RADIATION HARDNESS TEST OF A SILICON DETECTOR AND PREAMPLIFIER OVER THE DESIGN LIFETIME FOR A REACTOR COOLANT LEAKAGE MONITORING SYSTEM

by

Kihong PAK*[1,4]*, Jongheon KIM*[2]*, Yong Hyun KIM*[1]*,
***Seung Beom GOH*[1]*, Young-Sik CHO*[3]*, and Yong Kyun KIM*[1*]**

[1] Department of Nuclear Engineering, Hanyang University, Seoul, Republic of Korea
[2] Korean Institute of Nuclear Safety, Daejeon, Republic of Korea
[3] Korea Atomic Energy Research Institute, Daejeon, Republic of Korea
[4] Department of Radiation Oncology, Asan Medical Center, Seoul, Republic of Korea

Scientific paper
https://doi.org/10.2298/NTRP2402089P

Radiation hardness tests were conducted on a silicon detector and preamplifier to develop a reactor coolant leakage monitoring system, which detects high-energy beta particles from ^{16}N in the primary reactor coolant of nuclear power plants. Monte Carlo simulations were used to calculate the doses that would be absorbed on components over a 60-year design lifetime. The components were exposed to a ^{60}Co gamma source with an activity of 2.4 kCi for 54 hours. The absorbed doses accumulated during the test were determined to be 0.99 kGy for the detector and 1.37 kGy for the preamplifier. During the test, the alpha count from a check source in the high-channel range disappeared in a high-dose-rate environment, and the gross gamma count decreased as the accumulated dose increased. The performance degradation of the detector and preamplifier was evaluated by comparing the alpha signals and background noise before and after irradiation. The energy resolution of the alpha signals in the high-channel range exhibited slight changes, whereas the electronic noise in the low-channel range increased by approximately 773 % for the irradiated detector and 17 % for the irradiated pre-amp. A method employing various low-level discriminator channels is proposed to mitigate noise effects in the monitoring system.

Key words: radiation hardness test, accumulative absorbed dose, silicon detector, reactor coolant, leakage monitoring

INTRODUCTION

Unidentified leakage of reactor coolant from the reactor coolant system (RCS) in nuclear power plants (NPP) can lead to component degradation or corrosion, accumulation of chemical compounds such as boric acid, contamination of work surfaces, and even loss-of-coolant accidents. According to Regulatory Guide 1.45 (RG 1.45) [1] released by the U.S. Nuclear Regulatory Commission (USNRC), various instruments are used for monitoring RCS leakage, including tanks, sumps, airborne particle/gaseous radiation monitors, and instruments for monitoring containment atmosphere humidity, pressure, and temperature. Although RG 1.45 reported that these monitoring methods are capable of detecting a leakage rate of 1 gallon per minute (1 gpm = 3.785 liters per minute) within an hour, recent cases have revealed vulnerabilities in existing monitoring systems, particularly in detecting small leakages, and significant delays in detection times have been observed. The primary causes of the delay in detection time include: the large area of the sump, leading to very small changes in the water level, the inability to detect leakages when there is no change in the radioactive levels within the containment atmosphere, and the condensation of steam before reaching the humidity sensors.

To address these issues, a beta particle detection system including a silicon (Si) semiconductor detector has been developed for monitoring coolant leakage of less than 0.5 gpm within 1 h (0.5 gpm per hour) in a previous study [2, 3]. This system employs a capture pipe positioned between the coolant pipe and insulation. The capture pipe collects the steam released from coolant leakage into the detection cavity, which is located in the annulus zone of an NPP containment building. It then detects beta particles emitted from ^{16}N that occupy over 90 % [4] of the radioactive

* Corresponding author, e-mail: ykkim4@hanyang.ac.kr

isotopes in the coolant with a maximum energy of 10.4 MeV, thereby facilitating the monitoring of coolant leakage occurrence. The Si detectors are less sensitive to gamma-rays, which have a relatively high penetrating power, owing to their thin depletion layers. Therefore, this feature is suitable for charged particle detection, avoiding interruption of the signal by background gamma-rays and neutrons. Radiation hardness is an important consideration when installing a Si detector and preamplifier (pre-amp) in the annulus zone. Because gamma-rays and neutrons produced from the reactor exist as background radiation during reactor operation, the Si detector and pre-amp must maintain their functional states against background radiation. Therefore, a radiation-shielding structure must be constructed for the detection system. Figure 1 shows a schematic of the developed reactor coolant leakage monitoring system and its monitoring procedures.

It is generally known that an absorbed gamma-ray dose of approximately 8.6 kGy leads to significant performance degradation in Si detectors [5]. Several studies investigated the radiation hardness and functional degradation of Si detectors after irradiation. Sueva *et al*. [6] studied the applicability of a Si detector in an environment with high-dose gamma-rays. To evaluate the properties of the Si detector in a high-dose field, it was irradiated with gamma-rays of up to 599 kGy using a ^{60}Co source. A shift in the alpha signal was observed and the self-annealing effect was confirmed 24 hours after irradiation. In the case of pre-amps, although there are variations in radiation hardness based on the composition of the components, functional damage is also caused by high-dose radiation [7-9]. However, to evaluate the applicability of a Si detector in specific radiation environments, such as inside the containment buildings of NPP, radiation hardness tests should be performed based on the knowledge of the detector properties. In this study, radiation hardness tests were conducted by irradiating a Si detector and preamplifier with gamma-rays to identify their functional states. The absorbed doses in the components over the design lifetime were calculated using Monte Carlo simulations, considering the background radiation in the annulus zone. The performance degradation in the irradiated components after the test was compared and a method to reduce the effects of radiation damage on detection performance was proposed.

ABSORBED DOSE CALCULATION FOR COMPONENTS

The final Safety Analysis Report (FSAR) for APR1400 [10] reported gamma and neutron flux at 0.5 ft (0.153 m) outside the midplane of a reactor vessel as shown in fig. 2. Using these data, the gamma and neutron fluxes in the annulus zone of the primary NPP system were calculated using Monte Carlo N-Particle (MCNP) [11] simulations, and the fluxes are listed in tab. 1.

The absorbed doses of the Si detector and pre-amp were calculated using MCNP. In the simulation, a lead shielding cylinder with a thickness of 5 cm, the 300 μm depletion layer of the Si detector, and the pre-amp shaped in a silicon board were implemented. The source term was located outside the lead cylinder. The neutron and gamma-ray fluxes were converted into intensities by considering the design criteria for the dose rate in the annulus zone, which was 10 mSvh^{-1}. The F6 tally was used to calculate the absorbed dose to the components over a period of 60 years, which is the design lifetime of NPP. For the entire duration, an 18-month refueling cycle and an overhaul period were considered. The dose absorbed in the

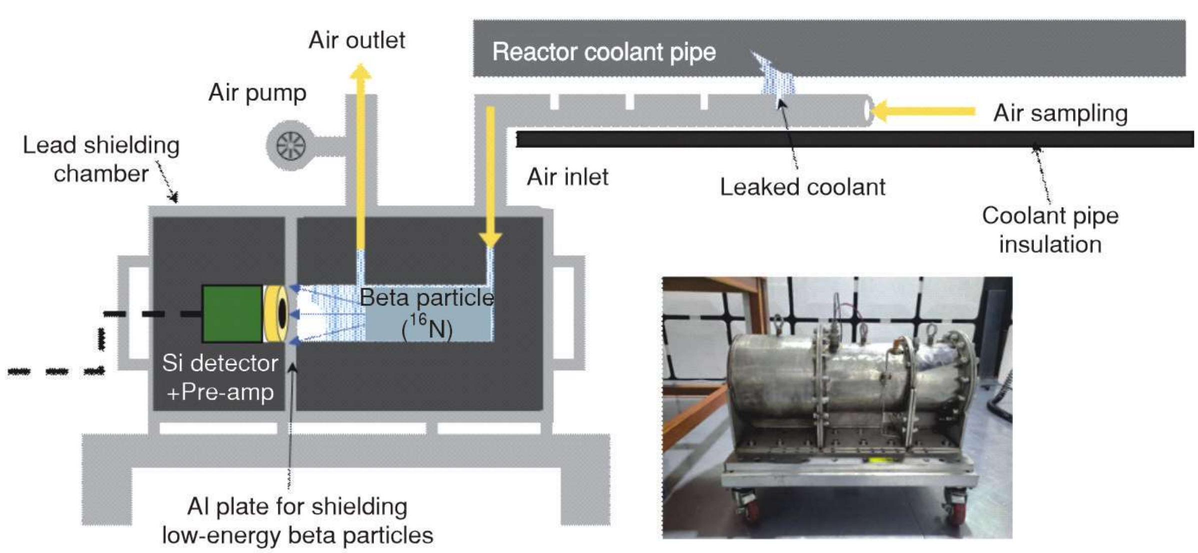

Figure 1. Schematic of the developed reactor coolant leakage detection system

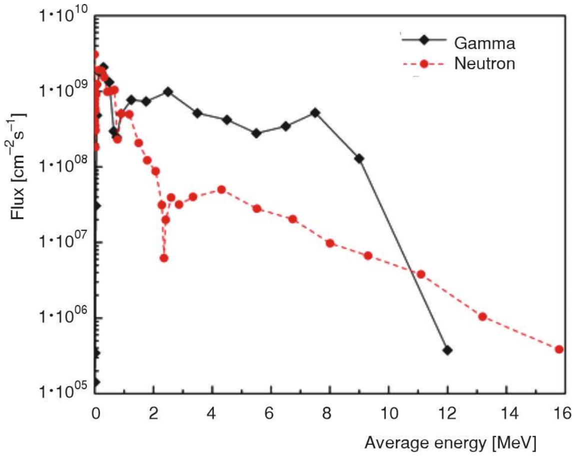

Figure 2. The flux of gamma-rays and neutrons at 0.5 ft outside the midplane of a reactor vessel

Table 1. Data of neutron and gamma flux in the annulus zone of an NPP primary system

Neutron		Gamma	
Energy [MeV]	Flux [cm^{-2}s^{-1}]	Energy [MeV]	Flux [cm^{-2}s^{-1}]
$1.11 \cdot 10^{-2}$	$7.01 \cdot 10^{5}$	1	$3.10 \cdot 10^{5}$
$8.92 \cdot 10^{-2}$	$1.44 \cdot 10^{4}$	2	$4.62 \cdot 10^{4}$
1.18	$1.12 \cdot 10^{4}$	3	$3.71 \cdot 10^{4}$
5.52	$2.87 \cdot 10^{2}$	4	$1.47 \cdot 10^{4}$
11.1	2.09	5	$1.81 \cdot 10^{4}$
		6	$8.74 \cdot 10^{3}$
		7	$1.50 \cdot 10^{4}$
		8	$5.04 \cdot 10^{3}$
		9	$4.07 \cdot 10^{2}$
		10	$1.78 \cdot 10^{2}$
		11	$4.59 \cdot 10^{2}$
Total	$7.27 \cdot 10^{5}$	Total	$4.56 \cdot 10^{5}$

reaction area (depletion layer) was considered for the Si detector, and the dose absorbed in the entire panel that housed several transistors was considered as the pre-amp for conservative evaluation. Figure 3 shows the geometry of the simulation used for the calculations. The absorbed doses accumulated in the components over 60 years of age are listed in tab. 2.

RADIATION HARDNESS TESTS

To observe the functional changes in the detector and pre-amp owing to the amount of absorbed dose accumulated over the design lifetime, the effect of radiation quality was not considered. The radiation damage induced by the displacement per atom (DPA) mechanism differs between neutrons and gamma-rays. Therefore, a comparison of the results from neutron and gamma-ray exposures is currently being planned. The gamma-ray irradiation tests were conducted at the Advanced Radiation Technology Institute facility of the Korea Atomic Energy Research Institute using a ^{60}Co source with an activity of 2.4 kCi (1 Ci = $3.7 \cdot 10^{10}$ Bq). The Si detector (ORTEC ULTRA BU-037-1200-300) with a 300 μm depletion layer and pre-amp (ORTEC ^{142}A) was shielded using 5 cm thick lead bricks to mimic the shielding structure. Furthermore, an amplifier (ORTEC 460), power supply (ORTEC 428), and multichannel analyzer (ORTEC 928) were connected to obtain the spectra during irradiation. The experimental parameters included amplifier gain of 50, shaping time of 0.1 μs, bias voltage of 90 V, lower-level discriminators (LLD) of 250 channels, conversion gain of 1024 channels, and spectra recording time of 10 minutes. The MAESTRO (ORTEC) software was used to analyze the spectra. Figures 4 and 5 show the block diagrams of the devices and the experimental set-up, respectively. As shown in fig. 5, alanine pellets were attached to the top of the vacuum chamber and the side of the pre-amp to measure the absorbed doses in the Si detector and pre-amp.

Owing to the thin depletion layer of the detector, the spectra for electrons (beta particles), gamma-rays, or electronic noise are formed in the low-channel range (approximately 0-400 channels). Therefore, a

Table 2. Absorbed doses accumulated for 60 years on a Si detector and pre-amp

Components	Absorbed dose for 60 years [Gy]		
	By gamma-rays	By neutrons	Total
Si detector	434.43	595.41	1029.84
Pre-amp	385.68	107.59	493.27

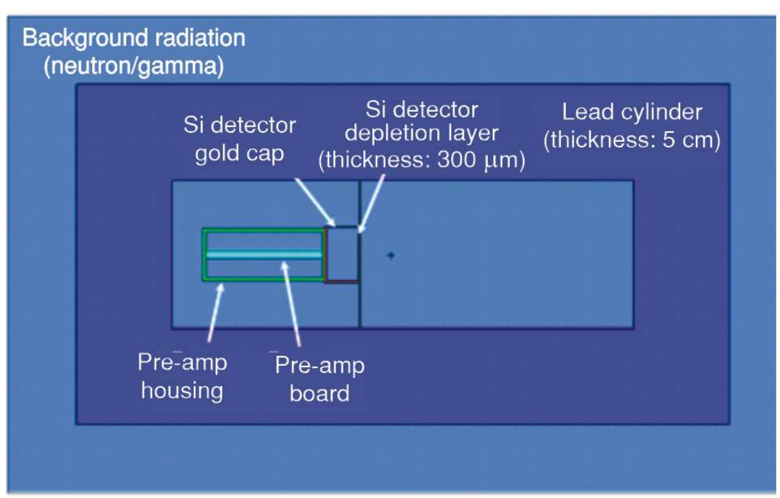

Figure 3. The geometry of MCNP simulation to calculate the absorbed doses of each component over a 60-year design lifetime

^{210}Po alpha source was used to evaluate the functional state of the detector during high-dose gamma irradiation, including its influence on the relatively high channel range (approximately 400-600 channels). The components were irradiated with gamma-rays for 57 hours to reach 1.03 kGy, which was the accumulated dose of the Si detector obtained from the simulation.

The actual absorbed doses of each component were derived from those of the alanine pellets using the mass absorption coefficient [12]. The measured doses of alanine pellets were based on the dose absorbed in water at a density of 1 gcm^{-3}. The appropriate conversion equation is as follows

$$D_{\rm Si} = \frac{\mu_{\rm Si}}{\mu_{\rm water}/\rho_{\rm water}} \cdot D_{\rm water} \qquad (1)$$

where D is the absorbed dose, and μ/ρ – the mass absorption coefficient. Table 3 lists the measured doses of each alanine pellet and the corresponding actual doses of each component. The detector received approximately 12 % less irradiation than the calculated dose, whereas the pre-amp was exposed to approximately 150 % more irradiation than the estimated dose. Despite these variations, it was concluded that investigating the effect of accumulated doses should not be problematic.

RESULTS AND DISCUSSION

Signal loss of alpha particles under a high-dose-rate environment

In the experiment, the spectra of gamma-rays and alpha particles were formed in the low-(250-350 channel) and high-channel range (500-600 channel), respectively. Spectra were recorded at 10 minute intervals over a total duration of 57 hours. In the high-dose-rate environment, the alpha spectrum was not detected (left panel in fig. 6). However, each time the gamma source was shut down for a few minutes during the experiment, alpha counts were recorded again (right panel in fig. 6). After the experiment was concluded, alpha counts were measured normally, with approximately 1 kGy of dose accumulated in the components.

Radiation incident on Si detectors ionizes the material in the semiconductor, creating electron-hole pairs. Subsequently, these electron-hole pairs move to each electrode and generate charge signals in electronic devices such as pre-amps and amplifiers. Owing to this process, the count rate of the detectors inevitably decreases in a high-count-rate environment. Consequently, there is a limit to the processing time of the generated signal, known as dead time. Patil [13] re-

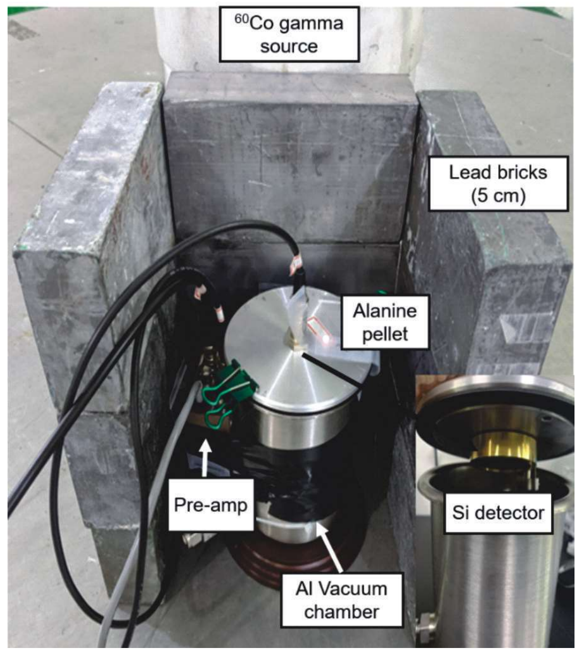

Figure 5. Experimental set-up for the radiation hardness test; the Si detector was inserted in an aluminum vacuum chamber without vacuum pumps

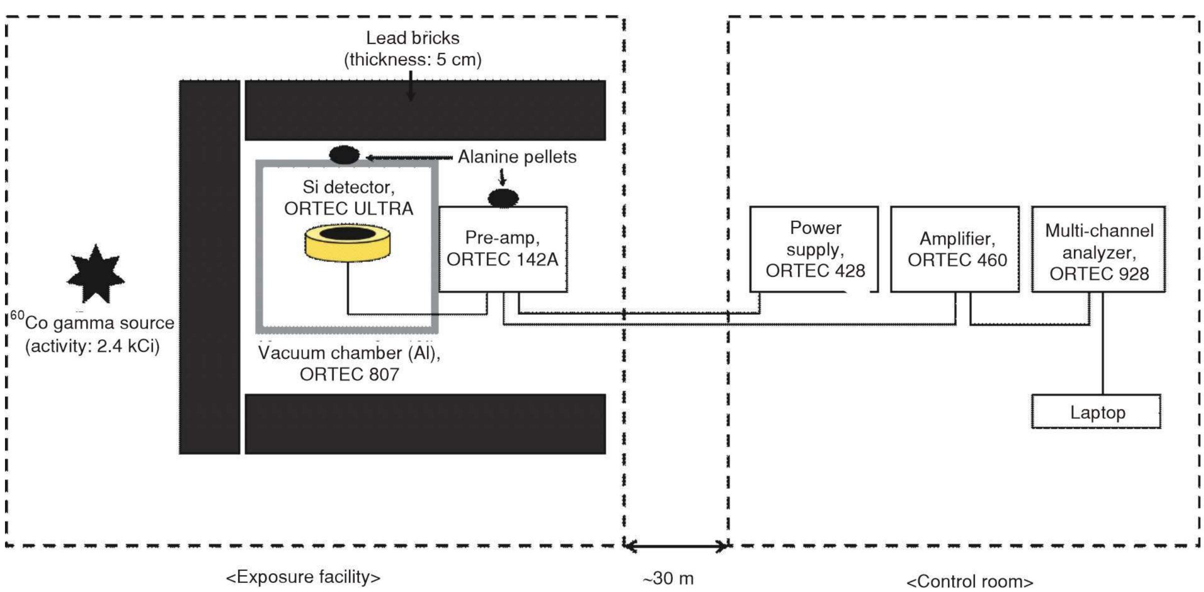

Figure 4. Schematic of the experimental set-up

Table 3. Experimentally accumulated doses in the Si detector and pre-amp

Components	Accumulated absorbed dose for 57 h [kGy]	
	D_{water}	D_{Si}
Si detector	1.13	0.99
Preamplifier	1.56	1.37

ported that the dead time associated with various units can be divided into three major categories, as shown in fig. 7. There is no dead time owing to the rapid charge transit time (inherent detector dead time) of a semiconductor detector. Therefore, only the pulse processing dead time and the MCA dead time must be considered.

The LLD was set to 250 channels to minimize MCA dead time during the experiment. Under these conditions, the MCA dead time value was only a few percent. Therefore, the alpha spectrum was not detected in the high-count-rate environment owing to the dead time of the pulse processing.

Decrease in gross counts by a defect in charge collection efficiency

Figure 8 shows the decreasing gross count of ^{60}Co gamma-rays as the absorbed dose increased. The counts decreased relatively rapidly at the beginning of dose accumulation. Notably, the counts slightly increased owing to the self-annealing of the detector when the dose was accumulated again after a 6 minutes removal of the source to check the alpha signal.

Radiation damage in Si detectors can be classified into two categories: surface damage, which occurs from ionization in SiO_2 and at the Si-SiO_2 interface, and lattice defects in the silicon bulk created by radiation exceeding certain thresholds energies [14]. Aldosari [15] reported that gamma-rays can cause bulk damage to Si detectors. For irradiation tests using ^{60}Co, the Frenkel pair is the only type of defect that decreases the charge-collection efficiency and can reduce gross counts. This is a representative defect caused by the bulk damage to a Si detector.

However, defects in this experiment, such as signal loss or gross count decrease, originated from the high-dose field conditions. This condition simulated the quantity of radiation that would be absorbed over 60 years, but it was applied all at once during a 57 hours test. A previous study [16] showed that the detector exhibited no defects when tested at an actual dose rate of approximately 4 mGyh^{-1}, which is typical for the annulus zone.

Variability of alpha counts before and after gamma irradiation

Figure 9 shows the gross count of the alpha signals formed by ^{210}Po before and after irradiation. The total count for alpha particles was 16138 ±127 on average before irradiation and it decreased to 15758 ±126 after irradiation. Therefore, the gross count in the high-channel range decreased by approximately 2.3 %. The full width at half maximum (FWHM) of the alpha spectrum peak, shown in fig. 10, changed from 52.95 to 46.75 after irradiation. The functional integrity in the high channels was

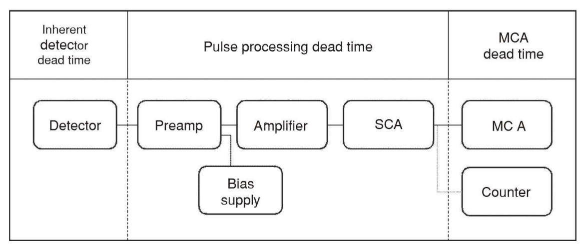

Figure 7. Sources of dead time in a typical detection system

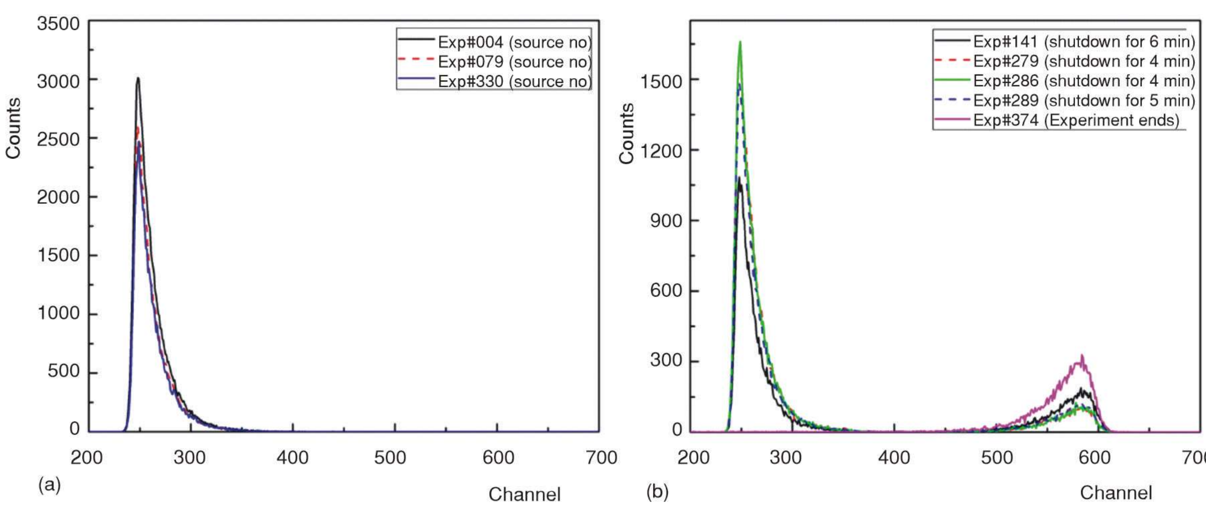

Figure 6. Measured spectra with lost alpha counts under high-dose rate conditions (a) and spectra with alpha counts recorded again when the source was shut down (b); each experiment has a 10 minute interval

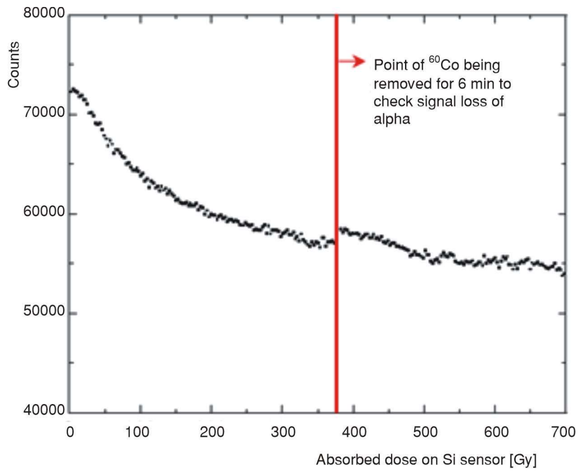

Figure 8. Decrease in count as the accumulated dose increases; the sensor was self-annealed while it was not exposed to gamma-rays

maintained within a dose accumulation of approximately 1-1.4 kGy in the components.

Performance degradation of the components after irradiation

Degradation of the detector

After irradiation of 0.99 kGy to the detector, the count rate increased by 773 % from 3338 to 29152. Figure 11 shows the electronic noise spectra before and after radiation exposure of the detector. Generally, gamma-ray doses of approximately 8.6 kGy can lead to significant performance degradation in Si sensors [5], and the leakage current increases linearly with radiation fluence [17]. In addition, random fluctuations in the leakage current generate small current signals. Therefore, despite the relatively small gamma-ray dose, which did not exceed 1 kGy, the leakage current that could affect the low channels of the spectrum may increase.

Degradation of the pre-amp

Figure 12 shows the change in the count rates of the noise spectrum before and after irradiation of 1.37 kGy to the pre-amp. The noise count rate increased by 17 % from 2785 to 3259. Notably, the height of the peak decreased, whereas the spectral tail widened. Even if variations in radiation hardness are observed based on the composition of the components of the pre-amp, functional damage is usually caused by high-dose radiation. The test revealed that an absorbed dose of 1.37 kGy on the pre-amp could lead to increased noise, indicating damage.

Determination of the level of valid pulse height discriminator

An increase in the leakage current and electronic noise in the lower channels caused by radiation exposure can reduce the performance of the detector system. Therefore, it is important to set an appropriate LLD channel to avoid misinterpreting noise as signals from charged particles, particularly when a coolant leakage detection system is installed in an annulus zone with background radiation.

Figure 13 shows the changes in the count rates of the noise and charged particles according to the LLD channel setting. In this case, the target radiation was beta particles from ^{16}N in the leaked coolant, with an assumed activity of $2.13 \cdot 10^7$ Bq based on the estimated amount of ^{16}N reaching the detector after 30 seconds when the coolant leaked in a specific geometry [3]. This shows that the

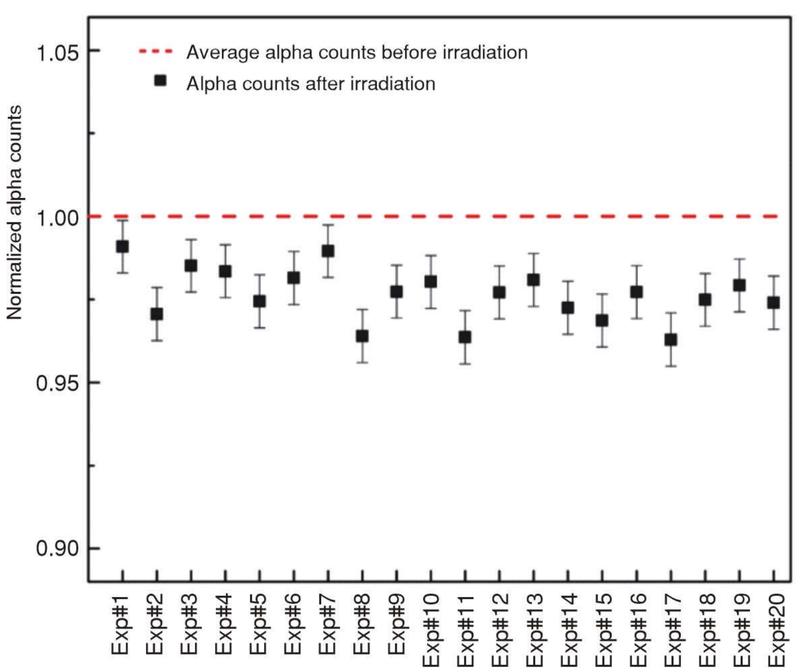

Figure 9. Normalized alpha count by a ^{210}Po alpha source: before (dash line) and after irradiation (black dots)

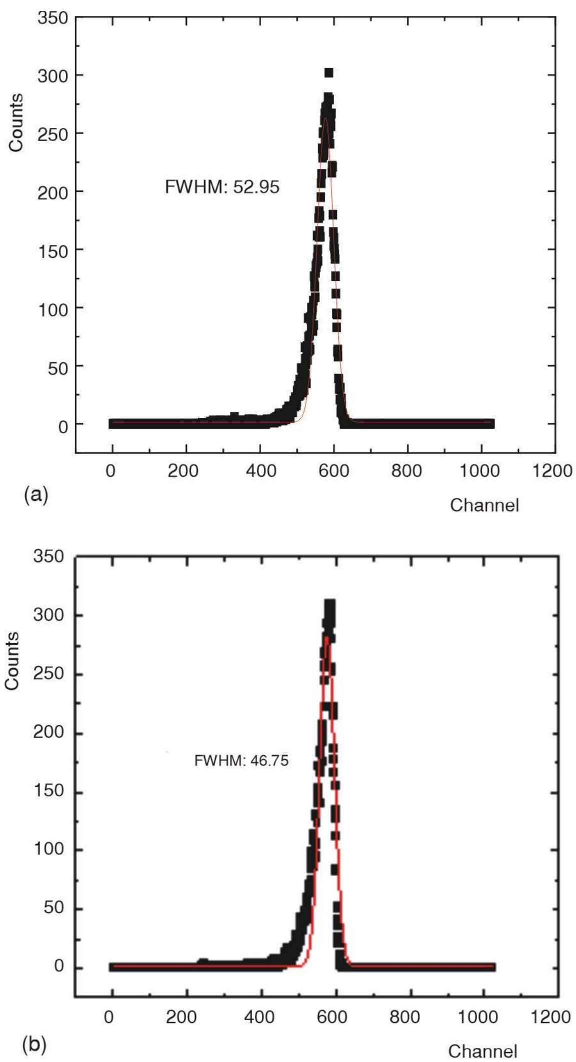

Figure 10. Spectra formed by a ^{210}Po alpha source; before (a) and after irradiation (b)

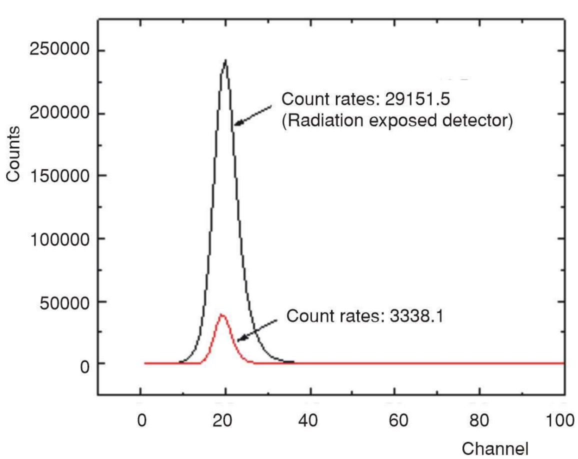

Figure 11. Change of electronic noise spectrum in the low channel range before and after irradiation on the detector

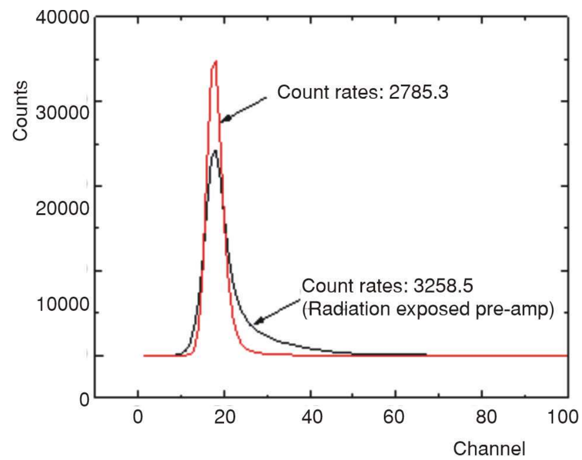

Figure 12. Change of electronic noise spectrum in the low channel range before and after irradiation on the pre-amp

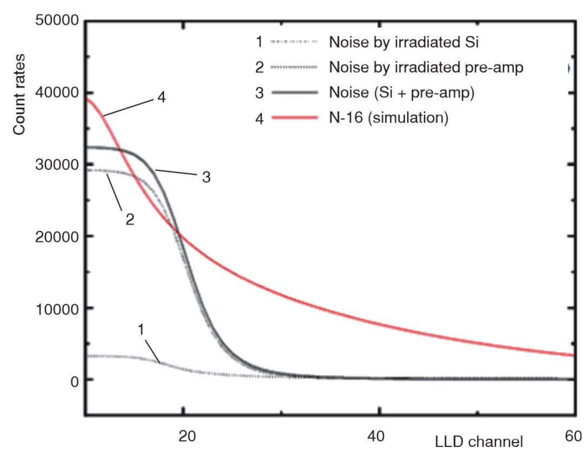

Figure 13. Change in count rates of noise and simulated source (^{16}N), according to the LLD channel setting

count rates of ^{16}N and the noise varied with different LLD channel settings. This allows the selection of an LLD channel that reduces the noise effect in low channels and maximizes the signal-to-noise ratio, thereby providing a valid detection threshold.

CONCLUSIONS

In this study, a Si detector and pre-amp were irradiated with gamma-rays at a high dose rate to evaluate the functional stability of a coolant leakage detection system installed in the annulus zone of an NPP. The absorbed doses for the detector and pre-amp were derived using MCNP simulations. Based on these calculations, the detector and pre-amp were exposed to ^{60}Co at an activity of 2.4 kCi for 57 hours. Doses of 0.99 kGy and 1.37 kGy accumulated in the detector and pre-amp, respectively, from the conversion of the absorbed doses in the alanine pellets to those in silicon. A ^{210}Po alpha source was used as a check source to identify functional states during gamma exposure. After the irradiation, the functional states in the high-channel range remained stable. However, the electronic noise increased in the low channels owing to the increased leakage current caused by the gamma irradiation of the detector. Additionally, defects, such as signal loss of alpha count and a decrease in charge collection efficiency, were observed.

The absorbed doses that accumulated over 57 hours in the experiment corresponded to the doses that would accumulate on the detector and pre-amp over a period of 60 years. The defects were caused by irradiation at a high dose over a relatively short period, representing severe test conditions. Additionally, previous studies have confirmed that similar defects were not observed under the actual dose rate, suggesting that the monitoring system could operate in an actual environment by utilizing various LLD settings to reduce the effect of noise in the low-channel range. The results of this study can be used to provide information for determining the maintenance and repair schedules during the operation of coolant leakage monitoring systems.

Since it is known that the radiation damage in a Si detector causes different aspects depending on the radiation quality, additional tests using neutrons will be performed to evaluate the specific degradation of the components in the future.

ACKNOWLEDGMENT

This work was supported by a Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korean Government (MOTIE) (20181510102340, Development of a real-time detection system for unidentified RCS leakage less than 0.5 gpm).

AUTHORS' CONTRIBUTIONS

K. Pak: visualization, formal analysis, writing review, and editing. J. Kim: conceptualization, resources, writing-original draft. Y. H. Kim: methodology, validation. S. B. Goh: investigation. Y. -S. Cho: software, resources; Y. K. Kim: supervision, project administration.

ORCID NO

Kihong Pak: 0009-0004-3236-6063

REFERENCES

[1] ***, Regulatory Guide 1.45, *Reactor Coolant Pressure Boundary Leakage Detection Systems*, U.S. Nuclear Regulatory Commission, Washington, DC

[2] Jang, J., *et al*., Feasibility Study of Beta Detector for Small Leak Detection Inside the Reactor Containment, *Journal of Radiation Protection and Research, 43* (2018), 4, pp. 154-159

[3] Jang, J., *et al*., Feasibility Study of β-Ray Detection System for Small Leakage From Reactor Coolant System, *Nuclear Engineering and Technology, 54* (2022), 7, pp. 2748-2754

[4] ***, KEPCO, and KHNP, APR1400 Design Control Document Tier 2. Chapter 11: Radioactive Waste Management, APR1400-K-X-FS-14002-NP, Rev.0, KEPCO & KHNP, 2014

[5] Knoll, G. F., *Radiation Detection and Measurement 4th ed.*, Don Fowley, New York, USA, 2010

[6] Sueva, D., *et al.*, Measurement of Strong Gamma Fields by Silicon Detectors Working in a Current-Generation Mode, *Nuclear Instruments and Methods in Physics Research Section A, 588* (2008), 3, pp. 375-379

[7] Lee, T., Kim, H., Radiation Hardness Test of Preamplifier Circuits Composed of Commercial Bipolar Transistors, *Nuclear Instruments and Methods in Physics Research Section A, 579* (2007), 1, pp. 260-263

[8] Baschirotto, A., *et al*., Radiation Damage Investigation for the Design of a Hardened Fast Bipolar Monolithic Charge Sensitive Preamplifier, *Nuclear Instruments and Methods in Physics Research Section A*, *362* (1995), 2-3, pp. 466-471

[9] Spieler, H., Introduction to Radiation-Resistant Semiconductor Devices and Circuits, *American Institute of Physics, 390* (1997), 1, pp. 23-49

[10] ***, Korea Hydro & Nuclear Power Co., Ltd, *Final safety analysis report of ShinKori Nuclear*, Unit 3,4, Republic of Korea, 2015

[11] Pelowitz, D. B., *et al*., MCNPX 2.7.0 Extensions, (2011), https://doi.org/10.2172/1058045

[12] Lamarsh, J. R., Baratta, A. J., *Introduction to Nuclear Engineering 3rd Edition*, Horton M. J., N. J., USA, 2001

[13] Patil, A., *Dead Time and Count Loss Determination for Radiation Detection Systems in High Count Rate Applications*, Doctoral Dissertation, Missouri University of Science and Technology, Mo., USA, 2010

[14] Becker, J., *Signal Development in Silicon Sensors Used for Radiation Detection*, Doctoral Dissertation, University of Hamburg, Hamburg, Germany, 2010

[15] Aldosari, A. H. A., *Innovative Silicon Detectors for Dosimetry in external Beam Radiotherapy*, Doctoral Dissertation, University of Wollongong, New South Wales, Australia, 2015

[16] Kim, J., *et al*., *Radiation Hardness Test of a Silicon Detector Under Radiation Dose Rate of Nuclear Power Plant for In-Containment Coolant Leakage Detection System*, ANIMMA, 2021

[17] Taylor, G. N., *et al*., Radiation Induced Bulk Damage in Silicon Detectors, *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 383* (1996), 1, pp. 144-154

Received on March 29, 2024
Accepted on September 24, 2024

Кихонг ПАК, Ђонгхеон КИМ,
Јонг Хјун КИМ, Сеунг Беом ГОХ, Јунг-Сик ЧО, Јонг Кјун КИМ

ИСПИТИВАЊЕ ЧВРСТОЋЕ НА РАДИЈАЦИЈУ СИЛИКОНСКОГ ДЕТЕКТОРА И ПРЕТПОЈАЧАВАЧА ТОКОМ ПРОЈЕКТОВАНОГ ВЕКА СИСТЕМА НАДЗОРА ЦУРЕЊА РАСХЛАДНЕ ТЕЧНОСТИ РЕАКТОРА

Тестови чврстоће на радијацију спроведени су на силицијумском детектору и претпојачавачу како би се развио систем за праћење цурења расхладне течности реактора, који детектује високоенергетске бета честице из ^{16}N у примарном хладиоцу реактора нуклеарних електрана. Монте Карло симулације коришћене су за израчунавање доза које би се апсорбовале на компонентама током 60-годишњег пројектованог века трајања. Компоненте су биле изложене ^{60}Co гама извору активности од 2.4 kCi током 54 часа. Утврђено је да су апсорбоване дозе акумулиране током теста биле 0.99 kGy за детектор и 1.37 kGy за претпојачавач. Током теста, алфа одброј из тест извора у опсегу високих канала нестајао је у окружењу са великом јачином дозе, а бруто гама број смањивао се како се акумулирана доза повећавала. Деградација перформанси детектора и претпојачавача процењена је поређењем алфа сигнала и позадинског шума пре и после зрачења. Енергетска резолуција алфа сигнала у високо-каналном опсегу показала је мале промене, док је електронски шум у нискоканалном опсегу повећан за приближно 773 % за озрачени детектор и 17 % за озрачени претпојачавач. Предложена је метода која користи различите дискриминаторске канале ниског нивоа за ублажавање ефеката ћума у систему за прачење.

Кључне речи: тест чврстоће на радијацију, акумулирана апсорбована доза, силицијумски детектор, мониторинг цурења хладиоца реактора