Transactions of the Korean Nuclear Society Spring Meeting
Chuncheon, Korea, May 25-26 2006

A Study on the Polarity Effect of Ionization Chamber Combining Electric Field, Ion-pair Distribution, and Electron Attachment Probabilities

Jae Cheon KIM,a Yong Kyun KIM,b Soon Young KIM,c Jong Kyung KIM a
a Hanyang Univ., 17 Haengdang-dong, Seongdong-gu, Seoul 133-791, Korea, macpie@nural.hanyang.ac.kr
b Korea Atomic Energy Research Institute, Deokjin-dong, Yuseong-gu, Daejeon 305-353, Korea
c Innovative Technology Center for Radiation Safety, Haengdang-dong, Seongdong-gu, Seoul 133-791, Korea

1. Introduction

Ionization chamber is known as one of the most widely used radiation detectors. The current created by interactions with incident radiation is affected by ion-pair distribution as well as electric field in ionization chamber.

It is known that the current collected from an ionization chamber exposed to constant radiation intensity changes in magnitude when the polarity of the collecting potential is reversed. There are many possible causes that induce the polarity effect and one of them can be a field distortion due to a potential difference between the guard electrode and the collector.

In this study, the polarity effect of thimble-type ionization chambers, which were designed and fabricated by KAERI, was evaluated in detail, considering electric field, ion-pair distribution, and electron attachment probabilities in chamber.

2. Methods and Results

2.1 Calculation of Electric Field

Two types of ionization chambers, Type-A and Type-B, were used in this work. Electrodes are made of Shonka air-equivalent conductive plastic C552. The insulators are made of Teflon. The chamber is filled with the typical air gas [1]. Figure 1 shows the ionization chamber used in this work.

Figure 1. The ionization chamber fabricated by KAERI

In the Type-A, a relatively small portion of the guard electrode enters into the gas space. The guard electrode of type-B prominently enters the gas space in Figure 2.

MAXWELL® and Garfield were employed to calculate the electric field and the electron drift line inside the chamber as shown in Figures 2 and 3. Magboltz were used to solve the Boltzmann transport equation for electrons in gas mixtures under the influence of electric and magnetic field. Heed simulates the ionization of gas molecules by particles traversing the gas detector [2]. Magboltz and Heed are incorporated into the Garfield program.

(a) Type-A (b)Type-B

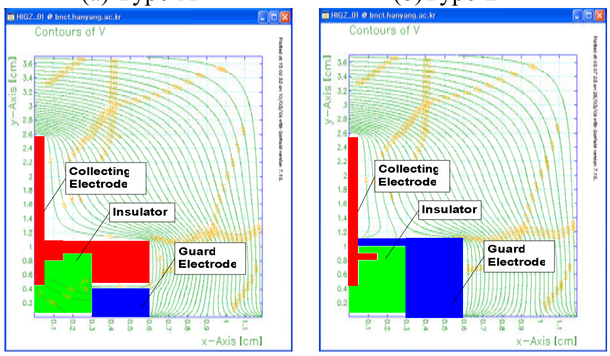

Figure 2. Electric field of Type-A and Type-B calculated by MAXWELL

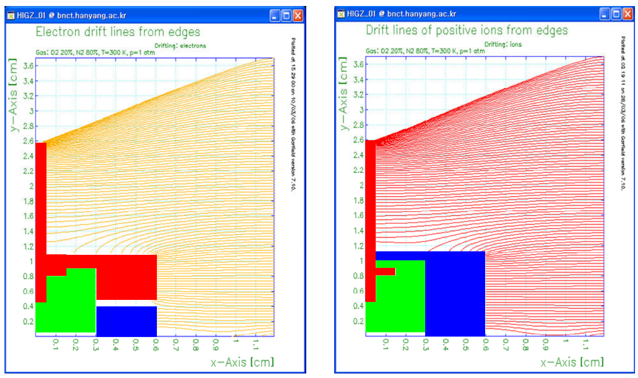

Figure 3. Electron drift line of Type-A and Type-B calculated by Garfield

2.2 The Ion-pair Distribution and Electron Attachment Probabilities

Drifting electrons can be absorbed by electro-negative impurities, mainly O_2. The signal loss due to this electron attachment for a given total pressure p and O_2 partial pressure $p(O_2)$ follows an exponential behavior, depending on the drift time t_{drift}:

$$\frac{N(t_{drift})}{N(0)} = \exp(-p \cdot p(O_2) \cdot C_{att} \cdot t_{drift})$$

The attachment coefficient C_{att} depends on the types of gas mixture [3]. Electron will be attached until the end point of its drift path during the drift time according to electron attachment probabilities.

Ion-pair distribution was calculated by DOSRZnrc, one of the NRC user codes of EGSnrc [4]. Figure 4 shows distribution of electron attachment probabilities and ion-pair inner ionization chamber.

(a) Electron attachment probabilities (b) Ion-pair distribution

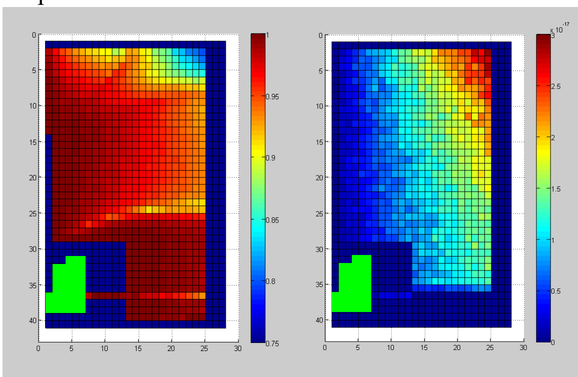

Figure 4. Electron attachment probabilities and ion-pair distribution inner ionization chamber

2.3 Polarity effect due to Potential Difference

The polarity effect due to the potential difference between the guard electrode and the collector was estimated considering the electric field and ion-pair distribution of ionization chamber. In the calculation, the bias of the collector was set to 0 V and the bias of the high voltage electrode was set to -300 V. The voltage of the guard electrode (V_{guard}) was varied from -30 V to 30 V.

To calculate the current in ionization chamber, the amount of dose in the chamber was obtained by using DOSRZnrc. After that, each dose is multiplied by electron attachment probabilities at each position calculated from MAXWELL and Garfield. Finally, total dose is obtained through summing the dose contributed to the collecting electrode.

$Current_{diff}$ is defined by

$$Current_{diff} = \frac{Current_{guard} - Current_0}{Current_0}.$$

Here $Current_{guard}$ is the calculated current when V_{guard} is not equal with 0 V, and $Current_0$ is the calculated current when V_{guard} is equal to 0 V. Figure 5 shows the $Current_{diff}$ as a function of V_{guard}.

To evaluate the polarity effect of ionization chambers, the current difference was calculated using ^{241}Am and ^{137}Cs source. Through the results, $Current_{diff}$ of Type-A is shown to be smaller than Type-B.

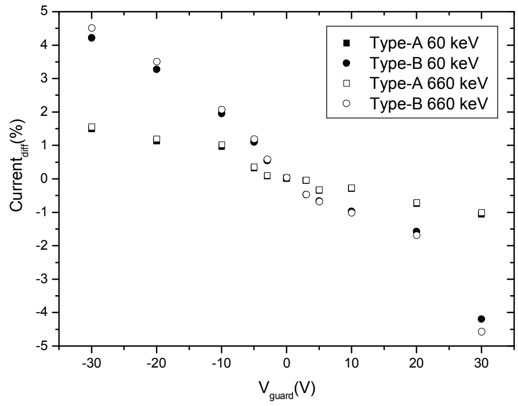

Figure 5. The variation of the current difference due to the electric field between the guard electrode and the collector

3. Conclusion

Combining the information of the electric field, ion-pair distribution, and electron attachment probabilities, the polarity effect of two types of ionization chambers have been evaluated. From the study, it is found that the polarity effect depends on the design of the electrodes, and it can be estimated in detail combining the electric field, ion-pair distribution and electron attachment probabilities.

Acknowledgement

This work has been supported financially by iTRS (Innovative Technology Center for Radiation Safety).

REFERENCES

[1] Jae Cheon KIM, Jong Kyung KIM, Yong Kyun KIM and Se Hwan PARK, Analysis of Design Characteristics of Cylindrical Ion Chamber Made by KAERI: A Comparison between EGSnrc, MCNP, and Experiment, Journal of NUCLEAR SCIENCE and TECHNOLOGY, Supplement 4, p. 299-302, 2004

[2] Yong-Kyun Kim, Se-Hwan Park, and et al., Polarity effect of the thimble-type ionization chamber at a low dose rate, Physics in Medicine and Biology, Vol. 50, p4995-5003, 2005

[3] ALICE: Technical Design Report of the Transition Radiation Detector, CERN/LHCC2001-021 ALICE TDR9, 2001

[4] D.W.O. Rogers, I. Kawrakow, J. P. Seuntjens and B. R. B. Walters, NRC User Codes for EGSnrc, NRCC Report PIRS-702 (Rev. A), National Research Council of Canada, 2001