Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 29-30, 2014

Simulation study for high resolution alpha particle spectrometry with mesh type collimator

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1. Introduction

Alpha particle spectrometry has been used in the measurement of nuclear materials in various fields, such as safeguard verification, nuclear security, nuclear decay data and environmental surveys [1]. In order to verify nuclear experiments or reprocessing, it is important to identify specific radionuclide, such as ^{235}U, among various nuclear species in a radioactive source. An alpha particle spectrometry with a mesh type collimator plays a crucial role in identifying specific radionuclide in a radioactive source collected from the atmosphere or environment [2]. The energy resolution is degraded without collimation because particles with a high angle have a longer path to travel in the air. Therefore, collision with the background increases. The collimator can cut out particles which traveling at a high angle. As a result, an energy distribution with high resolution can be obtained. Therefore, the mesh type collimator is simulated for high resolution alpha particle spectrometry.

2. Methods and Results

2.1 Simulation description

The detector system with the collimator consists of a Silicon detector, a radiation source and an aluminum collimator as shown Fig. 1. The collimator is placed between the detector and the source. The detector diameter is 100 mm, and the collimator thickness is 2~10 mm. Also, the gap between the collimator and detector or source is several millimeters. The mesh is hexagonal type which is close packed structure. The collimation of alpha particle spectrometry is simulated by Monte Carlo method, GEANT4 [3]. The simulation particles are 7 species, shown as Table 1, which are randomly generated from a source and, then bombard to detector after passing through collimator.

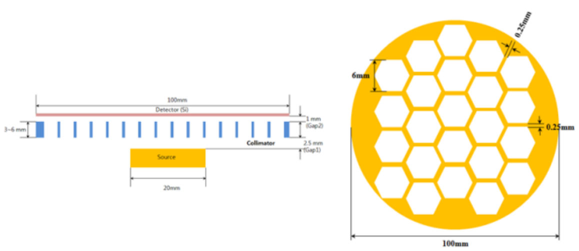


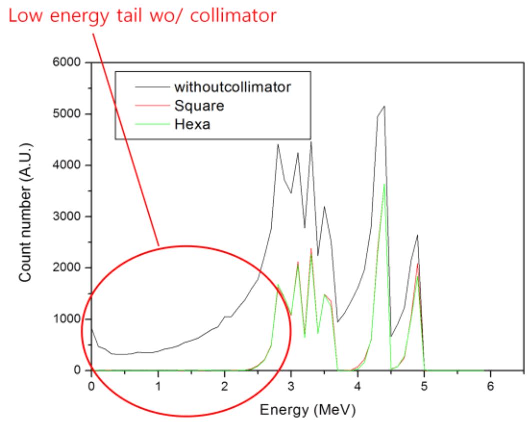
Fig. 1 Alpha spectrometry with hexagonal mesh type collimator

Nuclear species	Energy (MeV)
^{232}U	5.32
^{235}U	4.40
^{238}U	4.20
^{226}U	4.78
^{222}Rn	5.81
^{232}Th	4.01
^{210}Po	5.30

Table 1 Nuclear species for simulation

2.2 Results and discussion

Fig. 2 shows the energy distribution of alpha particles with and without collimator at atmosphere pressure (760Torr). For various nuclear materials, low energy tails are observed and the energy distribution is broadened without a collimation. As shown Fig. 2 (a) and (b), the low energy tail and broadened energy distribution does not clearly identify each radionuclide ranged from 2.5 to 4 MeV (alpha particle energy loss at atmosphere is ~1 MeV/cm). Since particles with a high angle have longer path than particles with a low angle, the collision with background increases. As a result, the particles lose more energy. On the other hand, with collimation, the low energy component is not observed because the particles with a high angle are screened by the collimator.



(a) Total energy distribution of each collimator and no collimator

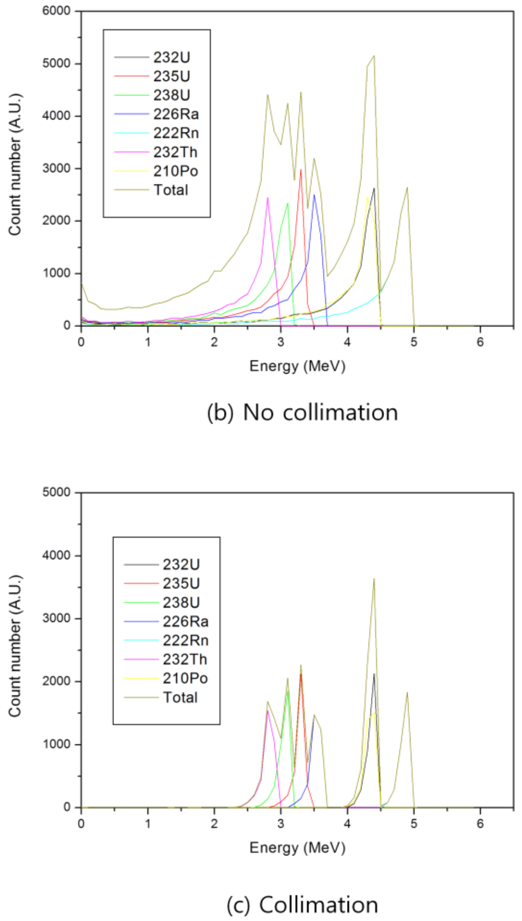


Fig. 2 Alpha particle energy distribution with and without a collimator

The mesh geometry influences the counting efficiency and resolution. At fixed thickness, 6 mm, of the collimator, the effect of diameter of the mesh is calculated. Shown Fig. 3 (a) and (b), as the mesh diameter increases, the counting efficiency increases, but low energy tail of the energy distribution is observed, and the resolution is also degraded. The large mesh diameter is not enough to cut out incident particles with a high angle. In case of the smallest diameter, the resolution is the most improved. However, the counting efficiency is degraded. Therefore, it is important to find sweet zone satisfying counting efficiency and resolution. Through this simulation study, we can propose guidelines of design of high resolution alpha-particle spectrometry with collimator.

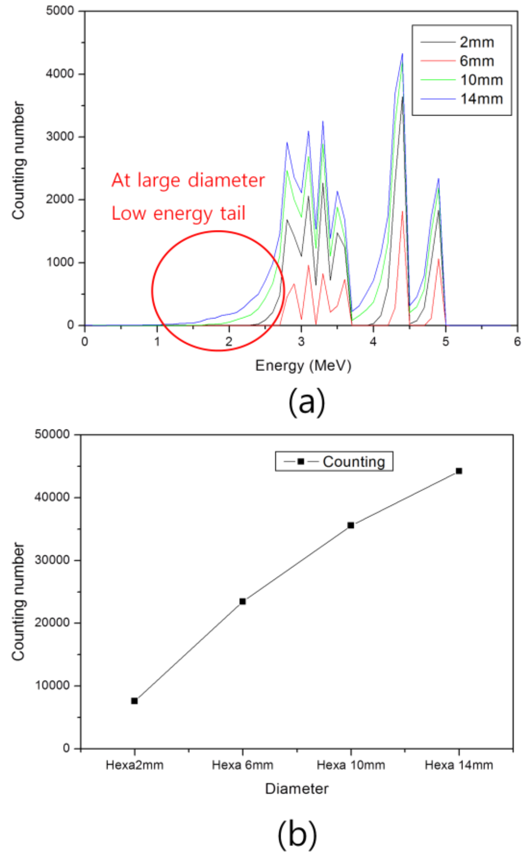


Fig. 3 Mesh diameter effect of alpha spectrometry

3. Conclusions

In conclusion, the collimator can improve resolution. With collimator, the collimator is a role of cutting out particles with a high angle, so, low energy tail and broadened energy distribution can be reduced. The mesh diameter is found out as an important factor to control resolution and counting efficiency. Therefore, a target particle, for example, ^{235}U, can be distinguished by a detector with a collimator under a mixture of various nuclides, for example: ^{232}U, ^{238}U, and ^{232}Th.

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