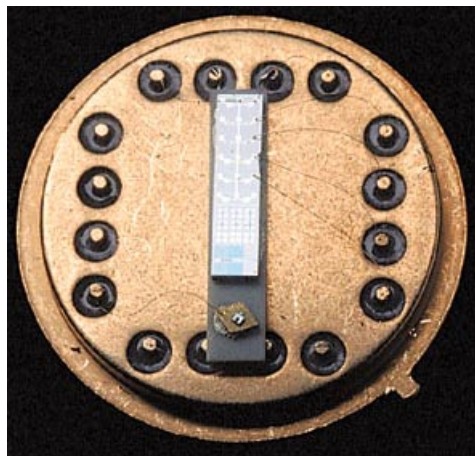


Technology / Sensors / FE

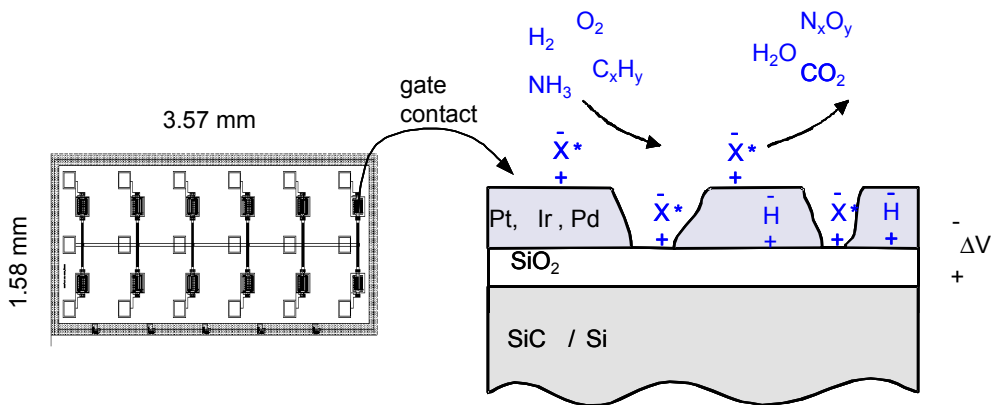
The AppliedSensor field effect (FE) sensor technology is based on the field effect generated by gases in metal oxide semiconductor field-effect transistor (MOSFET) devices with catalytic metals. The charging of the gate contact by the gas molecules results in a voltage change in the sensor signal. The choice of operation temperature, gate metal, and structure of the gate metal determine the selectivity of the gas response. For devices based on silicon (Si) as the semiconductor, Si-MOSFET, the operation temperature is 150-200°C. For devices based on silicon carbide (SiC) as the semiconductor, SiC-MOSFET, the operation temperature is 200-600°C.



Photograph of a Si-MOSFET sensor. The size of the sensor chip is 2 x 4 mm.

CHEMICAL PRINCIPLE

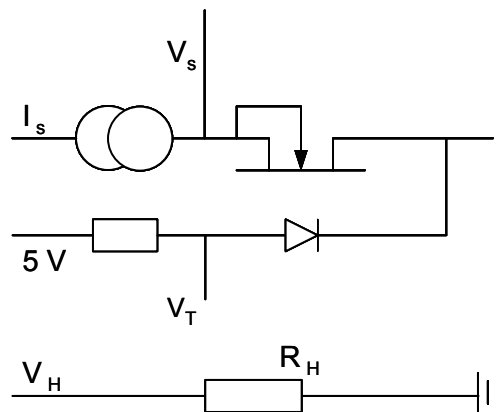
In a FE sensor, the interaction of gases with the catalytic gate metal induces dipoles or charges, which give an additional voltage to the gate contact. The choice of operation temperature, type of catalytic metal, and structure of the metal influence the chemical reactions on the gate of the sensor, and thus the selectivity and sensitivity of the sensor. Using silicon carbide as the semiconductor instead of silicon makes it possible to use the FE sensors at elevated temperatures. This gives response times in the order of milliseconds due to the fast chemical reactions. Furthermore, the catalytic metal remains clean even in highly contaminated environments.



Sketch of a MOSFET sensor illustrating the detection principle. The threshold voltage of the transistor changes due to the dipoles produced by the gas molecules.

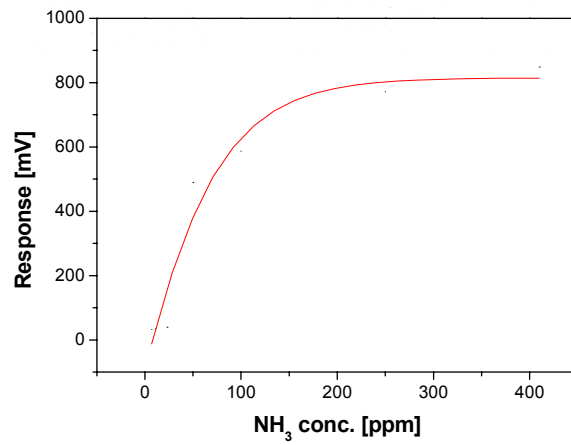
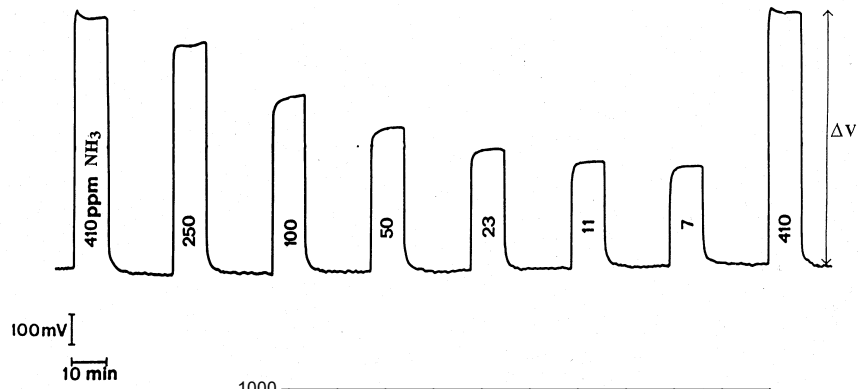
TRANSDUCER PRINCIPLE

The MOSFET sensor device is based on a field effect transistor with a catalytic metal as the gate contact. The gate voltage controls the current through the MOSFET device. The gas molecules will affect the voltage to the gate contact and thus change the current through the transistor. For the MOSFET sensor, gate and drain are connected and the sensor operates as a two-terminal device. The voltage (around 2 V) at a constant current (100 μ A) is recorded. The gas response is recorded as a voltage change in the sensor signal.



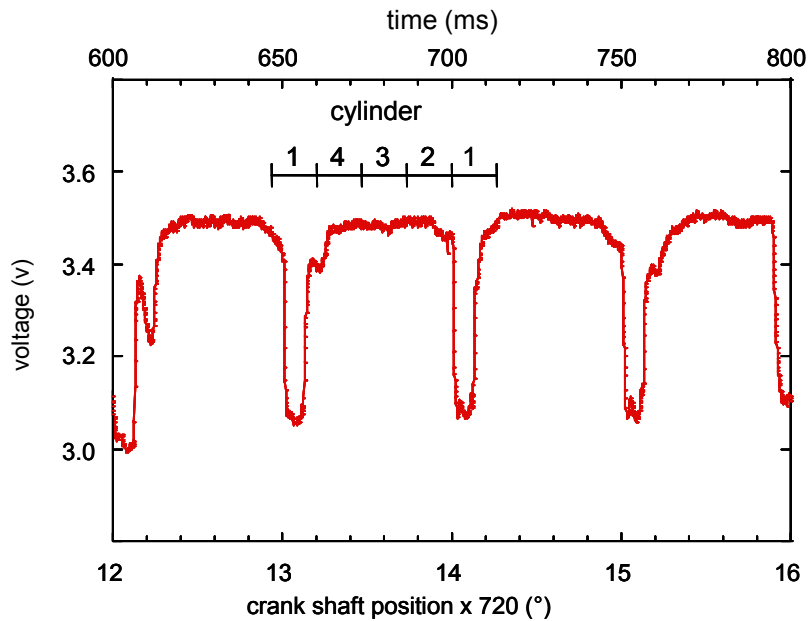
Electronic circuitry for operation of a MOSFET sensor with heater

Ir, 6nm, 215°C carrier gas: 20% oxygen/argon



TYPICAL RESPONSE CURVES

Typical response curve for a Si-MOSFET sensor to ammonia, and the response versus concentration of the sensor to ammonia.



At an operation temperature of 600°C, the signal of a SiC-MOSFET device is fast enough to follow air-to-fuel ratio variations of individual cylinders by measuring the exhaust gas in a car manifold system.

IMPORTANT FEATURES

FE sensors respond to gases like hydrogen, ammonia, amines, ethanol, acetone, hydrocarbons, CO, and NO₂. The sensitivity of the sensors is normally high for low concentrations of the gases, while it becomes saturated for high concentrations of the gases.

The operation temperature range is 100-200°C for Si-based FE sensors and 200-600°C for SiC-based FE sensors.

SiC is chemically very inert and a semiconducting material even at high temperatures. The SiC-based FE sensors can therefore withstand corrosive environments and high temperature environments like car exhaust and flue gases.

MINIATURIZATION POSSIBILITIES

A low power Si-MOSFET device has been designed in a CMOS and micro-machining compatible process. Four gas sensors together with a temperature sensor and a heating element have been integrated on a thin silicon carrier. The device is supported with a sub micrometer thermally isolating membrane. A low thermal time constant (<100 ms) and a low power consumption (<100 mW/device for 170°C) enable new modes of operation.

The excellent heat conductivity of the SiC-MOSFET sensors also offers possibilities for miniaturization. In a future development, heater and temperature control can be integrated on the SiC sensor chip, which will enable

a sensor chip with low power consumption and low time constants for the heating.

APPLICATION IDEAS

1. Identification of carton board qualities

Reference: Identification of carton board qualities using gas chromatography or gas sensitive sensors in combination with multivariate data analysis, Gunnar Forsgren and Jaana Sjöström, Nordic Pulp & Paper Research Journal, 4, 12 (1997) 276-281.

2. Cylinder specific monitoring in car exhaust

References: Fast responding air/fuel sensor for individual cylinder control, A. Baranzahi, P. Tobias, A. Lloyd Spetz, I Lundström, P. Mårtensson, M. Glavmo, A. Göras, J. Nytomt, P. Salomonsson, and H. Larsson, SAE Technical Paper Series 972940, Combustion and Emission Formation in SI Engines, SP-1300 (1998) 231-240.

Platinum – Insulator – Silicon Carbide Structures as Small and Fast Sensors for Exhaust Gases, P. Tobias, P. Rask, A. Göras, I. Lundström, P. Salomonsson, and A. Lloyd Spetz, Sensoren und Messsysteme 2000, VDI Berichte 1530, ISBN 3-18-091530-7, VDI Verlag, Düsseldorf, March 13-14, (2000) 179-190.

3. NH₃ monitoring in diesel exhaust for NO reduction by SCR (selected catalytic reduction of NO by NH₃)

Reference: MISiC Schottky Diodes and Transistors as NH₃ Sensors in Diesel Exhausts to Control SCR, H. Svenningstorp, P. Tobias, P. Salomonsson, B. Häggendal, I. Lundström, L.-G. Ekedahl, and A. Lloyd Spetz, Proc. Euroensors XIV, Copenhagen, Denmark, August 27-30, (2000) 933-936 (W3E5).

4. Monitoring of flue gases in boilers

Reference: Flue Gas Measurements with an Electronic Nose Equipped with SiC Based High Temperature Sensors and Metal Oxide Sensors, L. Unéus, P. Ljung, R. Wigren, P. Mårtensson, L. G. Ekedahl, I. Lundström, A. Lloyd Spetz, Proc. ISOEN'2000, Brighton, England, July 24-26, 2000, 291-296.

LINKS TO RESEARCH ACTIVITIES

<http://www.ifm.liu.se/Applpahys/S-SENCE/>

<http://www.acreo.se/>

<http://www-samlab.unine.ch/>