Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 7-8, 2015

Design Case Studies of Anti-scattering X-ray Grid by MCNP Code Simulation

Jun Woo Bae*, Hee Reyoung Kim
UNIST-Gil 50 Eonyang-eup Ulju-gun Ulsan metropolitan city, 689-798, Republic of Korea
**Corresponding author: skypia12@unist.ac.kr*

1. Introduction

It is required to decrease individual exposure against the ionizing radiation from medical radiation such as x-ray [1]. It is needed to minimize exposure time and lower the energy of incident x-ray for it. But, in order to obtain an image which has sufficient resolution and contrast to read, the scattered photon from the patient should be removed as many as possible. The scattered photons cause reduction of the contrast of X-ray image and result in the degradation of the quality of the image [2]. The scattered photon cannot but be projected to the detector pixel where it is initially headed. Therefore, reducing the scattered photon in x-ray imaging system is essential to decrease unwanted radiation exposure to patient and increase the accuracy of diagnosis. In order to reduce scattered photons, an anti-scattering X-ray grid, which consists of shielding material and penetration materials, is equipped in X-ray imaging system. The x-ray grid of the structure of square-shaped lattice has been widely used [3]. In this study, the anti-scattering X-ray grid with the different types is analyzed to design the system with the reduced scattered photons by MCNP code simulation, where the designs are based on electroplating technique. The S/P (ratio of scattered photons to primary photons) is estimated for the performance of grid.

2. Methods and Results

2.1. MCNP

All simulations are performed using MCNPX 2.7.0 [4]. MCNP code is a particle transport tool that is widely used in nuclear core design and radiation protection. It is based on Monte-Carlo method. It can be used from 1keV to 100GeV in the case of photon. MCNP can transport various particles under user customized geometry and material. It is assumed that the shielding material is electroplated on glass and penetration material remains void.

2.2. Simulation design

Fig 1. shows overall view of the simulation geometry. It consists of four parts; source, target, detector and grid. As Fig 1. shows, source and target is departed by 30 cm, where the target has height of 20 cm and grid and the target is departed by 30 cm.

The source is 80 keV single energy photon. It is an area source and the photon is projected to the grid and detector vertically. Because of testing ability of reducing scattered photon, the source is assumed ideal vertical photon source. Grid is only placed on the left part of detector. To compare the data between grid and none-grid, there is no grid on the right part of detector.

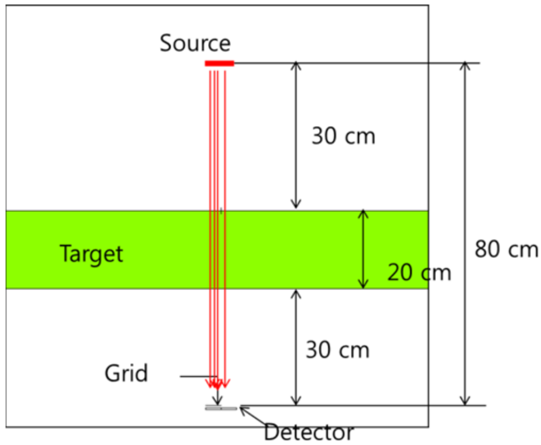
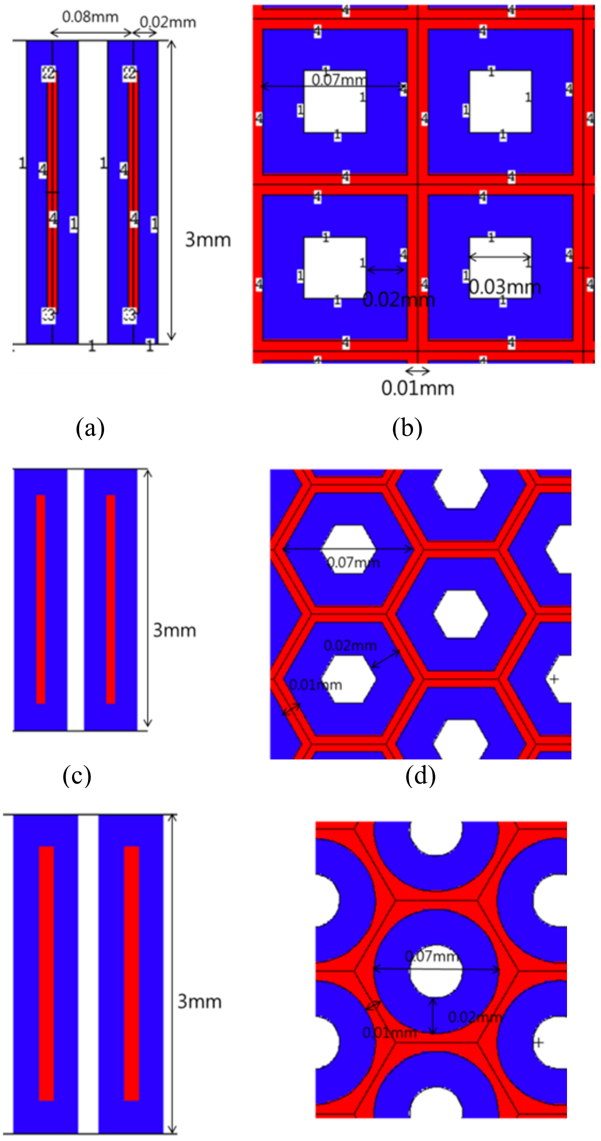


Fig. 1. Overall view of simulation geometry

2.3 Design of grids

The whole grid shape is 4 × 4 cm^2 square and thickness (z-direction) is 3 mm. Three electroplating types of square, honeycomb and circle are considered, where electroplating type means that shielding material is coated on the frame structure. Fig 2. shows the cross-section view of electroplating type grids. Fig 2. (a) and (b), (c) and (d), and (e) and (f) show cross-section view of square-type, honeycomb-type and circle type, respectively. The blue part means shielding material of gold, which has the density of 19.3 g/cm^3, and red part frame structure, glass. White part void.

For square-type, length of a lattice cell is 0.08 mm. The thickness of frame structure is 0.005 mm and thickness of shielding material is 0.02 mm. For honeycomb-type, it is hexagonal repeated lattice. Length of a side of hexagon is 0.035 mm. Thicknesses of frames structure and shielding material are 0.005 mm and 0.02 mm for each cell, respectively. For circle-type, it is hexagonal repeated lattice. Diameter of a circle is 0.07 mm. Frame structure is filled among each cell. The distance between each circle is 0.01 mm. Thickness of shielding material is 0.02 mm.



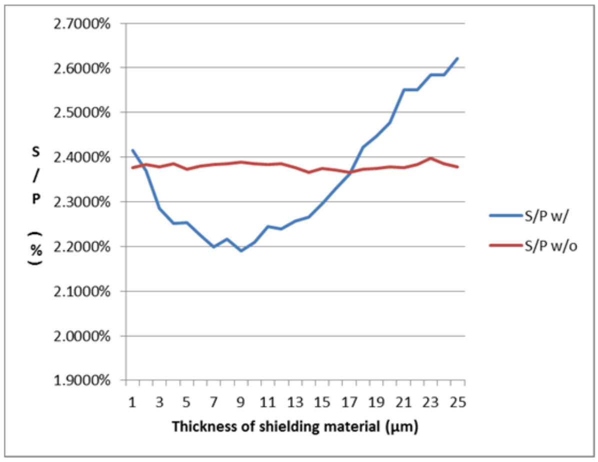
(a) (b) (c) (d) (e) (f)

Fig 2. The cross-section view of electroplating type grids. (a) view from XZ of square-type (b) view from XY of square-type (c) view from XZ of honeycomb-type (d) view from XY of honeycomb-type (e) view from XZ of circle-type (f) view from XY of circle-type.

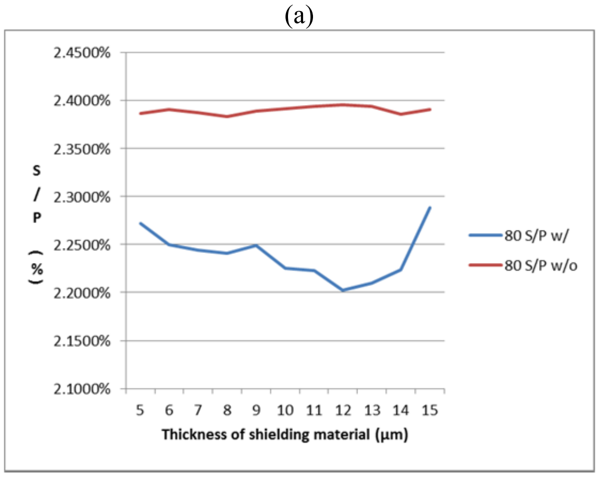
2.4 Result of simulation

Table 1 shows the results of S/P on the grids of three different types. S/P is scattered and primary photon ratio which means the number of scattered photon divided by of primary photon. Large S/P means many scattered photons reach a detector and, as a result, causes the reduction of the resolution of the image.

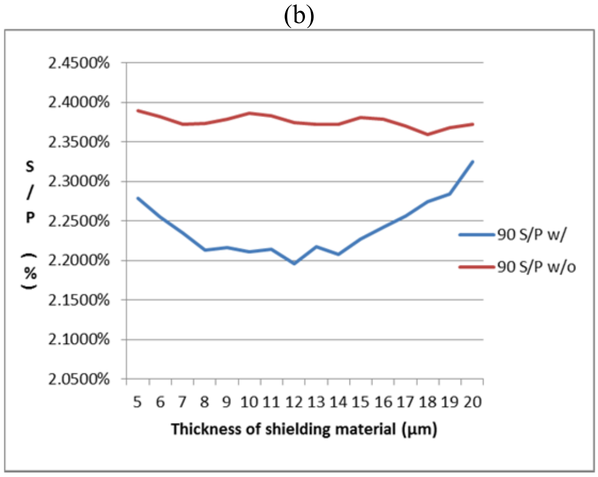
Therefore, it is important to decrease S/P ratio for good performance of the grid. As Table 1 shows, the numbers of scattered and primary photons for square, honeycomb and circle are smaller than that of none grid type by 40 % and 50 %, approximately. As a result, the S/P ratio for all three types is larger than that of non-grid type. For XY plane, the area ratio of shielding wall and void is too small to pass the primary photon as about 14 %. It is thought that this is because the thickness of shielding wall is too thick. Therefore, the thickness optimization study of shielding material is conducted.



(a)



(b)



(c)

Fig 3. The S/P (%) according to the thickness of shielding material (μm) for honeycomb-type. (a) Length of a side of hexagon is 0.035 mm. (b) Length of a side of hexagon is 0.040 mm. (c) Length of a side of hexagon is 0.045 mm.

As Fig 3. shows, the lowest S/P is seen when the thickness of shielding material is between 9 μm and 12 μm for each length. For cases of 0.04 mm and 0.045 mm, S/P is smaller than the result of non-grid type.

Table 1. The simulation result for each type. The number of scattered photon, the number of primary photon and their ratio.

Type	Number of Scattered photon	Number of Primary photon	S/P
Square	1.40E-05	5.30E-04	2.6368 %
Honeycomb	1.40E-05	5.30E-04	2.6428 %
Circle	1.48E-05	5.54E-04	2.6647 %
None	2.38E-05	9.90E-04	2.4084 %

3. Conclusion

The design case study of anti-scattering X-ray grid was performed for the three designs of square, honeycomb and circle type by MCNP simulation. The optimization of thickness of shielding material was conducted on three cases of the length of a side of hexagon of honeycomb type anti-scattering X-ray grid. It was understood that the performance of grid was not depend on the grid type in this fundamental approach. It was thought the analysis results could be extended to the further study on the thickness optimization.

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