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# Polymer and Colloid Highlights

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### Microfluidics Meets Printed Electronics

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Printed electronics uses a range of techniques to generate conducting electrical wires, pads or devices such as transistors. There are different processes to place high-resolution silver (Ag) nanowires on surfaces, such as photo-, electron or nanoimprint lithography (NIL).[1] However, they require the use of clean-room-based pattern transfer methods (physical vapor evaporation, etching or lift-off) to convert a resist pattern into metallic wires. Open microfluidics is a viable approach to use low-resolution additive techniques in combination with prepatterned polymer substrates. We developed different design elements: Patterned landing pads that spread impinging ink and serve as reservoirs for capillary filling, and grooves with both U- and V-shapes that can be filled from one or both sides (Fig. 1). The questions we were looking for in this research were the following: Up to which length can we fill 2–5 µm wide capillaries and what is the role of the solvent and its evaporation? How homogeneous is the wire thickness along the groove? Are U- or V-shaped grooves more favorable for filling and post-processing? These results help to choose suitable strategies for making transistors, sensors and transparent conductive electrodes by high throughput printing methods.

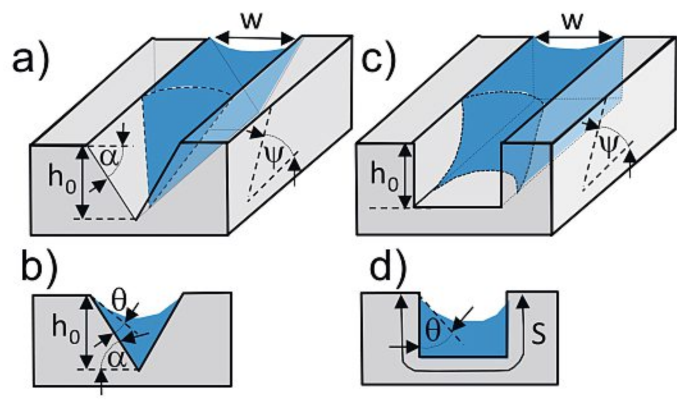


Fig. 1. Groove geometries and liquid spreading characteristics for a,b) V-grooves and c,d) U-grooves with flat bottom, with geometrical parameters width w, height $h_0$ and vertex angle α, and wetting parameters θ and ψ.

In the framework of the FOXIP project, we found out several underlying mechanisms that are very decisive for fabrication.[2] When filling with ink from the reservoirs, convective spreading and dynamic drying enables grooves to fill homogeneously up to a higher level than that given by calculation of a static case.[3] V-grooves were particularly suitable because of their filling characteristics. Furthermore, they enabled to shrink wire widths by confinement of nanoparticles (~50 nm) in the vertex of the groove. By spin coating highly diluted nanoparticle inks, wires below 200 nm width could be fabricated in 3 µm wide V-grooves.[4] For this, we took a specific volume ratio of nanoparticles in the solvent into account. Flash sintering enabled to reduce grain growth of the silver wires in comparison to thermal processing. Poly (methyl methacrylate) (PMMA) and polycarbonate (PC) films were used as substrates but results should be easily transferable to other materials such as poly (ethylene terephthalate) (PET), poly (ethylene naphthalat) (PEN), and Ormocer planarization layers. PMMA was particularly useful because it enabled to flatten the grooves by thermal reflow. Since adjacent grooves can be filled without overspill, single electrodes can be used for interdigitated electrode arrays with 100 wires (1 mm long), or for for heating elements. Fig. 2 shows an example of double Ag wires with 5 µm distance between each other. Low placement precision of the droplet on the landing pad proved to be unproblematic.

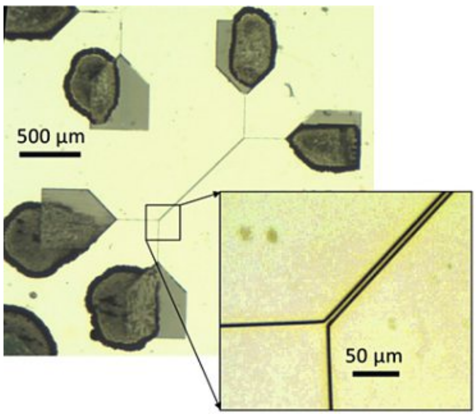


Fig. 2. Optical micrograph of 2 mm long, 5 µm wide double wires after filling two capillaries with Ag from two sides each. The thermoplastic polymer films were prepatterned by thermal NIL.

The results show that basic rules are valid for filling of capillaries with well-wetting inks. Open microfluidics enables shrinking dimension in printed electronics and reasonable wire lengths can be patterned for groove widths in the micrometer range.

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[2] FOXIP, SFA Advanced Manufacturing, *www.sfa-am.ch/foxip.html.*
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[4] B. Horváth, B. Krivová, H. Schift, *Micro and Nano Eng.* **2019**, *3*, 22.

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