AppliedSensor

Field Effect (FE) Sensor Technology

The AppliedSensor field effect (FE) gas sensor technology is based on the field effect generated by gas molecules in the metal oxide semiconductor field-effect transistor (MOSFET) device with a catalytic gate metal. The charging of the gate terminal by the gas results in a voltage change in the sensor signal. Detection properties can be modified, for instance, by the choice of operation temperature, gate metal, and structure of the gate metal. Usually, devices are based on silicon (Si) as the semiconductor, Si-MOSFET, and have an operation temperature of 150-200 °C. Other materials such as, silicon carbide (SiC) can also be used as the semiconductor, utilizing higher operation temperatures (200-600 °C).

Key Benefits

- High sensitivity
- Short response times
- Long-term stability
- Low power consumption
- Robust design of sensor chip
- Versatile system design

Substances Detected

- Safety (H_2, NH_3)
- Automotive (H_2)
- Leak Detection (H_2)

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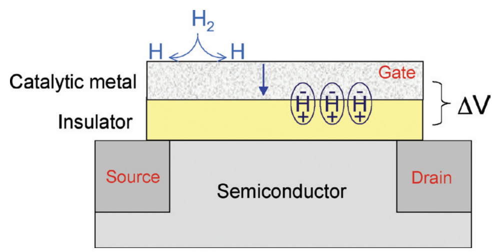
Chemical Principle

In a FE gas sensor, the interaction of gases with the catalytic gate metal induces dipoles or charges, which give an additional voltage to the gate terminal. The schematic below of a MOSFET illustrates the detection of hydrogen (H_2). Important steps are dissociation of hydrogen on the catalytic metal surface, diffusion of hydrogen atoms through the catalytic metal and trapping of polarized hydrogen atoms (dipoles) in the catalytic metal/insulator interface. The additional voltage on the gate terminal is denoted ΔV.



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 properties such as selectivity, sensitivity, and speed of response of the sensor. FE sensors can respond to gases like hydrogen, ammonia, amines, ethanol, acetone, and hydrocarbons. The sensitivity of the sensors is normally high for low concentrations of the gases, while it becomes saturated for high concentrations.

Transducer Principle

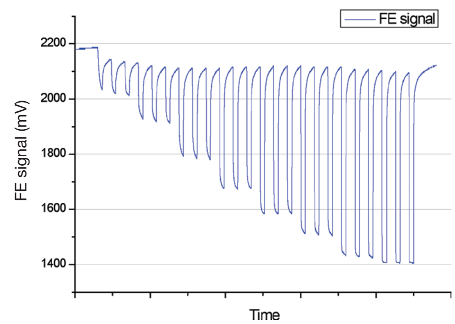
The MOSFET sensor device is based on a field effect transistor with a catalytic metal as the gate contact. The gate voltage controls the current through the MOSFET device. The gas molecules will affect the voltage to the gate terminal and thus change the current through the transistor. For the MOSFET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

Processing and Production

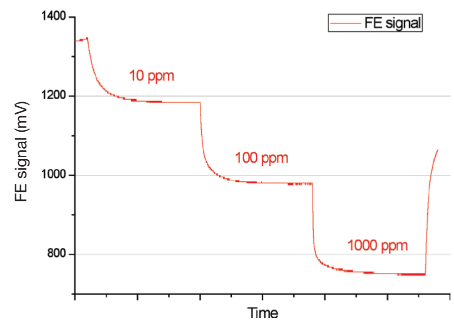
The sensor chip is manufactured in conventional n-type metal-oxide-semiconductor (NMOS) technology. There are three basic functions on the sensor chip; gas detection, temperature measurement, and heating that all are realized with transistors. Temperature transistors and heaters are fully processed and passivated by a wafer foundry sub-supplier. The gas transistor is finalized by AppliedSensor by deposition and anneal of the catalytic metal layer in a controlled clean room environment. Thus, the metal variations required by specific applications are managed and processed by AppliedSensor. The simplicity of the sensor chip as well as the relatively large critical dimensions of the silicon processing gives a robust platform for process optimization. Furthermore, the concept with only basic functions in the sensor chip provides versatility that allows circuitry variations depending on application demands.

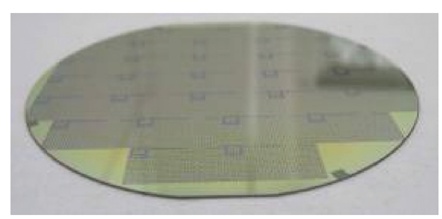
Examples of FE Signals

The graph below shows the FE signal (voltage) response to various H_2 concentrations. Each concentration has been repeated three times with exposure to air between the gas pulses.



The graph below shows the FE signal (voltage) response to various ammonia (NH_3) concentrations. It is a “staircase” exposure without exposure to air between the gas pulses.





Silicon wafer with numerous sensor chips

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