Inkjet Printing of Nanomaterials and Metal–Organic Frameworks on CMOS Electronic Nose Platform

BSc / MSc Thesis
HiWi Projects

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Motivation

We are a research group specializing in sensing technologies for early disease detection across various sectors through printed electronics.

Plant diseases cause significant economic losses worldwide, necessitating the development of reliable early warning systems. Our group is developing a CMOS-based electronic nose (e-nose) platform that detects volatile organic compounds (VOCs) emitted by healthy and diseased plants and fruits.

A key challenge is to deposit different sensing materials—such as metal–organic frameworks (MOFs), nanoparticles, and polymers—on a pixelated CMOS capacitive array in a controlled and reproducible way. Inkjet printing is an attractive route because it is additive, mask-free, and compatible with large-area, low-cost fabrication, but the ink spreading, film morphology, and thickness must be carefully engineered.

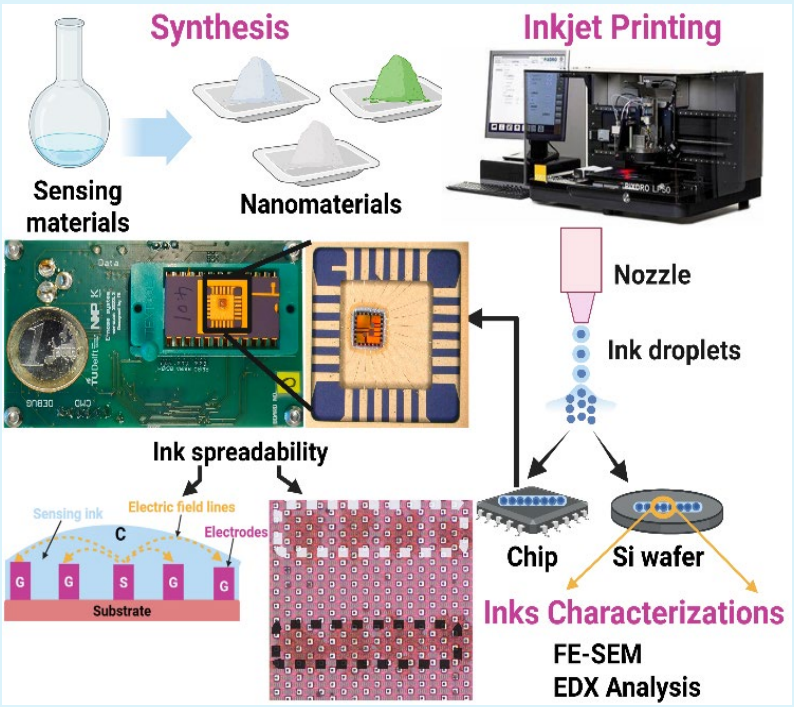
This project has a potential collaboration with the Technical University of Delft (TU Delft) and NXP Semiconductor Eindhoven, the Netherlands

This is a Master's or Bachelor's thesis project with the possibility of a student assistant (HiWi) position.

Description: To develop and characterize a reproducible inkjet-printing process for functional nanomaterial/MOF inks on CMOS e-nose chips, and to establish how process parameters and external stimuli (e.g., heating) control film thickness, morphology, and sensing performance.

Objectives:

1) Formulate and/or optimize inks based on selected MOFs, nanoparticles, and polymers for inkjet printing.
2) Determine suitable viscosity, surface tension, and stability windows for reliable jetting.
3) Control of ink spreadability and film thickness
4) Characterize printed films using FE-SEM, EDX, and optionally profilometry/AFM and contact-angle measurements.
5) Print selected inks on a subset of pixels of a CMOS capacitive array.
6) Measure the capacitive response to simple VOC test gases in a small test chamber.
7) Data analysis and thesis writing



Main Tasks:

1) Formulate printable inks (MOFs, nanoparticles, polymers).
2) Control droplet spreading and film thickness using printing parameters and substrate heating.
3) Characterize printed films (FE-SEM, EDX, thickness).
4) Print selected inks on CMOS pixels
5) Measure VOC response in a simple gas chamber.

Expected Outcomes:

1) A reproducible inkjet-printing protocol for MOF/nanomaterial inks on CMOS capacitive arrays.
2) Quantitative understanding of process parameters controls ink spreadability, film thickness, and microstructure.
3) demonstration of VOC responses from inkjet-functionalized CMOS pixels, providing a basis for future multi-material e-nose arrays and disease-detection studies.
4) Complete Dataset & Thesis

References. (1) Sankaran, S.; Mishra, A.; Ehsani, R.; Davis, C. A review of advanced techniques for detecting plant diseases. *Computers and electronics in agriculture* 2010, *72* (1), 1-13. (2) Widdershoven, F. Pixelated Capacitive Sensors (PCS) for Embedded Multi-Sensing. In *Imaging Sensors, Power Management, PLLs and Frequency Synthesizers: Advances in Analog Circuit Design 2023*, Springer, 2024; pp 23-35. (3) Yuan, H.; Tao, J.; Li, N.; Karmakar, A.; Tang, C.; Cai, H.; Pennycook, S. J.; Singh, N.; Zhao, D. On-Chip Tailorability of Capacitive Gas Sensors Integrated with Metal–Organic Framework Films. *Angewandte Chemie International Edition* 2019, *58* (40), 14089-14094. (4) Suh, J. M.; Eom, T. H.; Cho, S. H.; Kim, T.; Jang, H. W. Light-activated gas sensing: A perspective of integration with micro-LEDs and plasmonic nanoparticles. *Materials Advances* 2021, *2* (3), 827-844.