

Advancements in microsystem technology have a critical role in developing advanced sensing and wastewater remediation platforms to effectively address environmental issues. The integration of microsystem technology with nanotechnology has enabled the development of miniaturized systems with enhanced selectivity and sensitivity. These advances facilitate the design of functional platforms capable of detection of specific analytes, ensuring environmental and human safety, and efficient remediation of wastewater, including the removal of carcinogenic dyes and oily pollutants. However, the rapid pace of technological innovation and the limited operational lifespan of many microsystem devices have led to frequent disposal and replacement. This practice significantly contributes to the growing issue of electronic waste (e-waste), which presents substantial risks to ecosystems and ecological equilibrium. In this context, flexible functional microsystems have been proven to be of great interest in recent years because of their advantages such as mass production capability, lightweight, and mechanical flexibility. These features account for offering a more sustainable choice as they reduce e-waste, enabling the development of environment friendly microsystems.

This thesis work focuses on the development of cost-efficient multifunctional platforms for sensing and environmental remediation. These microsystems are designed to be energy-efficient, scalable, and reliable, tackling pressing challenges related to cost and performance. The research focuses on developing advanced functional platforms based on semiconducting nanostructures with systematic parametric and predictive modeling. One key outcome is the development of a high-performance nanosensor with exceptional stability, selectivity, and the ability to detect hydrogen (H_2) gas with a detection limit of ~ 9 ppt. In another study, a room-temperature operated flexible microsystem was developed using a ternary nanocomposite as a sensing material. The flexible microsystem is capable of detecting carbon monoxide (CO) gas, achieving a detection limit of 100 ppb. In the domain of healthcare diagnostics, the research advances non-invasive monitoring by developing an acetone nanosensor for exhaled breath, serving as a biomarker for diabetes. By incorporating machine learning (ML) algorithms, this sensor can accurately distinguish between signals from healthy breath and simulated diabetic breath samples. To address environmental concerns, the study further investigates wastewater treatment solutions for industries such as textiles. In this context, additively manufactured 3D micro-lattice structures and soft lithography-based engineered platforms were designed for the effective removal of carcinogenic dyes and oily pollutants from wastewater. These engineered microsystems facilitate on-site pollutant degradation, offering a sustainable approach to preserving water quality.

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