EcoNanoGuard: Energy-Efficient Nanosilver Sensor for Early-Stage VOC Leakage Detection

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With the rapid expansion of global manufacturing, emissions of volatile organic compounds (VOCs) have surged, posing serious threats to both public health and environmental safety. However, commercial VOC sensors typically require operating temperatures above 200 °C, leading to high energy consumption, elevated costs, and fire hazards. This study presents an energy-efficient alternative using monolayer-protected nanoclusters (MPCs)—silver nanoparticles surrounded by carbon chains with tunable surface chemistry. By optimizing carbon chain lengths to balance sensitivity and structural stability, and then introducing functional groups to enhance selectivity, the sensor demonstrated sensitive detection of N,N-dimethylformamide (DMF) at concentrations as low as 4 ppm. Beyond material design, a complete prototype with integrated circuitry and signal processing was developed to enable real-time VOC sensing. Compared to commercial sensors, this system lowers the operating temperature from 200 °C to room temperature, reducing energy consumption by over 99%, and cutting fabrication costs from USD 20 to USD 1. These results highlight the potential of MPC-based platforms as scalable, energy-efficient solutions for industrial gas monitoring. Future integration of multiple functionalized MPCs with computational models may enable selective detection of complex gas mixtures—paving the way for next-generation multi-gas sensing systems.

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