Fully printed flexible electrolyte-gated field-effect transistor

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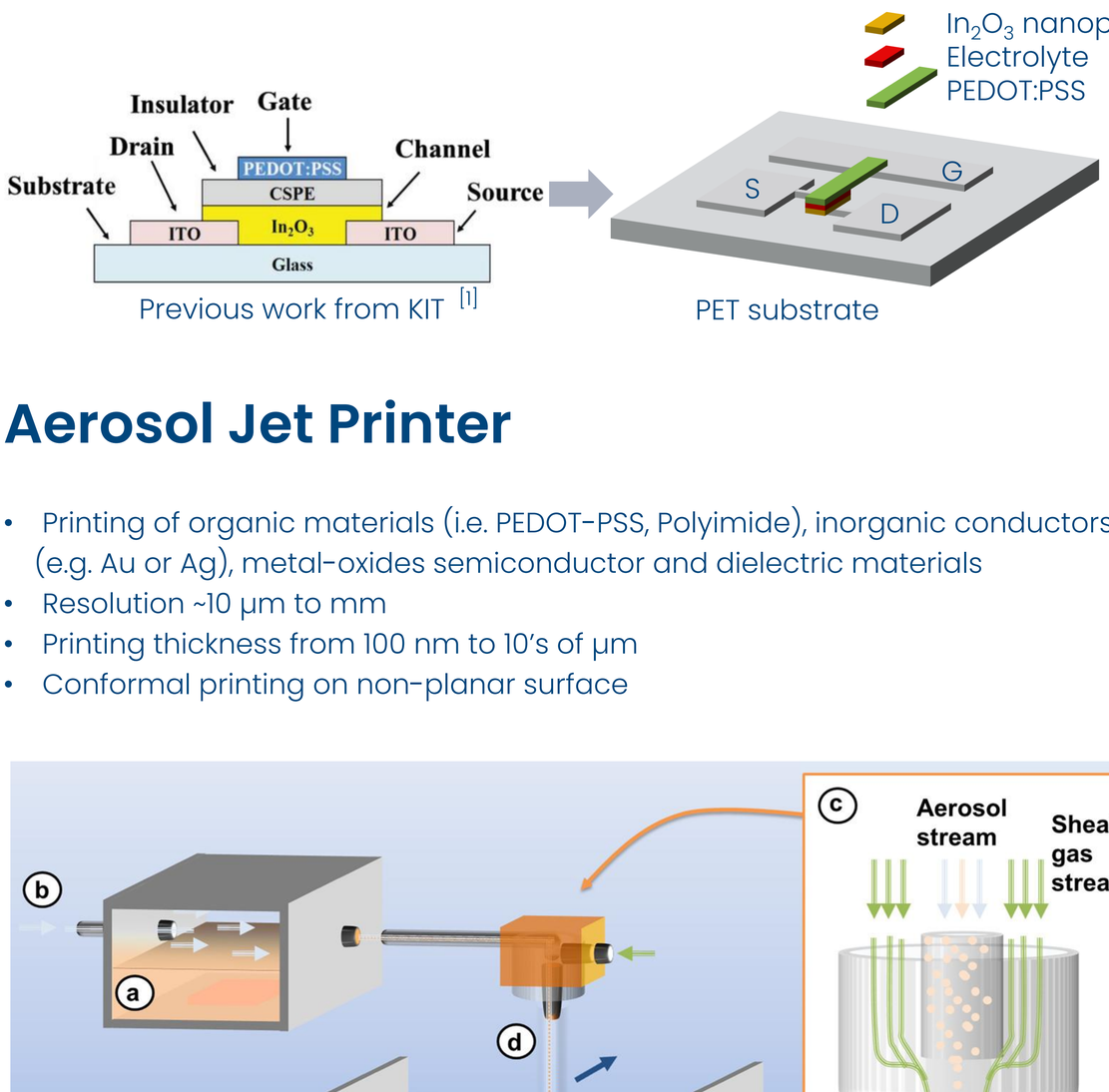
Introduction

Printed flexible electronic devices are widely used in wearable electronics, bioelectronics, and robotics. Among those, printed electrolyte-gated field-effect transistor (EGFETS) can transduce and amplify biological signals into electronic signals using solid polymer electrolytes or ion gels. Those devices provide stable work performance in an aqueous environment, low voltage operation possibility, and high gate capacitances. However, realizing fully printed inorganic transistors on flexible or even non-flat polymer substrates remains a great challenge. To achieve high gate capacitance and minimum printed electrolyte area, printed source/drain electrodes in the device usually required a gap distance below 10 μm. Here, we use aerosol jet printing for Ag electrode fabrication to observe fine resolution patterned structure, followed by inkjet printing to complete the semiconductor channel and gel electrolyte on polyethylene terephthalate. To improve the transistor performance with low voltage operation and high field-effect mobility, the gap distance is down to 10 μm and the electrode resistivity remains around 3 x 10^{-6} Ω·m. By integrating these two printing approaches, we focus to the pre-programming and realization of patterned structures for (semi) automated printing processes. In the future, we plan to demonstrate the use of printed flexible EGFETS-based circuits, including inverters, ring oscillators, and security circuits.

Fully printed electrolyte-gated field-effect transistors on soft substrates

- Low supply voltage requirements: sub 1 V region
- High operation frequency
- Stable in an aqueous environment
- Lithography free and fully printed electrode
- Reduced electrolyte area and channel length
- Challenge on reactive electrolyte with silver ink
- (semi)automated process
- Ultra- sensitive biosensor, synaptic and neuromorphic bio- interface, prosthetics and robotics



Previous work from KIT [1] PET substrate

Aerosol Jet Printer

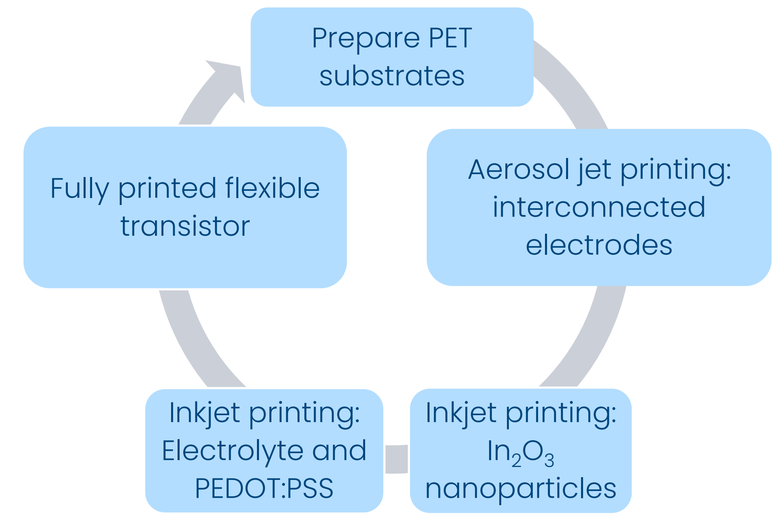
- Printing of organic materials (i.e. PEDOT-PSS, Polyimide), inorganic conductors (e.g. Au or Ag), metal-oxides semiconductor and dielectric materials
- Resolution ~10 μm to mm
- Printing thickness from 100 nm to 10's of μm
- Conformal printing on non-planar surface

[2]

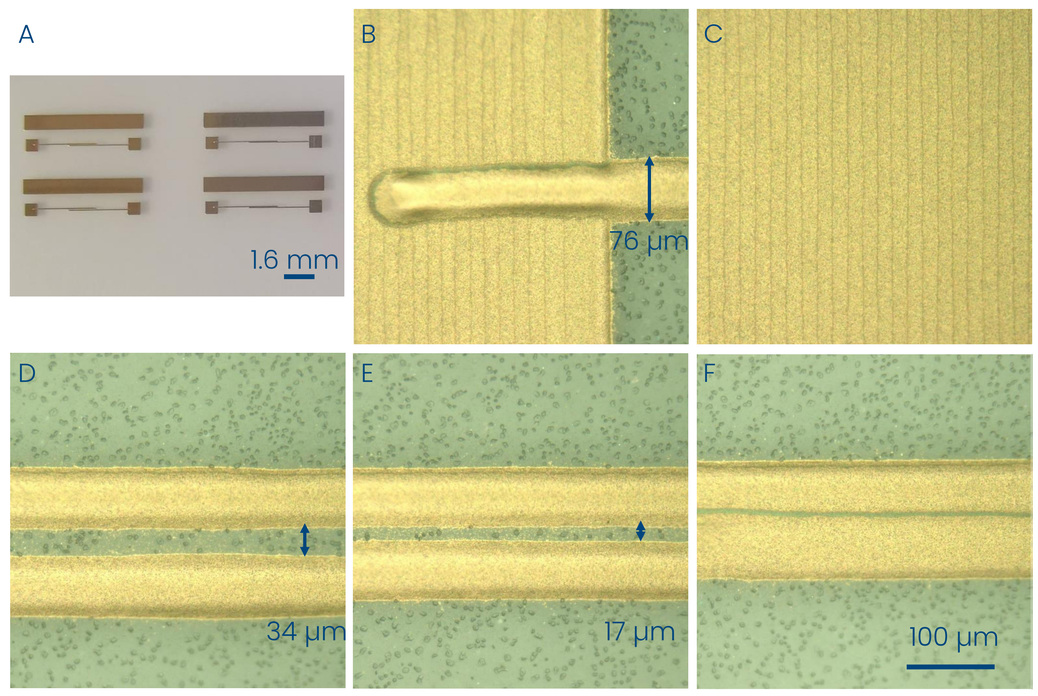
- Aerosol chamber equipped with ultra sonification atomizer
- Inert gas inlet enabling transport of aerosol to vertically movable print head
- Equipped with nozzles for aerosol deposition and for creating annular sheath gas stream
- Focus aerosol jet onto horizontally movable building platform

[1] Adv. Mater. 2019, 1806483. [2] Chem. Rev. 2017, 117, 10212..

Device fabrication

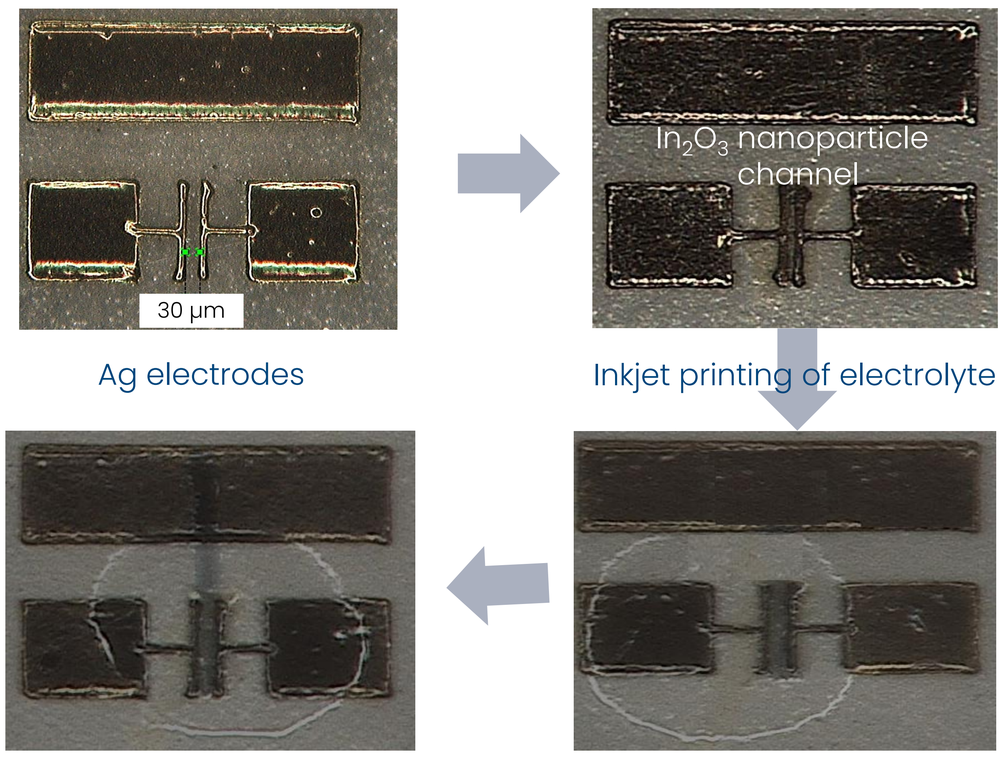


Aerosol printed Ag electrodes in Hereon



- Conductivity ~ 3 x 10^{-6} Ω·m (Ref: 6.2 x 10^{-7} Ω·m)
- Trace width: 76 μm, thickness: 1.5 μm
- Gap distance between source and drain electrodes: 0 to 34 μm
- Avoiding of micro cracks in Ag layer and optimized pattern design

Inkjet printing in KIT



Ag electrodes → Inkjet printing of electrolyte → Inkjet printing of PEDOT:PSS

Future plan

- Assembling of full transistor at KIT
- Larger In_2O_3 nanoparticles printing area
- Develop Ag compatible electrolyte
- Device miniature with high-resolution traces
- New layout for inverter
- Logic gate design for security application
- Pre-programming of patterned structures for automated process

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