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Millisecond response time measurements of high temperature gas sensors

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Abstract

We present a new apparatus for measuring the response times of a gas sensor with millisecond resolution, while also capturing the slower components of the response such as the steady state value. Laser Induced Fluorescence (LIF) imaging was used to quantify the exchange rate of the sensor's ambient gas. The millisecond response of high temperature (up to 950 K) field effect SiC sensors for detection of hydrogen containing gases was characterized.

MOTIVATION

Fast sensor signals are needed for feedback control of processes such as fuel injection in automotive engines and the loading of coal feedstock in a gasification plant. SiC based high temperature sensors have been shown to respond to gas changes within milliseconds [1]. In order to characterize our fast sensors in the laboratory, we need an apparatus to monitor the complete response of the sensor (including both the fast and slow components) without resorting to excessive gas flow rates.

EXPERIMENTAL

We have built a conceptually new set-up for measuring fast gas sensor responses using a fast, bistable electromagnetic actuator to move the outlet of two gas streams, see Fig. 1. By tagging one gas stream with acetone and exposing it completely to a UV laser pulse at 308 nm, we can image the boundary between the two gases and their mixing with laser induced fluorescence (LIF) [2,3]. We image the gas at different stages during the movement of the gas outlets. This allows us to measure how fast the gas environment of the sensor is exchanged and if the exchange is complete.

We report on the fast response of high temperature SiC capacitive sensors (see Fig. 2) to hydrogen and hydrocarbon gases. The sensors are mounted on Pt-microheaters, which allows us to heat the sensors up to 950 K in the fast sensor measurement set-up. During sensor measurements, the device capacitance is held constant while changing the gas environment and the corresponding gate voltage is recorded as the sensor signal, as indicated in Fig. 3.

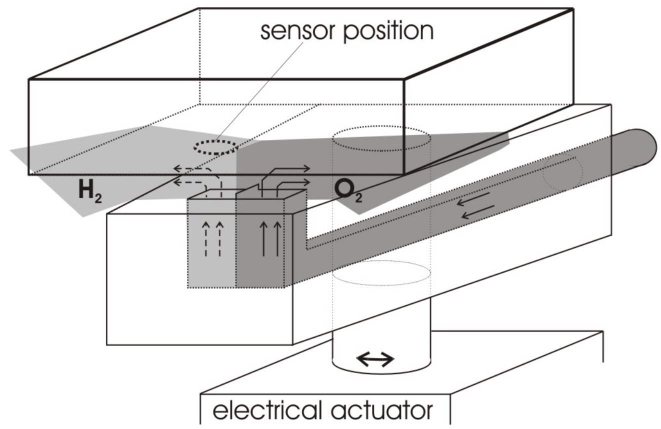

Figure 1: Schematic of the fast gas sensor measurement apparatus. The sensor is mounted face down. In the "moving part", the two gas jets are separated by a thin barrier, extending 0.3 mm above the surface. The electrical actuator can rotate the moving part between two stable positions. The actuation translates the gas outlets by 3 mm in 2 ms, thereby switching the gas under the sensor.

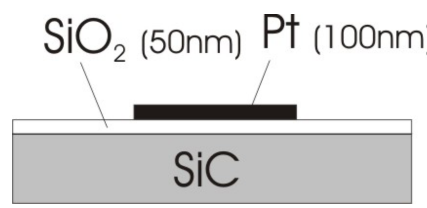

Figure 2: Schematic of the SiC sensor for detection of hydrogen containing gases. The Pt gate faces one of the two gas jets in Fig. 1.

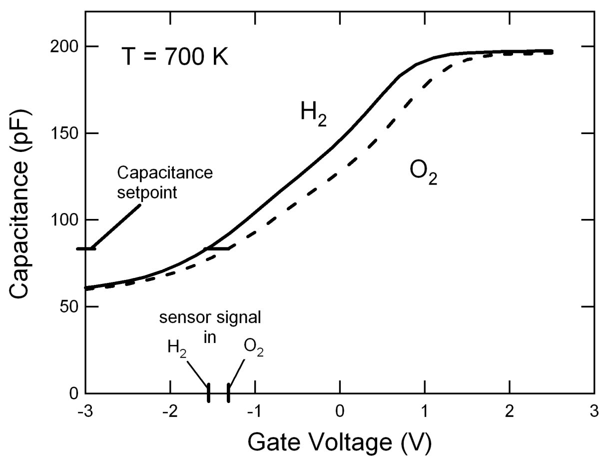

Figure 3: C-V characteristics of a SiC sensor, measured at 1 MHz in two gas environments, in 1% oxygen in nitrogen (O_2) and in 10% hydrogen in nitrogen (H_2). The gate voltage is swept from positive to negative voltages.

RESULTS

The LIF-images of the gas streams allowed us to study how the rate of the gas exchange is affected by a change in the gas flows or by a change of the separation distance between sensor and gas outlets. Both a smaller flow and a larger distance delay the exchange of the gas environment of the sensor. We find a small to moderate effect of the gas flow and a strong effect of the distance. For a flow rate of 400 mL/min of each gas flow and a distance of 0.9 mm, the sensor with a diameter of 0.5 mm, which is initially surrounded by one gas stream, is completely surrounded by the second gas stream within less than 1 ms.

The sensor responds fast to a change from oxygen to hydrogen containing gases and vice versa:

- To hydrogen, the sensor responds within 1 ms with 65% of the total response.
- To oxygen, the sensor responds with within 4 ms with 50% of the total response.

CONCLUSION

Our new set-up allows monitoring the fast (millisecond) and the slow parts of a gas response in a single measurement. A SiC based sensor responds to reducing and oxidizing gases within milliseconds, with 50% of the total response or more.

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