Study of Temperature Effect on Ion Implanted Silicon Detector for In-containment Radiation Monitoring System

Jongheon Kim [a], Kihong Pak [a], Junesic Park [a], Jaebum Son [a], Jihun Moon [a], and Yong Kyun Kim [a*]
[a]Department of Nuclear Engineering, Hanyang University, Seoul 04763, Korea
[*]Corresponding author: ykkim4@hanyang.ac.kr

Introduction

There has been studied to develop an in-containment radiation detection system for detecting small coolant leakage. The system could detect charged particles of radioisotope from the leaked coolant and a silicon semiconductor detector could be applied as a sensor of the system due to its compactness and good detection capability for charged particles with a simple detector design. As one of the most advanced charged particle detectors, an ion implanted silicon semiconductor detector has a good resolution and good efficiency for detecting alpha and beta particles, because of an extremely thin dead layer compared with other detectors. In order to investigate an effect of temperature on the behavior of an ion implanted silicon semiconductor detector for an in-containment coolant leakage detection system, we studied a Si sensor of 300 μm thickness depletion depth over the temperature range 283 K to 323 K, which the range is a design basis temperature of an annulus zone of a nuclear power plant, by recording the spectrum of a Po-210 alpha source (5.3 MeV).

Experiments

1. Detector and Electronics

To investigate an influence of temperature on a Si detector in temperature range of an annulus zone of a nuclear power plant, ULTRA ion implanted Si sensor(ORTEC) was used. The Si sensor had 300 μm thickness of depletion depth and 1200 mm^2 of an active area. As electronics devices, 142A preamplifier, 460 amplifier 428 bias supply, 928 MCB, and MAESTRO® 7 application software made by ORTEC were used for identifying spectrum during temperature changes.

2. Setting of Experiment Conditions

The Si sensor mounted in a lead shield which consists of 5 cm thickness lead cylinder to avoid damage by background radiation in containment building and preamplifier were equipped in an environmental test chamber, and other electronics were installed out of the chamber. The temperature was changed from 283 K to 323 K, and relative humidity was fixed by about 60 % while the test was conducted. During the experiment, the alpha energy spectrum from Po-210 and noise was recorded for identifying a state of function of the detector system. Fig.1 and Fig.2 present a block diagram and setting of an experiment.

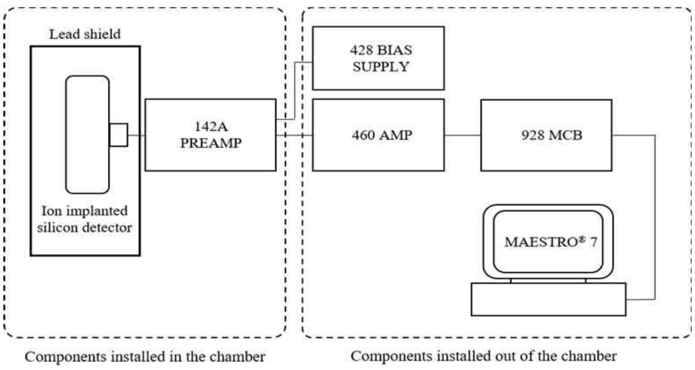

Fig. 1. Block diagram of the setting of a detector and electronics system

Fig. 2. (left) An environmental test chamber, (right) A setting of an experiment

Result and Discussion

In high channels that could ignore a noise spectrum(above 105 channels), it is confirmed that the FWHM(Ch.) get degraded about 5.3% at high temperature compared with room temperature. However, the degradation doesn`t have a significant influence to identify radioisotope in high channels. Fig. 3 shows a change of gross cps and FWHM(Ch.) in the range from 283 K to 323 K.

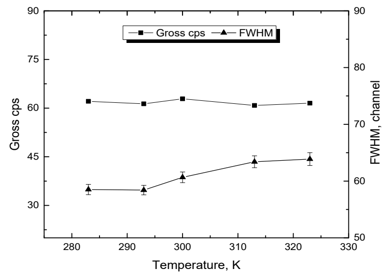

Fig. 3. Change of gross cps and FWHM of the alpha spectrum during temperature change

In low channels, thermally generated electron-hole pairs which exponentially increased by temperature change, theoretically, could make a leakage current which can make noise spectrum in low channels. Fig. 4 shows changes in gross cps by temperature changes and a theoretical value of thermally generated electron-hole pairs. The changes of gross cps are not exactly fit with the theoretical value because of other influences like a change of electronics noise from the preamplifier which equipped inside the test chamber with the Si sensor.

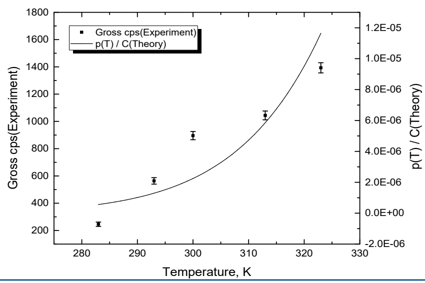

Fig. 4. The gross cps change in noise spectrum and the probability of electron - hole pair`s generation as a change of temperature

Conclusion

The effect of temperature on the Si detector by recording the energy spectrum was studied. We confirm that temperature could make just little influence in high channels. On the other hand, in the case of low channels, because of the increasing of thermally generated electron-hole pairs, while the temperature becomes higher, the gross cps could be increased. It indicates that the in-containment Si detector should be cooled and the level of discrimination should be determined carefully depending on target radiation energy and species.