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Research Article

The Vegetable Freshness Monitoring System Using RFID with Oxygen and Carbon Dioxide Sensor

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This paper proposes an oxygen and carbon dioxide concentration monitoring system for freshness management based on radio frequency identification (RFID). Freshness can be checked by various factors including humidity, temperature, oxygen, and carbon dioxide. This paper focuses on oxygen and carbon dioxide. The concentrations of these two gases are related to freshness and affect the food. We use a sensor for monitoring these gases and combine the sensor with an RFID tag. The RFID system is relatively easy to manage. With this combined system, we estimated the freshness of vegetables.

1. Introduction

The vegetable has relatively short product availability period. When we buy the vegetable, we want to check the freshness criteria. However, there is no such a system that can check the freshness of vegetables, so people just inspect visually. If the vegetable goes beyond the expiration date, people will throw it away, so it causes huge waste of money and may threat customers' health. There will be needed certain freshness monitoring system for both customers and seller to save money and health.

Oxide and carbon dioxide are needed for organisms to survive. Microorganisms absorb oxygen and emit carbon dioxide as food spoil [1]. The respiration of food in package also affects food freshness. We believe freshness can be estimated by monitoring the levels of oxygen and carbon dioxide. Freshness is affected by many factors including moisture and temperature, oxygen. Until now, the research of freshness was limited by temperature and humidity, and temperature and humidity have been managed by sellers themselves. Therefore there should be more research on oxide and carbon dioxide for checking freshness factors.

This paper proposes oxygen and carbon dioxide concentration monitoring system or freshness management based on RFID. The proposed system uses two sensors to measure oxygen and carbon dioxide for monitoring these two gases. The oxygen sensor's type is galvanic cell. This sensor does not need power supply device, so we can easily design the circuit for monitoring system. The RFID is very useful for various applications because this system is very small, uses non- or very small capacity battery, and is easy to use its application [2–5]. Thus, the proposed system uses RFID with two sensors, so freshness can be checked more convenently and faster.

In the next chapter, we will discuss the system proposed with circuit and block diagram. And finally, Chapter 3 concludes the paper.

2. Proposed Oxygen and Carbon Dioxide Monitoring System

Figure 1 shows the RQ (respiration quotient) of mature green mume (green plum) in packages with different transmission rates of oxygen and carbon dioxide. Table 1 shows the detailed data for Figure 1. This RQ links the oxygen consumption rate with the carbon dioxide creation rate. This happens as food "breathes." If the RQ is more than 1, food freshness will decrease [6, 7]. This paper proposes an oxygen and carbon dioxide monitoring system to check freshness.

In this paper, we use sensors for monitoring of vegetable freshness. So this paper selects the sensors that operate the low temperature and humidity of wide area because the food keeps storage of the low temperature for maintaining

Table 1: Package of different transmission rate of oxide and carbon dioxide.

Films	Real thickness (μm)	Gas transmission rate (RH of 76% @ 25°C) (mL/m^2·day·atm) O_2	CO_2	Water vapor transmission rate (RH of 100% @ 38°C) (g/m^2·day·atm)
LDPE A	18	2,694	9,776	19.81
LDPE B	27	2,142	6,711	17.68
LDPE C	51	1,568	4,580	12.84

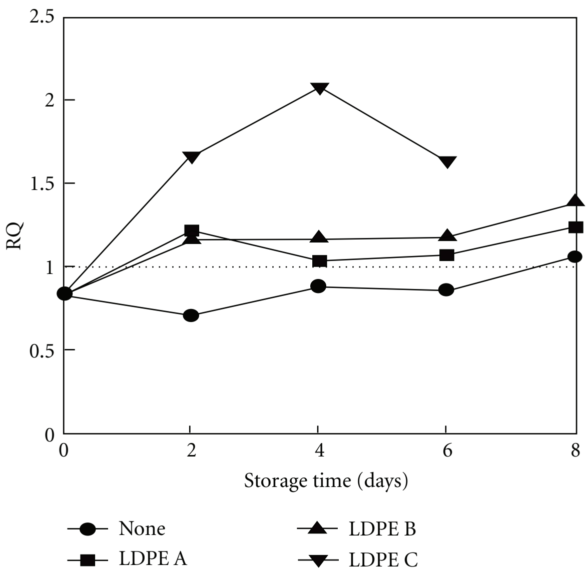

Figure 1: Changes in respiration quotient (RQ).

Table 2: SS1118 specifications.

Content	Specification
Measurement range	0∼100% oxygen
Output signal	6 ± 1 mV in RF of 40% 25°C
Temperature range	−10∼50°C
Operating humidity	0∼99% RH

Table 3: NAP-21A specifications.

Content	Specification
Voltage supply	D.C. 1.8 ± 0.18 V
Measurement range	0∼100% carbon dioxide
Output voltage	0∼20 mV
Temperature range	−10∼50°C
Operating humidity	0∼95% RH

freshness. In addition we also check the input and output volt and current of sensors, because these sensors connect the RFID. The RFID's output and input volt and current are very small. Therefore we have to select the sensors that output and input almost appropriate voltage and current at these RFIDs. So this paper selects the oxygen sensor and carbon dioxide sensor at SS1118 and NAP-21A. These sensors are shown in Figure 2. Figure 2(a) selects oxygen sensor (SS1118) and Figure 2(b) selects carbon dioxide sensor (NAP-21A).

The SS1118 oxygen sensor is of galvanic cell type as shown in Figure 3. The galvanic cell type has electrode, and this electrode generates the electric voltage according to oxygen concentration such as Figure 4.

This oxygen gas sensor requires no special preparation or calibration–just plug it into your interface and it is ready to take readings because it just generates the power. So it is very easy to use for connecting with RFID system that requires low power consumption battery. Especially, this sensor offers superior performance over the conventional oxygen sensor in that it is not affected by carbon dioxide, carbon oxide, and nitrogen oxides.

Table 2 is specifications of SS1118. We can see that this sensor is suitable for connecting with RFID and using freshness monitoring system. The range of operating temperature and humidity is suitable at checking the vegetable freshness. Typically the vegetable is stored in low temperature and high humidity. This sensor covers enough the storage environment of vegetable.

We design the circuit for measurement of output voltage and connect with RFID system such as Figure 5. This circuit produces more stable output. We do not need input circuit this sensor. The sensor type is galvanic cell. This type does not require the input power.

Next, we will check the NAP-21A carbon dioxide sensor. This sensor is thermal conductive type, and it is able to detect a wide range of carbon dioxide gases up to 100%. The thermal conductive type sensor measures heat conductivity according to carbon dioxide concentration.

This sensor is appropriate for our application system according to Table 3. It operates with the very low voltage and temperature irrespective of humidity.

Figure 6 is the suggested circuit, and this sensor is thermal conductive type whose accuracy is somewhat low. We use compensator in this circuit and make the bridge circuit like Figure 6. We can measure and connect the RFID using this circuit.

Finally, the RFID system stores the data in the RFID tag and receives data to RFID reader. This data is result of measurement from the sensors. Thus the system connects between sensors and RFID tag to store the sensing data. So this paper uses the MLX90129 chip for RFID tag because this chip combines a precise acquisition chain for external resistive sensors, with a wide range of interface possibilities.

We connect the oxygen sensor and carbon dioxide sensor like Figure 6. The input and output signal of sensors is

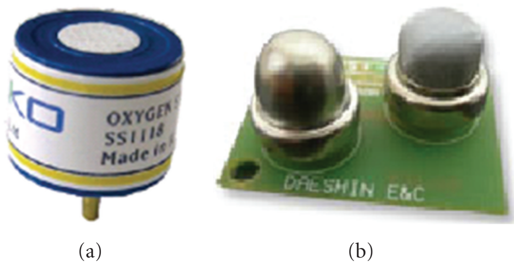

FIGURE 2: Using sensors: (a) oxygen sensor (SS1118) and (b) carbon dioxide sensor (NAP-21A).

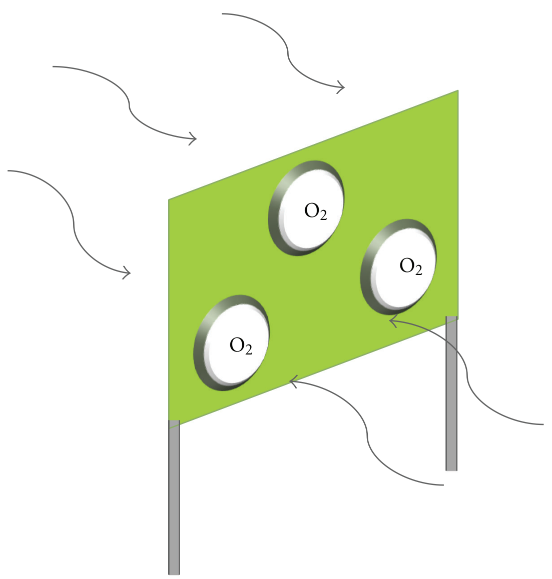

FIGURE 3: Operation of galvanic cell type sensor.

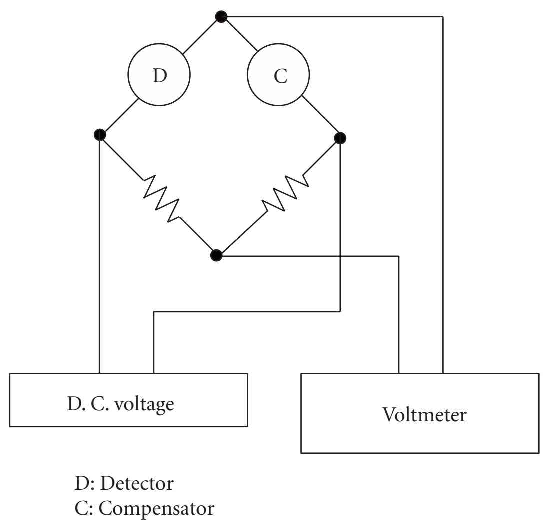

FIGURE 5: Circuit design of NAP-21A.

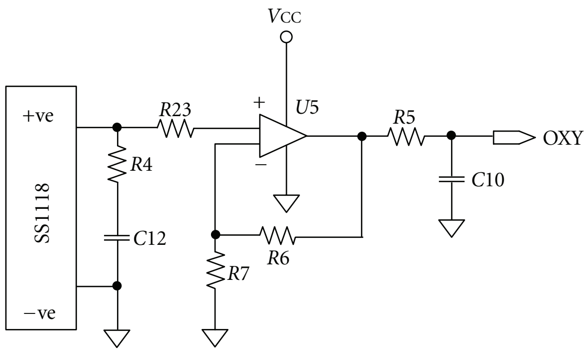

FIGURE 4: Output circuit design of SS1118.

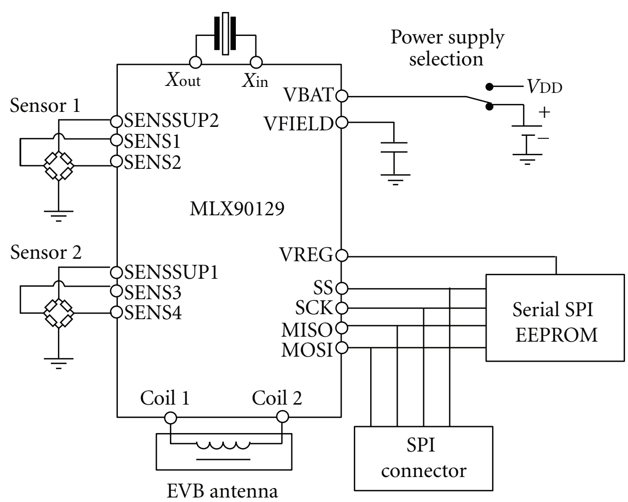

FIGURE 6: RFID block diagram in proposed system.

included in MLX90129 input and output signal range. So we do not consider adjusting the in-out signal size. This RFID tag senses oxygen and carbon dioxide and saves the collected data to EEPROM. This data will be read to RFID reader when the reader requests the data to the tag. If we use the RFID system, we can find the data easier.

3. Experiments

First we must check the operation circumstance of sensor. The sensor output is a voltage data but we need the data of oxygen and carbon dioxide concentration, so we set the experiment as Figure 7.

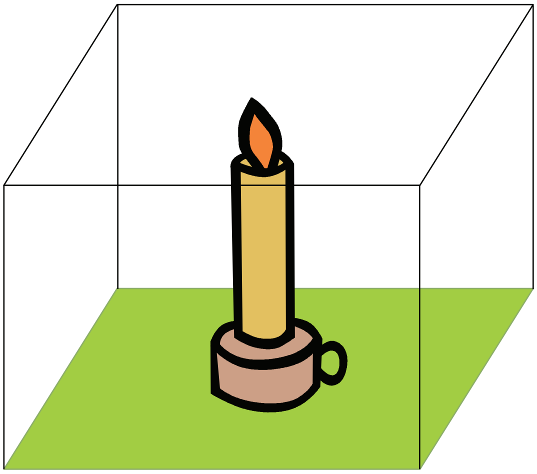

Figure 7: Experiment settings for transformation of the data form voltage to concentration.

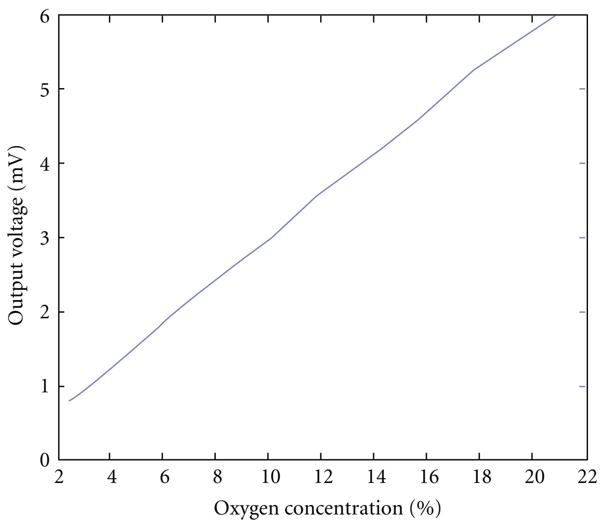

Figure 8: Oxygen concentration versus sensor output voltage.

We use a candle for transformation concentration of oxygen and carbon dioxide (in order to keep the light of candle, candle light consumes the oxygen in the experiment area and increases proportion of the carbon dioxide). We check the sensor data by DMM and compare it with data of oxygen and carbon dioxide concentration instrument.

Figure 8 is result of oxygen concentration versus sensing data. And Figure 9 is result of carbon dioxide concentration versus sensing data. Following this comparative result data, we will estimate the concentration of gases. The result data is almost linear so we can use it easily:

$$\begin{aligned} &\text{oxygen concentration } (\%) = 3.48 * \text{V (mV)}, \\ &\text{carbon dioxide concentration } (\%) = 5 * \text{V (mV)}. \end{aligned} \tag{1}$$

Equation (1) is derived by graph of Figures 8 and 9. If we use this equation, we can know the gas concentration to see

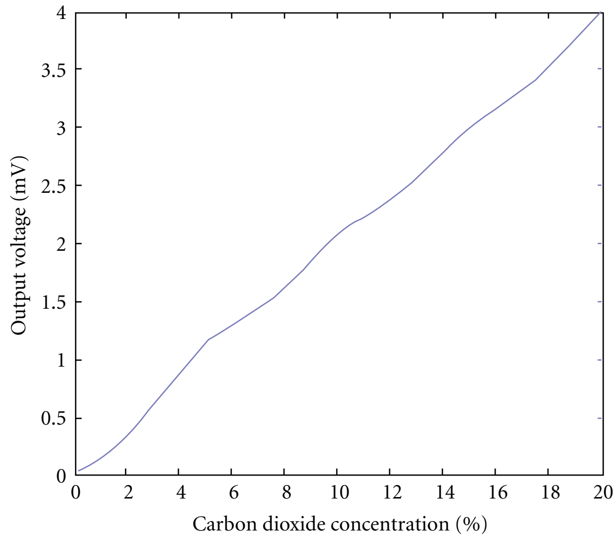

Figure 9: Carbon dioxide concentration versus sensor output voltage

the output voltage. The suggested system outputs the voltage information in RFID reader. So we need to calculate the gas concentration using voltage information.

Finally, we experiment on monitoring of oxygen and carbon dioxide concentration. This experiment uses the tag that is connected with sensors and checks the changed concentration of oxygen and carbon dioxide inside the package of the vegetable which is shown Figure 10. The experimental environment is as follows: temperature: 20°C and humidity: 35% RH. We can find the data easily showing RFID reader data as shown as Figure 11. We use shown data divided by 10000 and the value is mV.

Figure 12 is result of this experiment for a week. We can know that the oxygen and carbon dioxide concentration in package is changed every day through Figure 12. The vegetable in package consumes the oxygen and emits the carbon dioxide. And also the freshness of vegetable is changed. Therefore we can monitor the freshness checking the oxygen and carbon dioxide concentration. Furthermore, using this data, we can easily check and display the freshness with LEDs color as shown in Figure 13.

4. Conclusion

Nearly all organisms need oxygen and carbon dioxide to survive. Food also breathes and gradually spoils. If we observe oxygen and carbon dioxide used to breathe, we can check food freshness. In this paper, we observe these two gases concentrations using sensor. This sensor must have a wide operation range. Vegetables may be stored in low temperature and humidity, so a sensor has to endure this environment and others.

By combining gas sensors and RFID tags, it is relatively easy to monitor vegetable freshness. The proposed system uses RFID tags that get data on oxygen and carbon dioxide concentration. By checking RFID reader, we can track how

Figure 10: The vegetable inside the package for the experiment.

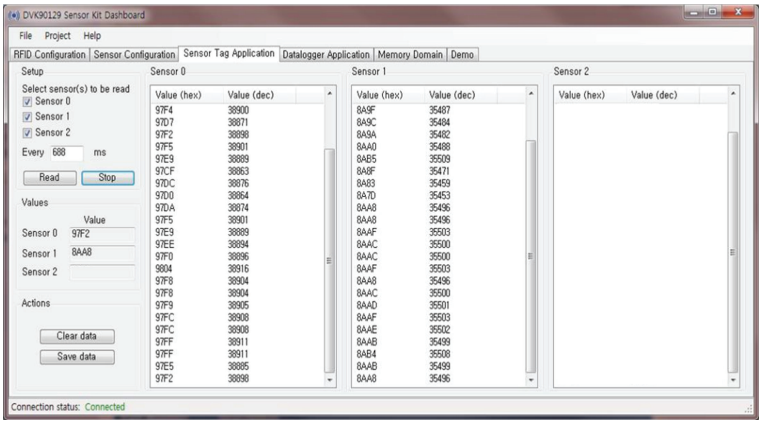

Figure 11: The reading data of RFID reader.

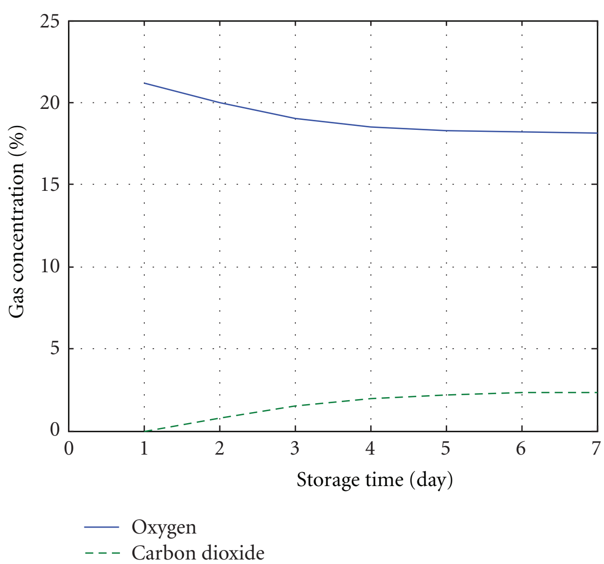

Figure 12: Results of monitoring gases concentration.

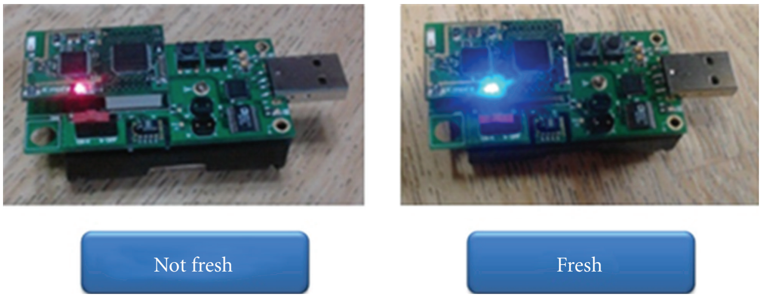

Figure 13: Display freshness using LEDs.

oxygen and carbon dioxide concentrations and vegetable freshness change over time. Furthermore, using this data, we can easily check and display the freshness with LEDs color.

Although this paper offered an initial contribution to combining two gas sensors and RFID tags, a further research could be continued on developing the smart RFID tag that has more sensors to get more precious data on food freshness.

Acknowledgment

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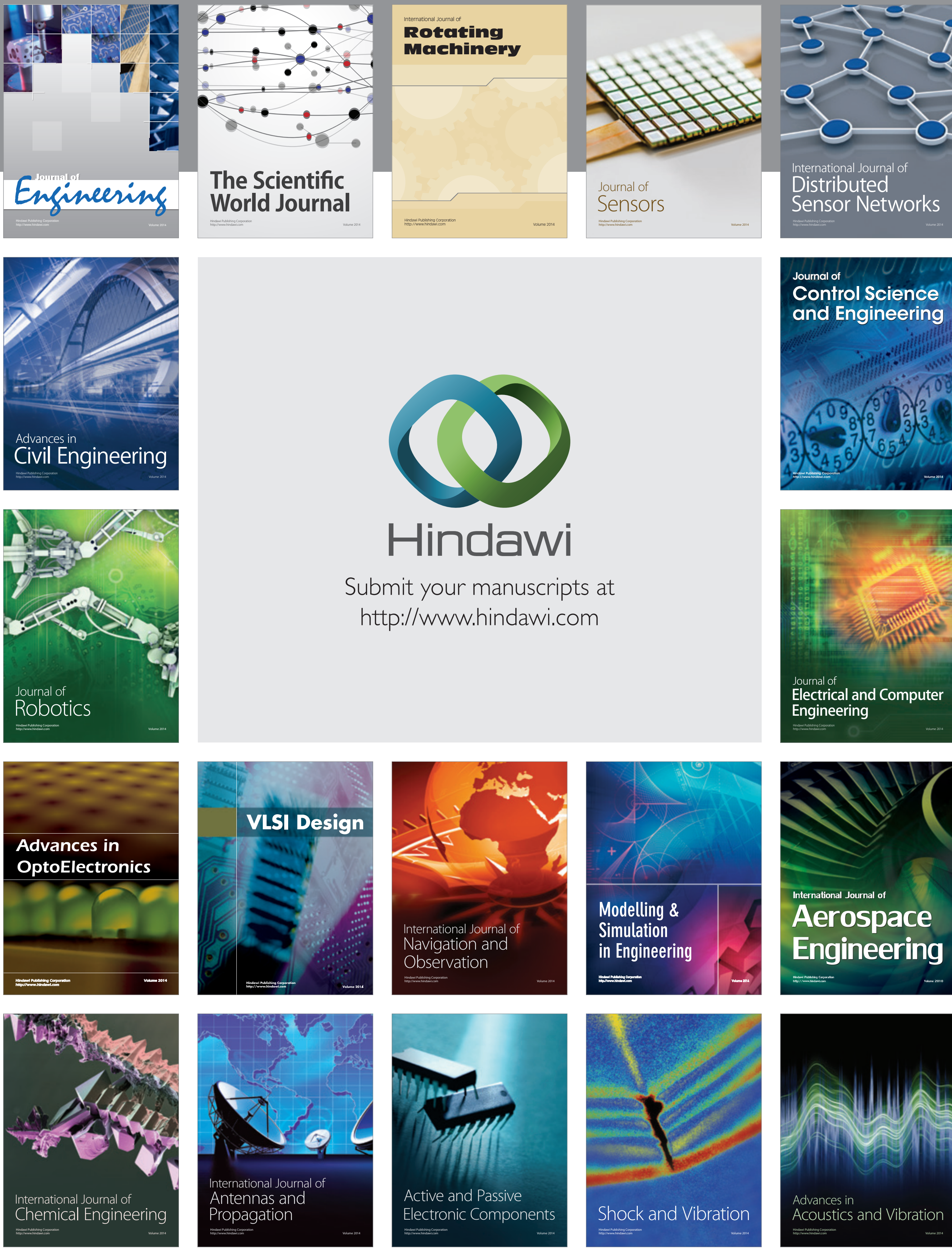
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