Gamma-ray spectroscopy using CsI(Tl) and silicon PIN photodiodes

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1. Introduction

The use of fast neutron and gamma-ray inspection techniques(FNGR) for scanning the composition of illegal drugs, agricultural products, and other contraband in customs applications and for the inspection of weapons and explosives in security applications has been widely reported [1-3]. The FNGR generally uses two detector modules which are parallel for each other. They are all scintillator coupled photodiode detectors and the thickness of each scintillator is designed to absorb about 80% of radiations entering the scintillator. In order to acquire more detail information and reduce the error of measuring the ratio (R), the sensitivity of each detector should be improved.

In this study, we proposed a new idea to increase the sensitivity of each detector by using two parallel detector modules for gamma-ray radiography. The aim of this work was to evaluate the ability of the new detector to improve the signal to noise ratio (SNR), and to establish the methodology for counting in the new detector module with coincidence spectroscopy circuit. For this purpose, we optimized the scintillator thickness for ^{60}Co by the Monte Carlo simulation code and the characteristics of operation and noise tests were accomplished after Scintillator coupling.

2. Characteristics of the fabricated detector module

In this study, two parallel detector modules suggested. In detail, the height of the 1 level is approximately 50 ㎜ and optimal thickness of the 2 level is approximately 40 ㎜. A detector consisting of cubic CsI(Tl) crystals coupled to a Hamamatsu S3590-01 and the PIN photodiode fabricated are two kinds of n-type (100) wafer having resistivity of 1.5 kΩ·cm and 5kΩ·cm are tested. For our design of n-type photodiode, the total thickness is 380 ㎛. It is a PIN diode where N+ doping is formed in the whole rear face and P+ doping is formed in the front face. Si_3N_4 of ~700Å, which is optimal to wavelength of 550 ㎚, was used as a anti-reflection coating film.

Our design of n-type photodiode allows for the attachment of a crystal on the p+ side of the photodiode. The aim of this design is to enhance the time properties of the detector module in coincidence mode, due to the fast hole collection near the surface of the p+ region. For the PIN photodiode, terminal capacitance, dark current and spectral response was measured as shown in the Table 1.

Table 1. Results for properties of PIN photodiodes

Manufacturer	Hamamatsu	Model1	Model2
Type	S3590-01	M1-1.5	M2-5
Active area [㎜]	10×10	10×10	10×10
Responsivity [A/W] (@550 ㎚)	0.31	0.51	0.50
Dark current [nA] (@V_R=5 V)	0.44	0.59	1.34
Terminal capacitance [pF] (@V_R=5 V)	100	200	100
NEC [rms] (@Shaping time =6 ㎲)	500	1200	900
Window	Epoxy resin	Epoxy resin	No window

3. Gamma spectreometer characteristics

The photodiode and preamplifiers coupled with crystal is located in the light tight box that can provide electromagnetic shield. The respective signals are applied into the shaping amplifier at a shaping time of 6 ㎲ having optimal noise from the preamplifier output. In Fig.1, and Fig.2, the experiment is performed on applying the same shaping time. For the photodiode used in Fig.2, the gamma-ray spectroscopy are accomplished using 5 kΩ·cm having the smallest noise derived through the NECs measurement.

The energy resolution is determined from the width of photo-peak areas of ^{60}Co source at 1.17 MeV and 1.33 MeV. The results of spectra are shown in Fig.1. The manufactured photodiodes showed about 16% and 12%, respectively, for 1.17 MeV and 1.33 MeV from ^{60}Co poorer energy resolution than Hamamatsu S3590-01. On the other hand, the two kinds of the manufactured photodiode are located in a position of larger peak in channel numbers and it means our detector has better signal amplitude that is generated within the detector.

Fig.2 shows that the results obtained by applying the coincidence method to the two parallel detector modules are about 17% better the sensitivity than that from the singles. This is attributed to coincidence summing arises from the possibility of detecting two truly coincident photons in the proposed structure.

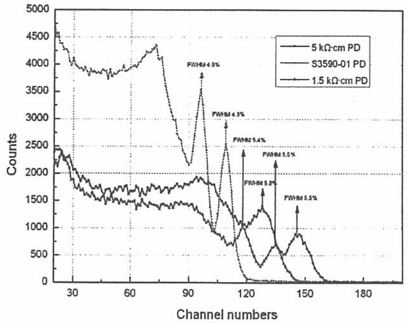

Fig. 1. Comparison of FWHM between our detector and the other detector based on S3590-01 photodiode for ^{60}Co source

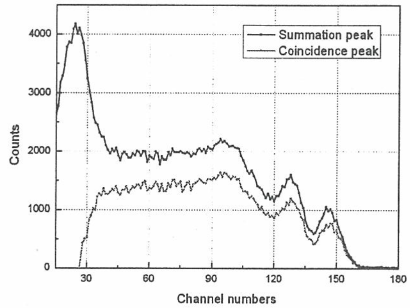

Fig. 2. Pulse height spectra of the two parallel detectors from a 1 μCi ^{60}Co

4. Discussion and conclusions

We fabricated the PIN photodiode coupled with crystal for the FNGR. We performed experiments and analyzed the results concentrating on the characteristics of signal and noise with PIN photodiode and CSA to detect high energy gamma and dominant factors to minimize system noise were capacitance than dark current of photodiode. As a result of measurement using the two parallel detector modules in this study, the sensitivity was considerably improved. We proved that our detector system is reliable for FNGR.

5. Reference

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