Application of Monte Carlo efficiency transfer method to calibration of coplanar-grid CZT detector

Qinjian CAO[1,2], Liye LIU[1,*], Wanchun XIONG[1], Yunshi XIAO[1], Hongjuan PAN[1]
[1]China Institute for Radiation Protection, Taiyuan, 030006, P.R. China
[2]China Institute of Atomic Energy, Beijing, 102413, P.R. China

ABSTRACT: Monte Carlo efficiency transfer method has been developed and used to calibrate several type HPGe detectors. It is much more convenient for FEPE calibration than the direct Monte Carlo method. In this paper, the efficiency transfer method was introduced to determine FEPEs of the coplanar-grid CZT detector. The comparison between calculations and point-source experiments showed that the relative deviation was mostly within ±10% for CZT detector.

1. Introduction

There are two different ways of calculation FEPE using Monte Carlo method. The one is named direct Monte Carlo calculation method, which is necessary to optimize the detector geometry parameters by comparing the computed efficiencies with experimental values. The other is named Monte Carlo efficiency transfer method. The FEPEs were calculated with the efficiency transfer factors, which were obtained by comparison the direct calculated FEPE using the manufacturer's detector parameters with point source experimental values at a reference position. The efficiency transfer method was developed by Moens et al. in 1981 and has been applied popularity as a means of calibrating the FEPE s for several type HPGe detectors. The results showed that the deviations found with Monte Carlo efficiency transfer method were generally below 5%, which is entirely satisfactory for the purpose of routine measurements. In this paper, the Monte Carlo efficiency transfer method was introduced to calculate the FEPEs of CZT detector. And some discussions about the application of the Monte Carlo efficiency transfer method to the in situ non-destructive radiological characterization were also presented.

2. Materials andMethods

2.1 detector and point sources

The semiconductor detector considered in this paper is Co-Planar Grid (CPG) CZT detector, produced by eV PRODUCTS. The application of the CPG electrode structure creates an electron-only collection device that allows for a reduction in tailing caused by the trapping of charge in the CZT crystal. The crystal size of the detector used in this paper is $10\times10\times10mm^3$. The FWHM at 662keV is about 12keV, and the energy range is from 30keV to 10MeV.

The point sources ^{241}Am, ^{152}Eu, ^{137}Cs and ^{60}Co, covering the energy range 59.54-1332keV, were used in the experiments.

2.2 Monte Carlo simulation

The Monte Carlo simulation software introduced in this work is MCNP. Several variance reduction techniques were introduced into the efficiency calculation, such as source directional bias sampling and energy cutoff. The statistic uncertainties of Monte Carlo simulation were below 5% mostly.

2.3 Monte Carlo efficiency transfer method

The Monte Carlo efficiency transfer method is found on the assumption that the transfer factors between Monte Carlo computed FEPEs using the manufacturer's detector data and measurement values are dependent on photon energy only, independent of source to detector relative position at a specific energy. This method can be divided into two steps. Firstly, the efficiency transfer factors were obtained for a series of photon energies at a reference position. And the efficiency transfer factor K_E can be described as $K_E = \varepsilon_{Mea.}(E, x_0, y_0, z_0)/\varepsilon_{MC.}(E, x_0, y_0, z_0)$, Where $\varepsilon_{Mea.}(E, x_0, y_0, z_0)$ is the FEPE measured at the position (x_0, y_0, z_0) for photons with energy E, $\varepsilon_{MC.}(E, x_0, y_0, z_0)$ is the directed calculated FEPE with manufacture's detector parameters. Secondly, we performed the efficiency transfer factor from the reference point source to the point sources at other positions through the formula $\varepsilon(E, x, y, z) = K_E \cdot \varepsilon_{MC.}(E, x, y, z)$, where the $\varepsilon(E, x, y, z)$ is the desired FEPE at the position (x, y, z) for energy E, $\varepsilon_{MC.}(E, x, y, z)$ is the direct calculated FEPE.

3. Results and Discussions

A fitted curve of efficiency transfer factors at different photon energies was determined by comparison the experimental FEPEs with direct calculated FEPEs (Fig.1). We computed the efficiency values for point sources located at 10cm from the detector window to source covering the energy range 59.54-1332keV with the efficiency transfer factors (see table 1). And the efficiency values at different point source positions were also obtained. As can be seen, the deviations between the calculated and experimental efficiency were less than 10%, which is entirely satisfactory for the purpose of non-destructive radiological characterization.Fig.2 is the in situ non-destructive measuring gamma spectrometry of a contaminated pipe. As can be seen, the radionuclides deposited in the inner surface of the pipe are ^{60}Co、^{58}Co、^{110m}Ag、^{54}Mn、^{51}Cr and ^{124}Sb. And the activity of the radionuclide was calculated based on the full energy peak efficiency obtained with the Monte Carlo efficiency transfer method. As can be seen in the table 2, the dose rate calculated from the computed activity of the radionuclide is similar to the measuring value.

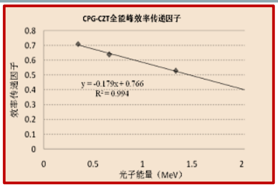

Fig.1 Fitting curve of efficiency transfer factor at different photon energy

Fig.2 In situ non-destructive measuring gamma spectrometry measured with CZT detector

Tab.1 Computed and experimental FEPEs for sources located at 10cm

Energy（keV）	59. 54	121. 78	661. 66	1173. 2	1332. 5
Cal. Effi.	5. 07E-04	5. 06E-04	3. 75E-05	1. 27E-05	9. 99E-06
Mea. Effi.	4. 76E-04	5. 23E-04	3. 64E-05	1. 18E-05	9. 66E-06
Deviation	6. 5%	-3. 3%	3. 0%	7. 63%	3. 42%

Tab.2 Activity calculated based on the gamma-spectrometry and FEPEs

radionuclides	activity (Bq/cm^2)	Cal. dose rate(μSv/h)	Exp. dose rate (μSv/h)
^{110m}Ag	2. 71E+03	401. 0	495. 4
^{60}Co	1. 48E+04		
^{58}Co	2. 90E+04		
^{51}Cr	3. 30E+04		

4. Conclusion

In this paper, we applied Monte Carlo efficiency transfer method to full energy peak efficiency calibration of a large volume CPG-CZT detector. The detector dimensions provided by the manufacturer are usually insufficient for accurate efficiency computations, and it is necessary to optimize the detector geometry parameters. Based on the Monte Carlo efficiency transfer method, the accurate efficiency can be computed directly using the detector parameters provided by the supplier. And the deviations between the calculations and point source experiments were mostly within ±10% for CPG-CZT detector produced by eV PRODUCTS in the energy range 59.54-1332keV. The method is also applied to the non-destructive radiological characterization for the contaminated pipes. The results showed that Monte Carlo efficiency transfer method is a simple and effective method for peak efficiency calibration for CZT detector.

*Corresponding Author. Tel:+86 351 2203139; Fax: +86 351 2202137
E-mail address: Liye.liu@gmail.com