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Abstract

A Chipless RFID Humidity Sensor for Smart Packaging Applications †

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Abstract: A chipless RFID humidity sensor suitable for smart packaging is proposed in this work. The sensor is flexible, fast, low-cost, easy to fabricate and can be read wirelessly. The results show a very high sensitivity in the low-humidity range (1–10%), making it especially suited to monitor and establish package integrity.

Keywords: chipless RFID; humidity sensing; smart packaging; microwave sensor

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1. Introduction

Environmental factors, such as temperature and humidity, influence food quality and increase the risk of product deterioration. As an alternative to traditional packaging, smart packaging can provide important information on food products in real time, reducing the amount of waste and the health risks. To implement these functions, it normally exploits internal or external electronic sensors and RFID devices [1]. RFID technology has progressed significantly in the past few years, and its capabilities in identification and traceability make a major contribution to food safety and quality. Chipless RFID sensors have the additional advantage of merging in a single component both the sensing and the wireless transmission functions, resulting in simpler, lower-cost, more robust and less power-demanding devices compared to more traditional RFID technologies [2].

In this contribution, we report the development of a low-cost humidity sensor for the wireless monitoring of moisture levels within packaged goods achieved with chipless RFID technology. The sensor is especially sensitive in the low humidity range, suited for the smart packaging of perishable goods where low levels of internal humidity are essential for proper conservation.

2. Materials and Methods

The sensor is composed of a metallic resonator over a flexible 168 µm thick low-loss substrate (Rogers 4350), covered by a 50 µm thick Nafion NRE-212 membrane, which is very sensitive to environmental humidity. The geometry is that of an Electric-Field-Coupled (ELC) resonator [3]. RF characterization was performed by using a dedicated apparatus, with a custom-made gas flow test chamber coupled with an Agilent E5061B ENA Vector Network Analyzer. Gas sensing measurements were performed at room temperature. The relative humidity (RH) was monitored by a digital humidity sensor (1.0% accuracy) at the chamber exit. RH control was achieved by injecting dry air into a gas bubbler filled with deionized water. The sensing circular probe [4] was directly connected to the VNA, outside the chamber, while the sensing tag was inside, and the detection took place wirelessly.

3. Discussion

The sensor measured in the range of 0–50% RH, between 1 and 2 GHz. The return loss intensity of the circular probe is reported in Figure 1a. Both the peak intensity and frequency vary with the environmental humidity, as reported in detail in Figure 1b.

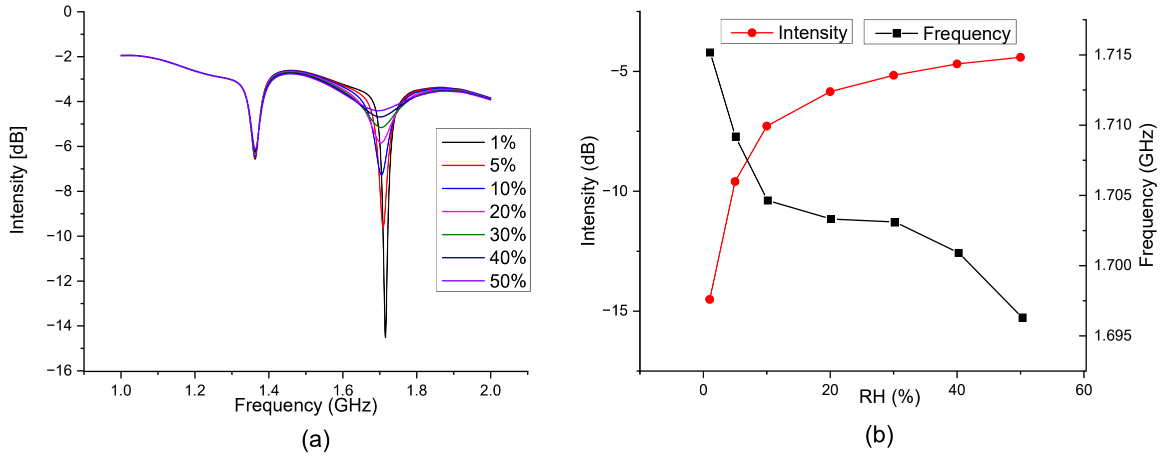

Figure 1. (**a**) Return loss intensity as a function of frequency in the range 1–2 GHz. (**b**) Variation in peak intensity and frequency as a function of relative humidity.

In particular, the variation is largest in the low humidity range, especially below 10% RH, for both frequency and intensity variation. Going from 1% to 10% RH, the intensity reduces to less than a half and the frequency shift is around 11 MHz. These values are extremely good compared to similar chipless RFID sensors [2]. The peak visible at 1.35 GHz is due to the internal resonance of the probe itself, and it does not change with humidity. This peak can therefore be used as an internal intensity or frequency reference for sensor calibration.

The high sensitivity of the chipless RFID sensor in the low humidity range, coupled with remote signal detection, makes it particularly suitable for smart packaging humidity control. Remote monitoring allows for the verification of the integrity status of the package's internal atmosphere in a totally non-invasive manner, even with non-transparent packages. Moreover, this simple integrity check does not require a precise determination of humidity, but simply the detection of a value above a threshold. This can be easily determined by comparing the intensity at the reference frequency of the internal probe with the peak frequency value of the sensor.

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