# Drop-on-Demand Inkjet Printing of Functional Composites

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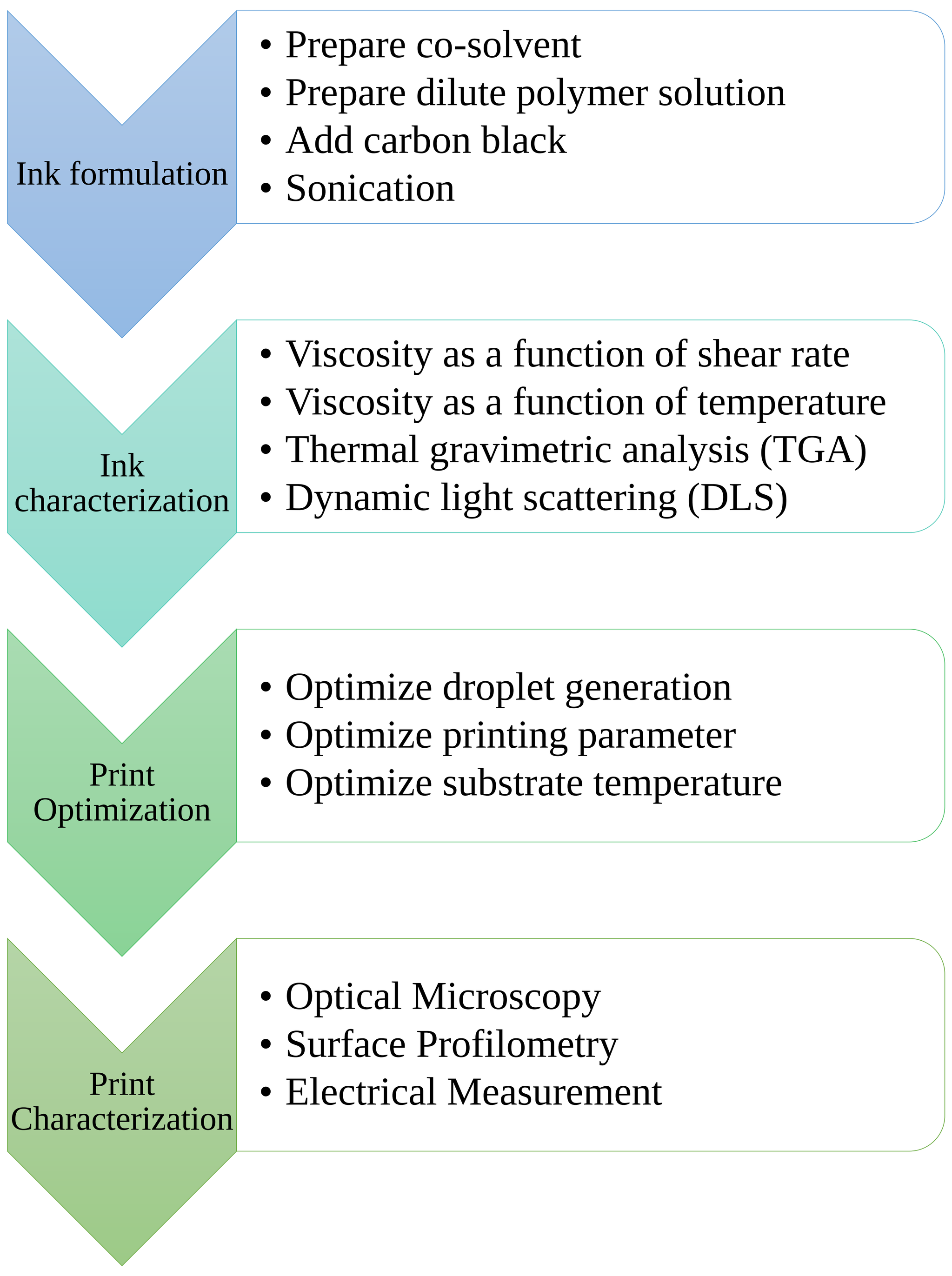
## Abstract

Drop-on-Demand Inkjet printing can be used as an effective technique to deposit the sensing layer in chemical sensors. However, formulation of inks containing functional materials remains challenging due to rheological constraints imposed by the inkjet printer. Here, we show a systematic process to formulate and print functional inks containing polymer and carbon black (CB) particles. The functional ink is used for sensing different analytes considering the polarity of the polymer[1,2]. We formulated inks containing polyvinylpyrrolidone (PVP) with the molecular weight of 40 kDa and 360 kDa. We used high-structured carbon black as the conductive filler. Printing parameters were optimized and the polymer composite was printed on the sensor platform with screen printed interdigitated electrode (IDE). The ink showed good stability over time and no sedimentation was observed even weeks after the formulation. In the next step we characterize the sensing behavior of the printed campsites.

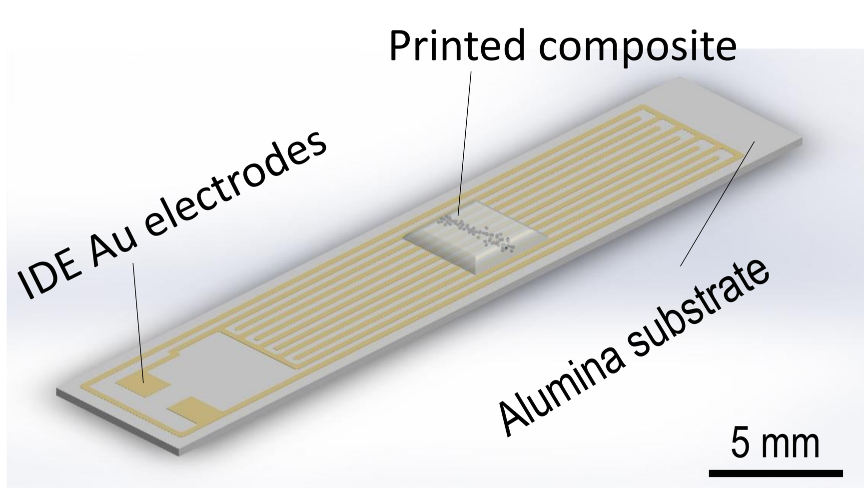
## Material and Method




**Solvent**
- DI water
- Gamma butyrolactone

**Polymer**
- Polyvinylpyrrolidone 40 kDa
- Polyvinylpyrrolidone 360 kDa

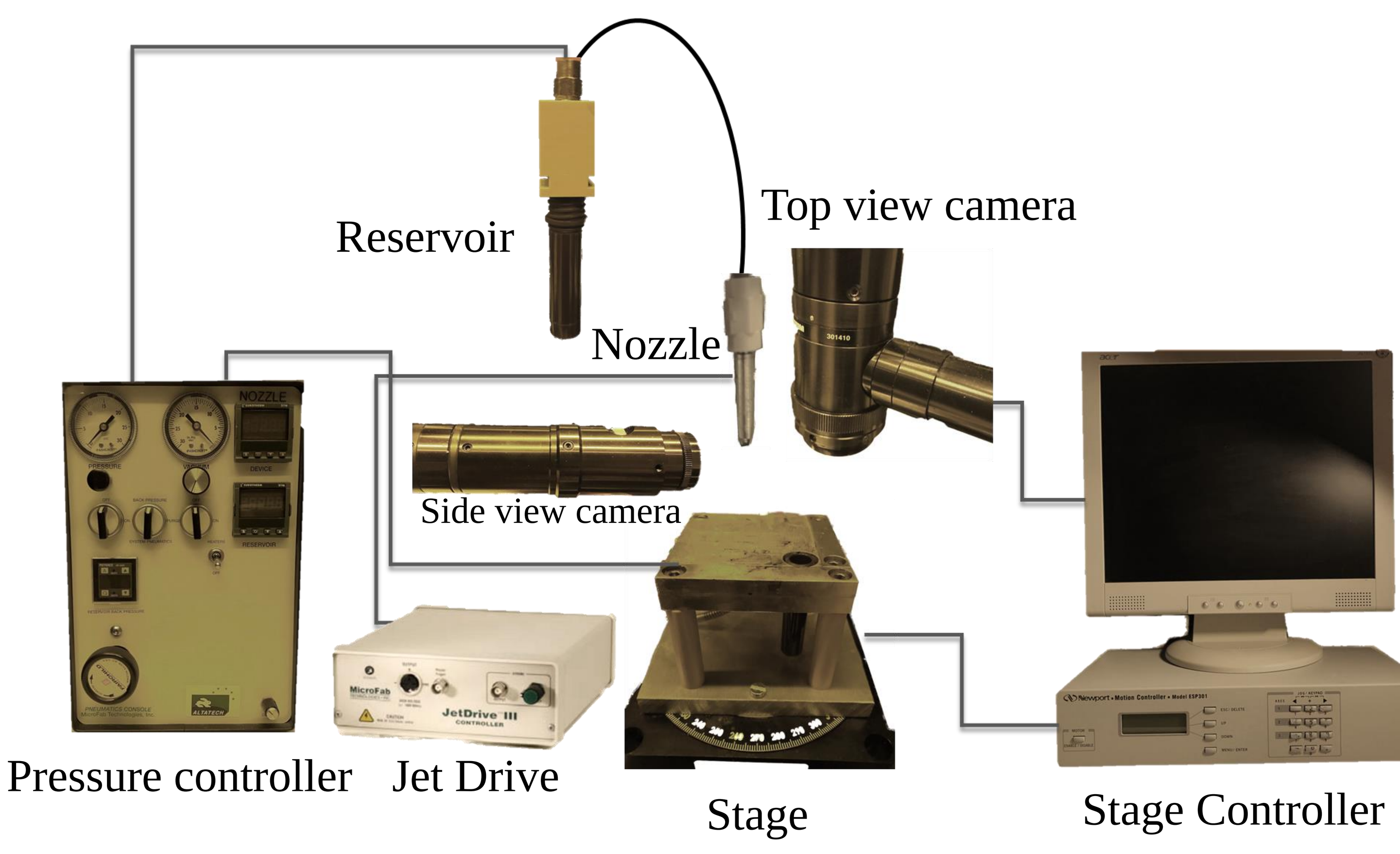
**Filler**
- Ketjen black EC-JD 600



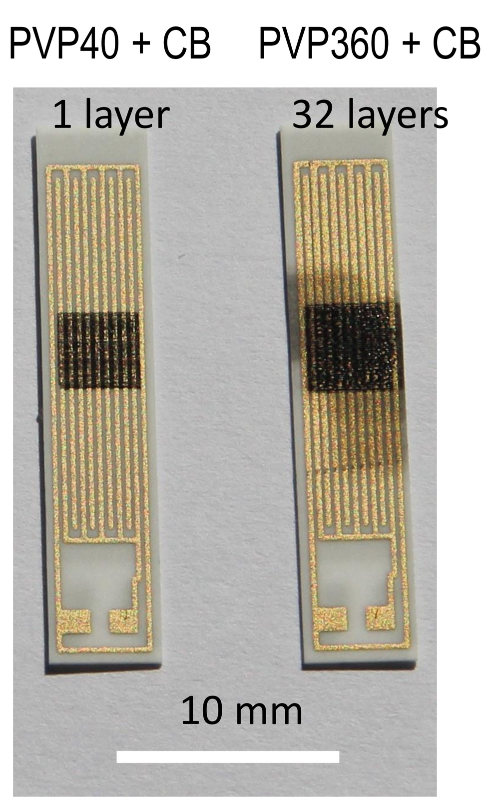

Schematic of the sensor platform with screen printed IDE

## Inkjet Printing

We used a Microfab inkjet printer with a print-head having an orifice diameter of 80 µm to print the composite directly onto the the sensor platform. The temperature of the substrate was raised to 60°C for a faster solvent evaporation. A layer of 4 mm × 4 mm of the polymer composite, consisting of an array of 40 × 40 array of droplets, was printed onto the substrate. The inter drop spacing was set to 100 µm with 100 ms wait time in between two droplet bursts.



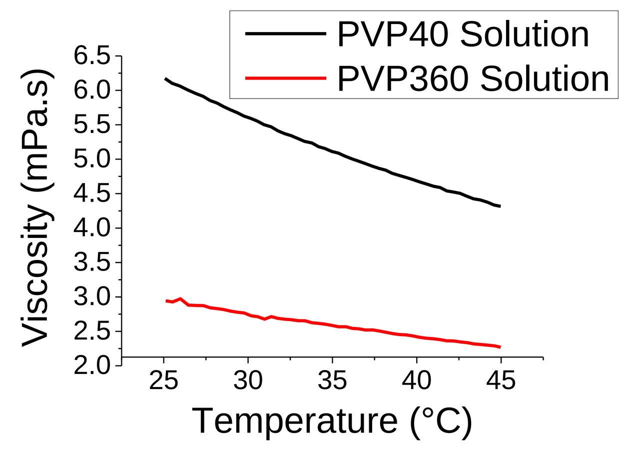

Inkjet printing setup



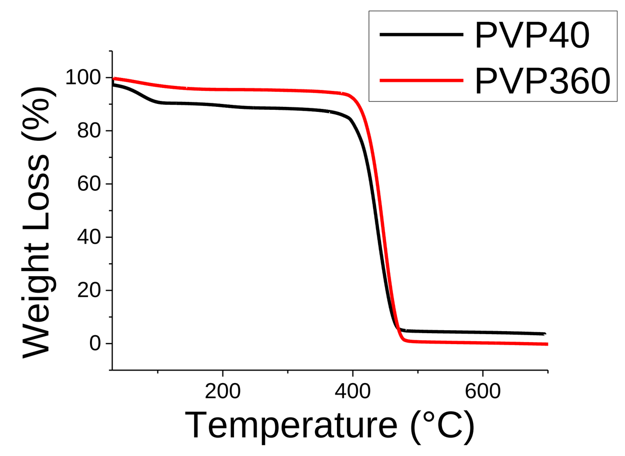

Sensor platforms with printed composites

## Material Characterization

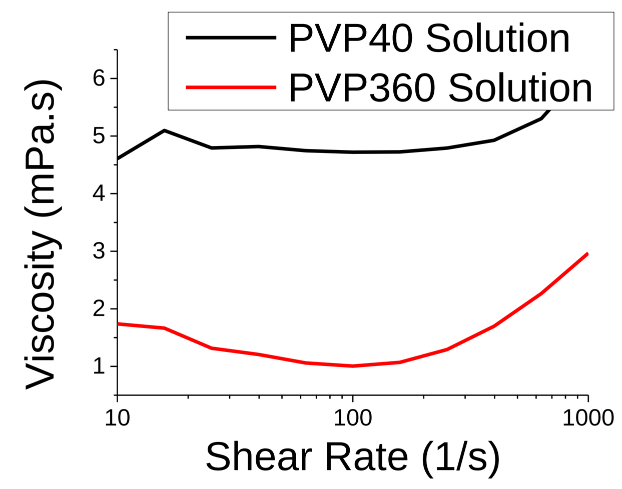
Thermal stability of the polymers was measured using TGA. The viscosity of the dilute polymer solutions was measured as a function of shear rate and temperature using the cone on plate geometry. The CB-loaded ink was sonicated for 5 min. The particle size distribution was measured by DLS. The ink shows good stability over time. After 7 days we did not observe any sign of sedimentation.



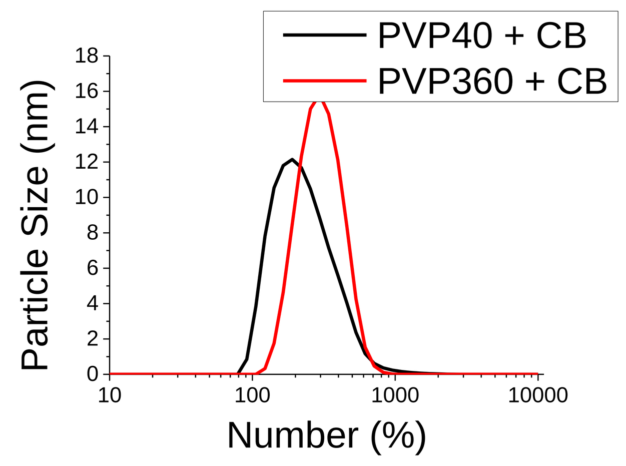

Viscosity as a function of temperature




TGA of the polymers



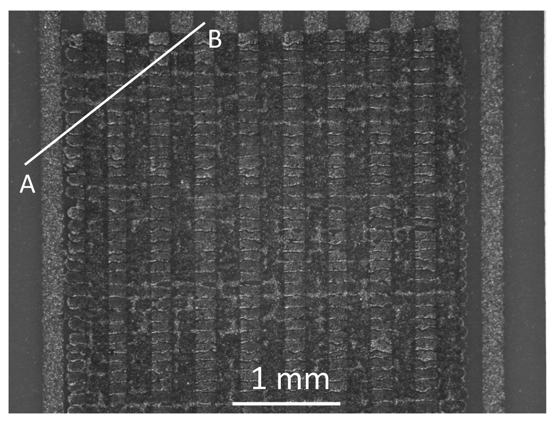

Viscosity as a function of shear rate



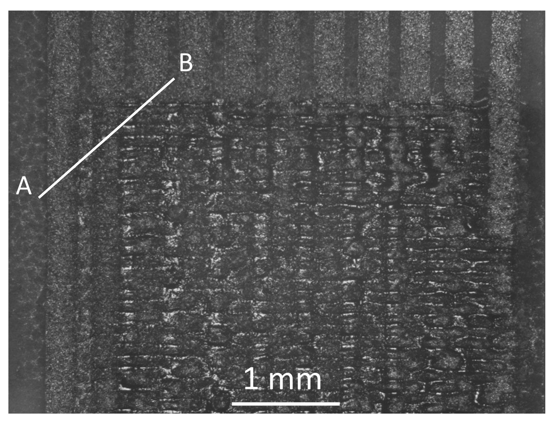

Size distribution of CB particles

## Print characterization

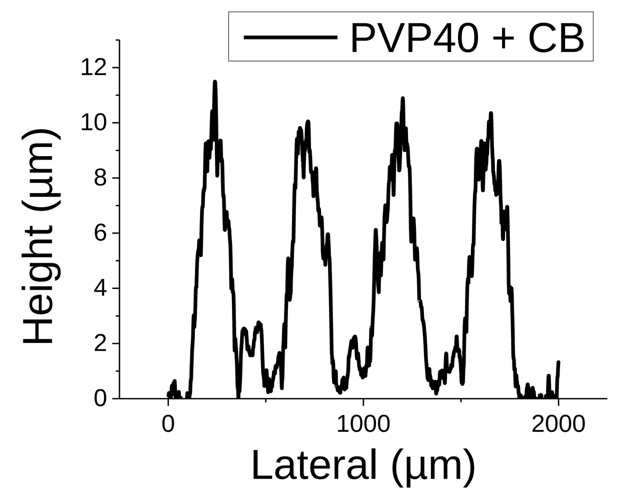
Film thickness was measured with a Dektak surface profiler. The thickness of the printed layer for both materials is around 2 µm. Electrical characterization was performed to obtain the resistance of the printed films. The resistivity of PVP40 and PVP360 loaded inks are $3 \times 10^6\ \Omega$ and $4 \times 10^3\ \Omega$ respectively.

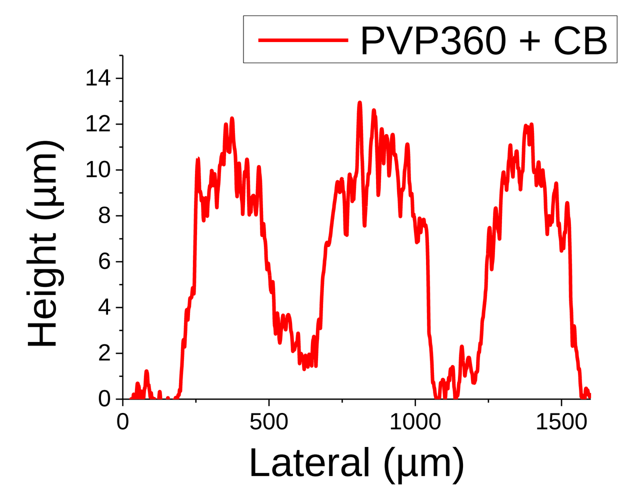



PVP40 + CB printed on the sensor platform

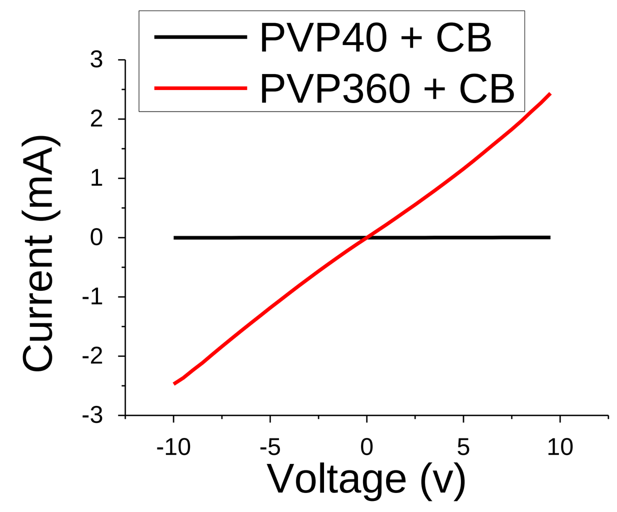



PVP40 + CB printed on the sensor platform




Surface profile of the printed layers




Electrical characterization of the printed films

## Reference

[1] X. Liu, S. Cheng, H. Liu, S. Hu, D. Zhang, and H. Ning, "A Survey on Gas Sensing Technology," *Sensors*, 2012.

[2] N. Komuro, S. Takaki, K. Suzuki, and D. Citterio, "Inkjet printed (bio)chemical sensing devices," *Anal Bioanal Chem*, 2013.

## Acknowledgments

This project is joint between EPFL and Moscow's Institute of Physics and Technology and is funded by the Swiss National Science Foundation (SNF).