DOI 10.5162/EUROSENSORS2025/MP46

Investigations on Ammonia Using Resistive and Photoacoustic Sensor Elements

Heike Wünscher, Christoph Heinze, Steffen Herbst, Toni Schildhauer
CiS Forschungsintitut für Mikrosensorik GmbH
Konrad-Zuse-Straße 14, 99099 Erfurt, Germany
e-mail address: hwuenscher@cismst.de

Summary:
Two different ammonia sensors are introduced which are designed for the measurement of residual ammonia traces in a pipe of an ammonia cracker. The resistive sensor enables a continuous monitoring by an impedance measurement of the gas in a condensate, and allows the detection especially of low ammonia levels. The photoacoustic sensor operates in the gas phase directly.

Keywords: ammonia, condensate, impedance, absorption, microphone

Motivation

Ammonia can be used in energy storage [1]. It can be transported much easier than hydrogen and represents a conceivable fuel [2]. After releasing from an ammonia cracker, the gas mixture from hydrogen and nitrogen can be fed into a fuel cell. Due to the limited durability of the materials against ammonia residues, the gas quality must meet the specific requirements [3-5]. An ammonia sensor is, therefore necessary to ensure the gas quality (Fig.1).

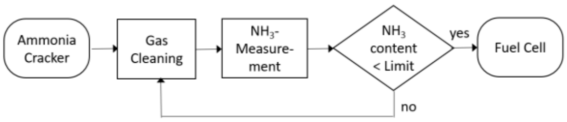

Fig.1 Sensor application field

For this purpose, the sensor should be suitable for the installation in a pipe and low maintainance. In this paper two different approaches are studied: the resistive and the photoacoustic sensor principle.

Sensor Principles and Description

A) Resistive sensor

The resistive gas sensor is based on the impedance measurement of an aqueous condensate of the ammonia. The gaseous sample is fed into alkaline water. According to Henry´s law all gas components are distributed between the liquid phase in the tank and the gas phase above the liquid. On cooling an interdigital structure above the liquid, a waterdrop arises which contains dissolved gas. Ammonia is the only component of this gas mixture which dissociates in the waterdrop, i.e. the electrical impedance of the drop decreases with increasing ammonia content. It can therefore, be used for concentration measurement. It has been shown that the chemical resistance is sufficient [6].

B) Photoacoustic sensor

The photoacoustic sensor is based on the effect of absorbed electromagnetic energy on the gas by means of acoustic detection. The absorption causes local heating, generating a thermal expansion which creates a pressure wave (Fig. 2).

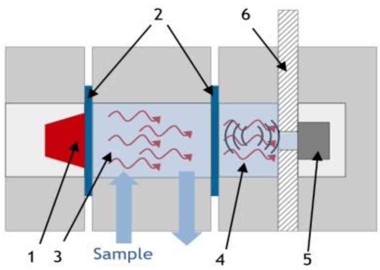

Fig. 2. Photoacoustic sensor principle

The gaseous sample from the ammonia cracker is introduced in the sample room (3). The sample is irradiated with infrared (IR) light coming from a thermal emitter which is operated in pulsed mode (1). Passing through both windows (2) and the sample room, the light reaches the reference chamber (4) which is filled with highly concentrated ammonia. Therein the sound is generated which is detected by a MEMS microphone (5). The latter one is mounted on a PCB with a hole (6). In the gas mixture coming from the cracker, ammonia alone absorbs the infrared light. With increasing ammonia concentration in the sample, the incoming light in the reference chamber decreases and thus the microphone signal decreases Due to the low radiation intensity in the long-wavelength region an innovative array from

16 MEMS-IR-emitter with a nominal power of 1600 mW has been prepared for ammonia detection.

Measurements

The resistive measurement system was prepared using a silicon sensor including an interdigital structure and a temperature diode which were mounted on a sealed tank. The interdigital electrode was directed to the bottom side so that the condensate could drop down into the liquid sample again. The condensate was formed by cooling the interdigital electrode using a peltier element. After equilibration a stable impedance was obtained. This process took at least several minutes. Low ammonia levels can be sensitively detected (see Fig. 3).

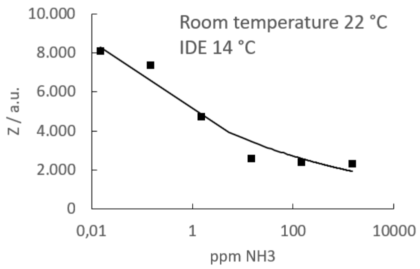

Fig. 3. Impedance of the condensate obtained at 50 kHz vs. ammonia content

For photoacoustic measurements a modular system has been created. The system is designed for IR emitter in a TO-39 housing. The emitter and the MEMS microphone are mounted at opposite ends (Fig. 4).

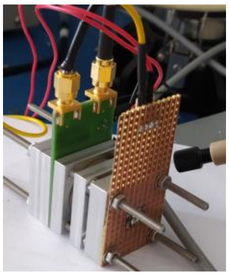

Fig. 4. Detection unit of the photoacoustic sensor

The mentioned IR radiator array was applied. The first functional tests were performed using the surrounding air. This one contains carbon dioxide and humidity which absorb IR light. Thus, it can act as a test medium. The detection unit consists of the reference chamber and the MEMS microphone. It was studied regarding its behavior towards broadband IR radiation when filled with air, pure nitrogen and after evacuation up to 200 ... 300 mbar. The sealing of the housing was checked. For this purpose, the chamber was evacuated and the subsequent penetration of the air into the sealed apparatus was recorded (see Fig. 5). With increasing observation time, the microphone signal grows due to increasing concentrations of carbon dioxide and water vapour in the chamber. It can be concluded that the system works as expected, although it is not completely hermetic.

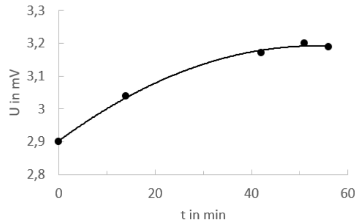

Fig. 5. Microphone signal in sealing test

Results

Both sensoric systems are designed to measure ammonia continuously in the special gaseous environment. The resistive system allows the sensitive detection low ammonia levels. A clearly nonlinear relationschip between impedance and ammonia content is obtained. Due to the need for equalization the response time is rather long. An alternative might be a photoacoustic system which is still in progress.

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Acknowledgements

Financial support of the German Federal Ministry for Economic Affairs and Climate Action (BMWK), for the projects NH3-BZ (49MF220229) and AmmoniaSens (KK 5085701CS0 Z) are gratefully acknowledged.