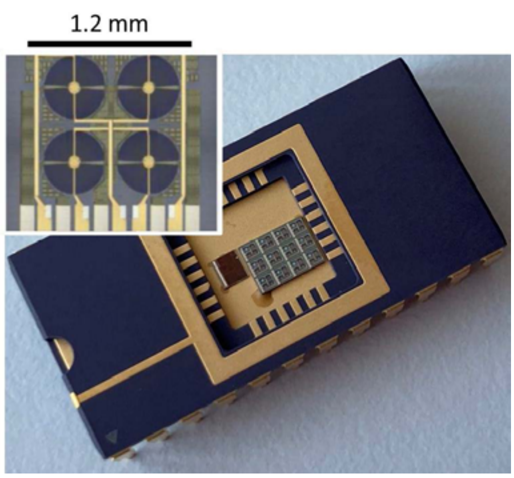
Multi-pixel gas sensor platform

FOR A WIDE RANGE OF APPLIANCE AND CONSUMER MARKETS

Additive Manufacturing for gas sensor fabrication

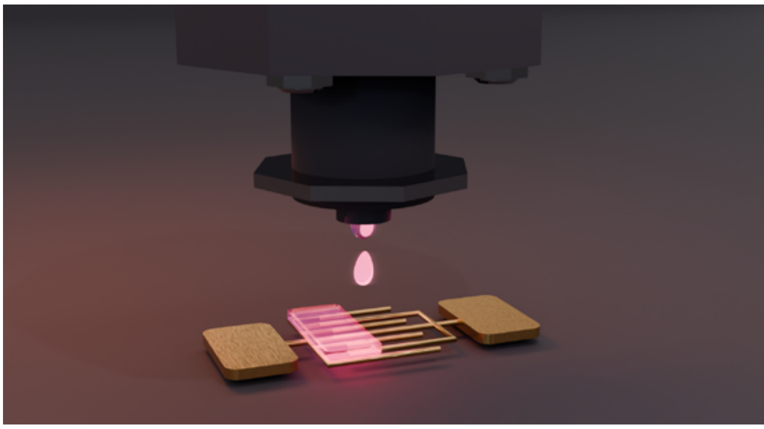
Multipixel Gas Sensors: Advancing Selectivity and Versatility in Gas Detection

Multipixel gas sensors represent a significant evolution over traditional gas sensors, offering superior selectivity and multi-analyte detection capabilities. Unlike conventional sensors that often struggle to distinguish between similar gases, multipixel systems leverage arrays of sensor pixels, each functionalized with a different sensing material, to target specific analytes with greater precision. When the platform is exposed to a mixture of gases, the response of each material is recorded and analysed through advanced signal processing and compared to a database to determine the composition of the mixture. Artificial intelligence (AI) and machine learning (ML) are used for this this real-time pattern recognition and adaptive learning, enabling intelligent interpretation of complex environmental or industrial gas mixtures.



Current fabrication methods for these sensors commonly involve lithography, which enables precise patterning at the micro- and nanoscale. However, emerging techniques, such as additive manufacturing, are a promising alternative to conventional lithographic methods for depositing multiple materials on a single chip, offering numerous advantages in flexibility, efficiency, and scalability. In AMUSENS, inkjet printing and Direct Atomic Layer Processing (DALP) are combined to create localized combinations of materials. These deposition methods are opening new frontiers by allowing for rapid combinatorial search of materials, expediting the discovery of optimal sensing compositions. The combination of these techniques facilitates the scalable development of advanced sensor materials suitable for industrial applications.

The first processing step of the multipixel sensors consists in the inkjet printing of colloidal metal oxide nanoparticles which offer tunable properties thanks to their various morphologies (sphere, rods, flakes) enabling diverse surface to volume ratios. This technique offers several advantages over traditional processes. For instance, it eases the material switching. In vacuum-based techniques like vapor deposition, changing materials requires complex processes—switching sources, re-optimizing deposition parameters, and often halting the system. In contrast, inkjet printing simplifies this dramatically: changing materials is as easy as replacing a cartridge. While formulating functional inks may involve some initial effort, once developed, they enable fast, repeatable, and modular printing of various materials. In addition, inkjet printing is a clean, contactless process, reducing the risk of contamination often associated with physical masks and mechanical handling.



Furthermore, inkjet printing also enables a highly selective spatial deposition, meaning materials can be deposited exactly where needed, without masks or etching, eliminating the need for time-consuming mask alignment and development. This capability makes it easy to adapt to any chip layout or design, significantly enhancing design freedom. From an environmental and cost perspective, inkjet printing excels with minimal waste. The localized deposition ensures material use efficiency of up to 99%, with scrap rates below 0.01%. Compared to lithographic processes, inkjet methods can eliminate 20–40 processing steps and reduce the need for 5–8 different machines, cutting energy use by up to 92% and water consumption by 40%.[1]

[1]Calculation based DTU Nanolab (Denmark) process flow for solar cell manufacturing.

Consortium
11 Partners
9 Countries

Budget
€ 8.6 Million
100% EU-funded

Duration
48 Months
06/2024 - 05/2028

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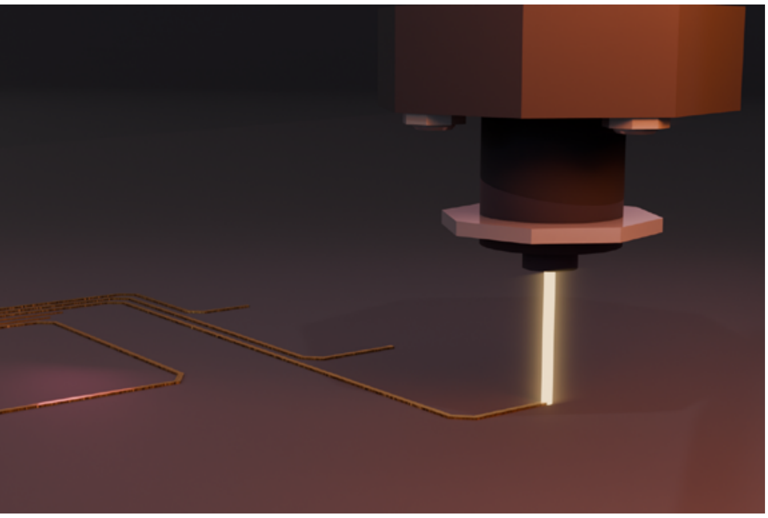
Finally, inkjet systems can be seamlessly integrated with robotic automation, enabling scalable, fully automated production lines suitable for high-throughput, multi-material device fabrication.

In a second step, the printed metal oxide nanoparticles are functionalized using Direct Atomic Layer Processing (DALP) which consists in the localized and selective deposition of metal oxide (or metals) in vapor phase to create a shell around the primary particles. DALP offers a powerful, next-generation approach to precisely modifying metal oxide materials at the atomic scale, making it particularly valuable for the development of high-performance sensors. The primary particles coated with DALP exhibits different properties from the naked particles which significantly improve the sensitivity, selectivity, and long-term stability of the gas sensors.



DALP is a non-contact, digitally controlled process, allowing for spatially resolved surface treatment with high precision. Unlike traditional post-processing methods, it does not require masks or physical contact, which reduces the risk of contamination and mechanical damage.

Moreover, DALP is especially well-suited for post-processing on complex or flexible substrates, such as those used in wearable or printed electronics. Its gentle, conformal coating method ensures minimal thermal or mechanical stress, preserving the integrity of delicate underlying layers while delivering functional enhancements exactly where needed.

Potential Applications of Multipixel Gas Sensors

Multipixel gas sensors offer a compact, versatile, and highly selective platform for detecting a wide range of gases simultaneously. Their unique ability to integrate multiple sensing materials onto a single chip opens the door to numerous applications across industries, from consumer goods to environmental management.

One promising area is smart packaging, where embedded gas sensors can monitor food freshness or pharmaceutical stability in real time. By detecting spoilage gases or degradation markers, multipixel sensors can help reduce waste and ensure product safety throughout the supply chain.

In wearable technology, multipixel sensors can be fabricated on flexible, skin-conformable substrates for continuous health and fitness monitoring. These devices can track breath composition or skin-emitted biomarkers, enabling non-invasive diagnostics.

In agriculture, distributed networks of multipixel gas sensors can provide localized insights into air quality or soil emissions, supporting precision farming practices.
These sensors can also be deployed in urban areas or industrial zones to provide high-resolution data on air pollution and emissions. Their ability to distinguish between multiple pollutants makes them ideal for real-time mapping of air quality and early warning systems.

Finally, in structural health monitoring, multipixel gas sensors offer solutions for detecting gases associated with corrosion, leakage, or material degradation in buildings, bridges, or industrial infrastructure. Their adaptability allows for tailored deployment across a wide range of environments and materials.

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