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Light Stimulation of Gas Sensors with an LED Array in a Compact Setup

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Summary:
The development and test of a multi-wavelength setup for optical stimulation of gas sensors consisting of an LED driver board and a gas measurement chamber is presented. The aim of this work was to facilitate dynamic sensor measurements under variable light wavelength and intensity to investigate the potential of light stimulation for improved sensor performance, i.e. sensitivity and selectivity. The setup was tested on two different sensors in varying gas atmosphere to evaluate its performance.

Keywords: light stimulation, LED array, gas sensor, tungsten oxide, tin dioxide

Motivation

Recent investigations on metal oxide gas sensors under light illumination show promising approaches for increasing sensitivity [1] and selectivity [2] at room temperature. Light activated gas sensors are expected to show a wavelength dependent reaction to various components of a gas mixture. The ideal wavelength is dependent on the sensor material and preparation as well as the target gas or gas mixture to be detected. As the response of semiconductor gas sensor under light stimulation is difficult to predict from first principles or modeling, empirical measurements at varying wavelengths have the potential of revealing characteristic sensor responses for specific gases even in mixtures. The measurement setup presented here enables easy switching between wavelengths and even simultaneous use of several wavelengths with static and dynamic stimulation.

Setup

A circuit board consisting of an LED driver (TLC59116-Q1, Texas Instruments) and twelve SMD LEDs with fifteen wavelengths in the range from 278 nm to 1300 nm, each with individual series resistors, was designed. The LEDs are grouped together on a 1.1 by 1.1 cm area and can be controlled individually. The intensity is adjustable via pulse width modulation (PWM).

The measurement chamber (see Fig. 1) enables a sensor (TO-5 package) to be mounted centered opposite to the LED array with a 1 cm gap. A thin fused quartz plate (GE124) placed between two PTFE parts below the LED array separates the gas channel with sensor from the LED chamber. The setup enables continuous measurements with any of the fifteen wavelengths without the need for installing a different light source. Both the LED driver and the gas sensor are connected to a microcontroller and are controlled and read out similar to [3]. Illumination control and sensor response are therefore synchronous.

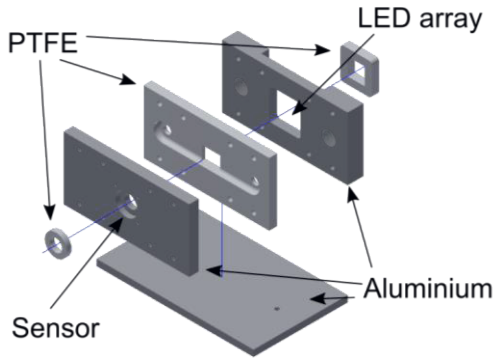

Fig. 1. Measurement chamber for dynamic light stimulation of gas sensors during gas exposure.

Measurement

The optical intensity of every LED was determined as a function of the duty cycle using photodiodes (FDS100 and FDS010, Thorlabs), thus allowing stimulation at different wavelengths with comparable intensity. Two commercial MOS gas sensors (SnO_2-based: AS-MLV-P2, ams Sensor Solutions Germany; WO_3-based: GGS 5530, UST Umweltsensortechnik) were exposed to varying concentrations of nitrogen dioxide (NO_2) and nitric oxide (NO) with and without background atmosphere (550 ppb H_2, 250 ppb CO

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and 50 % relative humidity) in zero air generated with a gas mixing apparatus [4]. The different LEDs were switched on successively with breaks in between. The response to light stimulation at room temperature (RT) was calculated by subtracting the sensor conductance before light exposure from the end value and normalizing to the start value.

Results

In the first measurement, the AS-MLV-P2 was exposed to zero air and 200 ppb NO_2. Here, the three longest wavelengths were excluded as previous tests had shown no response under infrared excitation. Fig. 2 shows the calculated response for each wavelength. The LED intensities have not been normalized and the data are presented in logarithmic scale. Sensor response in 200 ppb NO_2 atmosphere is significantly smaller compared to zero air by a factor of about 10. The increase in conductivity can be attributed to additional electrons transferred into the conduction band. The results imply a preferred adsorption of NO_2 under light activation. This effect can be observed even below the band gap of SnO_2 of 3.7 eV, corresponding to 335 nm [5].

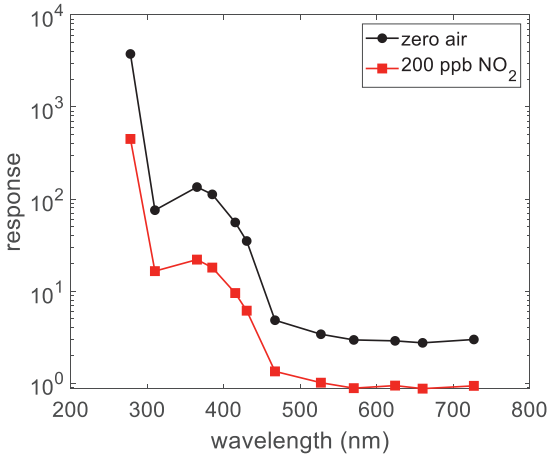

Fig. 2. Response for an AS-MLV-P2 operated at RT to twelve wavelengths from UV to red in zero air (black) and with 200 ppb NO_2 (red), logarithmic scale.

A more detailed experiment was performed with the WO_3 based GGS 5530 sensor. For better comparability of the response at different wavelengths the LED intensities were adjusted to the peak intensity of the weakest LED. The resulting response patterns for four different gas mixtures are shown in Fig. 3.

Compared to the previous measurement, the response of the GGS 5530 is considerably smaller, which might in part be due to the thicker sensor layer. Furthermore, the response in zero air is lowest while it was highest for the AS-MLV-P2. The response increases with addition of background gases and then decreases again with addition of NO or NO_2. Although WO_3 has a nominal band gap of 3.5 eV [6], a significant response at the corresponding wavelengths (278 and 310 nm) is only observed with background gas (CO, H_2), but not in zero air. This indicates a direct influence of the light stimulation on the chemical interaction on the sensor surface.

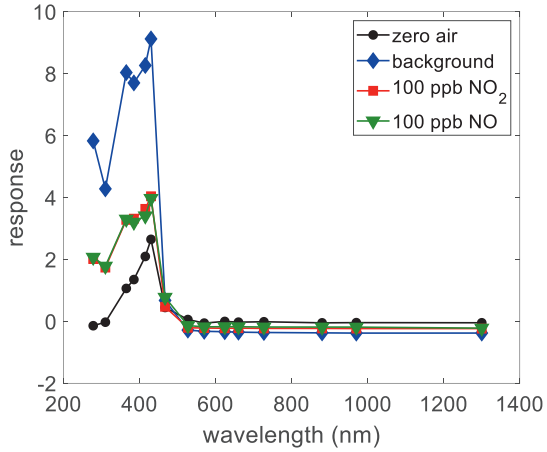

Fig. 3. Linear response of a GGS 5530 gas sensor operated at RT to stimulation with all the wavelengths in four gas mixtures. Measurements for NO_2 and NO were performed in background atmosphere.

Outlook

The setup presented allows simple successive light stimulation of gas sensors mounted on TO-5 headers. First measurements provide an insight into the complex chemistry of gas sensors which can be influenced by light activation, potentially achieving more selective behavior. The influence of intensity and the simultaneous use of several wavelengths needs further investigation.

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