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The study of measure Na/K ratio in urine through optical measurement

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Abstract. Most of the foods which we eat commonly contain salt. Body changes occur when the sodium concentration in the body gets out of normal range. The action of potassium, an electrolyte, releases sodium and then it can prevent the disease. Sodium and potassium are essential substances that must be maintained in proper concentration for normal life. We can prevent abnormal concentration by measuring the figures of these concentration. The figures of these in the body can be measured through blood or urine collection and analysis. We studied the method of measuring the ratio of sodium and potassium in the urine using optical techniques applied SiPM.

Keywords; SiPM; Aptamer; Photon; Na/K ratio; Counting mode

1. Introduction

Circulatory system diseases such as hypertension are the second leading cause of death in Korea, and one third of the population is in the risk group of this. Most of the foods which we eat commonly contain salt. Body changes occur when the sodium concentration in the body gets out of normal range (135-145 mmol/L) due to salinity intake. If the concentration of sodium in the body is high (145 mEq/L or more), blood pressure rises because of blood moisture and blood volume increase. When hypernatremia occurs, the moisture in the cells migrates out of the cell, resulting in a

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fall of the salivation and a physical change such as drying of the mucous membrane of the skin. In severe cases, some study results report that neurological abnormalities such as spasm and coma occur and the mortality rate increases. However, even if sodium concentrations is low (less than 125 mEq/L), hyponatremia can occur and this may also lead to brain edema, epileptic seizures, and other lesions. [1] The action of potassium, an electrolyte, releases sodium in the body, and then the blood pressure can be maintained by controlling the balance among the water content in the body, alkali and acid. Then this can prevent the disease. However, potassium concentration (over 7.0mEq / L) in the blood above the normal level (3.7 ~ 5.3mEq / L) may lead to 'hyperkalemia' which causes kidney function and muscle weakness. [2] On the other hand, when the concentration is less than 3.0mEq / L, it may occur abnormalities in muscle cell metabolism and result in 'hypokalemia' in which tiredness, muscle aches, general paralysis, and etc. occur. Sodium and potassium are essential substances that must be maintained in proper concentration for normal life. Various methods for diagnosing and preventing this are being studied. [3] The figures of sodium and potassium in the body can be measured through blood or urine collection and analysis. The urine examination using the urine salinity test equipment estimates the daily intake of salt. But it has problems with the measurement accuracy and measurement cycle. There are also inaccuracies and hygiene problems in the measurement because various types of urine analyzers utilize strips. To solve this problem, we discuss the method of measuring the ratio of sodium and potassium in the urine using optical techniques.

2. METHODS

A. Operating principle of photomultiplier and measurement of chemiluminescence

SiPM (silicon photomultiplier) is based on a reverse-biased PN diode, consisting of a small-sized matrix called a micro-cell (or pixel), all connected in parallel. Each microcell is a Geiger Mode avalanche diode operating above the breakdown voltage (Vbd). It features very high sensitivity, high efficiency and fast response time (<100 ps). Based on these characteristics, it is possible to measure wavelengths from near-infrared to near-ultraviolet rays, and thus it has been used in all fields where low-level light measurement is required. [4] When substances such as aptamer, TPG, and TMPG are injected into the urine, light is generated by the chemical reaction, but sodium and potassium interfere with the chemical reaction and make the amount of light emission changes. At this time, if the SiPM measures the emitted light, the amounts of sodium and potassium can be indirectly estimated based on the measured light.

When the circuit constructed in this paper operates repeatedly in the quiescent mode by the Avalanche effect, several pulse waves are obtained. Then the pulse signal of a certain size can be obtained by passing through the digitizer. In this study, the amount of chemiluminescence was measured by counting the pulses.

B. Circuit configuration and characteristics according to photomultiplier operating mode

The measuring method of photon is generally that a current from SiPM is converted into voltage signal through TIA (Trans Impedance Amplifier), and the spectrum is analyzed by sampling high speed through shaping amplifier and ADC circuit. This is shown in Figure 1. However, this measuring method has a problem that the entire readout circuit becomes complicated and the price of the final product increases due to the high-speed sampling, which makes it difficult to apply to the actual system.

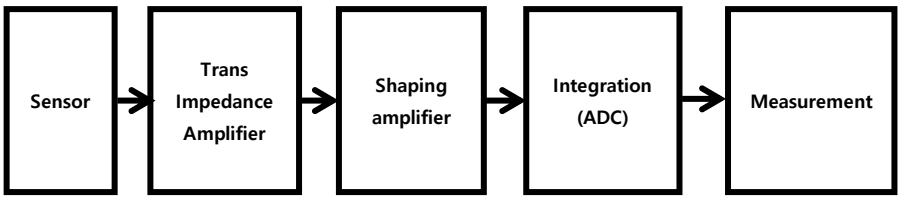

Figure 1 Integration mode

On the other hand, as shown in Figure 2, the counting mode measures photon generated by counting the signals which are above the predetermined level, without sampling the signals converted through TIA. This method can be used in applications where there is little need for pulse size spectrum analysis due to SiPM discharge. In this study, therefore, this method is applied due to the purpose of measuring a very small amount of chemiluminescence.

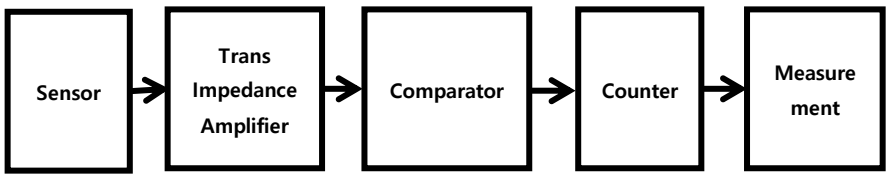

Figure 2 Counting mode

3. Results

A. Measurement for optical measurement experiment using SiPM

To verify the operation of the SiPM using the counting mode circuit, a circuit was designed using a discrete amplifier (OPA656), and a PCB module was fabricated as shown in Figure 3. The SiPM used in the experiment is Hamamatsu S12572-050C with characteristics of micro pixel size: 50um, operating voltage (Vop): 66.57V, and sensor size: 3mm x 3mm.

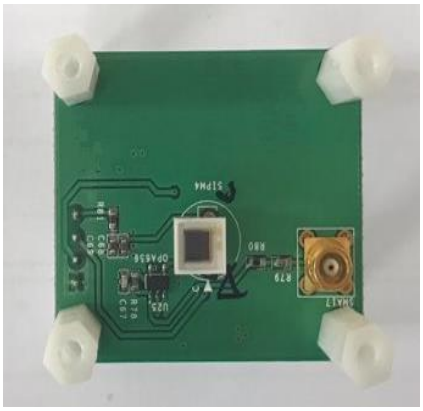

Figure 3 SiPM & Front-end circuit PCB module

The measurement was carried out in the chamber inside the dark box that blocks the ambient light. The total measurement time was 1 ms and the threshold level was set to 0.5 V, and measured 83 pulses. The results are shown in Figure 4. On this basis, we confirmed that the design valid signal selection circuit works normally in this study.

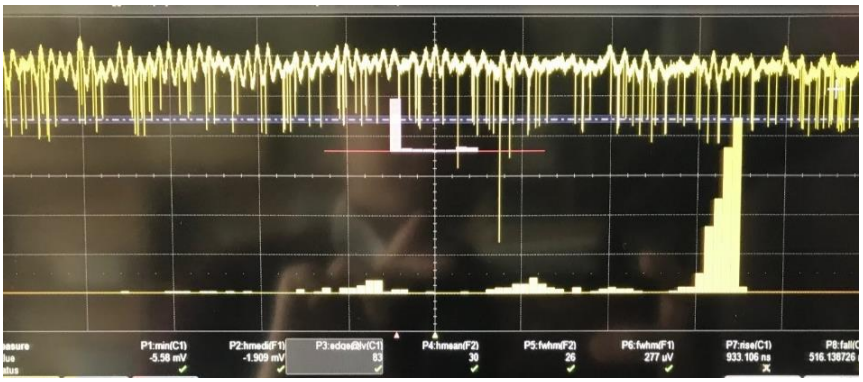

Figure 4 SiPM pulse counting test using oscilloscope

4. CONCLUSION

With the aging of modern society, people want to know their health condition easily at home without visiting a hospital. In this study, we designed and experimented optical measurement technique to measure sodium and potassium in body by analyzing urine using the SiPM. For this purpose, we analyzed the characteristics of the integration mode and counting mode applied to photon measurement using the SiPM. We have designed and manufactured a circuit to measure the sodium and potassium analyzer for the personal and household use by applying the relatively inexpensive counting mode because the SiPM signal readout circuit does not need fast sampling and then is simple. From the experimental results, it was confirmed that the circuit designed in this study can select the valid signal of the reference voltage. Using this circuit it is possible to evaluate the concentration of aptamer, TPG, TMPG and other substances according to sodium and potassium in the urine. Based on this, we will develop a prototype of the analytical module using the counting mode of SiPM and proceed with the counting experiment according to the chemiluminescence characteristics in the future.

Acknowledgment

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