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KAIST RDMIS Radiation Detection and Medical Image Sensor laboratory

Study of Applied Voltage on Ionization Chamber for Radon Detector

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1. Introduction

Radon (Rn-222) is one of Naturally Occurring Radioactive Materials (NORM), which mean radioactive materials found in environment. Radon decays with half-life 3.82 days and emit 5.5MeV alpha ray. The radon progeny also decays, emits radiation and increases lung cancer risk.

There is an increasing need for household Radon Detector. Our purpose is making a simple and inexpensive ionization chamber as radon detector. We studied about the applied voltage, which is the most affecting factor on the performance of ionization chamber. And we determine the appropriate voltage based on this study.

2. Theoretical Background

Ionization chamber is one of the gas detector which collect ion pairs generated by interaction of radiation and gas molecules. Applied voltage makes electric field inside of chamber, steady-state electric current is generated by collection of ion pairs at electrode.

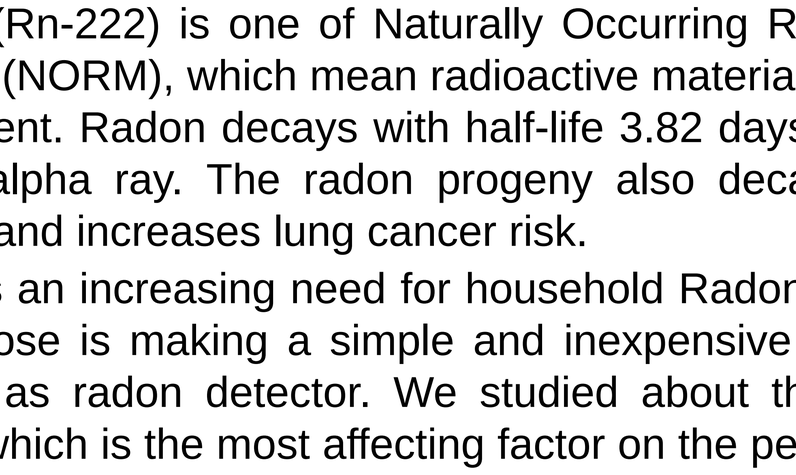

Fig. 1. Schematic diagram of Air Flow Ionization Chamber

Electric field is determined by applied voltage and design of chamber. intensity of electric field is following Eq. (1).

$$E(r) = \frac{V}{r ln(\frac{b}{a})} \quad (1)$$

Electric field makes electrons and positive ions move to each electrode. And the drift velocity of electrons and ions is following Eq. (2).

$$v = \frac{\mu E}{P} \quad (2)$$

Efficiency of ionization chamber is mainly decreased by ion loss. Recombination is a phenomenon that ion pairs become neutral molecules by collision and it is main ion loss process of gas detector. One is initial recombination and the other is general recombination.

The definition of collection efficiency of ion pairs is the ratio of measured charge $Q(V)$ and saturation charge Q_{sat}.

$$f(V) = \frac{Q(V)}{Q_{sat}} \quad (3)$$

Collection efficiency for initial recombination (f_i) and for general recombination (f_g) is a function of applied voltage *V* and V^2 respectively.

$$f_i(V) = \frac{1}{1+contant/V} \quad (4)$$

$$f_g(V) = \frac{1}{1+contant/V^2} \quad (5)$$

The induced charge produced by the moving charge on the electrode only depends on the location of moving charge. We can derive velocity and drift time from Eq. (1) and Eq. (2).

$$v\ (velocity) = \frac{\mu E}{P} = \frac{\mu V}{r ln(\frac{b}{a})} \cdot \frac{1}{P} \quad (6)$$

$$\mathrm{t\ (drift\ time)} = \int_a^r \frac{dv}{v} = \frac{P ln(\frac{b}{a})}{2\mu V} \cdot r^2 \quad (7)$$

Drift velocity of electron is much faster than that of positive ion. So the rise time of pulse depends on the collection of positive ion.

3. Design of Ionization Chamber

Our prototype ionization chamber is brass with 50mm diameter, 5 mm thickness, 220 mm length and 1 mm diameter cathode. Electric field simulation is done by Finite Element Method Magnetic (FEMM).

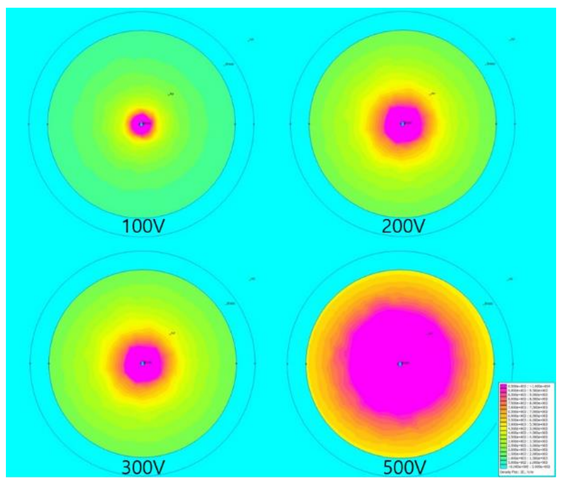

Fig. 2. The distribution of the electric field strength

Rise time of pulse can be calculated by the drift time of ions using Eq. (8). Mean mobility constant of positive ion is 1.36 $cm^2V^{-1}s^{-1}$ at STP. High electric field strength assures less ion loss and fast pulse time.

Applied Voltage	Electric field (V/m)	Maximum drift time (s)
100V	1.03×10^3~5.09×10^4	~92.2 ms
200V	2.07×10^3~1.02×10^5	~44.9 ms
300V	3.10×10^3~1.54×10^5	~30.1 ms
500V	5.18×10^3~2.56×10^5	~18.0 ms

Table I: Characteristics of ionization chamber according to applied voltage

4. Conclusion

Due to collection efficiency and pulse timing is dependent on electric field intensity, high applied voltage is needed to make good ionization chamber. In Further work, we will find the actual operate voltage and make making guard ring, new circuit, and long air way to distinguish radon and thoron.