

From FET Gas Sensors to Intelligent Machine Olfaction Microsystems

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Machine olfaction requires sensing interfaces that combine molecular sensitivity, low-power readout, and compatibility with integrated circuits [1]. Quantum dots (QDs) provide tunable surface chemistry and solution processability, but mobility-limited resistive transduction constrains the sensitivity–power trade-off [2]. Here, we present a device-to-circuit strategy that advances field-effect transistor (FET) gas sensors toward intelligent machine olfaction microsystems by integrating PbS QD surface chemistry with extended-gate MOSFET transduction. Spin-coated PbS QDs provide room-temperature NO₂ recognition, while the MOSFET supplies field-effect amplification. The devices exhibit an on/off ratio of approximately 103, a monotonic response over 50–1000 ppb, a response value of 11.01 at 1000 ppb, and good repeatability. Building on this material-functionalized platform, we further replace conventional resistive readout with quantum-capacitance sensing. Gas adsorption changes the local density of states near the Fermi level and therefore the quantum capacitance (CQ); capacitive coupling maps these small interfacial variations into pronounced threshold-voltage (V_{th}) shifts. This architecture achieves a detection limit of 83 ppt and a power density of 4.45 mW cm⁻² at room temperature. Controllable output modulation of an on-chip CMOS inverter under NO₂ exposure further demonstrates direct sensor–circuit interfacing. Together, these results establish a progression from functionalized FET sensors to integrated sensing–transduction circuits. Combining solution-processable receptor layers, transistor amplification, and CMOS-level output provides a scalable foundation for sensor arrays, on-chip signal conditioning, and pattern-recognition functions in compact machine olfaction microsystems.

Keywords: Extended-gate MOSFET; PbS quantum dots; Quantum capacitance; Capacitive coupling; CMOS integration; Sensor arrays

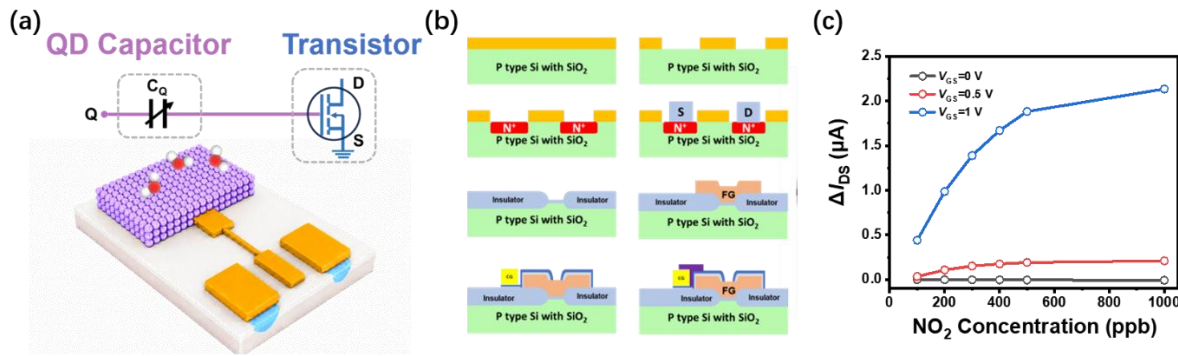


Figure 1. Device-to-circuit pathway of the quantum-capacitance-coupled MOSFET gas sensor: (a) extended-gate sensing principle, (b) fabrication process, and (c) room-temperature NO₂ response.

References

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