Novel Integrated System of RFID Tag and Self-Powered Oxygen Sensor Indicator

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Abstract. Recently, the combination of passive RFID tags with sensors has been absolutely required in various fields as well as distribution. In this study, we develop a novel sensor-type oxygen indicator based on a battery, which changes both color and electric signals depending on oxygen concentration, and propose the combined system of the self-powered oxygen sensor indicator with a passive UHF band RFID tag. Using this system, we monitored the oxygen concentration in a plastic package with oxygen absorber. The experimental results show that this novel system functions well.

Keywords: UHF band RFID tag, Oxygen indicator, Oxygen sensor, Self-powered sensor, Methylene blue

1 Introduction

Recently, an increasing interest in RFID technology has been spreading to various fields, and has been developed to become the smart RFID tag associated with sensors [1-2]. Colorimetric oxygen indicators show the presence of oxygen in the food package through a color change, and thus give consumers information about the food quality [3-4]. However, because indicators cannot generate electric signals required for smart RFID tags, we develop a sensor-type oxygen indicator for the first time. Our novel sensor-type oxygen indicator is based on a battery, so it is self-powered, and is combined with a passive RFID tag in the UHF band. Our new integrated system consists of UHF band RFID tag, self-powered oxygen sensor indicator, interface circuit, reader, and server. In order to test this new system, we also monitor the oxygen concentration in a plastic package with oxygen absorber online.

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2 Sensor-Type Oxygen Indicator

The novel sensor-type oxygen indicator was constructed based on a battery and composed of an anode made from electropositive metal and a cathode in an aqueous electrolyte containing a redox dye. Zinc foil with a diameter of 0.7 cm and carbon paper with a diameter of 0.7 cm were used as anode and cathode, respectively. The two electrodes placed in sodium acetate buffer (0.1 M, pH 4.5) containing methylene blue (MB, 0.02mM) as a redox dye were connected by an external circuit. The oxidation of electropositive metal, zinc, occurs at the negative electrode, and at the same time the reduction of MB oxidized by oxygen happens at the positive electrode. These redox reactions generate power like a battery. When an oxygen concentration is high, the concentration of oxidized MB is also high, resulting in high power; when an oxygen concentration is low, the concentration of oxidized MB is low, leading to low power. The self-powered oxygen sensor indicator invented in this study was tested with different oxygen concentrations. The sensor-type oxygen indicator was supplied with mixed gas with 0, 5, 10, 15, and 21% oxygen using an automatic gas mixing system [4]. The color changes of the oxygen sensor indicator with time depending on oxygen concentration are shown in Figure 1. The polarization curves in Figure 2 indicate the voltage and current increased with increasing oxygen concentration.

Fig. 1. Color changes of sensor-type oxygen indicator at 25°C

Fig. 2. Polarization curves of sensor-type oxygen indicator at 25°C
3 The passive type UHF band RFID tag

The block diagram of the passive type UHF band RFID Tag is shown in Figure 3 [1-2], and Figure 4 shows the manufactured passive type UHF band RFID tag.

![Block diagram of UHF band RFID Tag](image)

![Manufactured RFID Tag](image)

4 The Proposed Combined systems of Passive RFID Tag and Sensor Type Fuel Cell Oxygen Indicator

We propose the combined system of passive RFID tag and sensor-type oxygen indicator. Block diagram of proposed system is shown in Figure 5.

![Block diagram of proposed system](image)
The interface circuit of the sensor-type oxygen indicator is shown in Figure 6, and Reader is speedway revolution UHF RFID reader made by IMPINJ [5].

![Interface Circuit Diagram](image)

**Fig. 6.** The interface circuit

### 5 Experiments

In order to test this new integrated system, we performed a monitoring experiment of the oxygen concentration in a plastic package with oxygen absorber (HNS 30-LiPmen). We first put the nine oxygen absorbers in a plastic box and opened the box after 10 hours. The environmental conditions were a temperature of 25°C, a humidity of 50%, and the distance was 2 meters. Figure 7 is a photograph of the experimental device we used.

![Experimental Device](image)

**Fig. 7.** The photograph of experimental device

Figure 8 shows the sensor response change for 12 hours in which the voltage decreased rapidly for the first 1-2 hours and then declined slowly. This is because the oxygen absorber decreased the oxygen concentration in the package. After opening at 10 hour, it jumped to the initial value because the surrounding air rushed into the box.
6 Conclusions

In this study, we have invented a sensor-type oxygen indicator based on a battery. The novel self-powered oxygen sensor indicator was composed of an anode made from electropositive metal (zinc) and a cathode (carbon paper) in an aqueous electrolyte (buffer) containing a redox dye (MB). Its color and voltage/current were found to change depending on oxygen concentration. We have also combined the self-powered sensor indicator with passive RFID system. This new integrated system consisting of an RFID tag, the sensor-type oxygen indicator, interface circuit, RFID reader, and server successfully monitored the change in oxygen concentration in the package.

References