Inkjet Printing – Visualization of Three-Dimensional Flow Fields within Small Printed Structures

Max Tönsmann[1,2,3], Philip Scharfer[1,2,3], and Wilhelm Schabel[1,2,3]

[1]Institute of Thermal Process Engineering (TVT), Thin Film Technology (TFT), Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany
[2]Material Research Center for Energy Systems (MZE), Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany
[3]Innovation Lab (iL), 69115 Heidelberg, Germany

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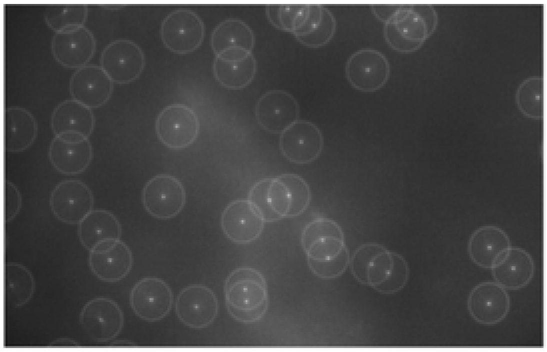
<u>Extended Abstract</u> (six page maximum):

Small, inkjet-printed structures are an essential component of novel organic electronic devices and low-cost sensors. Colloidal suspensions as well as micro- and macromolecular solutions exhibit super-elevated edges after drying. In the scientific community, this phenomenon is often summarized as Coffee-Ring-Effect although the underlying mechanism has not yet been fully resolved and might differ with distinct material systems. In some cases, this effect could be compensated using surface tension driven Marangoni-convection prior solidification. Since surface tension of multi-component solutions or suspensions depend on both temperature and composition, precisely tuning the material system or the boundary conditions while drying should lead to a homogenous solute deposition.

In order to investigate the flow-field within drying thin films and small printed structures, a new measurement technique (µPTV) has been developed in preliminary studies (Cavadini et al. 2018). It is based on tracking fluorescent particles in drying polymer solutions with an inverse microscope. A technique called “off-focus imaging” allows the tracking along the line-of-sight direction (Speidel et al. 2003), enabling us to measure three-dimensional flow fields while drying.

Figure 1 left shows a camera image of the µPTV setup. An aberration induced point spread function (PSF) results in ring structures around the tracer particles (Gibson and Lanni 1992). The ring diameter can be correlated to the line-of-sight distance between tracer particle and focal plane. With a GPU-enhanced ring detection algorithm the three-dimensional flow-field can be reconstructed from a two-

dimensional video feed. Due to a decrease in intensity with increasing ring-size, the vertical extension of the observable volume is limited. Therefore, a multifocal approach has been realized. Figure 1 right shows a schematic representation of the observable volumes for three cameras. It has been realized by splitting the signal onto multiple cameras and introducing meniscus lenses shifting the focal planes individually.



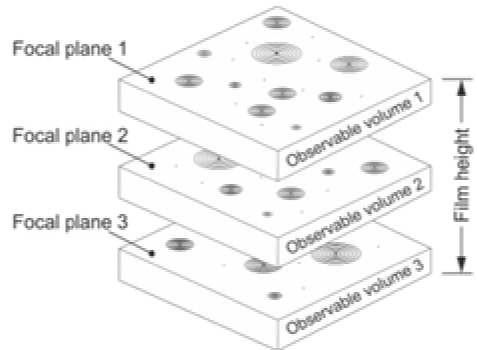


Figure 1: Left: image of tracer particles showing the point spread function (PSF). All tracer particles are at the same distinct distance to the focus plane. Right: schematic of the multifocal approach for the use of three cameras. (Cavadini et al. 2018)

As proof of principle a Methanol-poly(vinyl acetate) film from solution with 67 wt% methanol was dried under ambient conditions. Figure 2 shows the reconstructed flow field near the substrate recorded with two cameras.

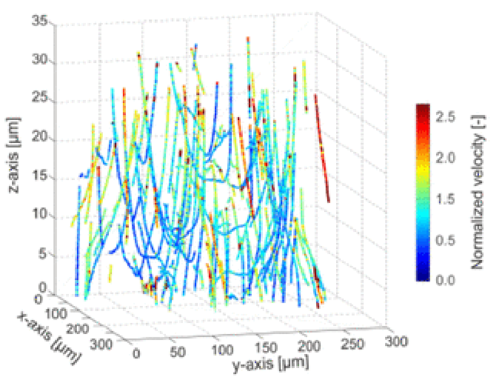


Figure 2: Flow field in the vicinity of the substrate visualized by particle tracks. The particle tracks are colored by velocity magnitude. The velocity magnitude is normalized with respect to the median value. Methanol–poly(vinyl acetate) solution with 67 wt% methanol: ambient temperature, T_∞ = 20 °C and initial film height, s_0 ≈ 150 µm. Film is dried at ambient conditions. The scene has been captured close to the substrate using two cameras with a distance of 15 µm between the focus planes. (Cavadini et al. 2018)

Since the Coffee-Ring-Effect is a local phenomenon manifesting at the edges of thin films or small printed structures, future work will focus on local transport processes. Besides varying ink composition and global drying conditions, local drying for instance with a focused IR-laser acting as a local heat source could affect the flow field and hence the surface topography of the deposit. The overall goal is to identify process parameters crucial to the surface homogeneity in order to facilitate inkjet process design and ink formulation.

References

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