(37) UHF BAND RFID TAG ENABLING COLOR CHANGE FOR INVENTORY MANAGEMENT SYSTEMS IN CONSTRUCTION SITES: A COLOR-CHANGE TAG

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This paper proposes an RFID tag that can change its color using a piece of a paper towel that absorbs a solution made from salt and anthocyanin solution extracted from purple cabbage leaves boiled in water. The proposed RFID tag employs a specific RFID tag integrated circuit (IC) that has an energy harvesting function, which enables it to generate direct current (DC) voltages to operate electronic devices. The obtained DC voltages are applied to the paper towel, changing the color of the paper towel from purple to green. The validity of the proposed method was demonstrated experimentally. We have succeeded in changing the color of the RFID tag at a distance of 27.5 cm using an RFID reader radiating 250-mW radio waves.

Key Words : *inventory management, building materials, UHF, RFID tag, color-change tag*

1. INTRODUCTION

Improvements on working styles and working efficiencies in construction industries are in demand in Japan, and various solutions have been proposed to achieve these objectives[1)-4)]. Inventory management systems for building materials based on radio frequency identification (RFID) tags [1)-2)] have been proposed to improve construction and inventory management efficiency. Furthermore, these techniques enable telework in construction industries [3)]. Inventory management systems based on flying drones [4)-5)], may also become available for inventory management at construction sites.

In addition, the Japanese Ministry of Economy, Trade and Industry issued a declaration to promote the use of RFID tags in convenience stores to overcome problems concerning the shortage of the labor force and food waste [6)]. The declaration has been further enhanced to improve working styles and environment in Japan.

In this paper, an RFID tag that can change color, referred to as a color-change tag, is proposed, and preliminary experimental results are presented to validate the proposed color-change tag. The research objective was to selectively change the color of specified RFID tags based on electronic product codes (EPCs) and register values stored in internal memory. The proposed color-change tags, for example, remove the work of staff who put discount stickers on specific items among those on shelves in convenience stores that are approaching their expiration dates.

2. COLOR-CHANGE TAG

Figure 1 shows an application image of color-change tags at a construction site. Many building materials are at the site, needing an efficient management system to improve work efficiency. By applying the proposed color-change tags to the building

materials, the required time to find the target materials is reduced and machine operators can efficiently identify and specify the current or next construction materials that should be processed.

Figure 2 shows a representative application image of the color-change tag, demonstrating the changing color of specified RFID tags. **Figure 3** shows the configuration of the proposed RFID tag. The proposed color-change tag consists of an RFID tag IC and a piece of a paper towel that absorbs a solution. Specific RFID tag integrated circuits (ICs) have power (Vdd) and ground (GND) terminals as direct current (DC) voltage sources to drive electronic devices, including light emitting diodes (LEDs) and various sensor systems. Andy 100 (Farsens) [7] was used to evaluate the validity of the proposed color-change tag. In addition, if Rocky 100 [8], which has a switch ground function, is available, this IC makes it possible to change colors of the RFID tags specified by the EPCs and register values stored in the internal memory of the RFID tags, as shown in **Fig. 2**.

The solution used in the proposed color-change tag is made from an anthocyanin solution extracted from a purple cabbage and salt; the anthocyanin solution is extracted by boiling purple cabbage leaves in water [9]. The solution is then absorbed by a piece of a paper towel and placed on a substrate made of a piece of aluminum foil. **Figure 4** shows the experimental setup for evaluating the proposed color-change tag. The foil is connected to a Vdd electrode, while the ground electrode, GND, contacts the paper towel that has absorbed the solution, as shown in **Figs. 3 and 4**. The RFID reader with a circularly polarized antenna, DOTR-910J (TSS), irradiates ultra-high frequency (UHF) band radio waves to the color-change tag, where a transmit power of 250 mW and a radio wave irradiation time of 200 ms are used. Note that the use of a transmit power of 1 W and an antenna gain of 6 dBi are allowed under radio wave regulations in Japan.

Figures 4 and 5 show that the color of the paper towel with the solution was obviously changed from purple to green after the ground electrode contacted the paper towel. The distance between the RFID reader and the color-change tag was about 5 cm. These figures also show a paper towel with the solution in the absence of radio wave irradiation by the RFID reader, demonstrating that there was no color-change.

Figure 6 shows the relationship between output open circuited voltages and the color-change phenomenon as a function of the distance between the RFID reader and the color-change tag. These results confirmed that open circuited voltages greater than about 1 V are needed to cause the color-change phenomenon. The maximum distance for causing the color-change phenomenon was 27.5 cm. As mentioned above, the use of the RFID readers with a radiation power of 1 W and an antenna gain of 6 dBi will achieve signals of much longer distances.

Figure 7 compares a solution-absorbed paper towel in the presence of radio wave irradiation with one in the absence of irradiation after drying, confirming that the color-change ability is preserved.

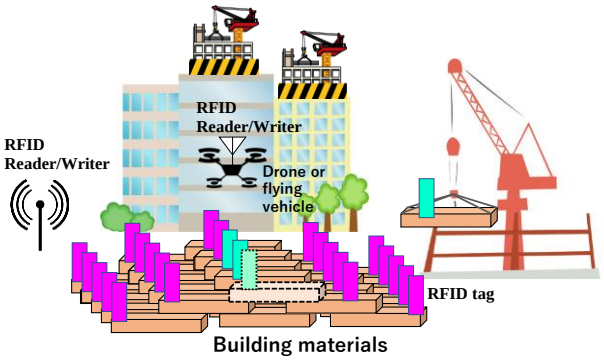

Fig. 1 Representative application image of color-change tags at construction sites.

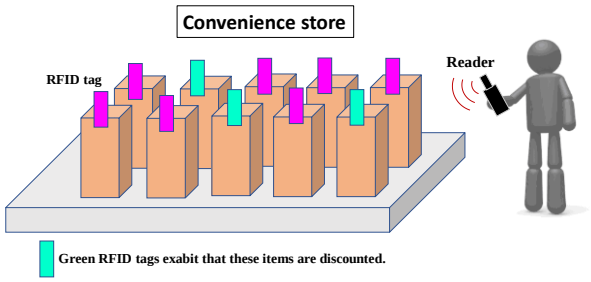

Fig. 2 Representative application image of color-change tags in convenience stores.

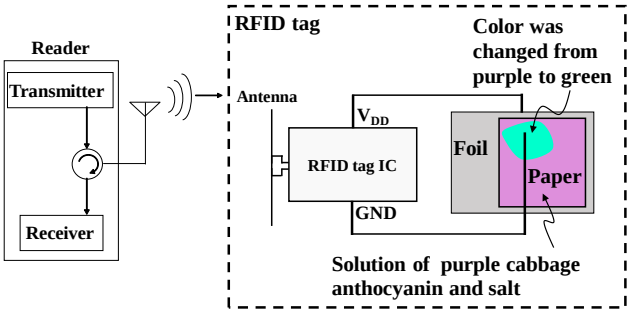

Fig. 3 Conceptual block diagram of a color-change tag.

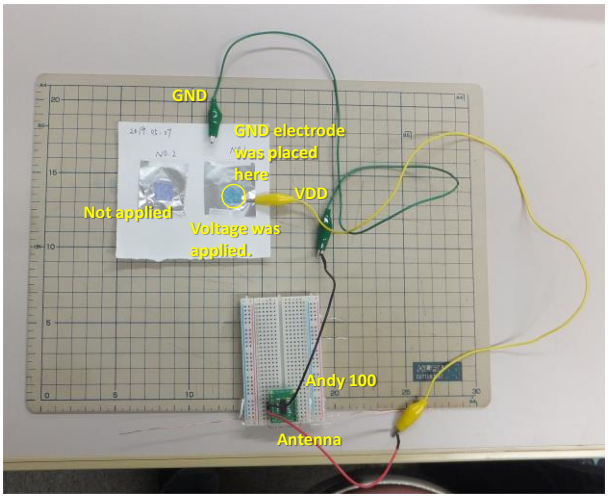

Fig. 4 Experimental setup of a color-change tag using the RFID IC Andy 100 provided by Farsens.

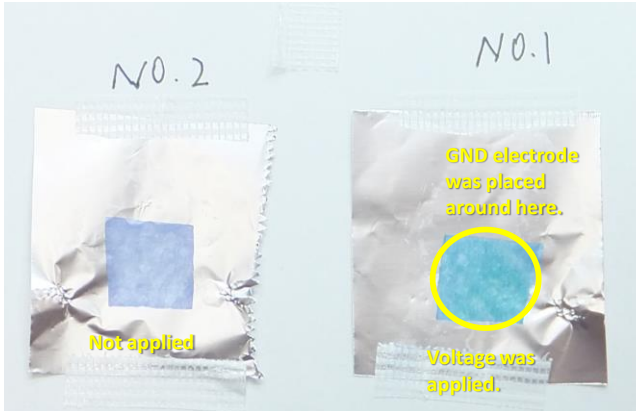

Fig. 5 Comparison between paper towels after absorbing the solution with and without the radio wave irradiation by an RFID reader.

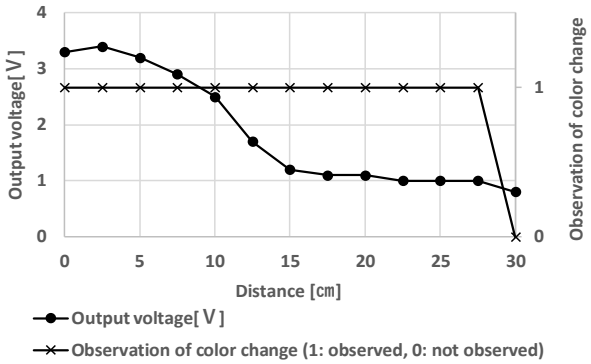

Fig. 6 Relationship between output open circuit voltages and color-change as a function of the distances between the RFID reader and color-change tag.

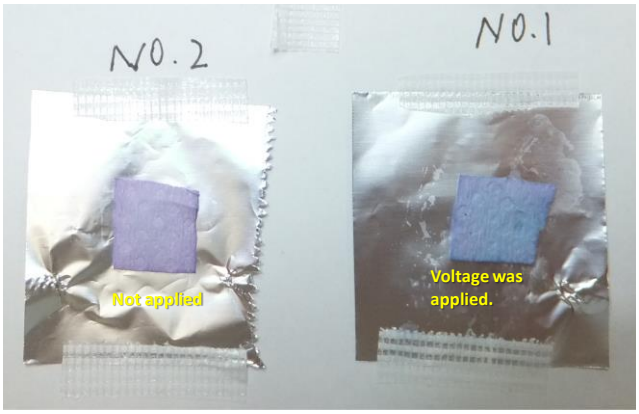

Fig. 7 Paper towels with the anthocyanin and salt solution after drying.

3. CONCLUSIONS AND FUTURE WORK

In this paper, an RFID tag using a solution made from anthocyanin and salt solution absorbed into a piece of paper towel to enable a change in color was proposed. The solution was extracted from leaves of a purple cabbage boiled in water. The Andy 100 RFID tag IC, which has an energy harvesting function, was employed to demonstrate the validity of the proposed color-change tag. An RFID reader with a 250-mW radiation power was used. The results confirmed that the color of the paper towel changed from purple to green at a distance of 27.5 cm between the RFID reader and the color-change tag. The obtained open circuit voltage was about 1 V at this distance. Note that this maximum distance will be enhanced by employing RFID readers that are allowed to radiate much higher power. Furthermore, if the Rocky 100 RFID tag IC, which can switch the connection of the ground terminal based on specific memory register values, is used, the color of the specified RFID tags will be selectively changed by specifying EPCs.

The development of laminating methods, structures of electrodes and more sensitive solutions for applied voltages will be studied further.

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