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Abstract

From a Memory Sensor to a Sensor without Memory: Trigger Mechanism †

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Abstract: In the context of environmental monitoring, maximum levels of nitrogen dioxide (NO_2) are internationally regulated since long exposure impacts health. In general, very low concentrations in the sub-ppm range are found for NO_2, which implies the need for very sensitive detection systems. Here, we demonstrate a chipless RFID sensing cell with both threshold detection and re-usability capabilities.

Keywords: chipless RFID sensor; environmental sensing; gas sensor; nitrogen dioxide; NO_2; near-field coupling; wireless sensing

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1. Introduction

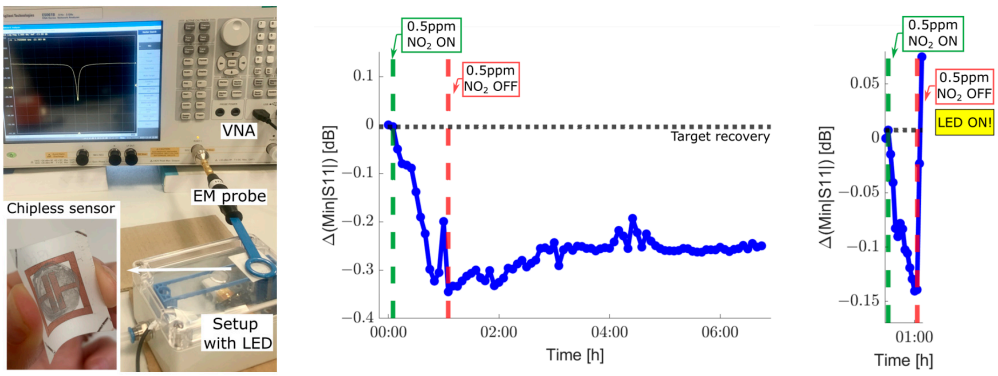
Chipless solutions are advantageous with respect to their chipped counterparts for the absence of integrated electronics on the tag. The tag is composed of conductive resonators that generate resonance peaks in the frequency or time domains. This feature makes chipless tags very attractive due to their low price, completely planar profile, mechanical/functional stability, which is especially convenient in the case of environmental monitoring in harsh environments. Moreover, the gas sensing functionality can be added simply by working on the effective permittivity properties of the tag, where a sensing material is selected for NO2 detection. In this study, a layer of tin-dioxide (SnO_2) is deposited on the conductive resonator to demonstrate a chipless sensing cell with NO_2 detection properties. The sensor behaves like a non-volatile memory sensor capable of detecting an NO2 event. The purpose of this paper is to demonstrate a trigger mechanism to turn a memory sensor into a sensor without memory, i.e., capable of detecting a new event. This is clearly advantageous for its reuse and in the context of a sustainable sensing network.

2. Materials and Methods

A typical frequency-domain chipless RFID tag is composed of a series of conductive resonators on a dielectric substrate, and the information is encoded in the resonance peaks that they generate in the frequency domain. If a sensitive layer is added in correspondence to the resonators, it interacts with a specific physical parameter or chemical substance present in the environment and modifies the intensity and the frequency of the encoding resonance peak accordingly. In this study, we investigate a single resonant cell to demonstrate its feasibility for NO_2 detection. We select an electric-field-coupled (ELC) resonator, already used in our previous research on humidity detection [1–3], and we scale it to resonate at 1.78 GHz (final size 20 × 20 mm^2). It is produced by a microlithography and wet-etching process on the 17 µm copper layer of a commercially available 168 µm

thick Rogers RO4350 flexible substrate. A thin layer of SnO_2 is produced using sol–gel, and adequate oxygen vacancies are created in this way. The paste is then deposited over the resonator through spin coating.

The sensor cell is tested for the detection of nitrogen dioxide in the sub-ppm range, specifically 0.5 ppm of NO_2. A gas-flow chamber prototype (as shown in Figure 1a) is arranged for the purpose of having a holder for the sensor and LED source. We acquire the sensor response at room temperature and under a fixed, controlled humidity (50% RH) considering the frequency range 1.5–2 GHz and using an Agilent ENA series vector network analyzer (VNA) connected to a Signal Hound near-field magnetic probe, which is placed outside the chamber. The sensor is therefore read wirelessly and is completely passive.



(**a**) (**b**) (**c**)

Figure 1. A non-volatile NO_2 chipless memory sensor turned into a reusable sensor. (**a**) Measurement setup; (**b**) response and recovery trend for the non-volatile memory sensor; (**c**) response and recovery trend when the sensor is turned into a sensor without memory using a UV LED source.

3. Results and Final Discussion

The response and recovery trends for the 0.5 ppm NO_2 flux are plotted in Figure 1b, where the resonance peak intensity of the $|S_{11}|$-parameter is tracked for the entire period. In particular, the sensor recovery was monitored for more than 6 h without reaching the full recovery condition. The sensor can therefore be classified as a non-volatile memory sensor which can detect the occurrence of a NO_2 event. To trigger sensor recovery, we exploited the irradiation of the sensor with an ultra-violet LED (wavelength λ = 405 nm, power 1 mW), which speeds up the complete reset of the sensor. As shown in Figure 1c, the UV LED is switched on as the recovery starts and the sensor resets in less than 7 minutes for the specific case of 0.5 ppm and an intensity difference of 0.15 dB.

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