

TECHNOLOGY SOLUTION

Sensors

Automated Picoliter-Scale Functionalization for High- Precision Sensor Arrays

Precision Manufacturing for Next-Generation Gas Sensor Arrays

Gas sensors detect target molecules through changes in electrical resistance when analytes interact with the sensor surface. To improve selectivity, sensors are functionalized, meaning they are coated with specialized materials that preferentially bind specific gases. These functional materials, which include quantum dots, nanoparticles, and polymers, act as selective interfaces that enhance the sensor's response to target analytes while minimizing interference from other compounds. However, manual functionalization of sensor arrays is slow, inconsistent, and prone to cross-contamination when multiple functional groups are applied to different sensors on the same chip. Manual methods also suffer from operator-to-operator variability and limited scalability, making them impractical for manufacturing larger quantities of sensor devices.

NASA's Goddard Space Flight Center has developed an automated picoliter dispensing method that functionalizes individual sensors with quantum dots, metal nanoparticles, metal oxide nanoparticles, or polymers. The system deposits picoliter volumes with micron-scale precision, enabling batch processing of entire wafers while maintaining sensor-to-sensor consistency and preventing cross-contamination between different materials.

BENEFITS

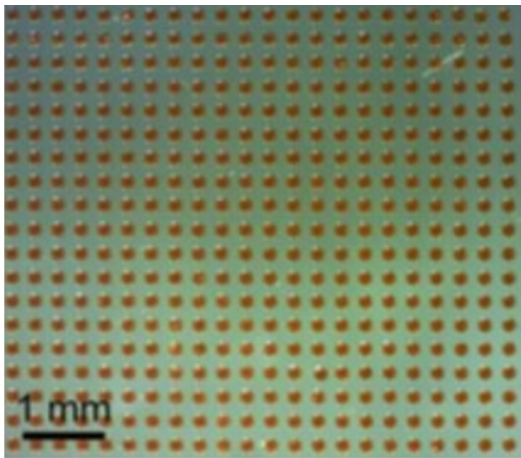
- **Prevents Cross-Contamination:** Applies different functional groups to adjacent sensors on the same chip without material transfer between devices, preserving the selectivity of each sensor element through precise picoliter dispensing.
- **Enables Batch Processing:** Automates coating deposition across entire wafers, replacing manual methods and supporting commercial-scale manufacturing workflows.
- **Improves Reproducibility:** Delivers consistent material coverage from sensor to sensor and chip to chip, reducing performance variation in manufactured arrays and ensuring predictable device characteristics.
- **Accelerates Production:** Reduces the time required to coat sensor arrays compared to manual methods, enabling faster development cycles and higher manufacturing throughput.



THE TECHNOLOGY

This advanced sensor functionalization technique uses an automated picoliter dispenser to deposit materials directly onto individual sensors in an array. The system accommodates a wide range of materials, including cadmium selenide (CdSe) quantum dots, metal and metal oxide nanoparticles, and suspended polymeric solutions. These materials serve as the active sensing layers that enable the detection and identification of target analytes in gas or liquid environments. The dispenser delivers picoliter volumes with micron-scale alignment precision, enabling different sensors on the same substrate to receive different coating materials without cross-contamination. This precise control over material deposition is critical for creating sensor arrays with diverse capabilities, where each individual sensor element can be optimized for detecting specific chemical compounds or contributing to a broader detection profile. The automated system can process an entire wafer in sequence, such as a wafer containing 49 chips with 10-12 sensors each, ensuring uniform coverage and consistent performance across all devices.

This batch processing capability represents a significant advancement over manual methods, which are time-consuming, subject to operator variability, and difficult to scale. The automation accelerates manufacturing while dramatically improving reproducibility from sensor-to-sensor and chip-to-chip, resulting in more reliable device performance. The method is compatible with various sensor platforms, including microfabricated and printed arrays, and addresses the critical need for reproducible, high-throughput sensor fabrication in applications ranging from environmental monitoring to spacecraft cabin air quality control. This technology is available for patent licensing.



Uniform pixels of approximately 300-micron size produced using the automated dispenser system. Credit: NASA

APPLICATIONS

The technology has several potential applications:

- **Environmental Monitoring Systems:** Enables production of multi-analyte sensor arrays for air quality monitoring, industrial emissions tracking, and hazardous gas detection in commercial and industrial facilities requiring simultaneous detection of multiple pollutants.
- **Medical Diagnostics:** Supports manufacturing of breath analysis sensors and point-of-care diagnostic devices that detect disease biomarkers through volatile organic compound signatures, enabling noninvasive screening and monitoring applications.
- **Industrial Process Control:** Provides sensor arrays for chemical manufacturing, food processing, and pharmaceutical production where multiple gas species require simultaneous monitoring to ensure product quality, worker safety, and regulatory compliance.
- **Automotive and Aerospace:** Facilitates production of cabin air quality sensors and leak detection systems requiring selective response to multiple target gases in vehicles, aircraft, and spacecraft environments.
- **Consumer Electronics:** Enables integration of gas sensing capabilities in smart home devices, wearables, and mobile platforms.

PUBLICATIONS

Patent No: 12449408

Patent Pending

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