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CALIBRATION OF PIN PHOTODIODE RADON COUNTERS USING AN ION CHAMBER TYPE RADON COUNTER

Chung-Hyuk Yim[1] and Gyu-Sik Kim[*2]

[1] School of Mechanical Design & Automation Eng., Seoul National Polytech. University, Korea
[*2] Department of Electrical Engineering, The Univ. of Seoul, Seoul, Korea

ABSTRACT

Radon is a radioactive gas that is colorless, odorless, and tasteless and is impossible to detect without the use of sensitive test equipment. Various types of equipment and components have been proposed to date for radon detection. In this paper, the calibrations of PIN photodiode radon counters are performed using an ion chamber type radon counter. Through some experimental studies, we found that the performances of PIN photodiode radon counters were improved by virtue of a linear regression analysis technique.

Keywords: *radon, calibration, PIN photodiode, ion chamber type, radon counter*

I. INTRODUCTION

Radon is a radioactive gas that is colorless, odorless, and tasteless and is impossible to detect without the use of sensitive test equipment. Radon is a naturally occurring gas produced by the breakdown of uranium in soil, rock, and water. When allowed to accumulate to high levels, it can be hazardous to long-term health. The Surgeon General has warned that radon is the second leading cause of lung cancer in the United States. Only cigarette smoking causes more lung cancer deaths. The EPA presently suggests that corrective action be taken to reduce the radon levels in one's home if measured over the long term at 4 pCi/L or greater.

Various types of equipment and components have been proposed for radon detection. In [1], a passive direct-reading radon monitor utilizing a custom α particle detecting MOS integrated circuit and electrostatic radon progeny concentrator has been designed. In [2], a silicon PIN photodiode was designed and fabricated in consideration of low-leakage-current and high-bias-voltage application. In [3], a fast-responding passive radon detector using electrostatic concentration and enhanced readout electronics has been designed. In [4], an electrostatic concentrator constructed by metalizing a plastic funnel is used to focus charged radon progeny onto the exposed surface of an optical image sensor from a webcam. Alpha particles emitted by the collected progeny strike the image sensor, generating sufficient charge to completely saturate one or more pixels. In [5], a radon counter using CCD image sensor module is implemented. They showed that the CCD image sensor module could be used for a radon counter. In [6], a radon concentration monitoring system is developed, which uses the Safety Siren Pro Series 3 Radon Detector for detecting the radon particles and a data processing module with WCDMA communication capabilities for measurement results transmission and management. This solution represents an inexpensive, easy to use, portable Safety Siren Pro Series 3 radon detector and a radon monitoring system which can be used for monitoring the radon level in a specific location or for being a part of a distributed monitoring system.

In this paper, the calibrations of PIN photodiode radon counters are performed using an ion chamber type radon counter. Through some experimental studies, we found that the performances of PIN photodiode radon counters were improved by virtue of a linear regression analysis technique.

II. PIN PHOTODIODE RADON COUNTERS

2.1 Siren Pro 3 Radon Counters : Safety Siren PRO 3 radon counter shown in Fig.1 was used for experimental studies in this paper. The numeric LED display shows the level of radon gas in Pico Curies per liter (pCi/L). The display range is 0.0 to 999.9. The Safety Siren Pro Series 3 Radon Detector display is designed to notify the user of

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the level of radon gas on either a short-term or long-term basis, and is updated every hour if there is a change in the level of radon gas. The display for the short-term reading is an average of the levels of radon gas over the past seven days. The short-term reading allows the user to monitor short-term fluctuations in the home and provide a better feel for problems relating to seasonal and weather related variations in the radon levels. A green LED next to the letter "S" indicates this reading. When the short-term measurement reaches 4 pCi/L or greater, for 30 consecutive days or more, the audible alarm will sound.

Figure:

Figure 1. Safety Siren PRO 3 radon detector

2.2 PIN Photodiode Radon Counters : In this paper, a radon counter assembled from consumer electronics at very low cost is implemented. The LCD module and Arduino MCU module are shown in Fig. 2. Based on the modules in Fig. 2, a PIN photodiode radon counter is assembled as shown in Fig. 3.

Figure:

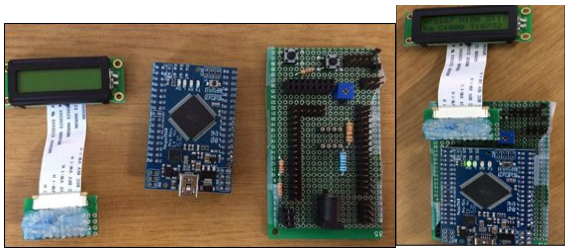
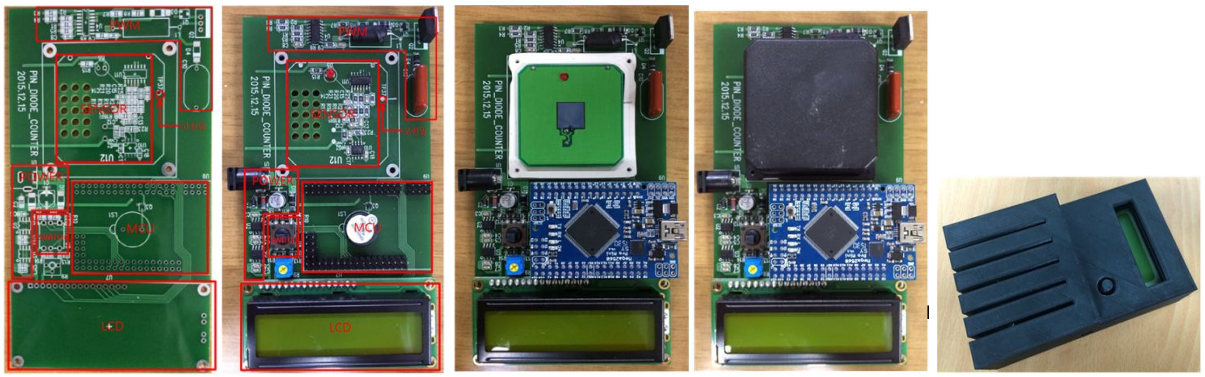


Figure 2. LCD display module and Arduino MCU module

Figure:



(a) PCB (b) LCD attached (c) Sensor, MCU added (d) Chamber added (e) Case

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Figure 3. Assembled PIN photodiode radon counter

III. ION CHAMBER-TYPE RADON COUNTER

The RD200M is the new innovative fastest radon sensor, which has the highest sensitivity, 30 cph/pCi/L on the market today. This sensor is optimized for the IAQ monitor, air purifier, radon detector and auto ventilation system. A breakthrough in FTLAB's patent technology which received a New Excellent Technology certification in 2015, the RD200M uses a dual probe structured pulsed ionization chamber and a special high impedance differential amplifier circuit to offer the highest signal to noise ratio. It effectively detects the secondary charges which were generated from collisions with air and **α**-particle caused by radon or radon's progeny. The accuracy and precision of the RD200M are ±10% at 10 pCi/L, which has been tested by the international standard Radon Testing Laboratory in KTL. Each sensor has been individually calibrated by equipments which are already calibrated to traceable international standards. Fig. 4 shows the ion chamber-type radon counter : RD200 (model:SN242), made by FTLAB, Korea. Table 1 shows the specifications of RD200.

Figure:

Figure 4. Ion chamber-type radon counter : RD200 (model: SN242)

Table:

Table 1. Specs. of RD200

Descriptions	RD200 is a real time smart radon detector for home owner which has the high sensitivity 0.5cpm/pCi/L, about 20~30 times more than conventional radon detector by FTLAB's high stable circuit technology
Type	pulsed ion chamber 200cc
First reliable data out	< 60min
Data interval	10min update (60min moving average)
Sensitivity	0.5cpm/pCi/L at 10pCi/L (30cph/pCi/L)
Operating range	10~40℃, RH<90%
Range	0.1~99.99pCi/L
Precision	<10% at 10pCi/L
Accuracy	<10% (min. error <0.5pCi/L
Power	DC 12 0.1V, 65mA (12V DC adapter)
Size	Φ80(mm) x 120(mm), 240g
Data communication	Bluetooth LE (Android/iOS)
Data log	max 1year(1h step)
Display	0.96 inch OLED

IV. CALIBRATION USING A LINEAR REGRESSION ANALYSIS

The methyl methacrylate box was made for radon concentration calibration as shown in Fig. 5. The calibration experiment was done for 96 hours for varied concentration of radon gas. Using a linear regression analysis technique,

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the measured radon counts per hour of Siren Pro 3 radon counters could be calibrated as shown in Fig. 6. As for the first Siren radon counter, the RMSE was 1.754 pCi/L and the correlation coefficient R^2 was 0.8417 as shown in Fig. 6 (a). As for the second Siren radon counter, the RMSE was 2.475 pCi/L and the correlation coefficient R^2 was 0.685 as shown in Fig. 6 (b). Similarly, the measured radon counts per hour of implemented PIN photodiode radon counters could be calibrated as shown in Fig. 7. As for the first PIN photodiode radon counter, the RMSE was 1.791 pCi/L and the correlation coefficient R^2 was 0.835 as shown in Fig. 7 (a). As for the second PIN photodiode radon counter, the RMSE was 1.891 pCi/L and the correlation coefficient R^2 was 0.8161 as shown in Fig. 7 (b). These experimental results suggest that the implemented PIN photodiode radon counters and Siren Pro 3 radon counters are improved by using a linear regression analysis technique.

Figure:

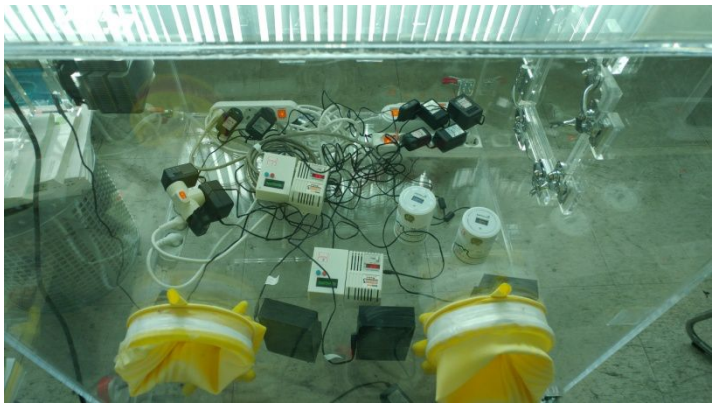
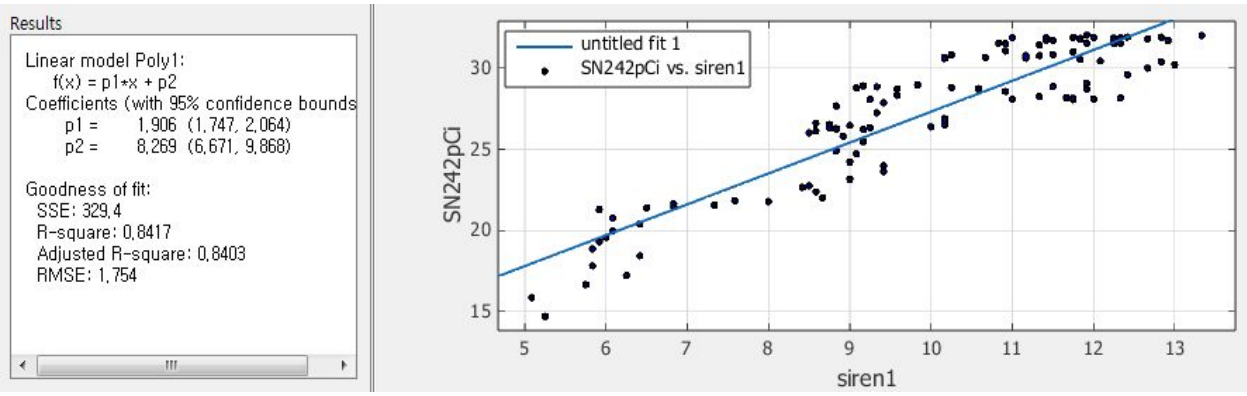


Figure 5. Experimental set-up for calibration study

Figure:



(a)

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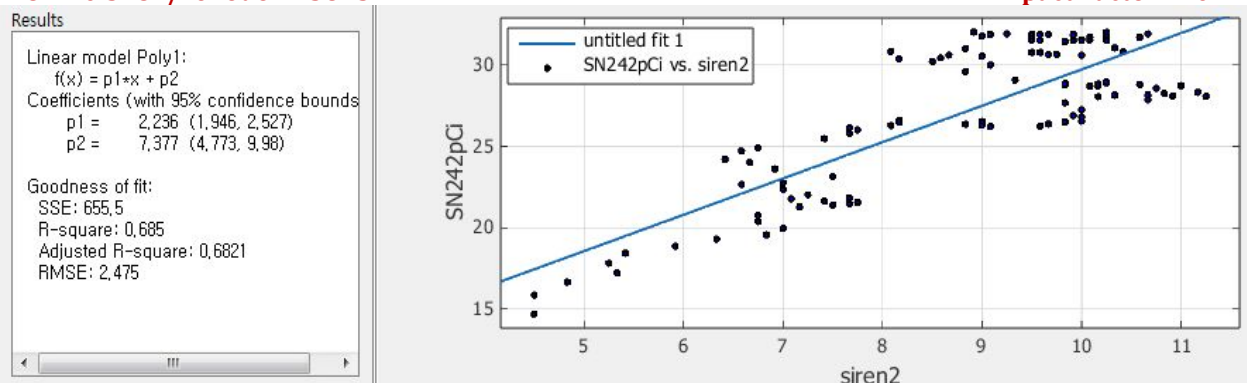
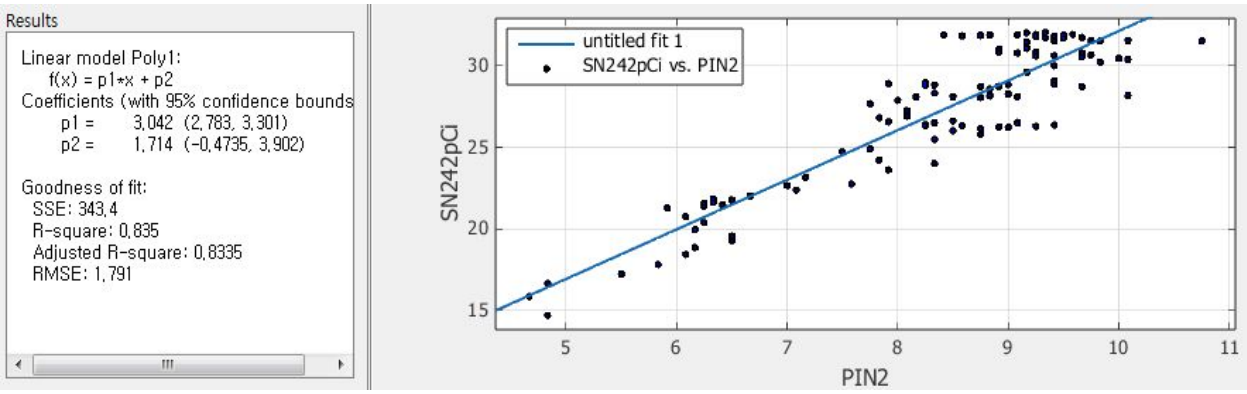


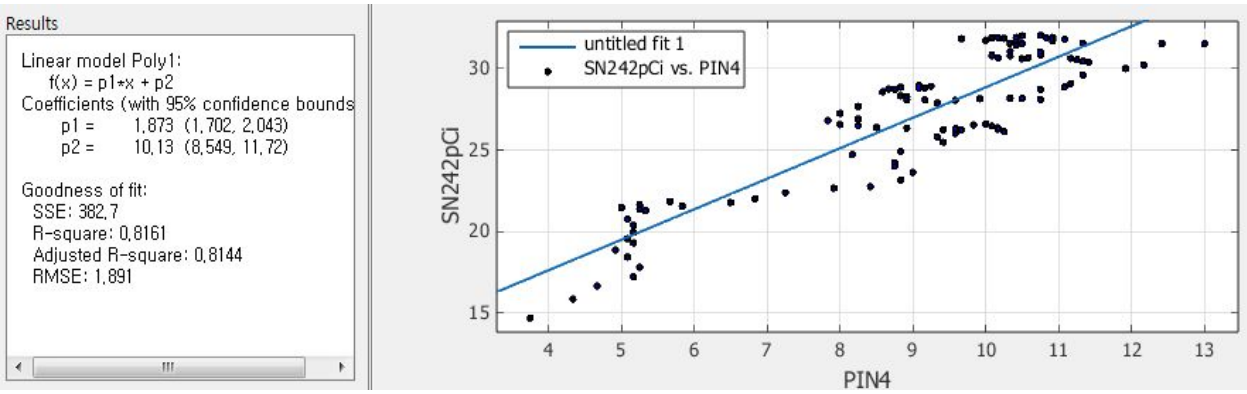
(b)

Figure 6. Calibration of Siren Pro 3 radon counters

Figure:



(a)



(b)

Figure 7. Calibration of implemented PIN photodiode radon counters

V. CONCLUSION

In this paper, a radon counter assembled from consumer electronics is implemented at very low cost. The calibration experiment was done for 96 hours for varied concentration of radon gas. Using a linear regression analysis technique, the measured radon counts per hour of Siren Pro 3 radon counters and implemented PIN photodiode radon counters

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could be calibrated. These experimental results show that PIN photodiode radon counters can be improved well and calibrated with the help of the ion chamber type radon counters.

VI. ACKNOWLEDGEMENTS

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