

Low-Power Odor-Sensing Network Based on Wake-Up Nodes [†]

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Abstract: The localization of bad odors is a long standing issue with high relevance for affected people because of the health and safety implications. In order to enable the detection and localization of bad odors we propose a wireless, low-power consuming sensor network. The sensor nodes are designed to wake-up upon initial detection of a bad odor to then start to measure the strength of the odor. Taking into account the spatial variation of the bad odor as well as environmental parameters the odor source may be identified. After the odor vanishes the sensor nodes return to sleep mode.

Keywords: bad odor detection; hydrogen sulfide; wake up sensor node; copper oxide; wireless sensor network

1. Introduction

The occurrence of bad odors is not only unpleasant for affected persons but also poses a threat to their health and safety. Possible sources of unpleasant smells include landfills, sewers, industrial processes, biogas fermenters, or miscellaneous sources in private homes. From a technological point of view the classification of a smell is challenging since the human olfactory system is able to distinguish between highly complex gas compositions, which are made up of up to 10,000 different molecules [1]. Because of the lack of cost-efficient sensing technologies to provide an objective assessment on the strength and origin of odors it is currently difficult to localize smells and subsequently establish accountability for the culprit. In the past, odor quantification has been approached using electronic noses [2,3], which have used e.g., semiconducting metal oxides, conductive polymers, or piezoelectric materials as gas sensitive transducer [4]. Because of the poor selectivity of the basic gas sensing methods used in electronic noses, the use of pattern recognition schemes is necessary for many scenarios [5]. However, due to the poor reproducibility, long term drifts, high calibration and computational expenditure for most of these approaches a large scale deployment of e-nose systems is difficult [6].

Therefore in this contribution we explore a different approach and try to exploit the fact that bad odors and the hydrogen sulfide concentration are highly correlated [7,8]. This opens up the possibility to employ a highly specific trace gas detection scheme to gauge the H₂S concentration using a percolation phase transition in copper (II) oxide [9,10] thus evaluating the odor level. Figure 1 depicts a possible deployment outdoor scenario for the bad odor sensor network. The distributed gas sensor

network uses well-localized odor nodes to infer strength and origin of the odor. This way, the origin of an odor may be identified and measures against future disturbances may be taken.

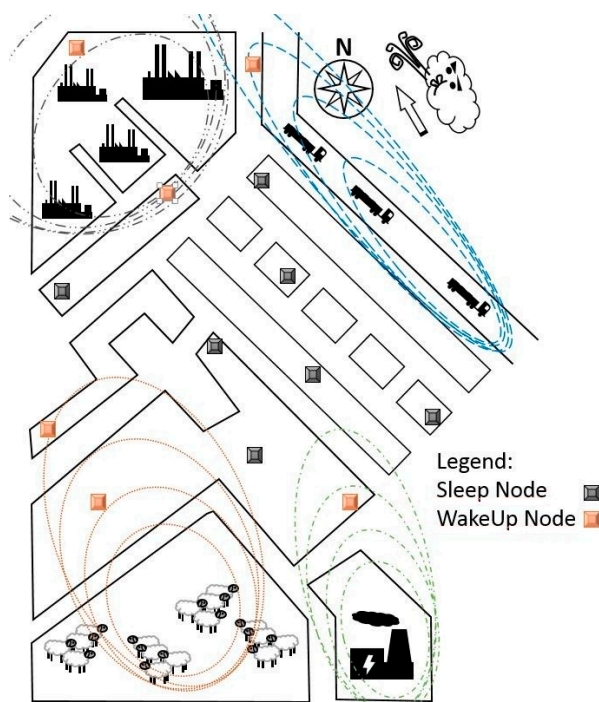


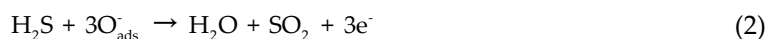
Figure 1. Schematic drawing of a possible deployment of the odor sensor network: Upon waking up the respective sensor node starts to determine the hydrogen sulphide concentration, which is a very good indicator for the odor level. Taking into account ambient weather conditions and information from the distributed sensor network it is possible to infer the source of the bad odor.

2. Experimental

The system design relies on the high correlation between bad odors and the appearance of hydrogen sulfide. To detect H_2S we employ copper(II) oxide (CuO) nanosphere-based functional layers [11] deposited onto micro-machined hotplates [12] via inkjet printing [13]. CuO is known to feature a highly specific reaction towards H_2S even at room temperature [14], which ultimately leads to a break-down in electrical resistivity via a percolation phase transition [9,10]. In a low temperature regime below $200\text{ }^{\circ}C$ the substitution reaction:



dominates. In order to save energy we employ a wake up approach that relies on this reaction: In the sleep mode, the hotplate is not powered permanently and the system checks the layer's resistivity once a minute using a time-to-digital read-out technique [15]. As soon as an odor event triggers the phase transition and a conductive path of copper sulfide (CuS) appears, the sensor node wakes up and switches into measurement mode. The H_2S concentration measurement scheme relies on the reversibility of Reaction (1) and at temperatures exceeding $300^{\circ}C$ the following reaction prevails:



The thermal modulation scheme to determine the H_2S concentration has been demonstrated in [16] and is used here. The protocol allows for determining the hydrogen sulfide concentration in the range between 100 ppb and 20 ppm, i.e., over more than two orders of magnitude [9]. These values are used as an indicator for the strength of the bad odor and transmitted via a Wi-Fi protocol. The wireless communication between localized sensor nodes allows for time and spatially resolved H_2S concentration information, which enables identifying odor sources. Figure 2 shows a schematic diagram of the components of the odor sensing node as well as their functionality. The node

design includes a temperature and humidity sensor to provide a basic assessment of the environmental conditions.

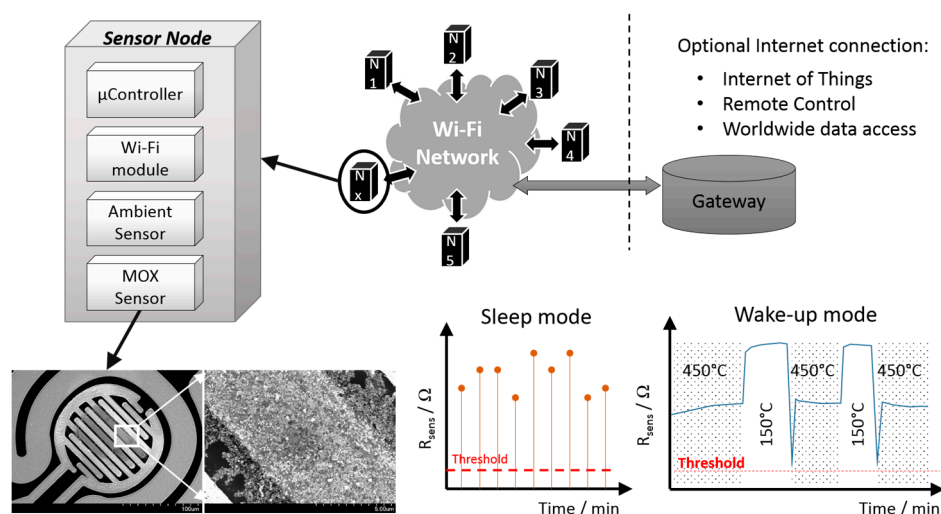


Figure 2. Concept of the wireless odor sensing network: A CuO based MEMS chip is used as central building block to enable the highly selective detection of H_2S , which is used as indicator for the amount of bad odor. In the sleep mode the system checks periodically whether or not a bad odor event has occurred. Once this has happened, the sensor node switches into measurement mode and determines the H_2S concentration based on the percolation time. All sensor node data are transmitted to the internet where data regarding spatial and temporal distribution of bad odors may be analyzed.

3. Results

So far the sensor node has been tested in a laboratory environment using an apparatus to simulate real-world conditions [17] and a sample measurement is shown in Figure 3. During three days the system has been kept in an environment of synthetic air with varying levels of humidity and subject to the ambient temperature. Then low levels of hydrogen sulfide were introduced and upon breach of the pre-defined resistivity threshold of $500 \text{ M}\Omega$ the measurement protocol started automatically.

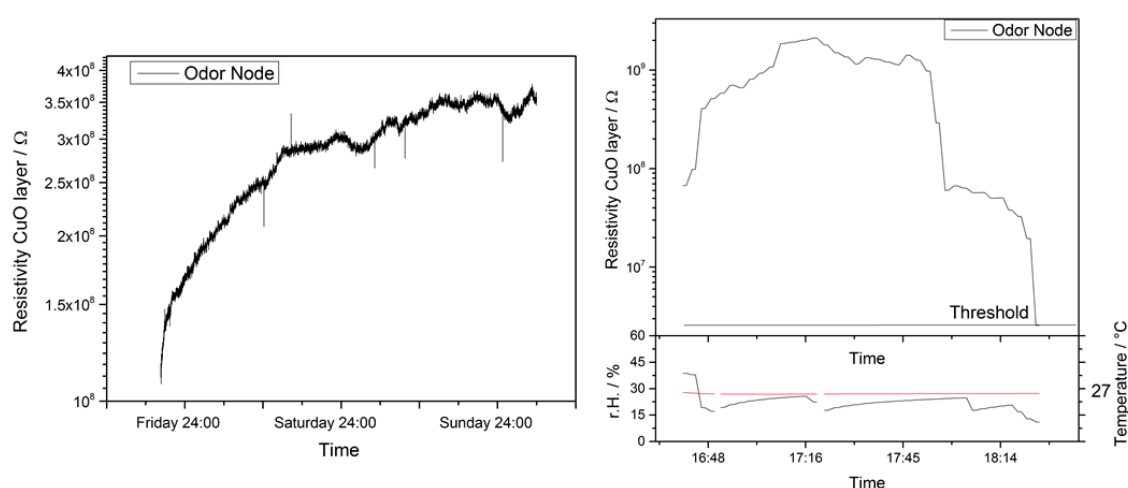


Figure 3. Sample measurement of a single odor sensing node in the sleep mode, i.e., at ambient temperature: The state of the gas sensitive layer has been checked every minute for several days and no odor event has been detected. The resistivity value varies due to ambient temperature and humidity changes. To simulate an odor event occurring we did expose the device to low levels of hydrogen sulphide of about 1 ppm. The steep decline of the resistivity below a threshold value triggers the odor detection mode.

Conflicts of Interest: The authors declare no conflict of interest.

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