On the Efficiency Curves of Ge(Li) Detectors

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The full-energy peak efficiencies (FEPE) of coaxial type Ge(Li) detectors of 31, 46 and 50 cm^3 have been determined for gamma rays in the energy range from 100 to 4000 keV. The slopes of FEPE curves to the gamma ray energy are discussed in relation with the active volumes of Ge(Li) detectors.

KEYWORDS: Ge(Li) detectors, full-energy peak efficiencies, slopes

I. INTRODUCTION

The full-energy peak efficiency (hereinafter described as FEPE) as a function of gamma ray energy is an important characteristic of Ge(Li) detector. The FEPEs of Ge(Li) detectors are measured by using standard sources calibrated by $4\pi\beta$-γ coincidence method, etc. and by using other radioactive sources[1,2].

As the attempts to obtain it through calculation, the studies on the FEPE by Monte Calro calculation, etc. have been submitted on some reports[3,4]. However, the calculation may lead to an incorrect FEPE, because the effective portion of Ge(Li) crystal has not been correctly understanded. Under the circumstances, the direct FEPE measurements of Ge(Li) detectors have been attempted by using the standard sources for each Ge(Li) detector. The FEPEs of coaxial type Ge(Li) detectors with different active volumes of 31, 46 and 50 cm^3 are measured as functions of gamma ray energy and source to detector distance. The slopes of the FEPE curves to the gamma ray energy are discussed in relation with the active volumes of Ge(Li) detectors.

II. EXPERIMENTAL

1. Radioactive Sources

Measurements were made with several radioactive sources to provide FEPEs in the energy range from 100 to 4000 keV. Sources of ^{140}La, ^{24}Na, ^{56}Mn and ^{49}Ca, and TRC standard sources† of ^{57}Co, ^{133}Ba, ^{22}Na, ^{137}Cs, ^{54}Mn, ^{60}Co and ^{88}Y, calibrated to the accuracies better than 5 %, were used for these measurements. These standard sources are 1 mm in diameter, and are sealed between two polyethylene sheets of 0.5 mm in thickness to minimize absorption of radiations. Correction of absorption for gamma rays in the polyethylene sheet is about 0.1 % for 122 keV gamma rays (^{57}Co). Additional aluminium absorber of 1 mm in thickness was used for the ^{22}Na source to stop the positrons. Correction of absorption for 1275 keV gamma rays in this case is about 1.5 %. The gamma ray energy,

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† Obtained from The Radiochemical Centre, Amersham.

half-life, branching ratio, etc. of these standard sources were based on the specification recommended by TRC. The sources of ^{140}La, ^{24}Na, ^{56}Mn and ^{49}Ca were prepared by neutron irradiation for lanthanum, sodium, manganese and calcium precipitated on filter papers in Kyoto University Reactor (KUR). The source size was 3 mm or less in diameter, and the gamma ray intensity ratios of these sources were based on the decay scheme data edited by Lederer *et al*[5].

2. Measurements of Gamma Ray Spectra

Ge(Li) detectors with different active volumes of 31, 46 and 50 cm^3 were used for the experiments. The geometrical parameters and specifications of these detectors are shown in **Table 1.** Acrylic resin or iron absorber was mounted to the front window of these Ge(Li) detectors to stop beta rays and low energy gamma rays. The gamma ray spectrum of each source was measured by a 1024 channel pulse height analyzer (NUCLEAR DATA) after amplifying the signals from the Ge(Li) detector with FET preamplifier and linear amplifier. The distances(D) between the source and the Ge(Li) crystal were selected as 2.9, 6.8, 12.8 and 22.7 cm. Indications of the dead time meter at these source positions were 10 % or less. The measuring time of the gamma ray spectrum was determined so that the full-energy peak area becomes 5000 counts or more.

Table 1 Geometrical parameters and specifications of Ge(Li) detectors

Detectors		31cm^3	46cm^3	50cm^3
Type		5-sided coaxial with rectangular cross-section (33×31 mm). p-core 12×11 mm. Closed end 8 mm behind window	True right circular cylinder coaxial	True right circular cylinder coaxial
Detector size (mm)			39.0ϕ×44.0	47.5ϕ×35.0
Diffusion depth (mm)		0.5	1.0	2.0
Drift depth (mm)		—	15.3	17.8
Active volume (cm^3)		31	46.0	50
Absorbing layers (mm)	Aluminium	—	0.5	0.5
	Teflon	—	1.0	—
Window to detector distance (mm)		8	5	8
Resolution (keV FWHM)*		2.75	2.4	2.12
Manufacturer		CANBERRA	ORTEC	HORIBA

* For 1332 keV gamma rays.

III. RESULTS AND DISCUSSION

The absolute FEPEs in the cases of the standard sources were calculated by $A/N\gamma$ from recorded full-energy peak area (A, counts/sec) and intensity of gamma rays ($N\gamma$, n/sec). In the FEPEs of ^{140}La, ^{24}Na, ^{56}Mn, and ^{49}Ca sources, at first, the relative FEPEs were calculated from intensity ratios and peak areas of the gamma rays, and they were normalized on the absolute FEPE curves obtained from the TRC standard sources. The errors in the FEPEs of the Ge(Li) detectors obtained from both radioactive sources are expected to be between 5 and 10 %.

In order to check the effects for the FEPEs of an acrylic resin and an iron absorber mounted to the front window of Ge(Li) detectors, the FEPEs of a 31 cm^3 Ge(Li) detector having an acrylic resin or an iron absorber were measured at source positions of D=2.9, 6.8, 12.8 and 22.7 cm. The results are shown in **Fig. 1**. The absolute FEPE with an acrylic resin absorber of 14 mm in thickness is slightly less for gamma rays in the energy range from 100 to 3000 keV in comparison with that of an acrylic resin absorber with 4 mm in thickness. The FEPE in the case of a 12 mm iron absorber was considerably small for gamma rays in the low energy range from 100 to 300 keV in comparison with the FEPE of a 4 mm acrylic resin absorber. The FEPE for 122 keV gamma rays with a 12 mm iron absorber at D=12.8 cm was about 6 % to that with a 4 mm acrylic resin absorber.

The FEPEs of Ge(Li) detectors with different active volumes of 31, 46 and 50 cm^3 are compared in **Fig. 2**. In this figure, the relative FEPEs of 31 and 50 cm^3 Ge(Li) detectors normalized at the FEPE of 662 keV gamma rays (^{137}Cs) are also shown. As shown in the figure, the FEPE is not always proportional to the active volume of Ge(Li) detector. It is considered to be related to the difference in the shape of Ge(Li) crystal. However, the FEPEs for the gamma ray energy (E) in the range from 500 to 3000 keV obtained from each detector indicated a linear relationship in log (FEPE) - log(E) plotting. Therefore, the FEPEs (ε) for gamma rays in this energy range can be given by the following function.

$$\varepsilon = cE^{-s}$$

c and s in the function indicate a constant and slope of the FEPE curve, respectively. The results of

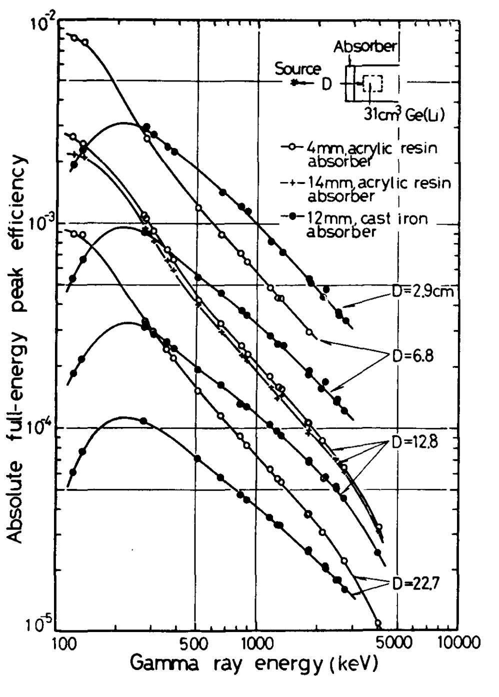

Fig. 1 Absolute full-energy peak efficiency curves for various source to detector distances and absorbers of a 31 cm^3 Ge(Li) detector.

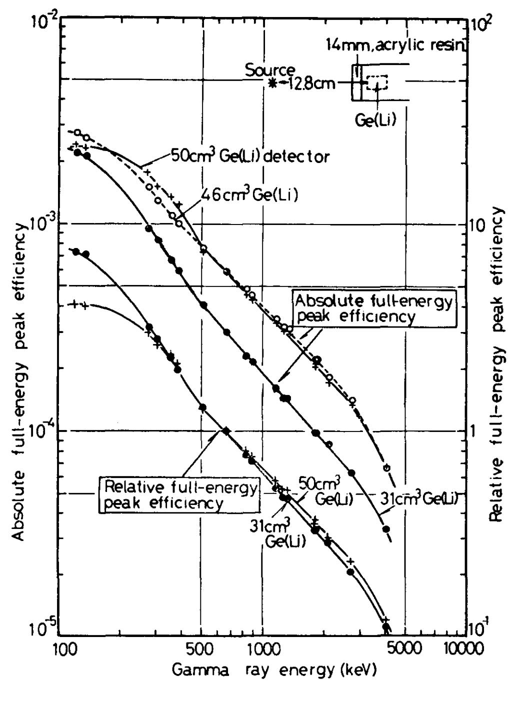

Fig. 2 Absolute and relative full-energy peak efficiency curves of 31, 46 and 50 cm^3 Ge(Li) detectors.

least squre fitting obtained by using this function is shown in **Fig. 3.** The difference between the fitted FEPE (ε_f) and the measured FEPE (ε_m) is shown in percentage along the vertical axis. As shown in the figure, the both ε_f and ε_m of 31 and 50 cm^3 Ge(Li) detectors agreed well within $\pm 5\%$ or less in the energy range from 500 to 3000 keV. Vaño *et al.*[6] reported a relation between the slope (s) in the FEPE curve and the active volume (V) of Ge(Li) detector, as shown in **Fig. 4.** The slopes obtained from the FEPE curves in the energy from 500 to 3000 keV of three Ge(Li) detectors with a 4 mm acrylic resin absorber were plotted to the active volmes of the Ge(Li) detectors with the results by Vaño *et al.*[6] The results are shown in **Fig. 4.** It was found out that three points obtained by our experiments agreed with the results by Vaño *et al.*[6]

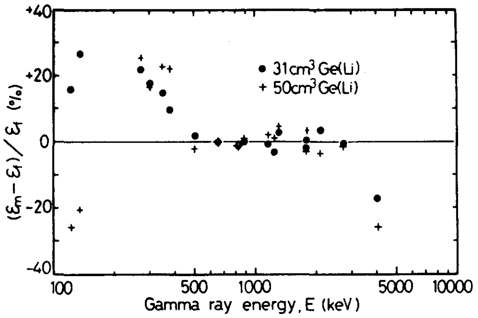

Fig. 3 Deviations between measured FEPEs (ε_m) and fitted FEPEs (ε_f) of 31 and 50 cm^3 Ge(Li) detectors.

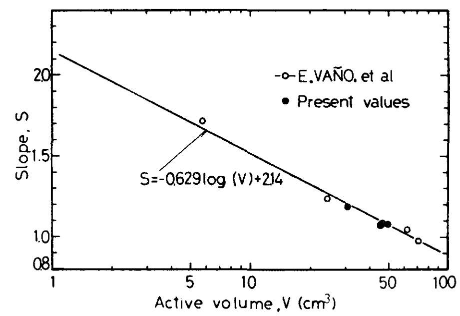

Fig. 4 Relation between slope of FEPE curve and active volume of Ge(Li) detector.

IV. SUMMARY

The results in this paper are summarized as follows. The absolute FEPEs of three Ge(Li) detectors did not always indicate proportional relationship to the active volumes. However, the FEPE for the gamma rays in the energy range from 500 to 3000 keV of three Ge(Li) detectors indicate a linear relationship between log(ε) and log(E), and their slopes agreed well with the values obtained from a relation between s and V reported by Vaño *et al.*[6] When the relationship was established between s and V, the relative FEPEs for gamma rays in the energe from 500 to 3000 keV could be easily calculated from the active volume of a Ge(Li) detector. Furthermore, if the absolute FEPE of one point in this energy range is measured by using a suitable standard source, it is possible to calculate the absolute FEPEs in this energy range. However, the FEPEs for gamma rays of 500 keV or lower involve a complicated circumstace as described above. Therefore, it is probably necessary to measure the FEPEs in this energy range for each detector by using suitable standard sources.

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