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Correction of Measurement by HP-Ge Detector for Incident Diagnostic X-ray Photons

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Abstract

It is necessary to obtain corrected X-ray spectra in order to produce diagnostic images and to evaluate exposure dose. In this study, the compensation of a spectra obtained using a high-purity germanium crystal was performed using Monte Carlo simulation code EGS4. The photon energy of the high-purity germanium crystal was consistent with manufacturer specifications. The stripping method was used to eliminate scattered radiation inside the high-purity germanium semiconductor detector. The HP-Ge detector was used to obtain an absorption spectrum, which includes a component of photon interaction in the HP-Ge crystal. The component of the spectrum, including Photo-Peak, sum-escape, K-escape and Compton escape, attributable to the interaction between the mono-energy state and high-purity germanium was obtained between 0 keV and the maximum energy of the X-ray tube using the Monte Carlo simulation code EGS4. The effect of scattered photons was successfully removed from the spectrum of photons emitted from the target of an X-ray Tube using this simulation code. It is important to apply this compensation in order to obtain correct spectra of incident photons inside the detector.

1 Introduction

The objective of this study is to eliminate the effect of scattered radiation inside a high-purity germanium (HP-Ge) semiconductor detector. This scattered radiation originates in the detector and is caused by incident photons. It is important to obtain a correct X-ray spectrum of a diagnostic region in and to evaluate exposure dose. The HP-Ge semiconductor detector is commonly used to measuring the X-ray spectrum. However, the spectrum obtained with an HP-Ge detector is an absorption spectrum and contains a component related to the interaction of photon within the HP-Ge crystal. Therefore, appropriate compensation is needed in order to obtain a corrected spectrum of the incident photons inside the detector.

2 Method

In this study, the spectrum was compensated (stripping method[1, 2]) using Monte Carlo simulation code EGS4. The utility of the code was examined by the following procedure:

1. The radionuclide of multiple energy emission was obtained in order to reveal the characteristics of the energy distribution.
2. The effect of scattered radiation in the HP-Ge crystal was simulated using Monte Carlo code EGS4 with mono-energy photons.
3. Measurements were corrected during continuous X-ray analysis using the stripping method.
4. This correction was compared with the equation of Birch & Marshall.

3 Materials and Geometry

The geometrical relationship of the radionuclide and the HP-Ge detector are shown in Fig. 1. The radionuclides used in the measurement were ^{241}Am, ^{57}Co, ^{133}Ba and ^{99m}Tc. The HP-Ge semiconductor was a GLP-06165/05-P (6 mm ϕ x 5 mm, planar type, EG&G ORTEC). The figure also shows the size of the materials inside the HP-Ge semiconductor detector. The photon energies emitted from the radionuclides and the characteristic X-rays are listed in Table 1. A schematic illustration of the X-ray Tube (CIRCLEX6/1.2P18DE, Shimadzu) is given in Fig. 2. In the X-ray Tube, the angle of the tungsten target is 12°, the silicic acid glass thickness is 0.75 mm, the thickness of the radiation aperture resin is 2.5 mm, the mirror is 0.618 mm thick, the aluminum plate is 2.47 mm thick, and the acrylic acid glass is 0.0618mm thick. The flow diagram of the stripping method procedure using EGS4 is shown in Fig. 3.

4 Result and Discussion

The photon energy distribution in the HP-Ge crystal was consistent with manufacture specifications. The photon energy efficiency inside the HP-Ge detector (6 mm ϕ x 5 mm, 6 mm ϕ x 10 mm) is shown in Fig. 4 with the efficiencies for the energies emitted from radionuclides. The absorption spectrum inside the HP-Ge detector is shown in Fig. 5 for a mono-energy photon of 110 keV. It was found that photo-peak, sum-escape, K-escape and Compton escape are included in the spectrum. The simulated spectra of the X-ray tube at 90 kV and 110 kV are shown in Fig. 6. Filtering is assumed to be a 2.5 mm Al filter, which represents the combined elements of an X-ray tube assembly. The observed X-ray spectra are shown in Fig. 7. Correction to the continuous X-ray by the stripping method produces a spectrum from a radionuclide with multiple-energy photon radiation that is almost the same as that obtained using the semi-empirical formula of Birch & Marshall. This suggests that the effect of scattered radiation in the crystal can be removed using the stripping method and energy distribution. The origin of the error in the high-energy region is currently being investigated. The effect of secondary electrons inside the crystal was ignored, however this problem will be addressed in the future.

5 Conclusion

Monte Carlo simulation code EGS4 and the stripping method were used to eliminate the effect of scattered radiation inside the high-purity germanium semiconductor detector on the X-ray spectrum obtained using the detector. The spectrum obtained is an absorption spectrum, which includes components attributable to the photon interaction within the HP-Ge crystal. The Monte Carlo simulation code was used to generate a response (including photo-peak, sum-escape, K-escape and Compton escape) of the high-purity germanium from mono-energy photons in the range 0 keV to the maximum energy of the X-ray tube. Using the simulation spectra, the effect of scattered photons in the spectrum of photons emitted from the target of an X-ray tube was removed. It is important that such compensation is applied in order to obtain the correct spectrum for photons incident on the detector.

References

[1] W. W. Seelentag and W. Panzer, "Stripping of X-ray Bremsstrahlung Spectra up to 300 kVp on a Desk Type Computer", *Phys. Med. Biol.* **24**(1979)767-780.

[2] H. Kato, M. Tsuzaka, S. Koyama and H. Maekoshi, "Development of Computer Code for Correction of X-ray Spectra measured with High-Purity Germanium Detectors", *Jpn. J. Radiol. Technol.* **51**(1995)462-468.

Table 1 The radionuclides used in the measurement, and the photon energies emitted from the radionuclides and the characteristic X-rays.

Radio Nuclide	*Energy*		*Ratio*
Am-241	*26.3keV*		*2.40%*
	33.2keV		*0.13%*
	59.5keV		*35.90%*
	13.9keV	*(Np-L)*	*42.00%*
Ba-133	*81.0keV*		*34.10%*
	276.0keV		*7.20%*
	31.0keV	*(Cs-K_α)*	*23.1%*
	35.0keV	*(Cs-K_β)*	*23.10%*
Co-57	*14.4keV*		*9.20%*
	122.0keV		*85.60%*
	136.0keV		*10.70%*
Tc-99m	*141.0keV*		*89.10%*
	18.4keV	*(Tc-K_α)*	*8.10%*
	20.6keV	*(Tc-K_β)*	*1.20%*

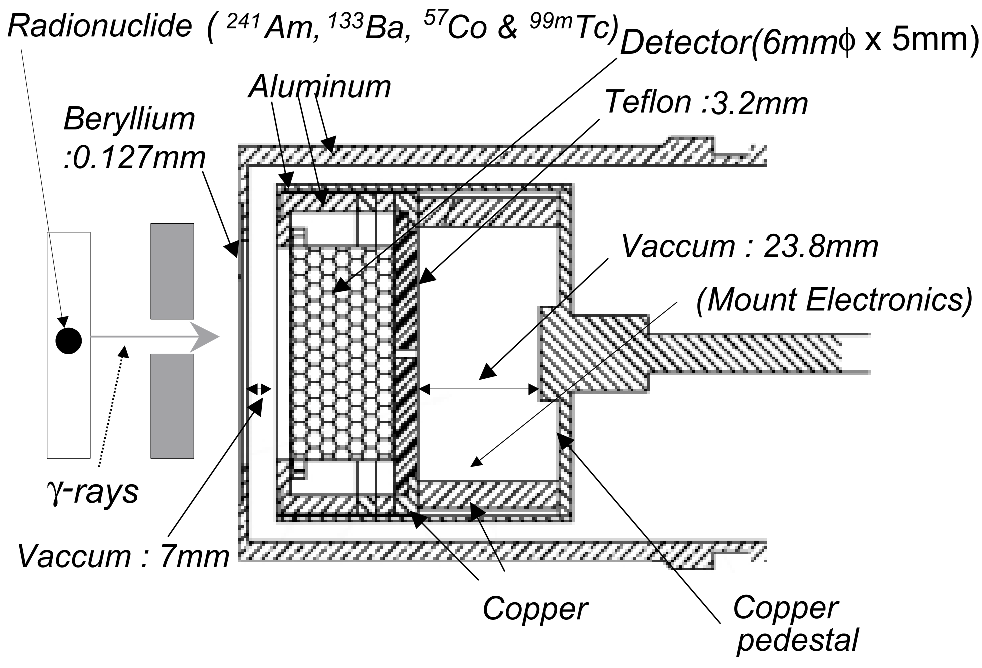

Figure 1: The geometrical relationship of the radionuclide and the HP-Ge detector.

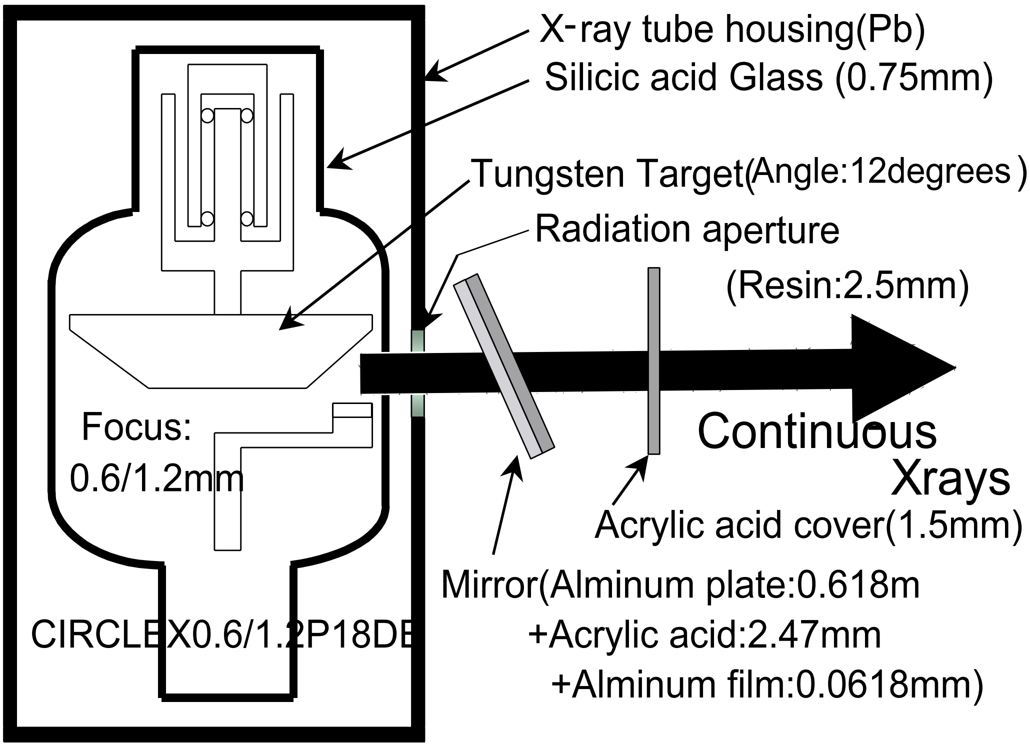

Figure 2: A schematic illustration of the X-ray Tube (CIRCLEX6/1.2P18DE, Shimadzu).

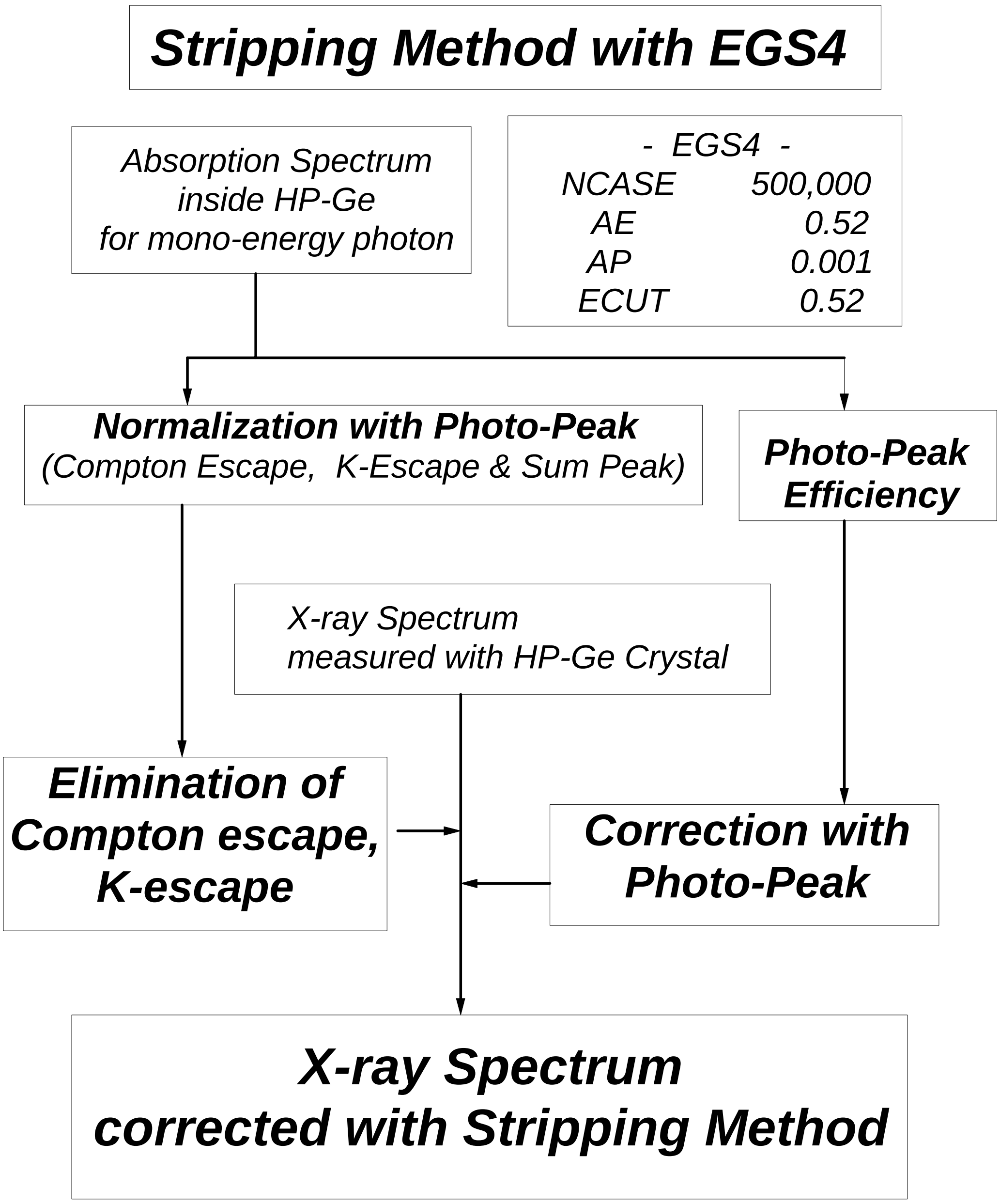

Figure 3: The flow diagram of the stripping method procedure using EGS4.

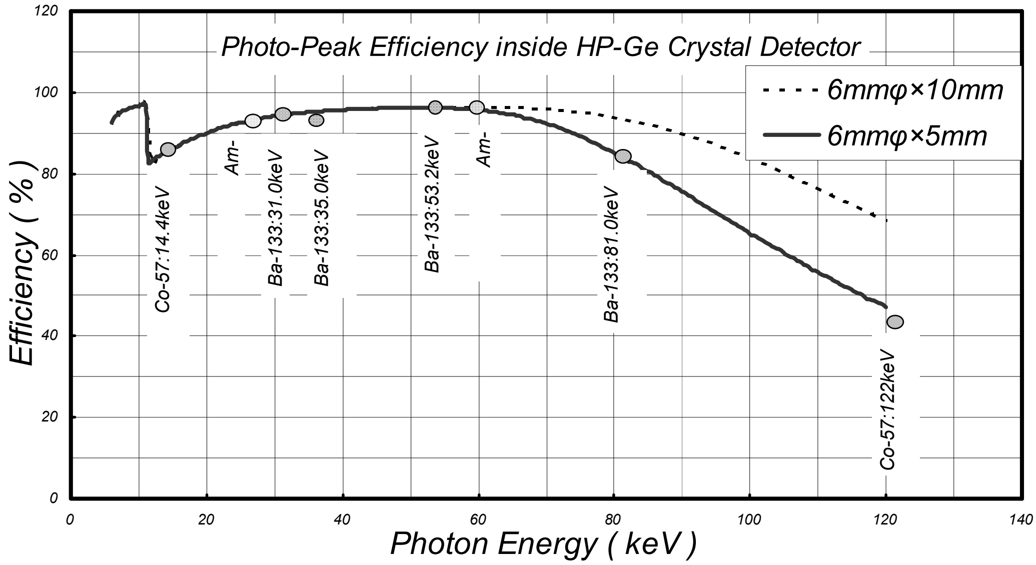

Figure 4: The photon energy coefficiency inside the HP-Ge detector (6 mm$\phi\times$ 5 mm, 6 mm$\phi\times$ 10 mm).

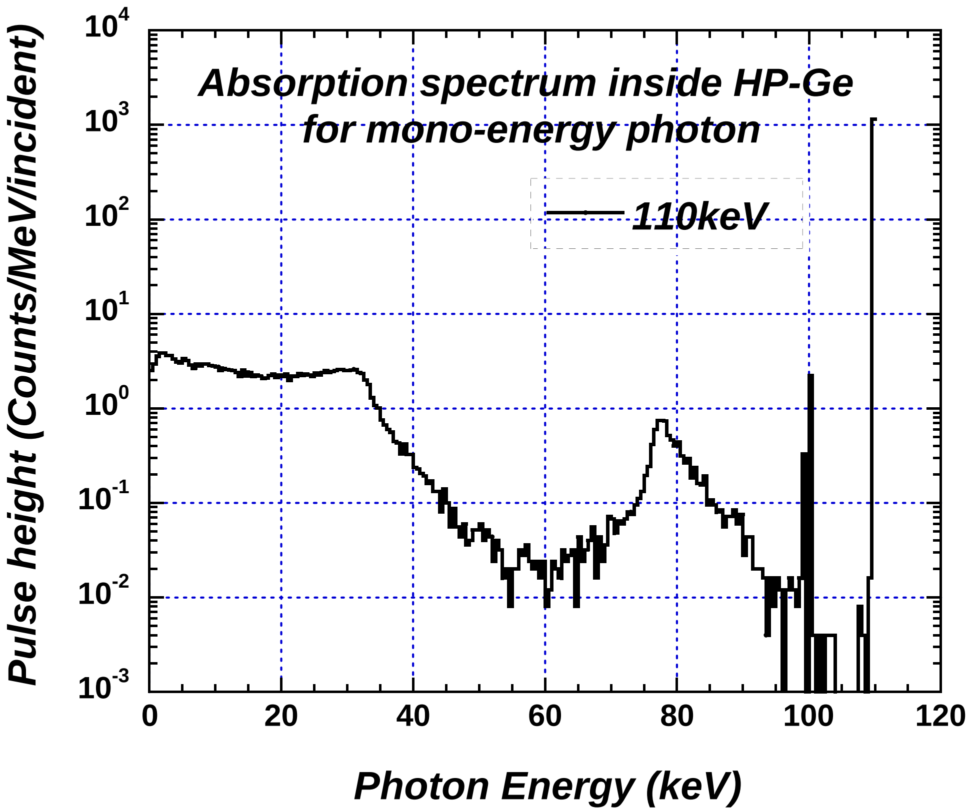

Figure 5: The absorption spectrum inside the HP-Ge detector for a mono-energy photon of 110 keV.

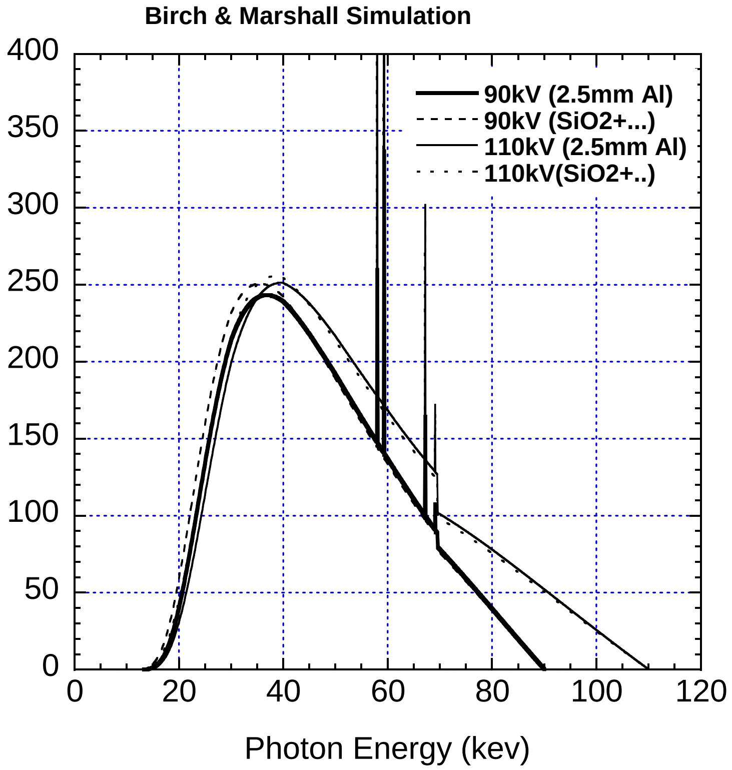

Figure 6: The simulated spectra of the X-ray tube at 90 kV and 110 kV.

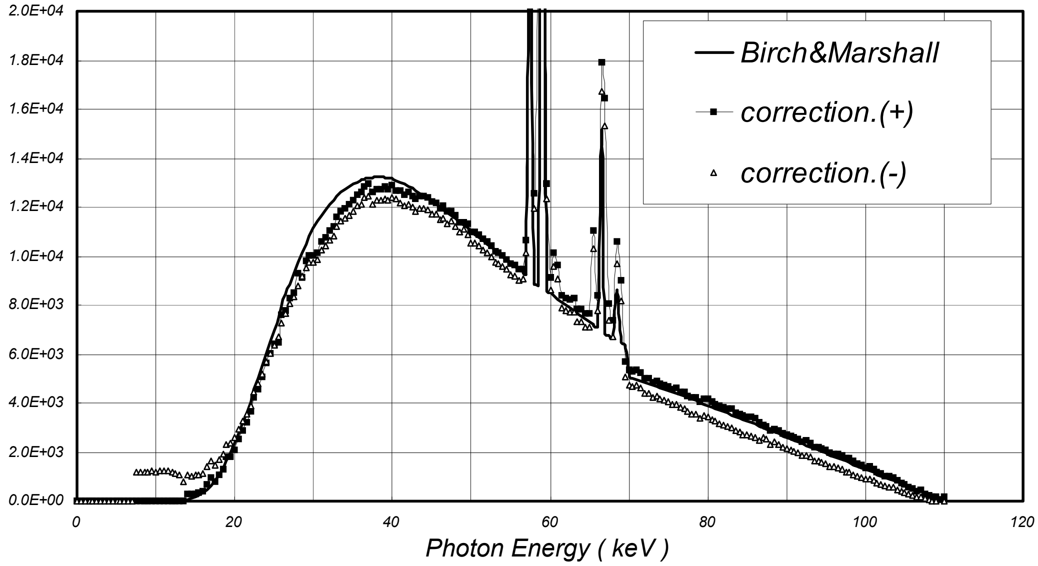

Figure 7: The observed X-ray spectra. Correction to the continuous X-ray by the stripping method produces a spectrum from a radionuclide with multiple-energy photon radiation that is almost the same as that obtained using the semi-empirical formula of Birch & Marshall.