Plastic Scintillator for an Electronic Personal Dosimeter

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1. Introduction

Electronic personal dosimeter (EPD) is one of the radiation monitoring device for radiation workers. It can measure the absorbed dose rate and accumulated dose in the radiation field for individual or objects immediately. To increase detection efficiency of EPD, inorganic scintillators such as a thallium doped cesium iodide, CsI(Tl), generally used as a scintillator of the EPD, which has different properties from human tissue. For instance, the density of the CsI(Tl) (4.51g/cm3) is much bigger than human tissue density (0.92~1.06 g/cm3). On the other hand, plastic scintillators have similar properties to human tissue and can play role as effective substitutes of the inorganic scintillators. Figure 1 shows that polystyrene is similar to tissue but CsI is much different from tissue in terms of the mass energy absorption coefficient.

In this paper, we tried to apply a plastic scintillator as a tissue equivalent to the EPD for the accurate absorbed dose rate measurement. To confirm that, it is compared the measured absorbed does rate with the plastic and the CsI(Tl) scintillator to the calculated dose rate using the mass energy absorption coefficients of the plastic and the CsI(Tl) with PMT and SiPM.

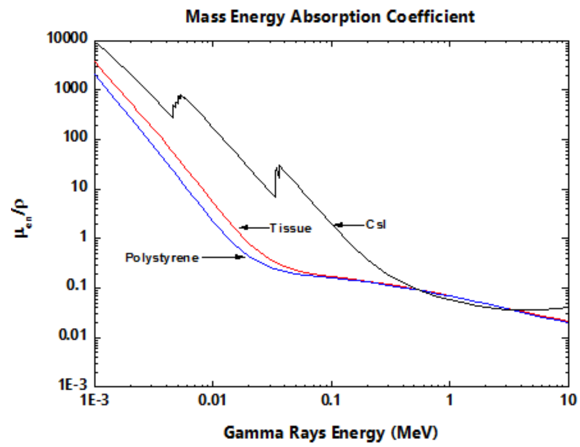

Figure 1. Mass energy absorption coefficient of tissue, polystyrene and cesium iodide

2. Methods and Results

2.1 Energy Spectrum Measurement

The energy of gamma ray is converted to photon in the scintillator and the photons are measured by PMT or SiPM. Figure 2 shows the schematic of the experiment setup.

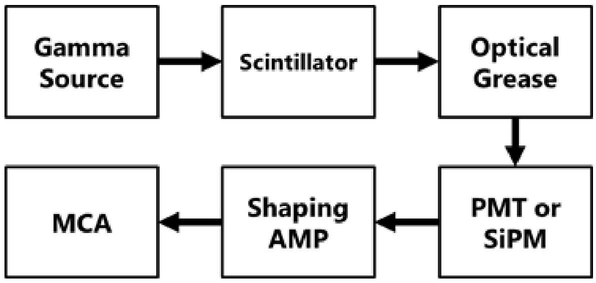

Figure 2. . Schematic of the experiment setup for gamma rays energy spectrum with PMT and SiPM

Disc type general calibration gamma sources and the scintillators located 1.4cm far from the source as shown at figure 3 (a). PMT and SiPM were coupled with scintillators. About 1g of the optical grease (BC630, Saint Gobain) was applied to between PMT or SiPM and scintillators to avoid light loss by scattered reflection. To measure the gamma energy spectrum, PMT or SiPM was connected to a shaping amp and the measured signal is amplified by the shaping amp and the signal transferred to a multi-channel analyzer (MCA).

The gamma energy spectrum using SiPM was measured and the schematic of the experiment set up is Figure 3 (b). SiPM (SPMArray4, SENSL, 4x4 array) was coupled with scintillator. One pixel has pixel chip area of 3.16 x 3.16 mm2 (pixel active area of 3.05 x 3.05 mm2). Therefore only nine pixels of sixteen pixels were used in this experiment because the plastic and the CsI(Tl) size was 10 x 10 x 10 mm3. So unused the other seven pixels were turned off by additionally attached switches. About 1g of optical grease also was applied to between the SiPM and the scintillators to avoid scattered reflection. Break down voltage of SiPM was 27.5 V and LLD was 60.

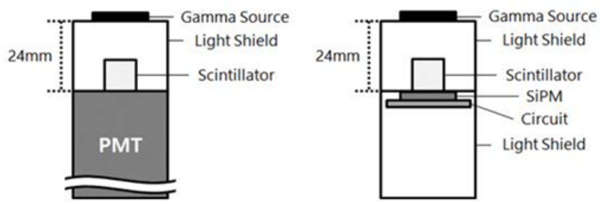

Figure 3. Scheme of the experiment setup for gamma rays energy spectrum with PMT and SiPM

2.2 Absorbed Dose Rate from Gamma Energy Spectrum

Due to the energy spectrum is deposited radiation energy in the medium of the scintillator, absorbed dose can be calculated using the spectrum. Absorbed dose rate calculation is based on the energy absorption coefficient. It would be expressed in the reference tables as the mass energy absorption coefficient from NIST. And the equation for absorbed dose rate calculation is expressed below.

$$\dot{D} = \varphi_{\gamma} E_{\gamma} \left(\frac{\mu_{en}}{\rho}\right) \quad (1)$$

The photon detection efficiency of SiPM, quantum efficiency of PMT and exposure time were applied to the equation for precise dose rate calculation.

3. Conclusions

According to the experiment result, plastic scintillator is more proper material to measure absorbed dose rate of the gamma rays with the energy from 511 keV to 1.33 MeV. The difference of absorbed dose rate of the plastic scintillator coupled PMT and SiPM were -12 % and 72 % when Cs-137 gamma source was used. When Co-60 source was used, those were -2 % and 113 % respectively. On the other hand, The difference of absorbed dose rate of the CsI(Tl) scintillator coupled PMT and SiPM with Cs-137 were 929 % and 131 %. When Co-60 was used, the difference were 876 % and 90 %. When Na-22 source is used, the dose rate differences of PMT and SiPM were 3125 % of 590 % respectively. But Co-57 source was excluded because the photo-peak and Compton peak exist in the noise of PMT and SiPM and dose rate difference was meaningless. Table 1 shows the difference of absorbed dose rate according to the scintillator materials, general gamma sources and detectors.

Table 1. Difference of absorbed dose rate according to the scintillator materials, general gamma sources and detectors

	Calculation Difference			Measurement Difference			
Source	Tissue	PS	CsI	PMT+PS	SiPM+PS	PMT+CsI	SiPM+CsI
Cs137	-	-2%	-8%	-12%	72%	929%	131%
Co60	-	-2%	-18%	-2%	113%	876%	90%
Na22	-	-2%	-11%	169%	398%	3125%	590%

Although a SiPM does not have remarkable performance as a PMT, a SiPM can be effective substitution of PMT for electric personal dosimeter through sensitivity revision. And a plastic scintillator can measure more accurate absorbed dose rate because of tissue equivalent energy absorption coefficient and is more suitable for the equivalent dose rate measurement instead of inorganic scintillator.

For the future work, we will try to find minimum measurable photon energy below 447keV using plastic scintillator and SiPM. And through experiment, minimum size and optimum material ratio of plastic scintillator for the application to the EPD will be found.

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