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Ammonia Sensor to Effectively Dose the Reducing Agent for NO_x SCR Systems in Biomass Combustion Systems

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Summary:
The detection of gaseous ammonia in the flue gas of biomass combustion systems is becoming increasingly important due to stricter legislation. The optimization of an existing sensor principle showed significant improvements in ammonia sensitivity in comparison to the original sensor. In further measurements in the flue gas of a wood combustion, the cross sensitivities to other components turned out to be very low. So, a high accuracy in the determination of the ammonia concentrations could be achieved in comparison to an FTIR spectrometer.

Keywords: gas sensor, ammonia detection, biomass combustion, exhaust gas aftertreatment, selective catalytic reduction

Background and Motivation

Previous developments of ammonia (NH_3) sensors for automotive exhaust systems have found limited application. One of the reasons for this is the cross sensitivity of typical mixed-potential sensors towards nitrogen oxides (NOx) that are present in engine combustion exhaust [1]. Ammonia is produced from an aqueous urea solution (AdBlue, DEF) for the Selective Catalytic Reduction (SCR) of the nitrogen oxides. The control of AdBlue dosing in vehicles is mostly based on empirical models, which are well understood by now. [2]

However, the extension of the legal guidelines for biomass combustion plants specifies stricter limits for the emission of ammonia and nitrogen oxides in many countries [3].

The dosing of the reducing agent in biomass combustion systems is more complex than in automotive applications due to the mostly individual setup. For this reason, there is a large interest in the development and implementation of selective ammonia sensors in order to meet the legal requirements regarding ammonia slip.

Design and further development

The basic concept of the original sensor has been optimized to produce all layers by cost-effective screen-printing process (schematic structure of the sensor in Fig. 1). By patterning the IDE structure from a solid gold area using a picosecond laser (LPKF Protolaser R4), fine line widths and spacings of 20 μm can still be achieved. [4]

A further optimized heater structure ensures a homogeneous temperature distribution in the area of the IDE structure covered by a gas sensitive zeolite film. In addition, flow effects are reduced by improved control of the four-wire resistance of the heater structure to minimize errors in concentration determination.

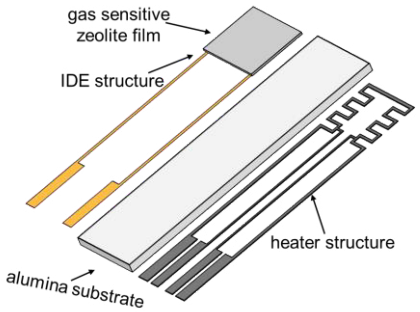

Fig. 1. Schematic structure of the zeolite-based ammonia sensor on a ceramic substrate with integrated heater and IDE structure for electrical characterization of the gas sensitive film.

The electrical behavior of the zeolite film can be approximated by a parallel *RC* element. The adsorption of certain molecules, such as ammonia, leads to changes in its electrical properties [5]. The determination of the capacitance *C* in contrast to the resistance *R* by means of an impedance measurement at high frequencies (> 500 kHz) also simplifies the development of an evaluation unit.

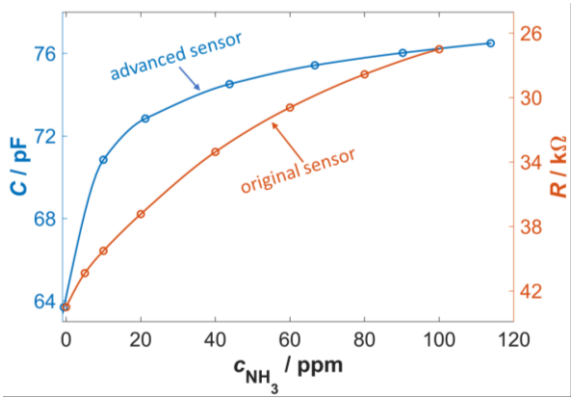

Fig. 2. Comparison of ammonia sensitivity of the original and advanced sensor, adapted from [4].

By further modifying the zeolite composition and operating temperature, the sensitivity to ammonia in the legally relevant concentration range (< 50 ppm) was notably improved in laboratory measurements (see Fig. 2), especially at low NH_3 concentrations.

Investigation of cross sensitivity in flue gas

Since the main application for the sensor is the field of biomass combustion, compared to automotive applications, the sensor is exposed to higher loads, e.g. from particulate matter, CO and HC emissions [6].

For this, a wood burning stove (5 kW) was used as an emission source for initial tests in flue gas. Small amounts of ammonia water (10 %) were also added to the combustion air to cover a concentration range between 0 and 150 ppm NH_3 in the flue gas.

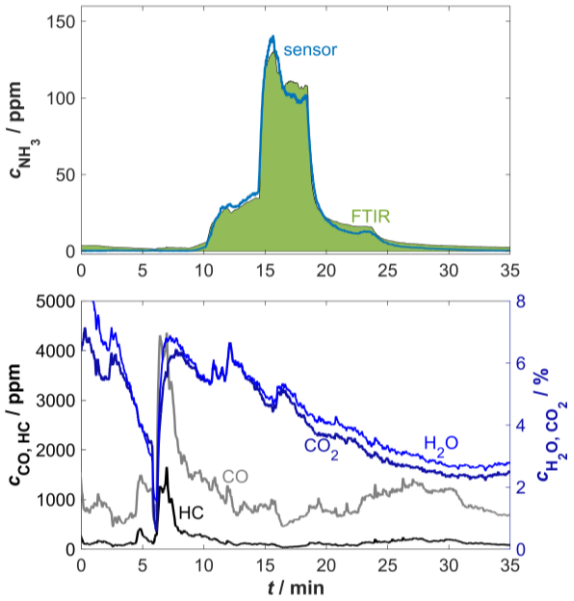

Fig. 3. Time course of the cross sensitivity measurement in flue gas from a wood burning stove with a comparison of the ammonia concentration measured by the sensor (full stream measurement) and FTIR spectrometer (bypass measurement).

The measurement showed that the sensor was not affected by changes in CO, HC, or CO_2 content. Only the cross sensitivity to water was corrected for a comparison with data from an FTIR spectrometer (MKS MulitGas 2030). The nearly linear influence of water vapor is about 0.3 pF/%$_{H_2O}$. In direct comparison, the ammonia sensor provided values matching to the concentration measured by the FTIR spectrometer (see Fig. 3).

Outlook

Future series of measurements will focus on long-term stability and the influence of the protective caps at high dust and soot levels. Further measurements will also be carried out in the flue gas of several biomass furnaces in the power range over 50 kW.

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