DOI 10.5162/IMCS2018/P1AP.2

NO_x sensor for exhaust applications

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Abstract:
Modern exhaust gas aftertreatment systems need robust and reliable sensors for in-situ control. We present a novel gas sensor that is easy to manufacture and should provide sufficient long-term stability. The impedimetric device is based on gas-depended electrical changes of a NO_x storage material, operated at higher temperatures in an equilibrium state. Experimental results demonstrate a stable baseline of the signal, high NO_x sensitivity and good NO_x selectivity regarding the missing influence of several typical exhaust gas components like CO, H_2, CO_2, or H_2O. Notably, we found also low ammonia cross–sensitivity. Therefore, the sensor device is an interesting candidate for exhaust applications, especially in the field of selective catalytic reduction (SCR) systems.

Key words: NO_x sensor, exhaust gas aftertreatment, selective catalytic reduction (SCR), on-board diagnostics, impedance measurement, interdigital electrodes (IDE)

Motivation and sensing principle

For emission control, cheap but reliable NO_x sensor devices are needed. For this purpose, we introduce a novel impedimetric sensor.

As functional sensing component, a typical NO_x storage material similar as it is already in use for so-called NO_x storage catalyst (a.k.a. lean NO_x traps, LNT). The material itself is similar as described in [1]. Such materials form for instance nitrites and nitrates when exposed to NO_x. This chemical transformation leads to different materials properties. In our former investigations $KMnO_4$/La-Al_2O_3 utilized the likewise effect for a NO_x sensing dosimeter as described in [1]. Here, the functional material acts as a NO_x sampling device at lower temperatures resulting in an integrating sensor response (dosimeter principle).

However, in the present contribution, the sensor device is operated at higher temperatures of about 400 °C to 650 °C. There is an equilibrium between ad- and desorption. Consequently, the measured signal, for example its impedance depends directly on the analyte concentration.

Since such materials are commonly used in exhaust gas catalysts, stability and robustness in exhaust gas applications should be quite high. Therefore, such sensors might be a cost efficient and serious alternative to the state of the art zirconia based devices.

Sensor setup

Sensors are built up on planar Al_2O_3 substrates. On the reverse side, a Pt heater is integrated to adjust the operating temperature. On the front side, interdigital Pt electrodes (Heraeus LPA 88, line = space = 100 µm) were screen-printed as planar capacitors. The sensitive layer was also applied as a thick-film (30 to 60 µm thickness) on top of the electrode area (Fig. 1). Its thicknesses could be a parameter to vary the sensitivity range.

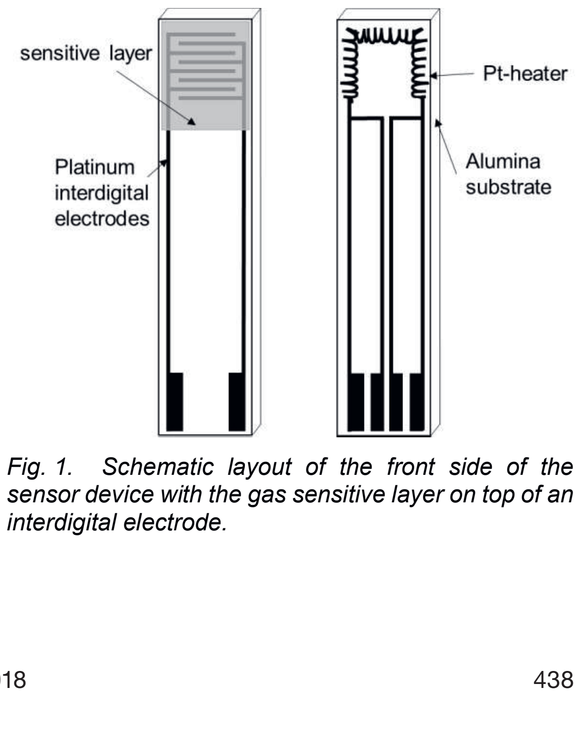

Fig. 1. Schematic layout of the front side of the sensor device with the gas sensitive layer on top of an interdigital electrode.

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In our experiments, the impedance $\underline{Z}$ and phase angle φ are recorded by an impedance analyzer (Alpha Analyzer, Novocontrol). From both, the resistance of the sensitive layer is calculated as shown by equation (1). R_{sens} is regarded as the sensor response.

$$R_{Sens} = \frac{|\underline{Z}|}{\cos(\varphi)} \qquad (1)$$

Experimental and results

Test were conducted in synthetic exhaust in the lab. We exposed the sensors to an atmosphere containing 3 % CO_2, 5 % O_2 and 3 % H_2O in N_2 base gas. The concentrations of the analytes were provided by several mass flow controllers. In Fig. 2, the sensor response can be seen at an operating temperature of 600 °C and a frequency of 100 kHz. The response to NO is reversible and there is no response to 100 ppm CO and H_2. In addition, the variation from 3 % to 5 % CO_2 or H_2O respectively is not influencing the response. There is a slight cross–sensitivity to ammonia. Regarding the state-of-the art, commercial devices show much higher signal response to ammonia (up to 70 % signal change for NH_3 compared to the similar NO_x concentration [2].

As the sensor device can be manufactured in simple thick-film technology and can withstand the harsh environment of an automotive exhaust, an application or on-board diagnostics in light and heavy-duty vehicles as well as in building machines might be a cheap and serious alternative.

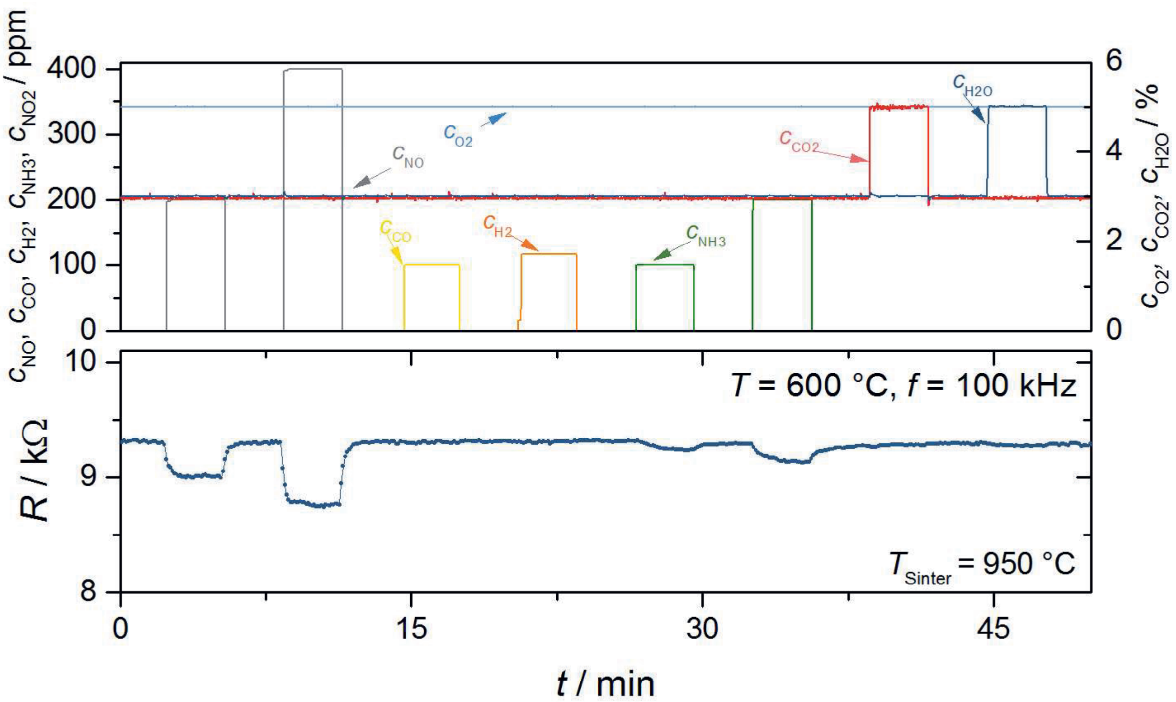

Fig.2. Sensor reaction to different gas atmospheres.

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