials are used in all sorts of optoelectronic devices like solar cells, architectural-glass coatings switchable windows, thin-film transistors, touch screens, and displays. Gilshtein et al. at the EMPA in Switzerland published work on transparent touch sensing systems based on ITO (indium tin oxide a very high performance TCO). In their work ITO patterns are generated using an inkjet printable nanoparticle ink containing small ITO particles. After printing and drying the layers are postprocessed using a light flash. To enhance the absorption of the energy provided by the flash a thin layer of an organic coloring agent was applied to the ITO film before flash lamp annealing (FLA). This process leads to patterned transparent and densified layers with high charge mobility making them suitable for touch sensor applications [Gil20][Gil21].

Velasco-Bosom and coworkers published work on surface electromyography (EMG) sensors fabricated using inkjet and other technologies [Vel20]. Essentially the group intends to fabricate sensors that can be placed on the skin in order to read electrical signals produced during muscle contraction. Such signals could be used to control prosthetic limbs without having to place electrodes into the muscles of the user. In their work they inkjet printed the silver-based electrodes that are placed on flexible Kapton substrates.

**Medical applications for individualized drug delivery**

In medical research individualized medicine along with individual drug dosing is a topic of increasing relevance. Within this field low-dose applications are required for various treatments.

In a rather broad approach Fiedler and coworkers investigated the possibilities of inkjet printing so called biologics [Fie22]. Such materials are of a very wide variety in molecular size and structure and other properties and can be used for different purposes and therapeutical applications.

In their research Kifer et al. investigated inkjet printing for the formation of so-called orodispersible films [Kif21] (ODF, very thin stamp sized films than can safely be given to patients and dissolve in their mouths releasing a defined amount of medicine). Being able to produce individualized ODFs in the hospital or nearby pharmacies would support the concept of individualized medicine and would allow more quick delivery and adaptation to the patient’s needs. To generate individualizable ODDs Kifer and coworkers applied different amounts of a widely spread and important drug (metoprolol tartrate, MPT). For this, corresponding inks with different formulations have been generated and printed using inkjet. Even though the group has reported significant progress with their activities they point out that there is still a long way to go to have such concepts being reliably applicable for the purpose of use. Not only the materials have to be well chosen and suitable but also the deposition technology itself has to be extremely reliable and well understood. Nozzle clogging, ageing processes or other instabilities can reduce process stability and product quality. Such challenges could be overcome when all parties co-operate and inspire each other in joint projects to push the limits of our technology development.

Delivering drugs via the eyes is also an issue as the common approaches are facing difficulties related to eye movement, blinking, tear fluid etc. Tetyczka et al. investigated inkjet printing of nanocrystals on 1 day hydrogel contact lenses [Tet22]. They analyzed the resulting lenses in a simulated tear fluid and state to have found a promising approach for ophthalmic drug delivery. This work is again a good example of how materials, ink, and deposition parameters must be adjusted very carefully to achieve a good result.

A further approach for personalized drug therapies is evaluated in the work of Alva et al. When it comes to provide small and defined amounts of liposome and lipid nanoparticle-based drugs the important question arises, whether the piezo driven jetting process would damage/alter these structures or not. Jettability investigations were carried out using the combination of the Fujifilm Dimatix Cartridge and the PiXDRO Dropview system of the LP50. Even though printing of the inks is not straight forward, and the work is stated to be rather early stage one main finding is, that in general the above-mentioned substances can be inkjet printed. This proof of principle is of high value for the next activities and the researchers point out that there is a very high potential for process improvement especially using the optical observation possibilities to characterize and optimize the jetting behavior. [Alv22].

Last but not least, the versatility and precision of the system allows to conduct fundamental research on how to set up an ink for good printability exploiting the powerful image analysis software this system is equipped with (Dropview). It allows to study drop form for individual waveform settings, generation of satellites, drop volume, drop velocity, and printing angle [Yua19].

Very interestingly Fujifilm recently presented a new generation of cartridges SAMBA-DMC which is based on the same technology as it is used in production scale SAMBA printheads. This closes the gap between research and application and allows to develop processes and materials on a small scale to subsequently transfer them to large scale applications.

JB Instruments GmbH, October 2022

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