Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 10-11, 2007

Characteristics of Noble Gas-filled Ionization Chambers for a Low Dose Rate Monitoring

Han Soo Kim[a*], Se Hwan Park[a], Jan Ho Ha[a], Jae Hyung Lee[a], Nam Ho Lee[a], Jung Bok Kim[a], Yong Kyun Kim[b], Do Hyun Kim[c], and Seung Yeon Cho[c]
[a] *Korea Atomic Energy Research Institute, Daejeon, 305-353, Republic of Korea, khsoo@kaeri.re.kr*
[b] *Department of Nuclear Engineering, Hanyang University, Seoul, 133-791, Republic of Korea*
[c] *Department of Environmental Engineering, Yonsei University, Wonju, 220-710, Republic of Korea*

1. Introduction

An ionization chamber is still widely used in fields such as an environmental radiation monitoring, a Radiation Monitoring System (RMS) in nuclear facilities, and an industrial application due to its operational stability for a long period and its designs for its applications. Ionization chambers for RMS and an environmental radiation monitoring are requested to detect a low dose rate at as low as 10^{-2} mR/h and several μR/h, respectively. Filling gas and its pressure are two of the important factors for an ionization chamber development to use it in these fields, because these can increase the sensitivity of an ionization chamber. We developed cylindrical and spherical ionization chambers for a low dose rate monitoring. Response of a cylindrical ionization chamber, which has a 1 L active volume, was compared when it was filled with Air, Ar, and Xe gas respectively. Response of a spherical ionization chamber was also compared in the case of 9 atm and 25 atm filling-pressures. An inter-comparison with a commercially available high pressure Ar ionization chamber and a fabricated ionization chamber was also performed.

A High Pressure Xenon (HPXe) ionization chamber, which was configured with a shielding mesh to eliminate an induced charge of positive ions, was fabricated both for the measurement of an environmental dose rate and for the measurement of an energy spectrum [1~7].

2. Experimental

2.1 Preliminary tests

A cylindrical ionization chamber was made from polyethylene with a consideration of an electronic equilibrium between the electrodes and a collecting volume. Electrodes were formed by using a carbon coating. To eliminate the out-gassing from a solvent of carbon coating, electrodes were dried for 2 weeks in a hood. Preliminary tests, such as leakage currents and a saturation curve at biased voltages, were performed by using a Keithley 6517A high precision current measurer and an Ortec 506 high voltage supplier when filled with air. The leakage currents were measured below several *f*A from 0 V to -1000 V. The applied voltage is determined at -300 V from the measured saturation curve and by using an experimental two-voltage method.

A 10 μCi ^{137}Cs, which is generally used as a calibration source in an ionization chamber, was used to measure the response at a low dose rate as a preliminary test. Fig. 1 shows the leakage current and the response to ^{137}Cs. The response to Cs-137 shows about a 43 *f*A signal difference with the leakage currents. Preliminary tests, when Xe gas was filled, were also performed with the same procedure.

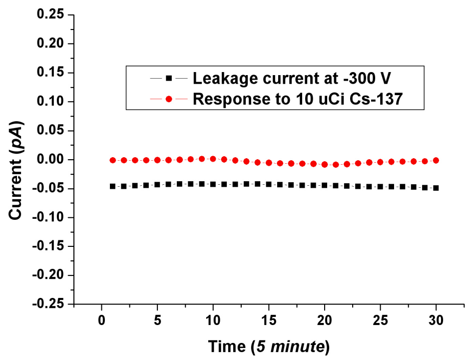

Fig. 1 The response of a cylindrical ionization chamber for 10 μCi ^{137}Cs calibration source. Signal difference with the measured leakage currents was about 43 *f*A. Error bars are smaller than symbols.

A spherical ionization chamber was fabricated with SUS 304 by using a molding method with a consideration of an isotropy for an incident radiation. Preliminary tests were also performed, similar to the cylindrical ionization chamber tests. The leakage currents were measured at about 250 *f*A from 0 V to -1000 V when Ar was filled at 9 atm and 25 atm.

2.2 Tests for a low dose rate monitoring

The performance of the ionization chambers at a low dose rate was tested by using the conventional shadow technique with a NIST certified 0.906 *m*Ci ^{226}Ra source in the calibration room. A schematic view of the experimental setup is shown in Fig. 2.

30 cm thick lead shield with a cross section measuring 10 X 10 cm was interposed so as to intercept all the primary rays from the source to all parts of the ionization chamber. The output signal was averaged over a 10 to 30 min period. And then, the source was removed and the output signal was averaged again over the same period to yield a ^{226}Ra primary beam calibration factor at the applied dose rates.

Linearity at low dose rates is shown in Fig. 3 in the case of a cylindrical ionization chamber and a spherical ionization chamber when these were filled with Ar gas.

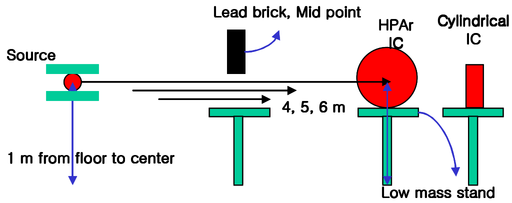

Fig. 2 Experimental setup for the measurement of a low dose rate in the standard radiation field.

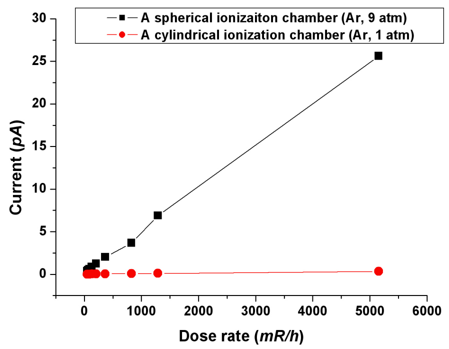

Fig. 3 Linearity against dose rates. Linearities are 99.9% and 99.91% in a cylindrical ionization chamber and a spherical ionization chamber, respectively. Error bars are smaller than symbols.

2.3 HPXe ionization chamber for energy spectrum measurement

The purity of a noble gas in an energy spectrum with an ionization chamber is essential. A gas system was constructed to create noble gas with a high purity and to inject noble gas up to 100 atm. The combination of an Oxisorb, a molecular sieve, and a high temperature getter can minimize the electro-negative impurities, such as O_2, N_2 and volatile organic compounds, to below a 1 ppb level. The circulation for a xenon purification flow could be achieved by the difference of the temperature between the reservoir in LN_2 and the high temperature getter. The circulation was performed for two weeks to obtain a 1ppb impurity level.

A cylindrical HPXe ionization chamber, which has a 498.5 cm^3 active volume, was fabricated with stainless steel 304 and machinable ceramics. The design of an HPXe ionization chamber is shown in Fig. 4. The thickness and the spacing of the shielding mesh were 0.05 mm and 1mm, respectively.

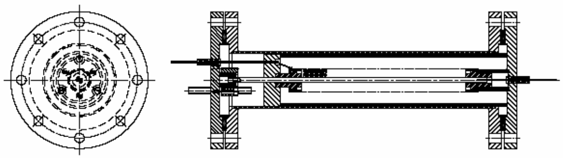

Fig. 4 The design of an HPXe ionization chamber for environmental radiation spectroscopy.

To measure the energy spectrum, a preamplifier was made with an Amptek A250 charge sensitive amplifier and two InteFET JFETs due to the high capacitance of an HPXe ionization chamber. The energy spectra for ^{226}Ra, ^{241}Am, ^{137}Cs, and ^{60}Co were measured. The energy resolutions were also calculated and compared with other HPXe ionization chambers, which were reported in literatures.

3. Conclusion

Ionization chambers, which were filled with noble gases, were fabricated and tested for monitoring low dose rates and measuring low energy gamma rays. Noble gases such as Ar and Xe are very attractive for constructing an ionization chamber due to their high atomic number. Tests with the conventional shadow technique showed that the fabricated ionization chambers can be used to monitor low dose rates even if its size is small.

*Acknowledgment

This work has been carried out under the nuclear R&D program of the Ministry of Science and Technology (MOST) of Korea. And we are also supported by the iTRS Science Research Center / Engineering Research Center program of MOST / Korea Science and Engineering Foundation (grant # R11-2000-067-02001-0) and partially supported by the BK21 program of Korea Research Foundation(KRF).

REFERENCES

[1] Sun Tae Hwang, Theoretical Aspects Associated with Pulsed Ionization Chamber, Journal of Korea Nuclear Society, Vol.21, p.231, 1989

[2] A. Derbin, A. Khusainov, V. Muratova, O. Mouratov and R. Arlt, How to Process Best Gamma Spectra of CdTe and CdZnTe Detectors, Nuclear Instruments & Methods in Physics Research A, Vol.458, p.169, 2001

[3] R. Arlt, M. Aparo, H. Boeck and H. Zwickelstorfer, Spectrum Catalogue of Gamma Spectra taken with CdTe and CdZnTe Detectors, Nuclear Instruments & Methods in Physics Research A, Vol.458, p.206, 2001

[4] R. Arlt, V.Gryshchuk and P. Sumah, Gamma Spectrometric Characterization of various CdTe and CdZnTe Detectors, Nuclear Instruments & Methods in Physics Research A, Vol.428, p.127, 1999

[5] Y. Eisen and A. Shor, CdTe and CdZnTe Materials for Room Temperature X-ray and Gamma Ray Detectors, Journal of Crystal Growth, Vol.184/185, p.1302, 1998.

[6] A. Ruzin and Y. Nemirovsky, Performance Study CdZnTe spectrometers, Nuclear Instruments & Methods in Physics Research A, Vol.409, p.232, 1998

[7] Stephane Ricq, Francis Glasser and Michel Garcin, CdTe and CdZnTe Detectors Behavior in X-ray Computed Tomography Conditions, Nuclear Instruments & Methods in Physics Research A, Vol.442, p.45, 2000