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Wireless low-power warning system for the detection of flammable gases

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Summary:
The detection of flammable gases is necessary to avoid explosive atmospheres. For this reason, low-cost pellistors are frequently used sensors, although they suffer from high operation temperatures and high power consumption. Within the scope of our work, we present a novel wireless low-power catalytic gas sensor system for flammable gases. The combination of a MEMS-based sensor and low power radio system provide the opportunity to monitor complex infrastructures without using the grid for power supply.

Keywords: flammable gas sensor, catalytic combustion, sensor node, low-power wireless

Background and Motivation

The early detection of flammable gases or explosive gas mixtures is extremely important in order to avoid endangerment of people and the damage of plants and facilities. Flammable gas sensors are sold in millions and are used for energy supply by gas, at filling stations, but also in the private sector for gas heaters and pipes. Due to their high-energy consumption, these sensors can only be operated by grid, whereby the installation of a sensor network becomes complex and expensive. Low energy consumption of the gas sensors offers the possibility to operate sensor nodes for the detection of flammable gases or explosive gas mixtures independently of the power grid. Here, we present a newly developed wireless sensor node for the detection of flammable gases. The node connects the intelligence of a low power wireless transceiver with a MEMS-based low-power, low-temperature catalytic combustion gas sensor.

The wireless gas sensing system

The main challenge is the connection of the gas sensor system to the energy management and the radio system (Figure 1), which should be as efficiently as possible in order to achieve all of the goals set, such as service life, real-time capability, maintenance, range, robustness and mesh network capability. For this purpose, a radio system was developed and evaluated, which uses a unique wake-up strategy to ensure that all sensors can be reached by radio permanently and in real time and yet have very low energy consumption. In contrast to current wireless communication systems (WLAN, Bluetooth, Zigbee), which minimize their energy consumption through periodic de- and activation [1], this system allows continuous real-time accessibility with low latencies. Since the individual sensor nodes also communicate with each other, measurement data can be recorded in star or multi-hop topology if required. This offers the opportunity of an almost unlimited distance coverage in networks and opens the way for a drastically reduction of costs. The radio system maintained is robust, simple, efficient, maintenance-free and energy self-sufficient. Even the radio protocol has been designed to be particularly robust and immune to interference for use in a safety-critical environment, where each measurement value is confirmed bidirectional at the receiver These features make it possible to place the measuring system in inaccessible places as well as to use it in a battery-powered mobile environment. The second elementary component is the gas sensor itself. Due to the development of new catalytic materials, the working temperature, which is currently at 450°C-500°C for commercial available sensors, could be decreased to 350°C. By using a MEMS-based hotplate [2] with a very low thermal mass, the power consumption of the sensor module decreases to approximately 100mW. This enables the usage of the sensor for mobile applications as well.

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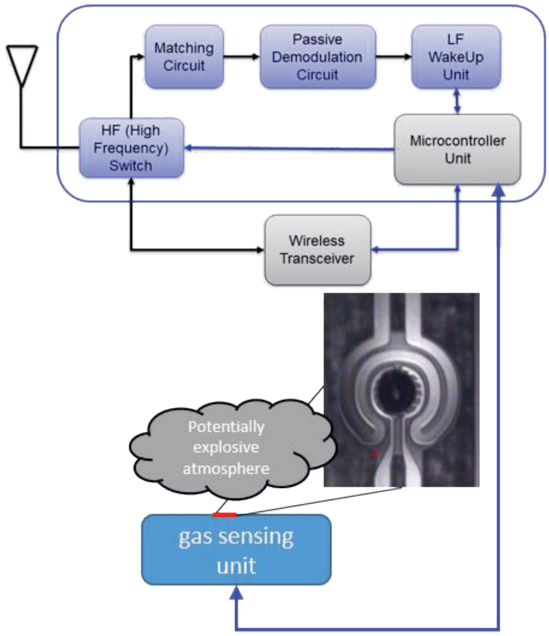

Fig. 1: Overview of the measurement system. The radio module receives the data from the sensor module and could send it to different application depended destinations. The diameter of the sensor is about 300 µm.

Results

For the monitoring of flammable gases, a reliable detection of the lower explosion limit (LEL) is necessary. To report leakages or to evacuate people in harmful areas, 10% of the LEL should be detected. Here we present a gas-sensing device optimized for the methane detection. Figure 2 presents the measured data for three different gas concentrations below the LEL of methane of 4.6% [3]. At a low working temperature of 350°C, the sensor signal shows, after a burn-in step, a very stable baseline and due to the high signal to noise ratio (SNR) concentrations far below the LEL could be safely detected.

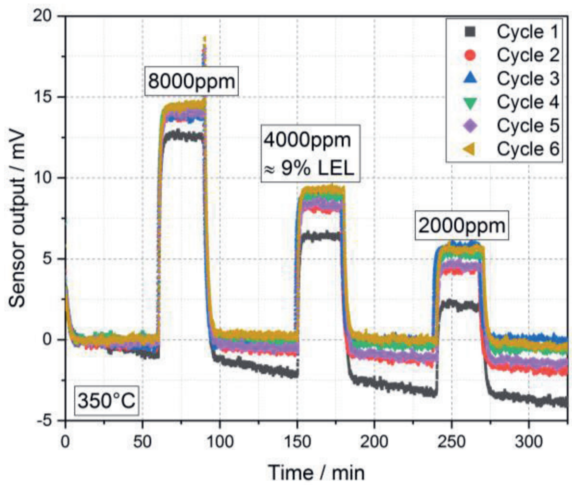

Fig. 2: Sensor output to three different methane concentrations below the LEL. The sensor reliability is shown within six cycles. Due to the high signal to noise ratio, methane concentrations down to 2000 ppm (4.5% LEL) in dry air could be measured at a sensor temperature of 350°C.

The sensor data could be transmitted to a gateway, which process the data and activates further steps, if necessary. A possible node to node range of over 250 m covers the majority of all industrial and consumer applications.

Conclusion

The use and the development of new materials as well as the optimization of the sensor design enable the reduction of the power consumption, whereby the lifetime of an autonomous sensor system increases significantly. Our investigations illustrate, for the first time, the possibility to develop a remote-query able and networkable low-power sensor system for the detection of flammable gases.

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