Design and Fabrication of an HPXe Ionization Chamber for a Harsh Environment Application

Han Soo KIM [a*], Se Hwan PARK [a], Jang Ho HA [a], Seung Yeon CHO [b], Chan Gi KIM [b] and Yong Kyun KIM [c]
[a]*Korea Atomic Energy Research Institute, 1045 Daedeokdaero, Yuseong, Daejeon, Korea*
[b]*Environmental Engineering, Yonsei University, 234 Maeji, Heungup, Wonju, Korea*
[c]*Nuclear Engineering, Hanyang University,17 Haedang, Seongdong, Seoul, Korea*
[*]*Corresponding author: khsoo@kaeri.re.kr*

1. Introduction

High-pressure xenon (HPXe) gas is an attractive gamma-ray detection medium due to its physical and nuclear properties. HPXe has a large detection efficiency for gamma-ray energies on the order of 100s of keV, due to its large atomic number (Z=54), which translate into a high photoelectric absorption and Compton scattering cross sections. In addition, the Fano factor for HPXe is quite good, measured near 0.13 ~ 0.1 [1]. HPXe ionization chambers are ideal for use in uncontrolled environments, as this detector's response has been shown to be uniform over large temperature ranges up to 170 ℃ [2]. In contrast to solid detection media that derive their radiation detection capabilities from their crystal structure, the HPXe performance is not degraded by high-radiation fluences. In this study, design parameters of an HPXe ionization chamber are described. And preliminary test is also addressed.

2. Methods and Results

2.1 Design of an HPXe ionization chamber

An HPXe ionization chamber was designed on the basis of the results of the EGSnrc simulation code [3]. The considered parameters were the densities of the xenon gas, the thickness of an outer shell, and the initial gamma energies. The calculated peak efficiencies versus the considered parameters are shown in figure 1.

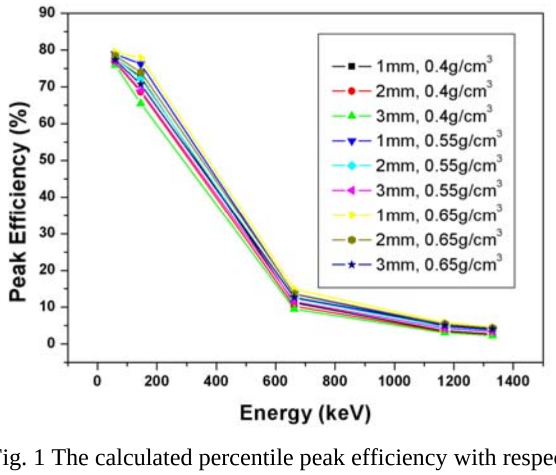

Fig. 1 The calculated percentile peak efficiency with respect to the outer shell and density of Xe.

The peak efficiencies throughout the initial energies can be improved when the xenon density is high. Thin outer shells also contribute to higher peak efficiencies. But the density of the xenon gas conflicts with the outer shell thickness.

The outer shell was 0.8 mm-thick and was made of stainless steel to stand a high gas-pressure. Ceramics were chosen as insulators by virtue of its high resistivity and radiation hardness. A shielding mesh was chosen to improve energy resolution [4]. The 0.1 mm-thick shielding mesh had over a 90% physical transparency and 1 mm wire intervals. The designed HPXe ionization chamber is shown in Figure 2.

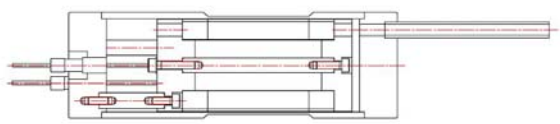

Fig. 2. The designed HPXe ionization chamber

2.2 Fabrication of an HPXe ionization chamber

All parts are cleaned with a surface agent, alcohol, and DI water. And then, they were baked at 100 ℃ in a vacuum oven for a day. The inner part of the 8 m-thick cylindrical ceramic was coated with metal solution to make this as an HV electrode. The inner parts of the fabricated HPXe ionization chamber with a shielding mesh is shown in Figure 3.

Fig. 3. The inner view of the fabricated HPXe ionization chamber with a shielding mesh.

2.3 Gas purification and injection system

The purity of Xe is essential in an HPXe ionization chamber due to an electron attachment by electro-negative gases. The purification and injection system was designed and constructed to eliminate the electro-negative impurities such as O_2, N_2, and hydro-carbon gases. The combination of an oxisorb, a molecular sieve, and a high-temperature getter can minimize these impurities. The circulation of Xe gas was based on the difference in the temperature of liquid nitrogen and a high-temperature getter (about 350 ℃). Two gas cylinders were incorporated to improve the electron drift drift velocity of Xe by an addition of 17 % of helium mixture will be stored in a reservoir and circulated for several days to reach several ppb impurity levels [5]. Figure 4 shows a diagram of the gas system.

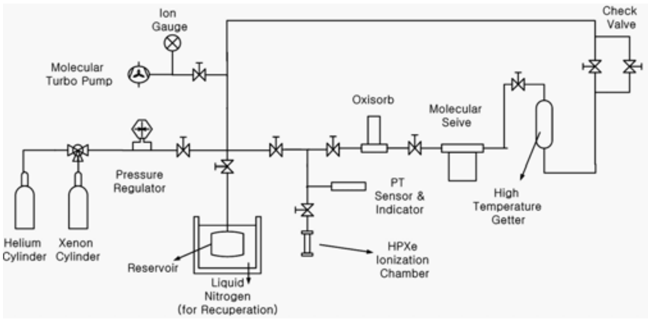

Fig. 4 The gas purification and injection system for an HPXe ionization chamber.

2.4 Preliminary test

A Keithley 6517A, an ORTEC 673 high-voltage supplier, and the LabVIEW program were incorporated to test the performance of the fabricated ionization chamber at a low dose rate. The leakage currents throughout the experiments were kept in the range of 200 fA and the resultant plateau were observed. The linearity of the HPXe ionization chamber is shown in Figure 5. Root-mean-square linearity was 0.991.

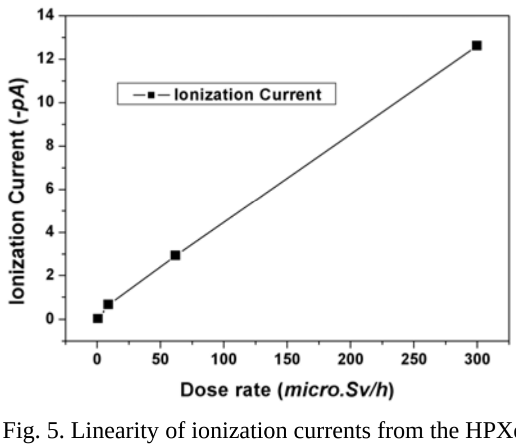

Fig. 5. Linearity of ionization currents from the HPXe ionization chamber against low dose rates. Root-mean-square linearity was 0.991. The error bars are smaller than the sizes of symbols.

3. Conclusions

An HPXe ionization chamber was designed in consideration of several characteristics and fabricated with radiation hardened materials such as stainless steel and ceramics to apply it to hash environments. Preliminary test was also performed. In a future work, energy spectra with the fabricated HPXe ionization chamber will be compared with simulated energy spectra.

*Acknowledgment

This work has been carried out under the nuclear R&D program of the Ministry of Education,Science and Technology (MEST) and under the Eco-technopia 21 Project of the Ministry of Environment (ME) of Korea. 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 was partially supported by the BK21 program of the Korea Research Foundation (KRF).

REFERENCES

[1] C. Levin et al., Charge collection and energy resolution studies in compressed xenon gas near its critical point, Nuclear Instruments and Methods A, Vol.332, p. 206, 1993.
[2] A. E. Bolontnikov et al., The spectroscopic properties of high-pressure xenon, Nuclear Instruments and Methods A, Vol.396, p.360, 1997.
[3] www.irs.inms.nrc.ca/EGSnrc/EGSnrc.html
[4] A. E. Bolontnikov et al., Improving the energy resolution of high pressure Xe cylindrical ionization chambers, IEEE Transaction on Nuclear Scince, Vol.44, p.1006, 1997.
[5] A. E. Bolontnikov et al., High-pressure Xe detector for gamma-ray astronomy onboard orbital station Mir, Proceedings of the International Conference on Liquid Radiation Detectors: Their Fundamental Properties and Applications (ICLRD), p.462, 1992